

## Appendix C. PRIORITY SERVICES (GETS, WPS, FIRSTNET, TSP, AND SHARES)

The Department of Homeland Security (DHS) Emergency Communications Division (ECD), formerly the Office of Emergency Communications (OEC), offers priority services programs to mitigate the impacts of communications threats such as EMP and to enhance the ability of our critical national security and emergency preparedness personnel to communicate during disasters. In addition, the DHS National Coordinating Center for Communications (NCC) provides resilient backup communications services through the SHARES program.

### Priority Telecommunications Services

DHS/ECD provides priority telecommunications services to support national security and emergency preparedness communications for government officials, emergency responders, critical infrastructure personnel, and industry members. The Government Emergency Telecommunications Service (GETS), Wireless Priority Service (WPS), and Telecommunications Service Priority (TSP) programs ensure key Federal, State, local, Territorial and Tribal governments, and first responder and industry organizations have communications capabilities available to support emergency response incidents.

**GETS** provides priority access on the landline networks:

- Increases call completion during telephone network congestion.
- Does not require special phone equipment.
- No charge for test calls or enrollment.
- Priority access, including calls to most cellular devices.

**WPS** provides priority access on the wireless networks:

- Increases call completion on cell phones during network congestion.
- Is an add-on feature to your cell phone.
- Can be used in conjunction with GETS to provide priority access.

**FirstNet** provides resilient, reliable wireless access on AT&T's network:

- Public safety receives preemption and priority access to the network with no throttling.
- FirstNet has a public safety only core that comes with FIPS 140-2 compliant end-to-end security solutions.
- The wireless coverage reaches more than 99 percent of Americans and covers 76.2 percent of the continental United States with further improvements ongoing.
- Deployables improve resiliency and can be used to extend coverage when needed.

**TSP** provides priority installation and repair of critical communications circuits:

- Federal Communications Commission (FCC) mandated program prioritizes restoration and installation of circuits.
- Vendors restore or install TSP circuits prior to servicing other non-TSP circuits.
- Covers voice and data circuits that support emergency operations.

## Government Emergency Telecommunications Service (GETS)

During emergencies, the public telephone network can experience congestion due to increased call volumes and/or damage to communications infrastructure, hindering the ability of critical personnel to complete their calls. GETS is accessible nationwide providing authorized personnel priority access and processing during an emergency or crisis situation when the landline networks are congested and the probability of completing a call is reduced. GETS facilitated response and recovery efforts during and after events such as 9/11 and Hurricanes Katrina, Ike, and Sandy by providing over a 95 percent call completion rate.

GETS is an easy-to-use calling card service that works on both local and long distance networks; no special phones are required. Calls placed through GETS will receive priority over normal calls; however, GETS calls do not preempt calls in progress or prevent the general public's use of the telephone network. GETS allows users to communicate even during the highest levels of network congestion and also provides priority calling to cell phones during times of congestion on most major carrier networks. There is no charge to enroll in GETS or to make calls to the familiarization line. When making GETS calls, subscribers can be charged the equivalent of long distance phone rates.

## Wireless Priority Service (WPS)

During emergencies, cellular networks can also become congested, hindering the ability of national security and emergency preparedness personnel to complete emergency calls on their cell phones. The WPS program is available nationwide, and is intended to provide authorized personnel priority access in an emergency or crisis situation when the cellular networks are congested and the probability of completing a call is reduced. After the April 2013 bombing at the Boston Marathon, up to 93 percent of calls placed through WPS were successfully completed, allowing critical personnel to carry out their missions to assist the public.

WPS is an easy-to-use, add-on feature that is offered by all nationwide cellular service providers. Authorized personnel can subscribe to WPS on a per-cell phone basis. Calls placed via WPS will receive priority over normal cellular calls; however, WPS calls do not preempt calls in progress or prevent the general public's use of the cellular networks. WPS subscribers are responsible for any cellular carrier charges for initial enrollment and monthly subscription, as well as per-minute usage fees.



FirstNet is an independent authority within the U.S. Department of Commerce (DoC). Its "mission is to deploy, operate, maintain, and improve the first high-speed, nationwide wireless broadband network dedicated to public safety."<sup>16</sup> The AT&T-based public safety communications platform includes all of the features found in commercial cellular networks together with several public safety related improvements:

### **Preemption & Priority**

- First responders receive guaranteed priority and preemption versus public traffic.

- Priority levels within public safety can also be boosted during an emergency.
- FirstNet users will not be throttled even if they are on unlimited plans.

#### **Network Security**

- “The FirstNet core comes with FIPS 140-2 compliant VPN solutions, radio, transport and network core encryption, and advanced physical and logical security protocols to keep all traffic on the network protected.”<sup>17</sup>
- FirstNet lab certifies applications and devices for public safety use although certification is not mandated.
- Certified applications can be downloaded from the FirstNet Applications Store.

#### **Coverage**

- “Wireless coverage will reach more than 99 percent of Americans, extending to 2.74 million square miles, covering 76.2 percent of the continental United States.”<sup>18</sup>
- AT&T is improving its coverage in each state and territory per commitments made in each of its FirstNet State Plans.
- Deployables can be used to extend coverage when needed.

#### **Resiliency**

- With a dedicated FirstNet core, resiliency is significantly increased.
- Deployables are available to provide communications to FirstNet users when the network is down or when extra capacity is required.
- Hardening of the network is expected to become more of a focus once the initial requirements (e.g., coverage) have been met.

First Responders include fire, law enforcement, emergency medical services, and emergency managers by default, but also includes authorized national security personnel. These users have access to all of AT&T’s commercial network. Further, as stated above, the public safety users receive priority on this network and can even preempt an existing user on any of the bands (not just the 700 MHz Band 14 that public safety was allocated). Dedicated care is also provided for additional support as needed.



Mission Critical Voice (MCV) is the only indispensable wireless voice service that is just partially implemented by FirstNet. Several MCV features have been implemented including Full Duplex, Talker Identification, Emergency Alerting, and Audio Quality. However, because the following MCV features have not been implemented, many MC personnel are continuing to use land mobile radio (LMR) in addition to cellular or FirstNet:

- **Mission Critical Push-To-Talk (MC PTT)** was finalized in Release 13 of the 3rd Generation Partnership Project (3GPP) LTE standards in March 2016 and is being implemented. FirstNet has committed to going live with this feature set by March 2019. The standard includes high availability/reliability, low latency, support for group calls and 1:1 calls, talker identification, and clear audio quality.
- **Device-to-Device Communications (D2D)** can be supported via Proximity Services (ProSE), but has not been implemented per public safety requirements where one cellular phone can contact another phone that might be 0.25 miles away without infrastructure. This is an area of research.

- **Coverage and resiliency**, including preventing EMP damage, may be better with some local LMR networks than it is with FirstNet. These are issues that need to be worked out by public safety agencies before relying upon FirstNet for MCV.

With the implementation of MC PTT, it is expected that more agencies will move their non-MC users fully onto FirstNet or Verizon and off LMR in areas where the FirstNet or Verizon coverage is adequate. Additionally, most agencies use these cellular networks for broadband data and FirstNet is continuing to move forward with features such as MC Video and MC Data, which are planned to be rolled out with 3GPP Releases 14 and 15.

Some MC users will move off LMR as well, but many agencies need more proof of the cellular networks resiliency or require improved D2D communication capabilities. Once the above have been resolved, cost concerns may continue to hinder some organizations from fully using FirstNet since they already have spent the capital for an LMR system.

The bottom line is that FirstNet's and Verizon's public safety services can help improve communications resiliency. However, until there is more evidence that these networks are resilient across many threats including EMP, it is recommended that agencies also consider other backup communications such as LMR and satellite. Agencies needing EMP Level 3 or 4 resiliency should include EMP hardened solutions using satellite communications and HF as discussed earlier in this document.

### Verizon's Priority Services

To better meet the needs of public safety, Verizon has rolled out FirstNet-like features that are specific to public safety, most of which are at no additional cost. Similar to FirstNet, this includes a Public Safety Private Core (PSPC), preemption and priority, excellent coverage, and deployables (see [www.verizonenterprise.com/Public-Safety](http://www.verizonenterprise.com/Public-Safety)). Further, Verizon is no longer throttling public safety users even if they have an unlimited data plan that states users may be throttled after they've used a specified amount of data.

Verizon is also working on MCV and D2D similarly to FirstNet and plans to offer MC PTT in 2019. Perhaps the primary differences between the Verizon and FirstNet offerings are coverage and performance that are dependent upon the local network capabilities. However, FirstNet also has an independent team that represents public safety and helps set the priority of public safety related requirements for AT&T. As part of this public safety support, this FirstNet team certifies new devices and applications for the network, which helps ensure that new features work as advertised.

### Telecommunications Service Priority (TSP)

Following hurricanes, floods, earthquakes, and other natural or man-made disasters, telecommunications service vendors can experience a surge in requests to restore existing services and/or install new services. TSP authorizes national security and emergency preparedness (NS/EP) organizations to receive priority treatment for vital voice and data circuits. The TSP program provides service vendors an FCC mandate to prioritize requests by identifying those services critical to NS/EP. A TSP assignment ensures that it will receive priority attention by the service vendor before any non-TSP service.

An organization can only receive a TSP assignment if it maintains services or infrastructures that are considered critical NS/EP communications assets. TSP subscribers are subject to minimal telecommunications carrier charges for initial enrollment and monthly subscription fees.

In the aftermath of Hurricane Sandy, TSP was critical to restoration and recovery efforts by facilitating the rapid repair of damaged circuits and processing over 200 requests to install new circuits for the response community.

### TSP Eligibility Criteria

The national security and emergency preparedness community spans the Federal, State, local, Tribal and Territorial governments, public safety and emergency responders, industry partners who are responsible for maintaining the Nation's critical infrastructure, and other authorized users. Organizations that rely on telecommunications on a daily basis to provide public health, maintain law and order, ensure public safety, or provide financial or utility service should enroll in these vital priority services.

Typical GETS, WPS, and TSP users are responsible for the command and control functions critical to management of, and response to, national security and emergencies. There are five (5) broad categories that serve as criteria for determining eligibility for the priority telecommunications services:

- Serve national security leadership;
- Support the national security posture and U.S. population attack warning systems;
- Support public health, safety, and maintenance of law and order activities;
- Maintain the public welfare and the national economic system; or
- Are critical to the protection of life and property or to national security and emergency preparedness and disaster recovery activities during an emergency.

### TSP Enrollment Process

The first step in the enrollment process is to establish a point of contact (POC) for your organization. Many organizations already have established POCs who facilitate the enrollment process. To determine the POC and enroll in the priority services programs, please contact the **DHS Priority Telecommunications Service Center at (866) 627-2255**, or visit one of the following websites: [www.dhs.gov/GETS](http://www.dhs.gov/GETS), [www.dhs.gov/WPS](http://www.dhs.gov/WPS), or [www.dhs.gov/TSP](http://www.dhs.gov/TSP).

### SHARES Program

National security and emergency preparedness (NS/EP) personnel need to transmit critical messages to coordinate emergency operations even when traditional means of communicating via landlines and cellphones are damaged or destroyed. The SHARED RESOURCES (SHARES) Program, administered by the DHS National Coordinating Center for Communications (NCC), provides an additional means for users with NS/EP missions to communicate when landline and cellular communications are unavailable.

SHARES members use existing HF radio and other communications resources of government, critical infrastructure, and disaster response organizations to coordinate and transmit **emergency** messages. SHARES users typically rely on HF radio and satellite communications to perform critical functions, including those areas related to leadership, safety, maintenance of law and order, finance, and public health. This program also provides the emergency response community with a single interagency emergency message handling and frequency sharing system. SHARES promotes interoperability between HF radio systems and promotes awareness of applicable regulatory, procedural, and technical issues.

More than 2,100 HF radio stations, representing 104 federal, state, and industry organizations located in all 50 states, the District of Columbia, and several locations overseas, are resource contributors to the SHARES HF Radio Program. Nearly 500 emergency planning and response personnel participate in SHARES. Approximately 180 HF radio channels are available for use by SHARES members.

Membership in the SHARES program by government (federal, state, and county), critical infrastructure, and disaster response organizations is voluntary. SHARES is available on a 24-hour basis and requires no prior coordination or activation to transmit messages. Members consult the *SHARES Handbook* to find stations, frequencies and/or Automatic Link Establishment (ALE) addresses of participating organizations they need to communicate/coordinate with. Participating SHARES HF radio stations accept and relay messages until a receiving station is able to deliver the message to the intended recipient.

Further information on SHARES may also be obtained at <https://www.dhs.gov/shares> or by contacting the SHARES Program Office at 703-235-5329 or [nccshares@dhs.gov](mailto:nccshares@dhs.gov).

## Appendix D. EXCERPTS FROM 2017 BRIEF TO INFRAGARD SUMMIT

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# Communication Vulnerabilities & HEMP Mitigation

InfraGard Electromagnetic Pulse  
Special Interest Group (EMP SIG™)  
Dupont Summit  
1 December 2017



Homeland  
Security

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### Electromagnetic Pulse (EMP) Background

- Over the past several decades, the EMP threat has grown
  - 9/3/2017 N. Korea tested “H-bomb”; claimed a “super-powerful EMP” capability
  - 11/28/2017 North Korea successfully demonstrated the Hwasong-15 ICBM
- Today’s power grid and information networks are much more vulnerable to EMP than those of a few decades ago
- We take seriously the U.S. EMP Commission’s recommendation that DHS “play a leading role in spreading knowledge of the nature of prudent mitigation preparations for EMP attack to mitigate its consequences” (Ref: 2008 EMP Commission Report, page 181)
- Presidential Policy Directive 21 (Critical Infrastructure Security and Resilience): “The Secretary of Homeland Security shall provide strategic guidance, promote a national unity of effort, and coordinate the overall Federal effort to promote the security and resilience of the Nation's critical infrastructure.”

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## EMP – Lessons from Soviet History Oct 1962 K-3 HEMP Test Results

**300 kT 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

**Overhead communications lines**

- Malfunction of radio-location
- Long line problems due to EMP "long tail"
- Backup Diesel generators found damaged, "later"
- Spark gaps breakdown
- Safety devices burning
- Amplification location unit
- Power supply breakdown
- Signal cable line

Distances: 1000 km, 600 km, 400 km, 600 km

Ground zero

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

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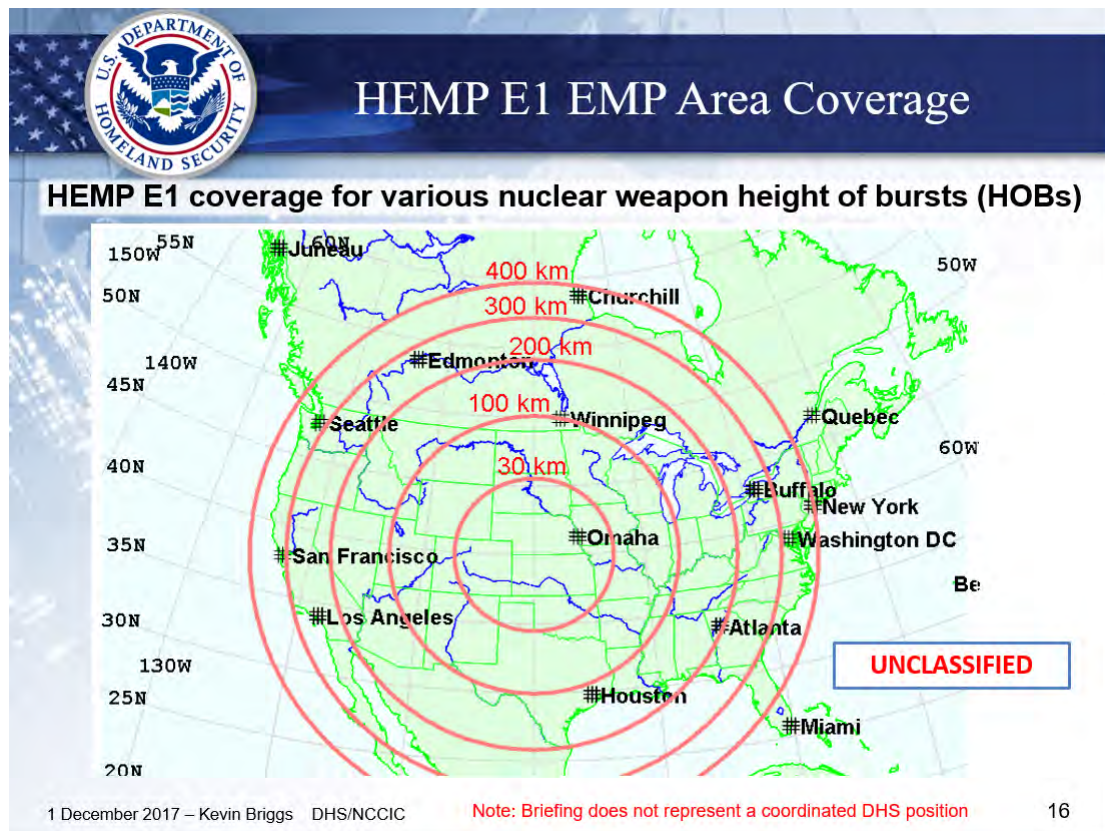
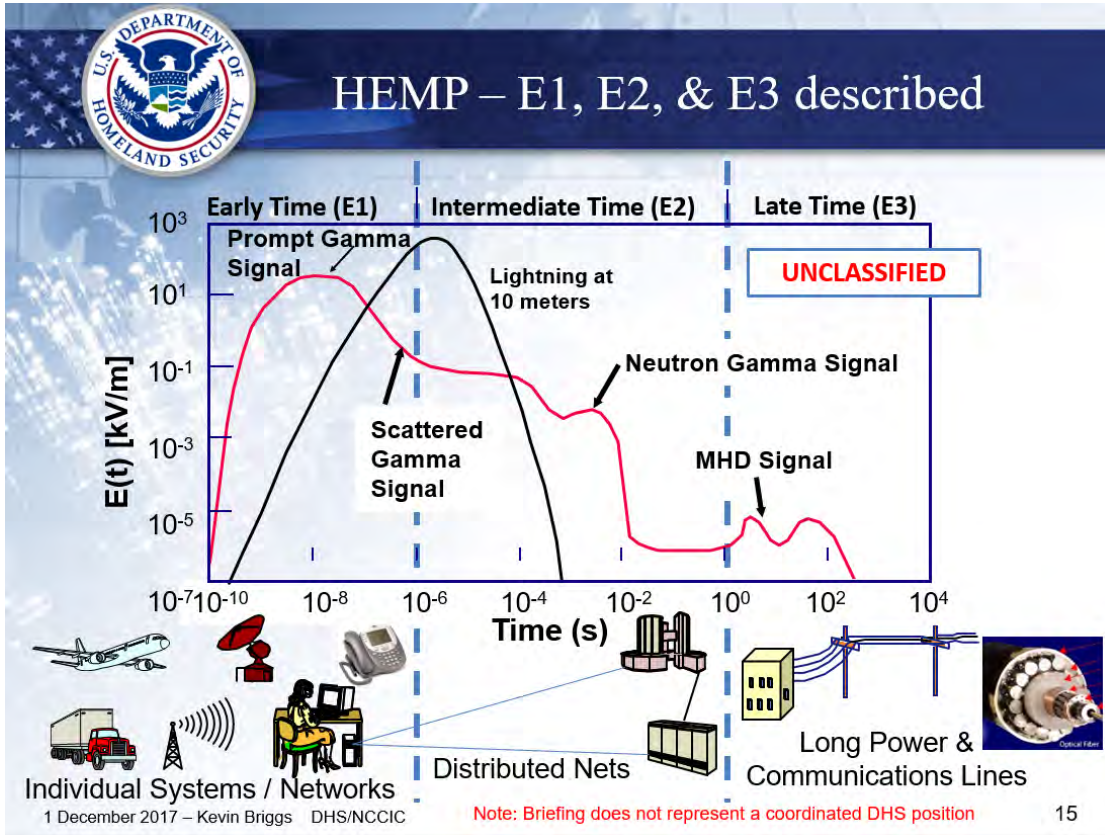
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## High Altitude EMP (HEMP) Most significant threat; has 3 components

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

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## North Korean missile threats against Guam



- **From NY Times (9 August 2017) article by Choe Sang-Hun**
  - “North Korea said Thursday that it was drawing up plans to launch four intermediate-range ballistic missiles into waters near Guam in the Western Pacific to teach President Trump a lesson, after the president warned of “fire and fury” against the North if it persisted in threatening the United States.”
  - “If the North were to follow through on its threat to launch an “enveloping strike” in the vicinity of Guam, it would be the first time that a North Korean missile landed so close to an American territory. The North’s official **Korean Central News Agency** reported that, according to the plan, **four of the country’s Hwasong-12 intermediate-range ballistic missiles would fly over the three southern Japanese prefectures of Shimane, Hiroshima and Koichi before hitting the ocean about 19 to 25 miles from the coast of Guam.**”

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17



## North Korean threatened “test” over the Pacific



**From Reuters (22 Sep 2017) article “A North Korea nuclear test over the Pacific? Logical, terrifying” by Hyonhee Shin, Linda Sieg**

- **North Korean Foreign Minister Ri Yong Ho suggested leader Kim Jong Un was considering testing “an unprecedented scale hydrogen bomb” over the Pacific** in response to U.S. President Donald Trump’s threat at the United Nations to “totally destroy” the country.
- “It may mean North Korea will fire a warhead-tipped (intermediate range) Hwasong-12 or Hwasong-14 intercontinental ballistic missile and **blow it up a few hundred kilometers above the Pacific Ocean,**” said Yang Uk, a senior researcher at the Korea Defence and Security Forum in Seoul.
- “They may be bluffing, but there is a need for them to test their combined missile-bomb capability. They could have already prepared the plan and are now trying to use Trump’s remarks as an excuse to make it happen,” said Yang.

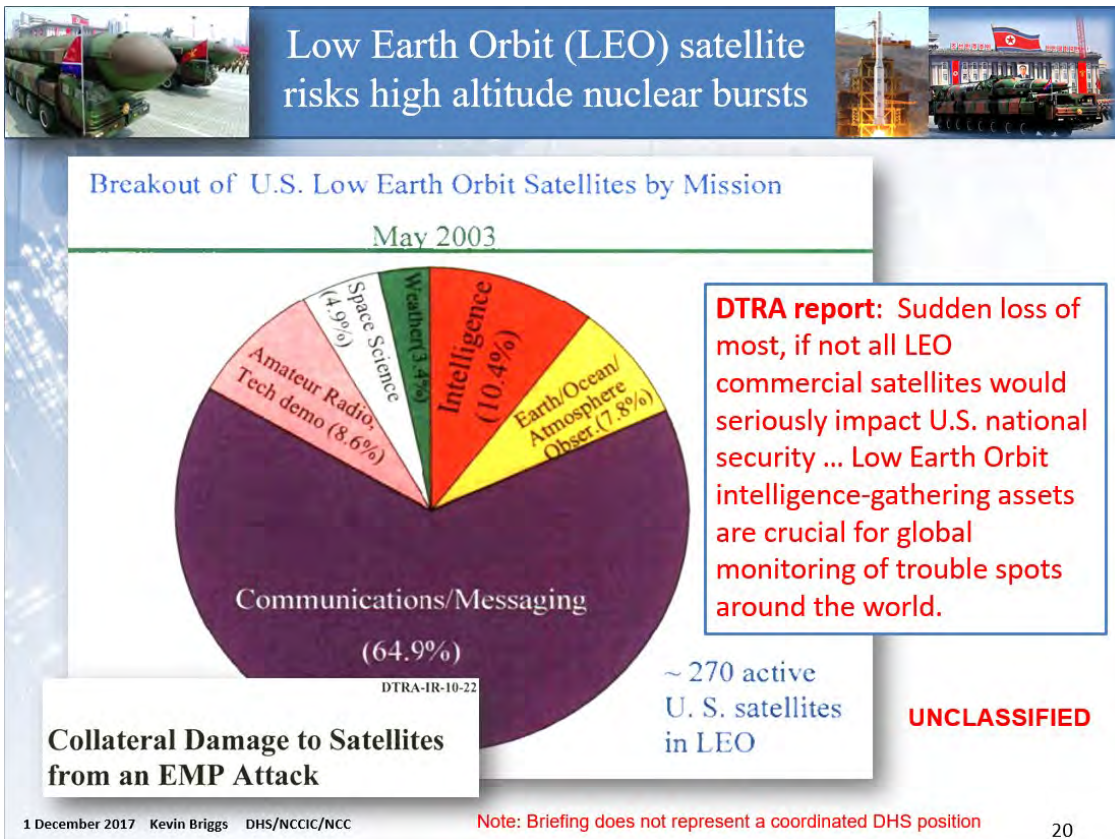
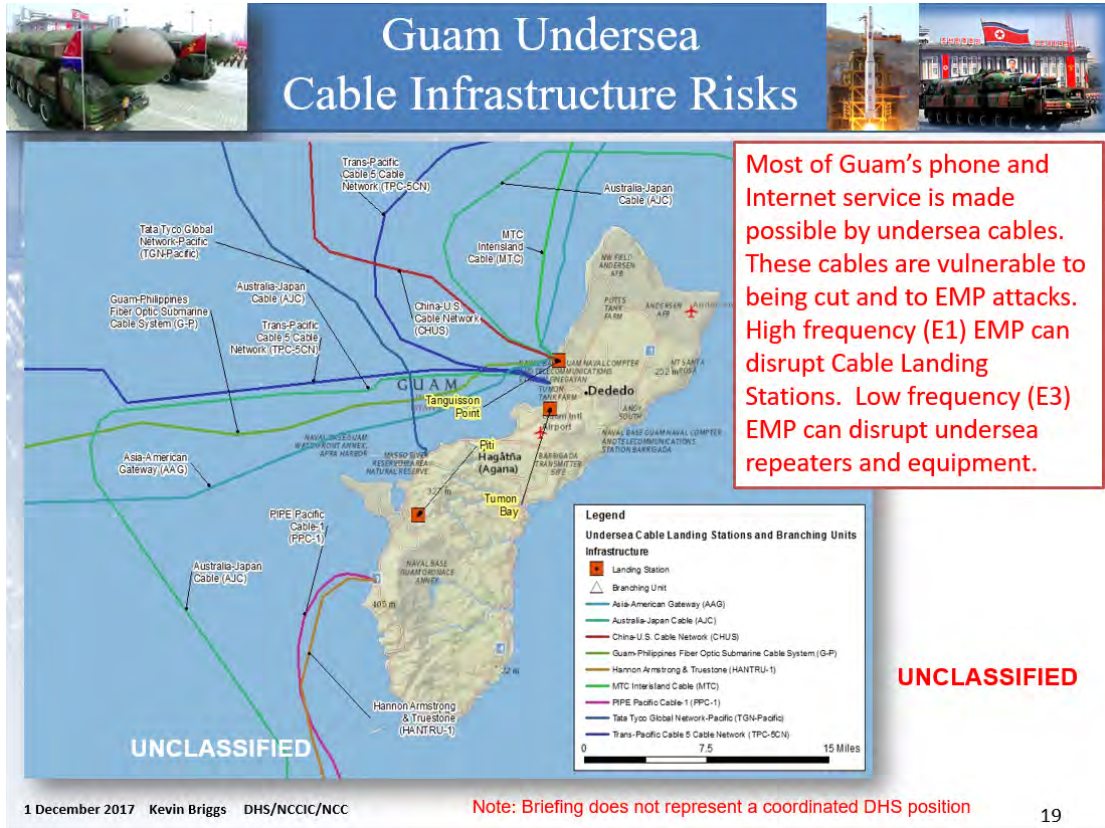
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18

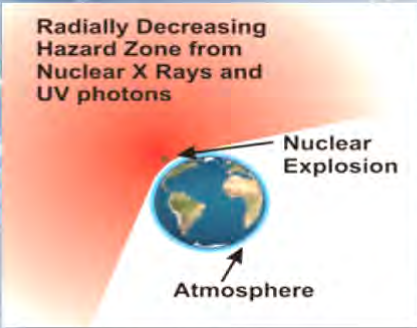


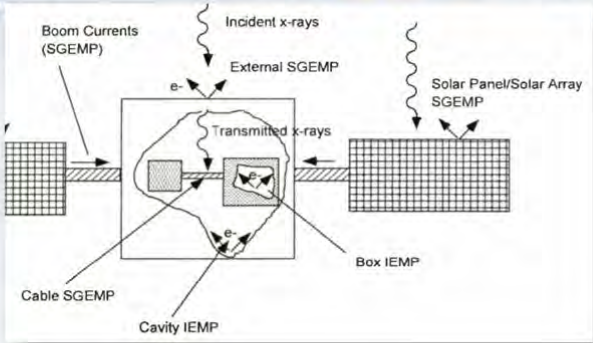
## Prompt satellite risks from high altitude nuclear burst



**Radially Decreasing Hazard Zone from Nuclear X Rays and UV photons**





**EMP Commission:** “Where not shadowed by the Earth or shielded by atmospheric attenuation, X-rays and UV photons travel great distances from a high-altitude nuclear detonation where they may inflict damage to satellites.”


**Derived from DTRA Report:** System Generated Electromagnetic Pulse (SGEMP) is depicted above. When X-rays irradiate a system, photo-Compton electron currents are emitted from the various surfaces, and are driven throughout the various system materials. Timescale: ~ 1 millisecond



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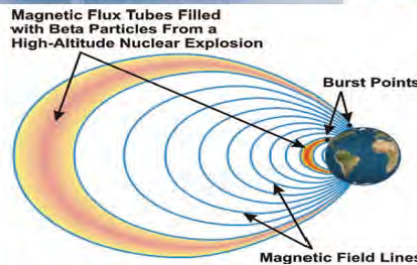
21

## Delayed satellite risks from high altitude nuclear effects



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**Figure 10-5.** Schematic diagram of relative intensities of trapped fluxes from two identical high-altitude nuclear detonations.

**EMP Commission:** An EMP attack ... could cause serious damage to LEO satellites. The STARFISH high-altitude nuclear burst greatly enhanced the high-energy electron environment in LEO, resulting in the early demise of several satellites on orbit at the time.

**DTRA report table:** “Far Eastern Events”

Location	Yield (kt)	HOB (km)	Time to failure (days)		
			NOAA	TERRA	ISS
35.7N	20	150	25	60	200
36N	100	120	60	200	200
36N	500	120	4	6	3
22.5N	100	200	10	20	30
22.5N	500	200	1	3	4
22.5N	5000	200	0.1	0.1	0.1

**DTRA report:** The ... analysis on LEO satellites assumed that the satellites started with their full 2-times-natural radiation budget. In reality, satellites on-orbit have various radiation margins remaining due to cumulative time on orbit. For example, a satellite launched 10 years ago will most likely fail more quickly than a comparable satellite launched only a year ago.

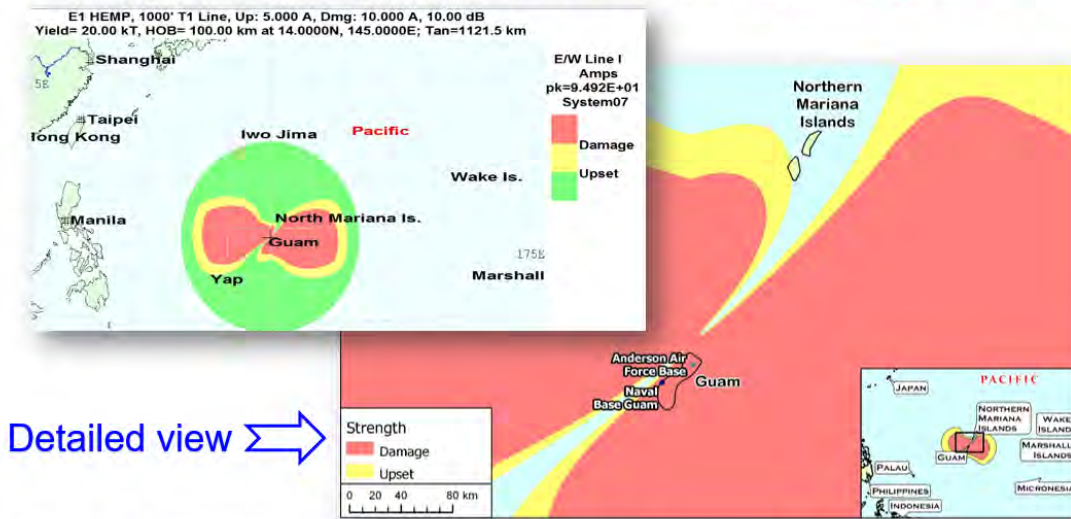
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22

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### EMP impacts from a hypothetical 20 kT weapon: 100' long Ethernet

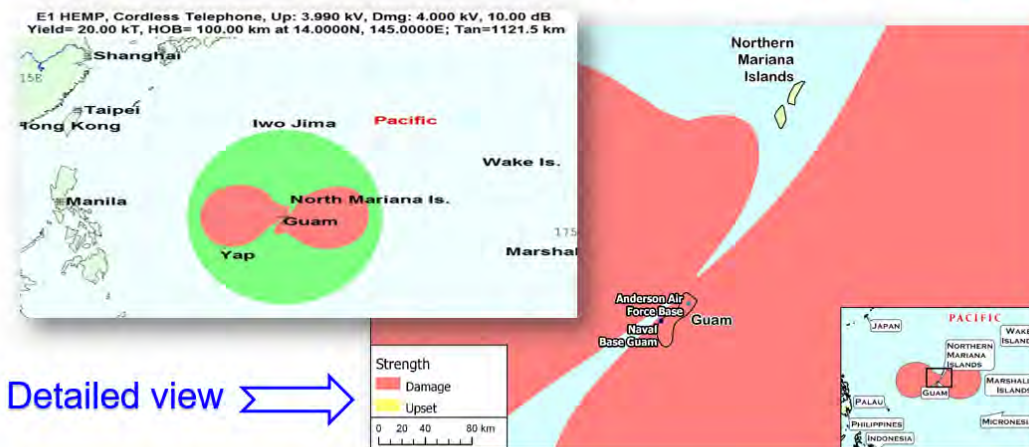


Detailed view →

**Above:** A 20 kT “generic” nuclear weapon detonated at 100 km altitude could generate EMP that could damage and/or upset devices connected to **100' long Ethernet cables** (oriented east to west inside a building that provides **10 dB** of shielding). **The areas shown in Red or Yellow, show the regions of possible damage or upset, respectively, to computers, phones, routers, switches, printers, and other Ethernet connected devices. All of Guam is in the possible “damage zone” for unprotected Ethernet connected devices.**

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### EMP impacts from hypothetical 20 kT weapon: AC/DC power adapters

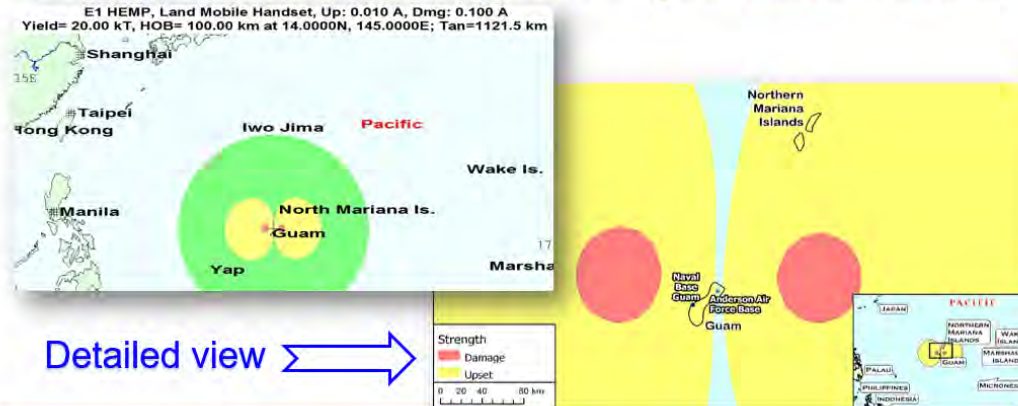


Detailed view →

**Above:** A 20 kT “generic” nuclear weapon detonated at 100 km altitude could generate EMP that could damage and/or upset AC/DC power adapters (like a “wall wart”) used to power cordless phones and numerous other devices. This slide assumes a modern solid state AC/DC adapter with 10 dB of protection, that has a damage threshold of 4 kV ... a reasonable worst case based on NCC’s testing of devices. **The Red areas show the regions of possible damage to AC/DC adapters. All of Guam is in possible “damage zone” for unprotected AC/DC adapters.**

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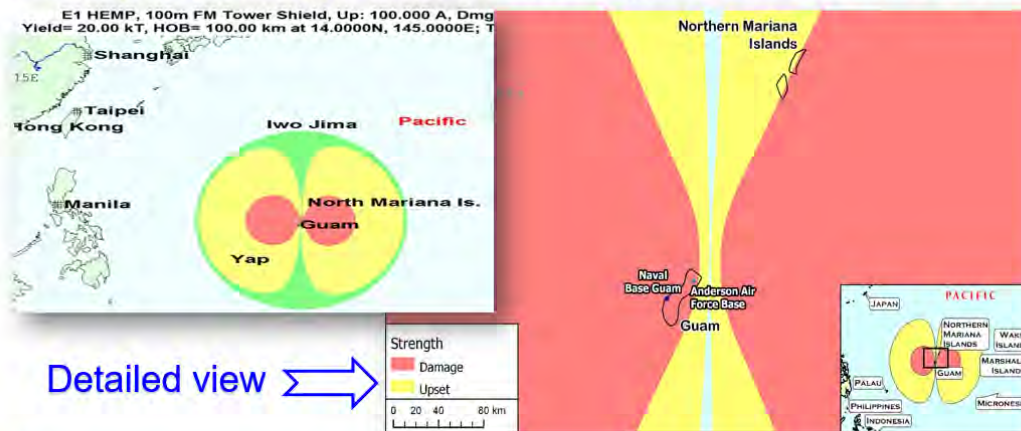
EMP impacts from a hypothetical 20 kT weapon: Land mobile radio



**Above:** A 20 kT “generic” nuclear weapon detonated at 100 km altitude could generate EMP that could upset Land Mobile Radio handsets used by public safety officials (like fire, EMS, and police). Land mobile radios that rely on wireline trunking would likely be “red”, but those that use direct radio-to-radio connection between handsets could be “yellow” (upset, but not damaged, if “on” when EMP occurs), as shown on this slide. If a Land Mobile Radio handset is “off” at the time of the EMP, it is likely to be “green” and work properly. If it is on at the time of the EMP, the radio may need to be cycled “on and off” to work properly. Trunked systems have a large wireline infrastructure that would likely be damaged. Backup generators may be needed to recharge radios. **Most of Guam in potentially “upset zone” for unprotected Land Mobile Radio.**

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EMP impacts from hypothetical 20 kT weapon: 100m FM Radio tower

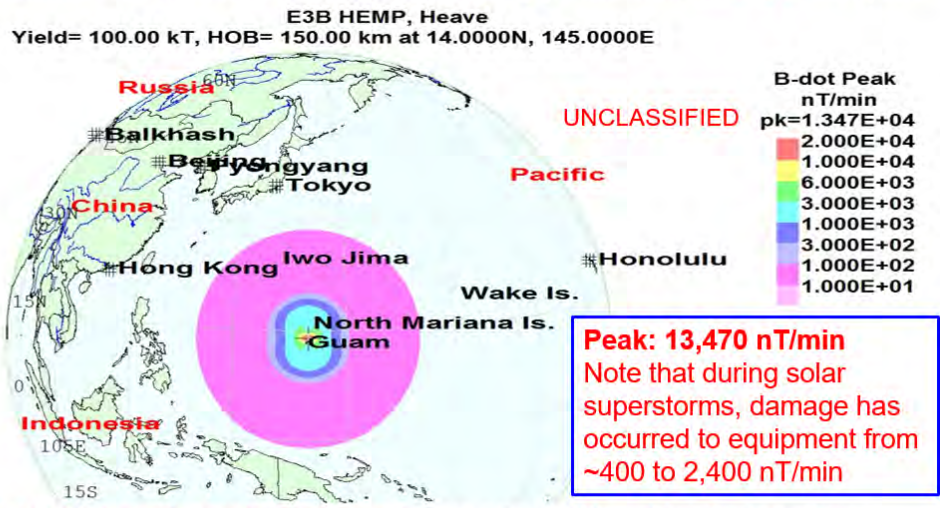


**Above:** A 20 kT “generic” nuclear weapon detonated at 100 km altitude could generate EMP that would likely upset or damage FM radio station equipment at the base of a 100 meter FM radio transmission tower if the FM equipment isn’t properly EMP shielded. Handheld “battery operated” FM radios and those in cars are likely to work, if cycled “off and on” or if turned “off” prior to the time of the EMP burst. 200 meter AM radio towers, if not EMP protected, are likely to fare worse than the FM stations. Hence, if a radio station is shielded, as with those Emergency Alert System (EAS) Primary Entry Point (PEP) radio stations with “in-line” EMP hardening, then public alert, warning, and messaging can occur to those with handheld or car-based radios. **Result: All of Guam is in the potentially “upset or damage zone” for unprotected FM (and AM) radio stations.**

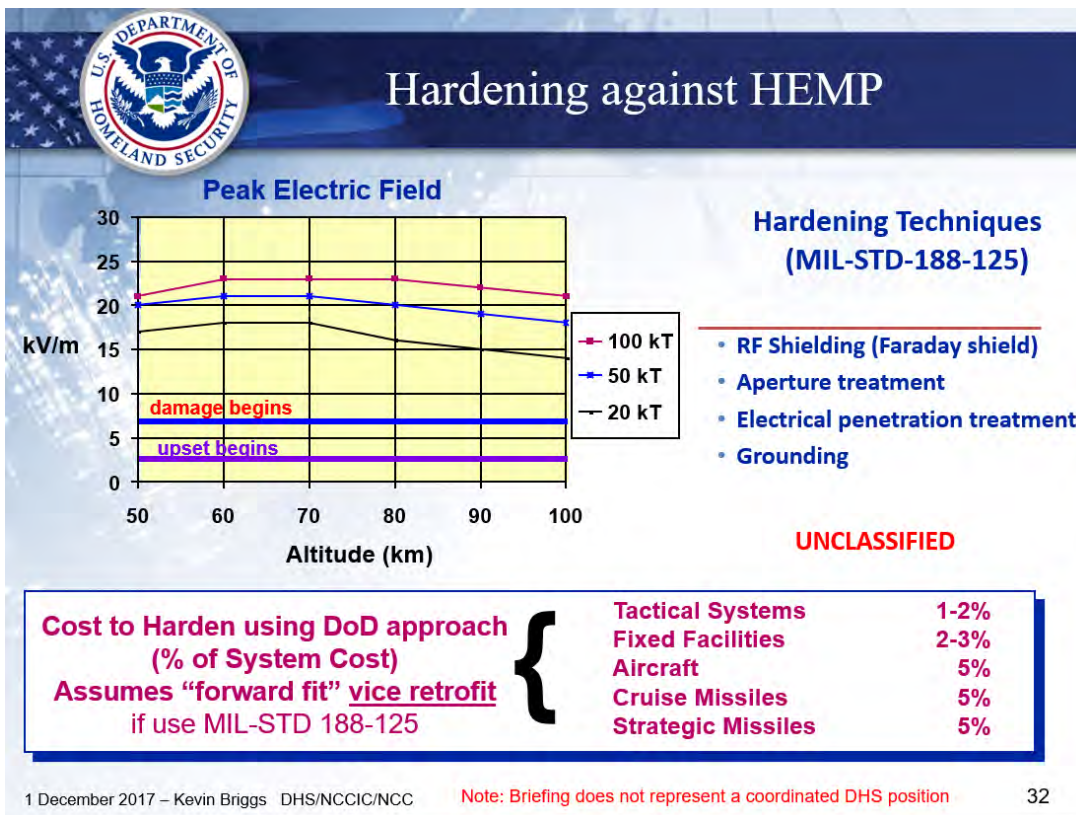
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### High-altitude EMP (HEMP) E3B from a hypothetical 100 kT weapon




Above: A 100 kT “generic” nuclear weapon detonated at 150 km altitude above Guam could generate a powerful low frequency “heave” E3B pulse that could couple into power lines and other long conductors, such as undersea cables. This graphic shows that Guam is covered by significant, low frequency EMP for a period of up to 300 seconds after the burst (at levels up to a maximum of 13,470 nanoteslas/minute).



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Possible impacts to infrastructures resulting from High-altitude EMP (HEMP) <span style="float: right;">UNCLASSIFIED</span>	
Infrastructure (rating assumes not EMP protected)	Days ↔ Months
<b>Undersea Cable Infrastructure</b> (main risks: E1 + E3)	Upset and damage
<b>Satellite in space</b> (System Generated EMP (SGEMP) + radiation belts)	Upset/degradation
<b>Satellite terminals/support</b> (vulnerable to HEMP E1)	Upset and damage
<b>HF radio equipment</b> (vulnerable to HEMP E1)	Upset and damage
<b>HF sky wave media</b> (heals in hours); HF groundwave not impacted	HF propagation
<b>Computers and Ethernet Interfaces</b> (vulnerable to HEMP E1)	Upset and damage
<b>Desk phones</b> (vulnerable to E1 EMP conducted on power/data cords)	Upset and damage
<b>Cell phones</b> (risk to towers/backhaul from E1; handsets generally OK)	Upset and damage
<b>Routers and phone switches</b> (vulnerable to HEMP E1)	Upset and damage
<b>Radio and TV stations</b> (likely to go off-air immediately due to E1)	Upset and damage
<b>Portable battery operated radios</b> (eventual power problem)	Battery dependent
<b>Land mobile radios</b> (OK if not trunked; eventual power problem)	Power dependent
<b>Unprotected parts of the electric grid</b> (main risks: E1 + E3)	Upset and damage

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## EMP Mitigation Conclusions

- **The 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, FirstNet 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 ...)**

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## Appendix E. ACRONYMS AND EXPLANATION OF DECIBELS

3GPP	3rd Generation Partnership Project
A	Ampere or Amp
AC/DC	Alternating Current/Direct Current
AEHF	Advanced Extremely High Frequency
AM	Amplitude Modulation
ARO	Amateur Radio Operator
CCMG	Continuity Communications Managers Group
COTS	Commercial off the shelf
D2D	Device-to-Device Communications
dB	Decibel (see Table E1 at the end of this Appendix for additional information)
DHS	Department of Homeland Security
DoC	Department of Commerce
DoD	Department of Defense
DTRA	Defense Threat Reduction Agency
DTV	Digital Television
EAS	Emergency Alert System
ECD	Emergency Communications Division
EFT	Electric Fast Transient
EM	Electromagnetic
EMAT	Electromagnetic Assessment Tool
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
ESA	Electrical Surge Arrester
FCC	Federal Communications Commission
FM	Frequency Modulation
GDT	Gas Discharge Tube
GETS	Government Emergency Telecommunications Service
GIC	Geomagnetically Induced Current
GMD	Geomagnetic Disturbance
HCI	Hardness Critical Item
HEMP	High-Altitude Electromagnetic Pulse
HF	High Frequency

HIRF	High-intensity Radiated Field
HM/HS	Hardness Maintenance/Hardness Surveillance
HOB	Height of Burst
HPM	High Power Microwave
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
IC	Integrated Circuit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEMI	Intentional Electromagnetic Interference
IMT	Infrastructure Mapping Tool
IND	Improvised Nuclear Device
ISR	Intelligence, Surveillance, and Reconnaissance
IT	Information Technology
ITU	International Telecommunication Union
IRA	Impulse Radiating Antenna
kA	kiloamp
km	Kilometers
kT	Kiloton
kV/m	Kilovolts/meter
kW	Kilowatt
MA	Mega Amp
MC	Mission Critical
MC PTT	Mission Critical Push-To-Talk
MCV	Mission Critical Voice
MHD	Magneto hydrodynamic
MOV	Metal Oxide Varistor
ms	Millisecond
MT	Megaton
MHz	Megahertz
NB HPRF/M	Narrowband, High Pulse Repetition Frequency mode Microwave
NCC	National Coordinating Center for Communications
NOAA	National Oceanic and Atmospheric Administration
ns	Nanosecond

OEC	Office of Emergency Communications
PBX	Private Branch Exchange
POE	Point of Entry
POTS	Plain Old Telephone System (wireline)
ProSE	Proximity Services
ROM	Rough Order of Magnitude
RF	Radio Frequency
RFW	Radio Frequency Weapon (RFW)
RP	Receiver Protection
SCADA	Supervisory Control and Data Acquisition
SHARES	SHARed RESources
SPD	Surge Protection Device
SREMP	Source Region Electromagnetic Pulse
TBB	Telecommunications Bonding Backbone
TEMPEST	Transient Electromagnetic Pulse Emanation Standard
TPD	Terminal Protection Device
TOP	Test Operations Procedures`
TRX	Transceiver
TSP	Telecommunications Service Priority
TVSS	Transient Voltage Suppression System
UHF	Ultra High Frequency
UPS	Uninterruptible Power Supply
µs	Microsecond
USSR	Union of Soviet Socialist Republics
UWB	Ultra-wideband
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio
WBC	Waveguide Below Cutoff
WPS	Wireless Priority Service

Table E-1. Explanation of Decibel (dB)

dB	POWER (like mW/cm <sup>2</sup> )			FIELD (like V/m or kV/m)		
	Power Ratio	% Attenuation	% Transmission	Field Ratio	% Attenuation	% Transmission
0	1.000	0	100	1.00	0	100
1	1.259	21	79	1.12	11	89
2	1.585	37	63	1.26	21	79
3	2.000	50	50	1.41	29	71
4	2.512	60	40	1.58	37	63
5	3.162	68	32	1.78	44	56
6	4.000	75	25	2.00	50	50
7	5.013	80	20	2.24	55	45
8	6.310	84	16	2.51	60	40
9	7.941	87	13	2.82	65	35
10	10	90	10	3.16	68	32
15	31.6	96.8	3.2	5.62	82	18
20	100	99	1	10	90	10
25	316	99.7	.3	17.8	94.4	5.6
30	1,000	99.9	.1	31.6	97	3
35	3,162	99.97	.03	56.2	98.2	1.8
40	10,000	99.99	.01	100	99	1
50	100,000	99.999	.001	316	99.7	.3
60	1,000,000	99.9999	.0001	1,000	99.9	.1
80	100,000,000	99.999999	.00001	10,000	99.99	.01
100	1,000,000,000	99.99999999	.000001	100,000	99.999	.001

## Appendix F. IEC SC 77C BIBLIOGRAPHY

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## Appendix H. EXAMPLE EMP IMPLEMENTATION FOR HF COMMUNICATIONS SITE

Many Federal Government departments and agencies use high frequency (HF) radio transceivers for backup voice and email communications. To enable better interoperability using HF during emergencies, the Department of Homeland Security operates the SHARES Program (see *SHARES Program* in Appendix C). It is recommended that all critical infrastructure operators with a national security and/or emergency preparedness mission join the SHARES program.

The three most commonly used SHARES HF transmitter power ratings are 100-150 W, 500 W, and 1 kW. The lower power ratings are typically good for regional communications while the higher power ratings may be required for communicating across the country although the actual area covered is highly dependent upon many factors (for example: location, antenna type/position, solar weather, and time of day). For amateur radio operators, the lower power options are the most popular due to lower costs and ease of operations.

The sample EMP implementation in this Appendix is designed to help enterprises better understand the equipment, supplies, and rough order of magnitude (ROM) funds needed to install an HF transceiver system with EMP resiliency versus installing it with protection only against lightning. If the site already exists, these estimates could increase depending upon the EMP level being implemented and the existing equipment and installation. Costs shown do not include maintenance partially because those costs are operationally dependent and since the EMP material maintenance costs are minimal (e.g., replace a very inexpensive GDT every few years).

For this sample implementation, it is assumed that the site consists of the following:

- **Equipment**
  - HF transceiver, power supply, built-in antenna tuner, and power amplifier (PA) connected to a combined microphone and speaker that are a 1 meter (m) away.
  - Antenna system including RF antenna cable
  - UPS for computer and networking equipment (only required for Level 2 and 3 with data)
  - Computer (optional for data).
- **Data Cables**
  - Fiber connection from external data source (i.e., outside of the equipment building/room) to an internal fiber optic media converter (assumed fiber is standard from the facility operator or the communications provider).
  - 20 m Ethernet cable from fiber optic media converter to computer.
  - 3 m meandering Ethernet cable from computer to HF transceiver.
  - 1 m – 2 m speaker/microphone cable
- **Rooftop** – The antenna is placed on top of a building and has a 100' RF cable running from the antenna to the HF base station.
  - This antenna could be placed on an antenna tower instead of a rooftop with no technical impact on the HF EMP prevention suggestions.
  - Deploying an antenna on a tower could impact the labor costs to deploy the HF equipment, but in many cases this deployment will occur at the same time as when either installing the HF equipment initially, making an upgrade, or performing

maintenance in which case the additional labor to add the EMP improvements discussed below would be minimal.

- Excellent grounding is available and can easily be connected to.
- **Equipment Building/Room** – The equipment building/room provides **10 dB** of protection (bricks, wood, and windows are not good shielding material as discussed in “Figure 21. Effect of Building Materials on EMP Attenuation” and “Table 9. Building shielding “rules of thumb” for E1 HEMP”). See Table E-1 for more information on decibels (dBs).

Potential solutions to achieve EMP Level 1, 2, and 3 results with the above assumptions are shown below in two sets of tables. The first set, consisting of Table H-1 through Table H-3 below, discusses the technical requirements that are specific to an HF site to make an HF site Level 1, 2, or 3 EMP resilient. The second set consists of just one table shown in Table H-4, which discusses non-HF specific requirements, such as food and fuel supplies.

As shown below in Table H-1, an enterprise can meet EMP Level 1 guidelines with no equipment costs beyond implementing best practices for lightning protection.

**Table H-1. Level 1 EMP Resilient HF Site Specific Technical Costs**

HF Specific Requirement	Level 1 EMP Cost Details	Cost
Unplug power and data lines from spare or backup equipment where feasible.	Best practice for lightning and energy savings and there is no extra cost to leave a cable unplugged.	\$0
Turn off equipment that cannot be unplugged and is not actively being used.	Best practice for lightning and energy savings and there is typically no extra cost to turn off something.	\$0
Use at least a lightning rated surge protection device (SPD) on power cords, antennas, and data cables; maintain spare SPDs	Best practice for lightning and energy savings as well as EMP; thus, assume these are already deployed or will be used if it's a new installation. <ul style="list-style-type: none"> <li>● Power Supply SPD (e.g., \$15 for 6 outlet APC SurgeArrest that will alert the operator when it's no longer fully operational).</li> <li>● SPDs with Gas Discharge Tubes (GDTs) that are not soldered are preferred for easy replacement. For example, the Alpha Delta TT3G50 lightning SPD costs around \$50, its replacement cartridge costs under \$15.</li> </ul>	\$0
Wrap spare electronics with aluminum foil or put in Faraday containers.	Store spare electronics in an area with at least 20 dB protection. This is adequate for smaller electronic devices (or battery powered devices) as might be required for an HF site.	\$0
Join SHARES, if applicable.	There are no fees and the effort is negligible to join SHARES. This is also independent of EMP.	\$0
Consider HF radios	This HF site meets suggestion.	\$0
<b>Level 1 EMP Resilient HF Site Incremental Technical Costs</b>		<b>\$0</b>

For Level 2, the HF specific EMP changes from Level 1 are the following:

- Implementation of a power SPD with a clamp time of 10 ns or less.
- Addition of an EMP rated RF SPD.
- Addition of ferrites to the antenna cable (minimal cost)
- Use of a UPS, which in this case is a line interactive unit since it is less expensive and more efficient at low power loads than an online unit.
- A small amount was also allocated for a shielded Ethernet cable.

The material cost to implement Level 2 versus Level 1 is \$630, which includes providing the site with extra functionality via a UPS.

**Table H-2. Level 2 EMP Resilient HF Site Specific Technical Costs**

HF Specific Requirement(s)	Level 2 Cost Details	Cost
<p>Use EMP-rated SPDs on power cords, antennas, and data cables to protect critical equipment.</p> <p>Also...</p> <p>Use fiber optic cables (with no metal); otherwise use shielded cables and ferrites and/or SPDs. Note: shielded racks, rooms or facilities may be more cost-effective than hardening numerous cables.</p>	<p><b>HF Transceiver &amp; PA Power Supply SPD</b> – To obtain an SPD for the power cable that protects against EMP, the SPD’s recovery time should be 10 ns or less. Note: The \$200 Transtector 6 outlet AC Surge Protection device SL-V Surge Cord has a published tested specification of 5 ns. It costs about \$180 more than a lightning only SPD.</p>	\$200
	<p><b>Shielded RF Antenna Cable</b> – No extra cost since low inductance and lightning protected cables can be selected that also provide EMP protection. For instance, RG-214 is double shielded/braided, or can use low loss LMR-400, which is braided plus has a foil (this is not as good as double shielded/braided).</p>	\$0
	<p><b>Antenna RF Cable SPD</b> –The NexTek HF (1-50 MHz) sub-n response SPD part FPNNMNFBCA3B, which has been tested per MIL-STD-188-125-1, costs approximately \$200 (minimum order may apply). Note: This is \$150 more than the Level 1 SPD listed (plus the replacement cost is considerably higher).</p>	\$200
	<p><b>Antenna Cable Ferrites</b> – Can buy a package of these for under \$10.</p>	\$10
	<p><b>Antenna Tuner SPD</b> – Use extra SPD outlet purchased above or can connect into the UPS for surge protection.</p>	\$0
	<p><b>Computer Power Cable SPD</b> – Connect to UPS for surge protection.</p>	\$0
	<p><b>Fiber Optic Media Converter SPD</b> – Connect to UPS for surge protection.</p>	\$0

HF Specific Requirement(s)	Level 2 Cost Details	Cost
	<b>20 m Ethernet Cable to Computer</b> – Use a shielded Ethernet cable from the fiber optic media converter to the computer. Ground shield at one end only. Wireless can also be used to connect to the computer.	\$20
	<b>Computer Microphone and Speaker Cable</b> – Use EM shielded cabling, which likely came with the system. Thus, there it is assumed that there is no extra cost (no SPD is required given the short distance).	\$0
	<b>Meandering 3 m Ethernet Cable to HF Transceiver</b> – Use a shielded Ethernet cable from the computer to the HF transceiver. Note: Could use an unshielded Ethernet cable in this case since the cable is inside and it's not straight, but a shielded cable is better for consistency and improved EMP protection with no material cost increase. Regardless, no SPD is required given the above.	\$0
Use on-line/double-conversion uninterruptible power supplies (UPS) or a high quality line interactive UPS.	<ul style="list-style-type: none"> <li>• The UPS includes back up power for everything but the HF transceiver and the HF power supply.</li> <li>• The pricing assumes the purchase of an interactive UPS for Level 2 (and an online UPS for Level 3).</li> </ul>	\$200
Implement EMP protected, high frequency (HF) voice and email for long-distance communications.	The above includes a computer and data connection to enable these communications.	\$0
<b>Level 2 EMP Resilient HF Site Costs (includes Level 1 costs)</b>		<b>\$630*</b>

\* Can save \$90 if going straight to Level 2 and not purchasing standard lighting SPDs then replacing them as well as installing shielded Ethernet cable from the start.

For Level 3, shown in the table below, the HF specific EMP changes from Level 2 are the following:

- **UPS** – Level 3 uses an online UPS instead of a line interactive unit in this example although a line interactive unit could have been used.
  - The online version will block EMP by default through its design.
  - Unless the line interactive unit has been specifically tested for EMP, there is a risk that it may not effectively block the EMP pulse if the built-in surge protection is insufficient. Therefore an online version is used in this table.
- **IEC and SPDs** – The surge suppression components in Level 3 must the IEC requirements. However, in this case all Level 2 surge suppression components meet Level 3.
- **Maintenance Program** – Although the upfront costs of this are minimal (create a plan and procure spare equipment), the ongoing costs to replace UPS units and SPDs, surveil the antenna site, etc. can impact the budget although most of the maintenance program

should be implemented for a normal lightning protected site (e.g., swap out defective power SPDs).

The estimated material cost for Level 3 is over \$7,000, but most of this cost is driven by buying a Faraday enclosure which is the most expensive option listed and often will not be required. Further, this assumes that Level 2 has not been implemented and therefore those parts cannot be reused. Lastly, Level 3 uses an online UPS instead of a less expensive line interactive UPS.

In addition to the material costs, there is labor involved to maintain the system and potentially resources involved to test the HF transceiver to ensure that it can tolerate higher levels of EMP transients that bypass the selected voltage level of an SPD.

**Table H-3. Level 3 EMP Resilient HF Site Specific Technical Costs**

HF Specific Requirement(s)	Level 3 Cost Details	Cost
Use International Electrotechnical Commission (IEC) EMP and IEMI protection standards (IEC SC 77C series).	<ul style="list-style-type: none"> <li>Equipment vendors should use the IEC SC 77C generated series of standards. In particular, the 61000 series of standards could be listed, which were prepared by the 77C subcommittee.</li> <li>These standards include specifying the EMP test and measurement techniques.</li> <li>The standardized EMC test for immunity to surges is IEC/EN 61000-4-5</li> <li>Alternatively, MIL-STD-188-125-1 and MIL-HDBK-423 may be met.</li> </ul>	\$0 (cost occurs under other requirements)
UPS (see Level 2 requirement)	<ul style="list-style-type: none"> <li>Assumes use of online UPS.</li> <li>Online UPS cost shown is around \$500 (\$300 more than the Level 2 line interactive UPS)</li> </ul>	\$500
Shielding should be 30+ dB of protection through 10 GHz.  Use EMP shielded racks, rooms, or facilities to protect critical computers, data centers, phone switches, industrial and substation controls and other electronics.	<p><b>First Option:</b> Appropriately shield all internal components to meet 30 dB protection requirement (shielding is additive). Note: Since it is assumed that the building offers 10 dB of protection, the shielding may just offer 20 dB of protection to meet the 30 dB requirement.</p> <ul style="list-style-type: none"> <li><b>Shield Cables</b> – Ensure all RF, data, and power cables are shielded. RF cables should already be shielded. Using shielding on data cables is very low cost (assume \$10). Shielded power cables are also very inexpensive, but assume a few of these needs to be replaced for \$10 each.</li> <li><b>Shield Equipment</b> – Some equipment is manufactured with all sensitive electronics in a</li> </ul>	\$40

HF Specific Requirement(s)	Level 3 Cost Details	Cost
	<p>fully enclosed metal shield and do not require extra shielding.</p> <ul style="list-style-type: none"> <li>This option is usually the least expensive for smaller EMP-protected operations.</li> </ul> <p><b>Second Option:</b> Shield the room to at least 20 dB or put the equipment in a shielded enclosure. Note: This protection together with the assumed 10 dB of shielding from the building will equal 30 dB.</p> <ul style="list-style-type: none"> <li>Might be able to move the equipment from a room with windows into a room in the middle of a building with no windows or into a more protected area of the basement.</li> <li>Could put EMP composite on walls and ceiling in sealed windowless room to improve EMP protection (may need to use EMP rated ventilation guides).</li> <li>Procure a Faraday cage for the equipment. The cost of a Faraday cage varies depending upon several characteristics, but this example assumes that it costs \$6,000 together with the necessary accessories.</li> </ul>	<p>\$6,000 (assumed; Faraday cage costs can vary significantly)</p>
<p>Use “Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures” from EMP Commission for grid and undersea cable protection planning. Use 85 V/km for CONUS E3 threat.</p>	<ul style="list-style-type: none"> <li>This requirement is primarily applicable to long power and communications cables, such as used in the electric grid or undersea – this is part of the reason behind the required EMP protected backup power.</li> <li>As part of the maintenance plan, power SPDs should not be replaced during an E3 HEMP event, which can last for hours, unless there are plenty of spare power SPDs.</li> </ul>	<p>\$0</p>
<p>Use EMP tested SPDs and equipment.</p>	<ul style="list-style-type: none"> <li>The Level 2 Transtector power SPD is sufficient for Level 3 as well since it’s tested to MIL-STD-188-125. List price is around Level 2: \$200.</li> <li>The Level 2 NexTek HF (1-50 MHz) SPD part FPNMNFBCA3B can continue to be used since it has been tested per MIL-STD-188-125-1. List price is around Level 2: \$200.</li> <li>The HF transceiver should be tested to ensure that it can tolerate higher levels of EMP transients that bypass the selected voltage level of an SPD. The cost shown assumes that the</li> </ul>	<p>\$400</p>

HF Specific Requirement(s)	Level 3 Cost Details	Cost
	organization can reuse someone else's test results.	
Institute hardening maintenance and surveillance (HM/HS).	<ul style="list-style-type: none"> <li>• HM/HS combines preventive maintenance, inspection, test, and repair activities accomplished on a HEMP protected operational facility to ensure that HEMP hardness is retained throughout the lifecycle.</li> <li>• The cost shown assumes that spare SPDs are purchased as part of the HM/HS program.</li> </ul>	\$400 upfront (On-going effort is required)
<b>Level 3 EMP Resilient HF Site Upfront Costs (includes Level 2 costs)</b>		<b>\$7,340 *</b>

*\* If reusing Level 2's SPDs and line interactive UPS and if the first shielding option can be used, these material costs can be substantially reduced to \$40 plus the cost of the spare parts (which likely would have been purchased in Level 2).*

## General EMP Requirements

General EMP requirements help sites prepare for a HEMP or SREMP event, but are also applicable to other manmade disasters as well as natural disasters. These requirements impact the overall operations or the site characteristics (e.g., priority phone service, EMP protected backup power). The suggested requirements and the general nature of the costs to implement the requirements are shown in the table below. The estimated costs are not specified both because they are highly variable and they are not HF specific requirements.

**Table H-4. General, Non-HF Specific EMP Requirements for Levels 1-3**

Level	Non-HF Specific Site Requirement	Details
1	Have either EMP protected backup power or a generation source that is not connected to the grid with one (1) week of on-site fuel or equivalent (e.g., renewable source).	<ul style="list-style-type: none"> <li>• A 3 kW generator could backup all of the equipment, including a 1 kW transmitter.</li> <li>• If using a lower power transmitter or a battery backup system for the HF transceiver system, then a smaller generator could be used with improved fuel efficiency.</li> </ul>
2, 3	Use EMP protected backup power that is not vulnerable to EMP coupled through the power grid.	The backup power generation is often handled by the facility.
1, 2	Have one (1) week of on-site fuel or equivalent (e.g., renewable source).	The fuel supplies is often handled by the facility's emergency planners.

Level	Non-HF Specific Site Requirement	Details
3	Have thirty (30) days of EMP protected fuel/power.	It may be helpful to shut off power to all non-essential equipment to meet this requirement.
1,2,3	Use priority phone services like GETS, WPS (for cell phones), and TSP.	The costs for these services are dependent upon the service provider, but they tend to be minimal as discussed under Appendix C.
1,2,3	Consider land mobile radios with standalone capabilities and FirstNet.	There is no extra cost to use FirstNet or Verizon's priority services versus one of their non-priority cellular services.
1,2,3	Use battery operated AM/FM/NOAA radios to receive Emergency Alerts.	Need just one of these radios to receive alerts.
1,2	Store one week of food, water, and other supplies for personnel.	Could work with on-site food provider, such as a cafeteria to help ensure that food is available.
3	Store 30 days of food, water, and critical supplies for personnel.	Maintenance of the critical supplies also needs to occur.
2,3	Consider geosynchronous earth orbit (GEO) satellite services, like BGAN. Avoid low-earth orbit (LEO) satellite supported communications, unless EMP protected.	LEOs could be damaged or become dysfunctional due to a HEMP event. GEO satellites are too far from potential HEMP events to be significantly impacted.
2,3	Shortwave radio for situational awareness.	This consideration is for the overall facility and not just the HF site.
3	Use time-urgent EMP resilient comms, like X, Ku and Ka satellite, and either HF groundwave or Automatic Link Establishment (ALE) HF.	The higher satellite frequency bands are more resilient to EMP bursts until the ionosphere stabilizes.

## Appendix I. ENDNOTES

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- <sup>1</sup> Title 47: Telecommunication, PART 215—FEDERAL GOVERNMENT FOCAL POINT FOR ELECTROMAGNETIC PULSE (EMP) INFORMATION, <https://ecfr.io/Title-47/pt47.5.215>
- <sup>2</sup> The White House, National Security Strategy of The United States of America (Dec 2017), <https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf>
- <sup>3</sup> Graph courtesy of Metatech (Oct 2018)
- <sup>4</sup> Quartz Media LLC, North Korea’s latest missile test traveled 10 times higher THAN THE ISS, <https://qz.com/1140566/north-koreas-latest-missile-test-traveled-10x-height-of-iss-and-suggests-it-could-hit-us/> (7/16/18)
- <sup>5</sup> Statement Dr. PETER VINCENT PRY, EMP COMMISSION STAFF BEFORE THE UNITED STATES SENATE SUBCOMMITTEE ON TERRORISM, TECHNOLOGY AND SECURITY AND HOMELAND SECURITY, MARCH 8, 2005, FOREIGN VIEWS OF ELECTROMAGNETIC PULSE (EMP) ATTACK, [http://web.archive.org/web/20121108204504/http://kyl.senate.gov/legis\\_center/subdocs/030805\\_pry.pdf](http://web.archive.org/web/20121108204504/http://kyl.senate.gov/legis_center/subdocs/030805_pry.pdf)
- <sup>6</sup> Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack (July 2017), Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures, Courtesy of Los Alamos National Laboratory
- <sup>7</sup> William Radasky, Edward Savage, Intentional Electromagnetic Interference (IEMI) and Its Impact on the U.S. Power Grid (Jan 2010), [https://www.ferc.gov/industries/electric/industryact/reliability/cybersecurity/ferc\\_meta-r-323.pdf](https://www.ferc.gov/industries/electric/industryact/reliability/cybersecurity/ferc_meta-r-323.pdf)
- <sup>8</sup> ibid
- <sup>9</sup> Homeland Security Council, National Continuity Policy Implementation Plan (August 2007), <https://www.hsdl.org/?view&did=482817>
- <sup>10</sup> National Communications System (NCS), Volume I EMP/Transient Threat Test of Protection Devices for Amateur/Military Affiliate Radio System Equipment (October 1985)
- <sup>11</sup> Motorola Publication R56, “Standards and Guidelines for Communications Sites” (2005), [www.ronet.co.za/downloads/R56%20Guidelines.pdf](http://www.ronet.co.za/downloads/R56%20Guidelines.pdf)
- <sup>12</sup> ARRL, Grounding and Bonding for the Radio Amateur (2017), [www.arrl.org/shop/Grounding-and-Bonding-for-the-Radio-Amateur](http://www.arrl.org/shop/Grounding-and-Bonding-for-the-Radio-Amateur)
- <sup>13</sup> Digi, Indoor Path Loss (June 2012), <http://ftp1.digi.com/support/images/XST-AN005a-IndoorPathLoss.pdf>
- <sup>14</sup> MIL-STD-188-125-1 (7/17/1998), HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) PROTECTION FOR GROUND-BASED C4I FACILITIES PERFORMING CRITICAL, TIME-URGENT MISSIONS, Part 1, Fixed Facilities, <http://futurescience.com/emp/MIL-STD-188-125-1.pdf>
- <sup>15</sup> ibid
- <sup>16</sup> <https://www.firstnet.com/> (9/27/2018)
- <sup>17</sup> <https://www.firstnet.gov/newsroom/blog/firstnet-core-delivers-promise-dedicated-network-public-safety> (9/27/2018)
- <sup>18</sup> <https://www.firstnet.com/coverage>