May 4, 2017

Threat Posed by Electromagnetic Pulse and Policy Options to Protect Energy Infrastructure and to Improve Capabilities for Adequate System Restoration

Committee on Energy and Natural Resources, United States Senate, One Hundred Fifteenth Congress, First Session

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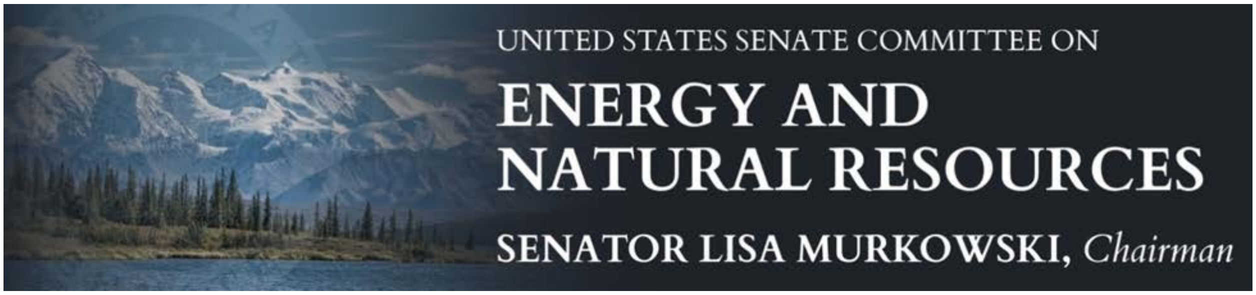

Opening Statement
ENR Hearing on Electromagnetic Pulse (EMP)
Chairman Lisa Murkowski
May 4, 2017

Good morning and welcome, everyone. The Committee will come to order.

Today we are here to examine the threat posed by electromagnetic pulse, better known as EMP, as well as policy options to protect energy infrastructure and provide for system restoration in the event of an EMP attack.

The United States has recognized a potential EMP attack as a national security threat for decades, and our efforts to understand a potential EMP burst are certainly not new. The Department of Defense and our national labs have been grappling with these issues to one degree or another since we first started testing nuclear weapons. Extensive tests in the 1950s and 60s examined the potential impact of an EMP burst on both military and civilian infrastructure. However, today there is a renewed focus on understanding the effects of such an attack, and an increase in efforts directed at mitigating and recovering from such an event should it occur.

This issue is perhaps more salient now than ever for several compelling reasons.

First is the proliferation of nuclear technology, which is no longer limited to the U.S., Russia, China, the U.K., and France. Other nations have tested nuclear weapons and missiles to deliver them. Rogue nations such as North Korea may already have or be close to obtaining these capabilities. We must also be mindful of the potential for a non-state actor to obtain a nuclear device—while their ability to use a missile as a delivery vehicle for a high-altitude EMP attack would likely be more limited, we know that it cannot be ruled out.

Second is the proliferation of electronics in today’s society. Just about everyone in this room has a smart phone, and that’s just the start of the devices that we rely on, that in turn rely on electricity and electronics to function. This has magnified the impact, as compared to the potential impact in the 1960s that an EMP burst could now have on the electric grid, the technologies that rely on electronics, and our daily lives.

We must recognize from the start of today’s discussion that the threat posed by an EMP attack is a matter of national defense. Defending our nation from a missile carrying a nuclear warhead is clearly beyond the scope of the owners and operators of energy infrastructure and their regulators. Nevertheless, these institutions do have a role in protecting critical energy infrastructure and providing for its restoration.

As the owners and operators of critical energy assets, our utilities must assist government EMP experts in understanding how the electric grid works. For its part, government must prudently share its knowledge and expertise with industry on a timely basis and approve or direct prudent reliability standards as warranted. There's no way around this. On one hand, we have defense and national security personnel who are very familiar with the effects of a nuclear detonation, but who are not responsible for the complexities of keeping the lights on. On the other hand, you have the professionals in the power sector know the grid, but are not familiar with the characteristics of a nuclear detonation.

It is critical that the electric industry and government improve upon their mutual understanding and trust, because it is essential to the productive relationships that are necessary to improve our ability to respond to EMP and other potential high impact but low frequency events.

Both camps must work together to share information and expertise. Our engineering schools and other conduits for professional expertise must embrace a new paradigm for considering and addressing security threats in the design and operation of electric systems. Improving our ability to respond to an EMP threat is also an area where, like cybersecurity – the subject of another recent hearing we just had – stronger public-private partnerships are needed and today's capabilities must be improved.

This hearing will consider, as a policy matter, whether the appropriate federal agencies have the authority they need to address this potential threat, and whether additional authority or direction is needed. Back in 2005, we established authority for the Electric Reliability Organization – now NERC – through an informed stakeholder process to establish, subject to FERC's approval, mandatory physical and cybersecurity standards for the industry. And more recently, in 2015, Congress codified the Department of Energy as the sector-specific agency for energy critical infrastructure and provided the Secretary with emergency authority to address a host of threats – cyber, physical, geomagnetic disturbances, and EMP.

We have taken some steps, but many argue and believe that those steps are not sufficient, and that we still have a great deal of work ahead of us in this area. Our task today is to consider the distinct points of view about EMP brought to us by our distinguished panel. I look forward to the testimony of all of our witnesses, but first let me turn to Ranking Member Cantwell for her opening remarks.

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Testimony of Cheryl LaFleur
Acting Chairman, Federal Energy Regulatory Commission
Before the Committee on Energy and Natural Resources
United States Senate
May 4, 2017

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee:

Thank you for the opportunity to appear before you today to discuss electromagnetic pulse (EMP) threats to the electric grid in the United States. I appreciate the Committee's attention to this important issue.

The Federal Energy Regulatory Commission (FERC) plays a central role in protecting the reliability of the Nation's electric grid against a range of threats, both naturally-occurring and manmade. Our work generally takes the form of both mandatory reliability standards and voluntary, collaborative efforts with our federal and state colleagues, industry, and other stakeholders. Before turning to EMP specifically, I would like to provide an overview of the evolution of FERC's reliability work, which I believe will help inform that discussion.

FERC's Oversight of Grid Reliability

In the Energy Policy Act of 2005, Congress entrusted FERC with a new responsibility to approve and enforce mandatory reliability standards for the Nation's bulk-power system. This authority is found in section 215 of the Federal Power Act (FPA), and is limited to the "bulk-power system," as defined in the statute, which excludes Alaska and Hawaii, as well as local distribution systems.

Under FPA section 215, FERC cannot directly write or modify reliability standards but must rely on the Electric Reliability Organization (ERO) that FERC certifies to perform this task. In 2006, FERC certified the North American Electric Reliability Corporation (NERC) as the ERO. Under the section 215 construct, NERC develops and proposes for FERC's review new or modified reliability standards. In addition, as I will discuss in more detail below, FERC may direct NERC to develop or modify a standard and has done so when FERC determines that new or modified standards are needed. Once NERC develops a standard, it is filed with FERC, at which time FERC can either approve or remand the standard. If FERC approves a proposed standard, it becomes mandatory and enforceable in the continental United States and is applicable to the users, owners and operators of the bulk-power system. If FERC remands a proposed reliability standard, it is sent back to NERC for further consideration.

In addition to its formal standards work, FERC has also supported grid security through voluntary and collaborative efforts. Largely conducted by FERC's Office of Energy Infrastructure Security, FERC has worked closely with other federal agencies, states, industry, and other stakeholders to improve coordination and knowledge-sharing regarding threats to the grid. This work includes, among other activities, the development, identification, and dissemination of best practices; participation in grid reliability exercises; and providing briefings to state colleagues.

FERC, NERC, and industry have made significant progress over the last decade to put in place a robust set of baseline standards to address basic day-to-day grid reliability issues, like tree trimming and relay setting. Reaching a steady state on those standards has allowed us to increasingly shift our attention to cutting edge or emerging threats, like cyber and physical security of critical grid infrastructure, and the risks associated with geomagnetic disturbances (GMD) from solar storms and EMP attacks. Going forward, I expect that our collective attention to these issues and the risks posed by high-impact, low-frequency events will only increase. Later in my testimony I will explain some of the work we have done to date on these issues and how it helps to provide protection against potential EMP threats.

EMP Threats

I will now turn to EMP, as well as a related discussion about the threats posed by GMD. The bulk-power system may be impacted by electromagnetic events, such as naturally-occurring GMD or man-made EMP. In the case of EMPs, equipment is available that can generate localized high-energy bursts designed to disrupt, damage or destroy electronics such as those found in control systems on the electric grid. EMPs can be generated by devices that range from small, portable, easily concealed battery-powered units all the way through missiles equipped with nuclear warheads. As described, for example, in a recent report from the Los Alamos National Laboratory, depending on the yield of the device and the altitude of its detonation, EMP devices can generate three distinct effects of varying magnitude, each impacting different types of equipment: a short, high energy Radio Frequency-type burst called E1 that can destroy electronics; a slightly longer burst that is similar to lightning, termed E2; and a final effect, termed E3, that generates electric currents in power lines and equipment, which can then damage or destroy equipment such as transformers.

In the case of GMDs, naturally occurring solar magnetic disturbances periodically disrupt the earth's magnetic field, which, in turn, can induce currents on the electric grid that may simultaneously damage or destroy key transformers over a large geographic area. GMD events are similar in character and effect to the final phase of EMP, termed E3, as they can affect the same equipment including transformers. Any of these effects has the potential to cause voltage problems and instability on the electric grid, which could lead to wide-area blackouts.

The risks posed by EMP and GMD events have been the subject of significant scientific research and debate, as well as broad discussion among regulators, elected officials, industry, and other stakeholders about the appropriate steps to address these threats. FERC has been actively involved in these discussions, and the threats posed to the grid by electromagnetic events, particularly GMD, have been a particular priority of mine during my time at FERC. While the threats posed by GMD and EMP overlap in part, our understanding of those threats and how to effectively mitigate them has led to different approaches to address them.

With these issues and challenges in mind, FERC has used both regulatory and more informal collaborative approaches to address EMP threats.

FERC Regulatory Actions

First, with respect to regulatory actions, FERC has acted through both its reliability authority under FPA section 215 and its ratemaking authority under FPA section 205 to support grid reliability efforts that help protect against EMP threats.

Through its work on GMD, FERC has taken steps that help to mitigate one aspect of EMPs, i.e., the effect of the E3 component on high-voltage transformers and other equipment. In 2013, FERC directed NERC to develop GMD reliability standards in a two-stage process. The first stage GMD reliability standard, which has been in effect since 2015, requires responsible entities to develop and implement operational procedures to mitigate the effects of GMDs. The second stage GMD reliability standard, which FERC approved in 2016, requires responsible entities to conduct initial and on-going assessments of the potential impact of a benchmark GMD event on bulk-power system equipment and the bulk-power system as a whole and to mitigate any assessed vulnerabilities. With respect to the second stage GMD reliability standard, FERC also directed NERC to develop modifications and perform additional GMD research on specific issues to ensure that the protections against GMD evolve with our improving understanding of the science.

FERC has also taken other actions that provide a measure of protection against EMP threats, particularly through its efforts to protect the grid against physical threats. The nature of physical attacks – which, like EMP events, are intentional, manmade efforts to disrupt the electric grid – introduce additional complexities not present in events that have caused wide-spread blackouts and reliability failures in the past, such as vegetation-related events. Recognizing these risks, in 2014, FERC directed NERC to develop a reliability standard that addresses physical security threats. FERC approved NERC's proposed physical security reliability standard later that year. The physical security reliability standard requires responsible entities to mitigate assessed vulnerabilities to critical transmission facilities through resiliency or security measures designed collectively to deter, detect, delay, assess, communicate, and respond to potential physical threats and vulnerabilities. This standard, insofar as responsible entities harden their substations and improve perimeter security to address their assessed vulnerabilities, can help address the use of small, portable EMP devices that require close proximity to their intended targets.

FERC, NERC, and industry have also dedicated significant attention to improving grid resilience. Resilience efforts cover a range of actions that grid owners and operators can take to reduce the risks associated with the loss of individual or multiple assets and to improve recovery and restoration following such losses. FERC has supported efforts to improve the design, planning, maintenance, and operation of the grid through its standards and rate work, as well as through collaborative efforts. For example, some of these efforts stem from requirements in mandatory reliability standards to ensure backup capabilities for the loss of critical assets, or to de-risk critical assets, which reduces the potential for cascading outages.

One important element of grid resilience is ensuring adequate inventories of critical grid infrastructure, particularly long-lead time construction items like high-voltage transformers. Through its rate-making authority, FERC has issued orders to provide clarity on how it will address services provided by Grid Assurance, a company created by several electric utilities and energy companies, and Edison Electric Institute's (EEI) STEP program. Over the last two years, FERC issued orders addressing important cost recovery and rate design questions concerning Grid Assurance's service model, which is intended to support transmission owners in the procurement, maintenance, and delivery of transformers and related equipment in the event of a loss of a critical transformer. Similarly, EEI's STEP program, which FERC approved in 2006, provides a sharing service for backup or spare transformers among participating transmission owners. These programs are intended to enhance grid resilience and protect customers from prolonged outages by providing electric utilities with timely access to emergency spare transmission equipment that otherwise can take months or longer to acquire.

As noted above, the GMD and physical security standards help provide protection against particular aspects of the EMP threat. However, FERC has not directed NERC to develop a standard specifically targeting EMP. To be clear, I believe this is the result of reasoned consideration of the issue. FERC has repeatedly demonstrated a willingness to direct NERC to develop or modify a reliability standard where FERC identifies a gap in the protection of the bulk-power system; indeed, the physical security and GMD standards, as well as an ongoing effort to develop a standard to address supply chain threats, were the result of FERC directives. It is also worth noting that directives to develop new standards have been supported by FERC commissioners from both parties, demonstrating a strong bipartisan commitment to grid reliability.

I recognize that some parties have challenged FERC's decision to proceed with a GMD standard that did not also include EMP threats more generally. I believe that FERC's approach has been prudent, given our understanding of those threats and potential mitigation to address them. With GMD, FERC was able to identify and direct a structured plan of monitoring, assessment, and mitigation that targets specific critical grid components (e.g., high voltage transformers) for protection against a GMD event. That plan was the result of years of FERC, NERC, and industry efforts to understand the GMD threat and determine how best to protect against it.

By comparison, large-scale EMP attacks pose a very different threat to the grid, and one that, to date, FERC has not determined is well-suited to a mandatory reliability standard at this time. Although much work has been done, there remains a significant amount of scientific research and debate underway about EMP threats. For example, in January 2017, DOE, in its role as the Sector-Specific Agency for the Energy Sector, issued its Electromagnetic Pulse Resilience Action Plan, which lays out a multi-year effort to improve our understanding of EMP threats, effects, and impacts; identify priority infrastructure; test and promote mitigation and protection approaches; enhance response and recovery capabilities; and share best practices. DOE, through the Los Alamos National Laboratory, is working with the Department of Homeland Security (DHS) to advance our understanding of EMP's effects on the electric power system. DOE's Idaho National Laboratory is also working to develop potential EMP strategies, protections, and mitigation for the electric grid. Similarly, the Electric Power Research Institute is currently conducting a multi-stage study of grid impacts associated with EMP threats, including evaluations of the impacts of E-1, E-2, and E-3 components.

In addition, last year, Congress directed DHS to conduct research and development on how to mitigate the consequences of threats of EMP and GMD, and report periodically over several years. A year earlier, Congress also re-authorized the EMP Commission, initially created in 2001, to continue to assess and report on the threats posed by EMP.

EMP threats present unique challenges as well. Unlike naturally-occurring GMD, which can be measured and subject to rigorous public scientific debate, EMP threats stem from hostile actors, particularly foreign nations, which introduces complexities regarding confidential national security information that are not readily adapted to FERC proceedings or the NERC standards development process. Any standard we may adopt in the future may need to differ from our usual standards, in order to avoid the security risk of announcing publicly the limits of our protective mitigation.

Furthermore, while there has been much written regarding the nature of the threat from EMP, consensus has not been reached regarding how best to protect against it. While the military has developed protocols to protect key assets, these protocols have been described by Los Alamos National Laboratory as "not widely implemented in civilian applications due to the expense," and by Idaho National Laboratory as "focused on load center protection for communication stations, control and mission critical facilities, not distribution, transmission and large generation assets for the electric power grid." Given the scope and potential cost of an effort to protect the entire grid against an EMP attack, I think it is prudent that FERC not launch a mandatory standard unless it concludes that the standard would effectively mitigate the threat at a justifiable cost. Ongoing research by DHS, DOE, and others eventually may support such a conclusion, but to date, FERC has not reached that conclusion.

That said, as described below, FERC remains actively engaged in efforts to understand and address the EMP threat. Those efforts will continue, and I am confident that, should FERC ultimately determine that a reliability standard is warranted, it will exercise its authority under FPA section 215 to require one.

Collaborative Efforts

FERC is also actively involved in efforts beyond its standards process. As noted above, FERC works closely with Federal agencies, state partners, and industry to identify key energy facilities; provide threat briefings, including on GMD and EMP threats; assist with the development and identification of best practices for mitigation; and cooperate with international partners to convey threat and mitigation information, as well as encourage adoption of best practices for mitigation. DOE, DHS, and the Department of Defense (DOD) have been particularly active on EMP issues, with DOE engaging the national labs to help support its efforts. In this regard, in 2015 I had the opportunity to visit the Idaho National Laboratory for a couple of days to learn about its work on cybersecurity and GMD issues.

Many of FERC's collaborative actions involve cross-sector, interagency, and public-private efforts to improve our collective understanding of GMD and EMP threats. For example, FERC participates in DOE's Electric Sector Coordinating Council, which is evaluating both EMP and GMD threats. In 2010 FERC, DHS, and DOE released a report conducted by the Oak Ridge National Laboratory that investigated and identified the effects of, and mitigation measures for, both GMD and EMP on the Nation's power grid. FERC is an active participant with the Energy Infrastructure Security Council, assisting with national and international collaboration. These efforts include the publication of resources in collaboration with DOE and participation in state and national table-top exercises simulating EMP attacks and coordinated responses as well as potential proactive protection measures.

FERC continues to monitor international efforts to address EMP and GMD, including collaborating on both foundational and best practices. In 2016, FERC exchanged information with Norway and expects to do so with both the UK and Israel later this year. On a national level, FERC briefed the EMP Commission earlier this year and has offered further collaboration to DHS, DOE, DOD, the national laboratories, and industry.

In addition, in November 2014, the National Science and Technology Council created the Space Weather Operations, Research, and Mitigation (SWORM) Task Force to develop high-level strategic goals for enhancing national preparedness for a severe space weather event. The SWORM Task Force is co-chaired by members from the Office of Science and Technology Policy, DHS, and the National Oceanic and Atmospheric Administration. FERC has participated in the SWORM Task Force's efforts from its inception. As a result of this work, FERC was an active participant with the development and release of both the National Space Weather Strategy and the National Space Weather Action Plan. FERC also assisted with the follow-up Executive Order released in October 2016 that, among other things, directed DOE and DHS to "develop a plan to test and evaluate available devices that mitigate the effects of geomagnetic disturbances on the electrical power grid through the development of a pilot program that deploys such devices." FERC has offered further assistance to DOE should this work proceed.

Most recently, FERC has assisted both DOE and DOD to identify defense-related critical electric infrastructure as directed under the FAST Act, thereby assisting with their decisions regarding EMP and GMD protection at these facilities. Further, in response to a directive of the FAST Act, DOE, after consulting with FERC and others, submitted a Strategic Transformer Reserve report to Congress in March 2017. This report described the importance of maintaining a strategic transformer reserve, as well as the current efforts underway by the industry and government to mitigate potential threats to the U.S. bulk-power system created by the vulnerabilities of these transformers. Specific to the subject of today's hearing, these threats include both EMP and GMD events. DOE recommends encouraging and supporting an industry strategic transformer reserve driven by voluntary industry actions and NERC's physical security reliability standard's requirements. DOE also recommends that it re-assess this approach in the future with FERC and electricity industry partners to determine whether sufficient progress has been made through this approach or if alternative actions by the government might be necessary. As noted above, FERC has encouraged these efforts through its collaborative outreach and ratemaking authority.

Thank you again for the opportunity to testify today. I would be happy to answer any questions you may have.

Hearing to examine the threat posed by electromagnetic pulse and policy options to protect energy infrastructure and to improve capabilities for adequate system restoration

10 a.m., May 4, 2017
Dirksen Senate Office Building
Room 366

Speaker Gingrich:

Good morning, I'd like to thank Chairman Murkowski, Ranking Member Cantwell, and the committee members for inviting me to testify today about the very real danger that electromagnetic pulse poses to the United States.

I wrote about this danger in my book *To Save America* in 2011.

Then, I acknowledged that we have known about the threat of electromagnetic pulse (EMP) since the mid-twentieth century. We learned then that setting off a nuclear explosion in the right way, and at the right altitude could simulate an enormous lightning strike, which could damage electronic devices and render them inoperable. Writing that book, I learned that testing hydrogen bombs in the Pacific resulted in burning out lights in Honolulu, which was 1,200 miles away from the test site.

As I wrote in 2011, anyone who has ever had a household appliance ruined by a power surge can understand the danger of EMPs, but our military has not fully assessed how an EMP strike could impact people in cities across the United States – and especially along the East Coast.

In 2004, Congressman Roscoe Bartlett called together a panel of nuclear physicists to study this issue. And according to their report, one EMP weapon detonated over Omaha would cripple half the economy. Further, they found that Russia, China and North Korea were working to develop EMP weapons – and the United States was quite vulnerable to an EMP attack.

Bill Forstchen, a friend who has co-authored books with me, wrote a sobering and horrifying novel about an EMP attack on the United States. The book is called *One Second After*, and in it Forstchen described how a small North Carolina town would be affected over the course of a year after a successful EMP attack. The story really illustrates how terrible such an assault could be.

As I argued in *To Save America*, within the next decade, there is no question that the United State should take action to develop a hardened, more resilient electrical system that could better withstand an EMP attack. Frankly, it is a matter of national survival.

The Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack reported in 2008 that, "the electromagnetic pulse generated by a high altitude nuclear explosion is one of a small number of threats that can hold our society at risk of catastrophic consequences."

The report went on to say: "Because of the ubiquitous dependence of U.S. society on the electrical power system, its vulnerability to an EMP attack, coupled with the EMP's particular damage mechanisms, creates the possibility of long-term, catastrophic consequences. The implicit invitation to take advantage of this vulnerability, when coupled with increasing proliferation of nuclear weapons and their delivery systems, is a serious concern. A single EMP attack may seriously degrade or shut down a large part of the electric power grid in the geographic area of EMP exposure effectively instantaneously. There is also a possibility of functional collapse of grids beyond the exposed area, as electrical effects propagate from one region to another."

Just consider if one of these pulses were to be unleashed and disabled the power infrastructure on the East Coast. This is not simply about the lights going out. Consider the consequences of hospitals and public safety agencies being without power, communication, or transportation for a significant amount of time.

This is a topic I am incredibly concerned – and passionate – about. I look forward to speaking with you about it today.

ON PROTECTING THE ELECTRIC POWER GRID

Testimony of Ambassador Henry F. Cooper

To

The U.S. Senate Committee on Energy and Natural Resources:

May 4, 2017 Hearing to examine the threat posed by electromagnetic pulse (EMP) and policy options to protect energy infrastructure and to improve capabilities for adequate system restoration.

Madam Chairman, thank you for this opportunity to share my views on the need to address the fragilities of the electric power grid and the means to do so. I view that the related current status and plans known to me leave the grid vulnerable to existential threats. And I believe we have the technical means to rectify these vulnerabilities—but are regrettably blocked from doing so, primarily because of political conditions that this Committee can, and hopefully will, address[1].

I consider that we are living in the most dangerous period of my lifetime for a number of reasons, but the vulnerability of our national electric power grid is among the most important ones. Moreover, I believe we have had clear warning of the nature of this threat for years, and are collectively continuing to ignore and/or take ineffective countermeasures to deal with it. Frankly, I have become so concerned about the dysfunctionality of the federal government in dealing with the threat that I am now spending whatever remaining time the Good Lord gives me to work with local and state authorities and private citizens to address the key issues from the "bottom up"—and I will address one of these important initiatives. If enough of our citizens gain an understanding of the issues and how they can—actually must—be addressed at the local level, then I believe Washington will eventually do its part in addressing this urgent problem.

The following sections briefly review some important lessons from recent events and their implications for understanding the various threats to the electric grid, including from natural and manmade EMP; the nature of this so far poorly addressed existential EMP threat; the maturing related threat posed by hostile adversaries and our thus far inept response; and recommended initiatives to counter that threat and protect the grid.

IMPORTANT LESSONS FROM RECENT EVENTS

To set the stage for discussing EMP issues, please consider the fragility/vulnerability of the electric grid illustrated by the events of Friday just three weeks ago (April 21st) when nearly concurrent grid outages occurred in New York City, in Los Angeles and particularly in San Francisco where, for hours, there was consequent jammed traffic, people stranded in elevators, hospitals on backup generators and other disruptions that continued for several hours before emergency management operations restored electric power[2].

[1] Please permit me to tell you why I believe you should consider my views on this important—and I believe—urgent matter. I am a PhD engineer, with very pertinent experience—from working on developing military and civilian systems at Bell Telephone Laboratories in the early 1960s, to over 20 years conducting research and developing simulators to test our strategic systems against nuclear weapons effects, to overseeing the Research, Development and Acquisition of U.S. Air Force Strategic and Space Systems under Presidents Carter and Reagan, to backstopping our bilateral negotiations with the Soviet Union while developing our national space arms control policy and serving as Chief U.S. Defense and Space Negotiator with the Soviet Union under President Reagan, as Strategic Defense Initiative (SDI) Director and Acquisition Executive for all our missile defense programs under President George H.W. Bush, and for 15 years as Chairman of the Board of Directors of a successful R&D company. In short, I've been around and solving technical and political problems of concern for essentially my entire professional career.

[2] See a Reuters review of these events at http://www.reuters.com/article/us-usa-sanfrancisco-power-idUSKBN17N27T

Joseph Weiss, an international authority on cybersecurity, control systems and system security regularly gives his views at http://www.controlglobal.com/blogs/unfettered/ . On April 24, he noted San Francisco's 7-hour outage was due to cascading effects triggered by a single breaker in one allegedly low-impact substation, the Larkin Street Substation. Weiss noted problems at this Larkin substation were identified years ago, but authorities have not taken remedial action. On April 28, he noted some root causes, like "thermally overloaded transmission lines" were well known years in advance and that this "home town" event should raise red flags at the Department of Energy (DOE), the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC) and the need for substantial improvements[3].

Indeed! This regulatory system is failing to protect the nation's electric grid from many threats, including EMP.

IMPORTANT IMPLICATIONS FOR THREATS TO THE GRID

From my perspective, Weiss' most important observation is that the major San Francisco grid failures cascaded from a single relatively "minor" event: A lowly breaker failure in a single substation, however caused[4]. This observation brings to mind conclusions by former FERC Chairman Jon Wellinghoff following the April 16, 2013 San Jose's Metcalf Substation attack that similar cascading failures from only nine identifiable substations could bring down the entire electric grid for an extended period[5]. But the Larkin Substation was enclosed in a structure that would have shown evidence of Metcalf kind of terrorist attack with rifle fire—not evidenced in San Francisco three weeks ago. Maybe terrorists with radio-frequency (RF) weapons could have triggered such a failure, but as Weiss pointedly wrote: "Given the walled enclosure, a physical attack such as the rifle attack against the PG&E Metcalf substation would not be possible."

Moreover, while simultaneous terrorist and cyberattacks could have been planned to occur across the nation[6], the concurrent events in cities on both the East and West Coasts more likely reflect the April 21 (updated on April 22) warning by *The Sun* (a United Kingdom News Company) that "a mega hole in the Sun could cause blackout mayhem" due to its "belching" of radioactive particles toward the Earth[7]. Thus, such "space weather" effects are understood and were anticipated.

NATURAL AND MANMADE EMP

This "Solar Hole" event was much less damaging than would be a Coronal Mass Ejection (CME) like in the 1859 Carrington event that interacted with the earth's geomagnetic field to produce a

[3] For more information, see http://www.controlglobal.com/blogs/unfettered/additional-information-concerning-the-april-21st-san-francisco-outage/ for Weise's April 28 message which includes a link to his April 24 message.
[4] Notably, Weiss told me this breaker failure brought to mind the 2007Aurora cyberattack demonstration conducted by Idaho National Laboratories that caused catastrophic damage to a generator associated with a nuclear plant, by commanding breakers out of phase with the grid's operating frequency. I do not believe this vulnerability has been rectified at all our nuclear plants—a very significant possibility if true, given their importance as discussed later.
[5] See the *Wall Street Journal* reports on this important matter at https://www.wsj.com/articles/assault-on-california-power-station-raises-alarm-on-potential-for-terrorism-1391570879?tesla=y and https://www.wsj.com/articles/u-s-risks-national-blackout-from-small-scale-attack-1394664965?tesla=y .
[6] See http://www.acq.osd.mil/dsb/reports/2010s/DSB-CyberDeterrenceReport_02-28-17_Final.pdf for a pertinent February 2017 Defense Science Board report, prefaced by the Chairman's conclusion: "The cyber threat to U.S. critical infrastructure is outpacing efforts to reduce pervasive vulnerabilities, so that for the next decade at least the United States must lean significantly on deterrence to address the cyber threat posed by the most capable U.S. adversaries."
[7] See https://www.thesun.co.uk/tech/3379806/solar-flare-spewing-from-mega-hole-in-the-sun-could-cause-blackout-mayhem-next-week/.

Geomagnetic Disturbance (GMD) that destroyed telegraph lines, with little impact on that low-tech agrarian society. Today, a Carrington-class CME/GMD would cause catastrophic damage to critical electronic infrastructure, particularly our unprotected electric power grid. We missed such an event by a week in 2012, as explained by NASA and other scientists[8] who study "Space Weather," or "natural" EMP. They project a 12-percent-per-decade likelihood for a Carrington CME/GMD.

While current efforts (however meritorious—see below) seek to protect the grid against such natural EMP events, little to nothing is being done to protect the grid against much more stressful "manmade" EMP, caused by nuclear weapons detonated high in or above the Earth's atmosphere.

Notably, if the grid is protected from manmade EMP attack, it will be protected from Natural EMP events—but the converse is not true, because of fundamental differences in the EMP pulses. Missing in the Natural EMP pulse are the high frequency components that threaten solid state electronics, like the supervisory control and data acquisition (SCADA) systems that control much of our critical infrastructure, including our electric grids and natural gas and petroleum pipelines.

OUR ENEMIES PLAN EMP ATTACKS—A RAPIDLY MATURING THREAT

Such manmade EMP attacks are known to be included in the doctrine and planning of Russia, China, North Korea and Iran. One particularly important report on Iranian doctrine and strategy was referenced by Rep. Trent Franks at the July 21, 2015 International Electric Infrastructure Security (EIS) Summit in Washington, DC[9]. He stated that the conclusion of this doctrine is that nuclear EMP is "an advanced and useful weapon in modern warfare."

These nations also have information on how to build low-yield "Super" EMP weapons. (It is a myth that high yield nuclear weapons are required to produce extensive and intensive EMP effects.) In 2004, the EMP Commission was advised by very senior Russian Generals, experts on nuclear EMP weapons, that this "Super" EMP knowledge had been transferred to North Korea, which would probably develop these weapons in a few years[10]. We should also assume that Iran knows whatever North Korea knows and has whatever the Mullahs wish to buy.

Thus, North Korea and Iran may now or in the foreseeable future actually have such low yield super EMP weapons—indeed, that possibility could explain North Korea's underground low-yield nuclear tests—and we should assume Iran also has that information. David Albright, an often quoted expert on these matters, estimates that North Korea already has 13-30 nuclear weapons and is capable of building 3-5 each year[11].

Both nations could deliver an EMP attack on the United States by simply detonating a nuclear weapon carried by one of their satellites as it passes over the United States—no hardened reentry vehicle or accurate guidance system is needed as would be the case for a conventional intercontinental ballistic missile (ICBM) targeted on a city or other surface target. Both nations have launched such satellites—Iran successfully placed satellites in orbit in 2009, 2011, 2012 and

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[8] See https://science.nasa.gov/science-news/science-at-nasa/2014/23jul_superstorm for a detailed discussion.

[9] Rep. Franks reported: "The National Intelligence University translated an Iranian military doctrine called *Passive Defense from 2010*, which emphasizes the importance of targeting critical infrastructure in warfare and references 22 times the use of EMP as a weapon to damage or disable the civilian electric grids of potential opponents. The Iranian doctrine states that nuclear and non-nuclear EMP weapons operate differently, but morally are the same.

[10] Personal Communication with Dr. William R. Graham, EMP Commission Chairman.

[11] See David Albright, "North Korea's Nuclear Capabilities: A Fresh Look," *Institute for Science and International Security*, April 28, 2017 at http://isis-online.org/isis-reports/detail/north-koreas-nuclear-capabilities-a-fresh-look

2015 but had a failure in 2016 and plans more attempts[12]; and North Korea, after several failed attempts, in 2012 and 2016[13].

These satellites were launched over the South Polar regions to approach the United States, from our mostly undefended South. The test launches generally are reported to be of concern because they could be a stepping stone to developing ICBMs—as is certainly the case. However, they also could be intended to develop a means to carry out an EMP attack on their first passage from the South over the United States[14]. And that is why that possibility should not continue to be ignored, especially since we have little if any defense against that possibility[15].

Moreover, the 2008 EMP Commission report[16] noted that Iran had in the late 1990s launched a ballistic missile from a barge in the Caspian Sea, and sent electronic signals that suggested it "triggered" a simulated a nuclear weapon detonation at altitudes up to 400 kilometers, to produce a potentially devastating EMP. To date, the United States has not deployed a ballistic missile defense (BMD) system to counter this identified threat that could originate on a vessel off our coasts—including from the Gulf of Mexico. We are essentially defenseless against this plausible threat[17].

MISSILE DEFENSE ROLE

Our Aegis BMD ships have demonstrated an ability to shoot down such threat missile/satellite attacks—if they operate with appropriately trained crews in response to the identified threat, especially when they are near our coasts.

Aegis BMD ships do not operate in the Gulf of Mexico, but the Aegis Ashore BMD system, now operational in Romania and slated to be operational in Poland by the end of this year, could be deployed on our military bases around the Gulf to protect us from such an attack[18].

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[12] See https://spaceflightnow.com/2015/02/02/iranian-satellite-successfully-placed-in-orbit/ and http://presstv.ir/Detail/2016/10/04/487619/Iran-Space-Agency-Mohsen-Bahrami-Sharif-Sat-Amirkabir-Nahid-I-satellite

[13] The most recent satellite http://www.space.com/31860-north-korea-satellite-launch.html was successfully placed in orbit but was subsequently reported to be "tumbling" and not transmitting signals.

[14] In February 2016, I joined Former CIA Director R. James Woolsey, Former Reagan Science Advisor (and EMP Commission Chairman) Dr. William R. Graham, Former Chairman of the National Intelligence Council Fritz Ermarth and EMP Commission Staff Director Dr. Peter Vincent Pry) to challenge underestimates of North Korea's and Iran's threat. See http://www.nationalreview.com/article/431206/iran-north-korea-nuclear-threats-are-very-real.

[15] U.S. Commander of Pacific Command Admiral Harry Harris testified last week that all nations should take the North Korean threat seriously because "North Korea's missiles point in all directions." Furthermore, Secretary of State Rex Tillerson also referred to this same fact in his Fox News interview with Bret Bair last Thursday. It would be reassuring if U.S. authorities also recognized that such missiles headed south can also deliver a devastating EMP strike by carrying a nuclear weapon payload and detonating it over us in its first orbit, rather than reentering the atmosphere to attack a American city. North Korea could plausibly accomplish this potentially existential threat attack today.

[16] The 2004 and 2008 reports of the Congressional Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, or the EMP Commission, can be found its webpage at http://www.empcommission.org/.

[17] Note that in 2013, a North Korean vessel was caught smuggling from Cuba two SA-2 rocket launchers and nuclear capable rockets (without warheads) under tons of sugar. See http://www.nbcnews.com/news/other/north-korean-ship-carrying-hidden-missile-equipment-detained-after-leaving-f6C10647045 .

[18] The Aegis BMD system, which I am proud to have originated as SDI Director, is in my opinion our most cost-effective BMD system with a very impressive test record, now deployed on 35 ships around the world and soon to be at several sites in a land based mode, including in Hawaii. It should be built on military bases around the Gulf of Mexico, beginning on Tyndall AFB in Panama City, Florida—home of 1st Air Force which has the lead mission for air defense of the continental United States, the Dominican Republic and Puerto Rico. No additional R&D is needed to protect Americans at home, just build the same Aegis Ashore system now deployed to protect our allies and overseas troops.

Congress and the President also should give our Aegis BMD ships a homeland defense mission when they are near or in our coastal waters—including while in port, e.g., at Norfolk, Virginia[19].

These BMD capabilities are technically available in the near term. I also urge that we return to the development of the most cost-effective BMD systems of the Strategic Defense Initiative (SDI) era (March 1983-January 1993)—those based in space that can intercept threat ballistic missiles beginning in their boost phase, while their rockets are still burning. We referred to this most cost-effective BMD concept as "Brilliant Pebbles." That program was cancelled abruptly in 1993 by the Clinton administration and as yet has not been revived. With the needed funding and management skills, I believe such a cost-effective system could be deployed within five or so years, now even more capable and for less money because of more advanced technology developed since 1993[20].

HARDEN THE GRID

But no defense is perfect—so we should "harden" our critical civil infrastructure, especially the electric power grid, against the full complement of threats. And it should be understood that if any adversary mounts an EMP attack against us, he will employ a preemptive combination of cyber, physical, radiofrequency and other weapon attacks to confuse and devalue our response.

As already acknowledged by the Obama administration, the grid must be hardened to protect against a GMD event that will surely one day occur, only its timing is uncertain. But as noted above, even if this hardening effort is successful (currently an unlikely prospect, based on my understanding of progress toward that end), it will not protect the grid from the manmade nuclear EMP threat—or from other threats that might be posed by terrorists or rogue regimes. Rather, we should be addressing the manmade nuclear EMP threat, together with protection against natural geomagnetic disturbances, with competently executed, integrated efforts that work the problem from the bottom up—beginning at the local level. Such efforts should also include protection against physical, cyber and radiofrequency weapon attacks.

As a prelude to my recommendations on how best to deal with this threat—which focus on protecting the grid from the bottom-up (beginning at the local level in conjunction with cooperative electric power companies (CoOps)), consider the Chairman of the EMP Commission Dr. William R. Graham's observations in his April 20 letter to Secretary of Energy Rick Perry[21]:

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[19] A few years ago, there were usually 4-6 Aegis ships near our East Coast or in port there. If coupled with one of our relatively inexpensive TPY-2 radars appropriately placed in New England, they could supplement our Ground Based Interceptors in Alaska—especially against ICBMs from Iran, long before an additional East Coast site can be built.

[20] See http://www.nationalreview.com/article/442532/ for a *National Review* article, "How Trump can Fulfill Reagan's Defense Vision" explaining the basis for a cost-effective "rapid startup" strategy, co-authored with Retired US Army Lt General Mal O'Neill, my Deputy SDI Director (and subsequently the BMD Acquisition Executive of the Clinton administration and Assistant Army Secretary for Acquisition, Logistics and Technology); Dr. Robert L. Pfaltzgraff Jr. president of the Institute for Foreign Policy Analysis (IFPA), Inc., and Shelby Cullom Davis Professor of International Security Studies at The Fletcher School, Tufts University, and chairman of the Independent Working Group on Missile Defense, and Retired USAF Colonel Rhip Worrell who was the SDI Brilliant Pebbles Program Manager.

[21] In introducing the following list, Dr. Graham indicated the context for these observations was to explore with the Secretary of Energy how the Energy Department was going to support to the Critical Infrastructure Protection Act (FY 2017 National Defense Authorization Act, Section 1913, "EMP and GMD Planning, Research and Development, and Protection and Preparedness" p. 1762), which directed the Department of Homeland Security: to develop plans to protect the electric grid and other critical infrastructures from EMP; to educate and train federal, state and local emergency planners and first responders on the EMP threat; and to conduct research and development to mitigate EMP.

1. Nuclear EMP is the ultimate cyber weapon in the military doctrines and plans of Russia, China, North Korea and Iran for Combined Arms Cyber Warfare that they see as a decisive new Revolution in Military Affairs.
2. Protecting the grid from the worst threat—nuclear EMP attack—can also mitigate lesser threats, including from natural EMP from solar storms, non-nuclear EMP from radiofrequency weapons, cyber-attacks, physical sabotage and severe weather.
3. State electric grids can be "islanded" by installation of surge arrestors, blocking devices, Faraday cages, and other devices to protect individual states, even though they may be part of a larger regional electric grid, from a prolonged catastrophic blackout. For example, Texas State Senator Bob Hall has introduced legislation to harden the Texas Electric Grid.
4. The Commission is profoundly concerned that the 2014 Obama administration intelligence community assessment of nuclear EMP is profoundly erroneous, and perhaps the worst ever produced on EMP, and that has been used to thwart efforts to protect the nation against nuclear EMP by dismissing the threat, despite overwhelming evidence to the contrary.
5. The Commission is very concerned over misleading and erroneous studies by the NERC and others that grossly underestimate the natural EMP threat from solar storms, and dangerously, have become the basis for grossly inadequate standards for EMP/GMD protection approved by the Obama administrations' FERC.
6. The Commission is also concerned over misleading and erroneous studies recently completed by industry's Electric Power Research Institute (EPRI), in cooperation with Obama administration holdovers in the Department of Energy, that grossly underestimate the nuclear EMP threat.

Dr. Graham's observations provide a sound basis for assessing and responding to the current vulnerabilities in the management and execution of efforts to provide a viable electric power grid. The EMP Commission is the most competent and technically credible source of such advice.

Below, I will elaborate on how I am actively seeking in South and North Carolina a stepping stone to achieve his third observation, by taking Texas State Senator Bob Hall's "islanding" approach to a more fundamental level.

It is interesting that when Dr. Graham and I were junior USAF officers at the Air Force Weapons Laboratory (AFWL) at Kirtland AFB, NM conducting research on nuclear weapons effects and developing simulators to test the nation's strategic systems and their essential command, control and communications (C3) systems to assure their viability under nuclear attack, Senator Hall was also a USAF junior officer at the Space and Missile Systems Organization (SAMSO) at Norton AFB, CA—helping to harden the Minuteman ICBM system, specifically to EMP effects. Our efforts were highly classified because all our systems were vulnerable to EMP—as then recently discovered on atmospheric nuclear tests. Our EMP knowledge base remained highly classified until most were downgraded and published in the 2008 EMP Commission report—see Footnote 16.

Now we have the opportunity again to cooperate on hardening the electric power grid (and other related critical infrastructure)—and to exploit the urgency of effecting change that I believe we all feel. This includes overcoming political challenges, which are in fact more daunting than the costs of making needed improvements or technical challenges, which were solved a half century ago by the Department of Defense (DoD) and its contractors expert in protecting military systems from the effects of nuclear weapons.

POLITICAL/BUREAUCRATIC CHALLENGES

Not the least of the political challenges is associated with ineptness in the responsible DoD agencies that have blocked progress—e.g., by stalling the initial startup of the Congressionally re-established EMP Commission by almost a year and, as I understand it, continuing to inhibit its effective operation. Moreover, DoD is withholding information it learned many years ago in establishing threat EMP environmental information standards to protect our strategic systems that our nation's power companies now need to develop, deploy and maintain effective hardening designs.

So, DOE laboratories and other agencies are conducting studies to learn again, under the best of conditions, lessons mastered by DoD nearly a half century ago. Under less desirable conditions on several fronts—and without the knowledge that comes from a half century of practical experience, the current efforts can easily—perhaps predictably—run amok.

In the decades when nuclear testing was conducted, the DOE had so little interest in EMP and other nuclear weapon effects that the DoD had to pay the DOE to calculate the necessary weapon gamma ray and other outputs to allow accurate EMP analyses to be performed by the DoD. Now that the DOE and its national laboratories are searching for relevant missions, both government and private monies are going to replicate what the DoD accomplished years ago at considerable taxpayer expense. See Dr. Graham's Items 5 and 6, above.

Moreover, political/bureaucratic problems come from mission conflicts between DoD and other government departments and agencies—particularly the Department of Homeland Security (DHS). Evidence of these difficulties was graphically illustrated a couple of years ago when then Commander of Northern Command (NORTHCOM) Admiral William Gortney made clear he understood the significance of the EMP threat (See Dr. Graham's Items 1 and 4.) by supporting a major program to improve the viability of his mission to provide warning to our strategic forces and the President (costing almost a billion dollars) to harden and move key equipment from Peterson AFB to his Cheyenne Mountain command center to assure viability of that mission against EMP.

At the same time, little has been done to assure the NORTHCOM's Homeland Defense mission is viable in the face of the same EMP attack—not NORTHCOM's job to protect the nation's critical civil infrastructure except in commanding our BMD systems. Admiral Gortney indicated his was a supporting role to DHS and the Justice Department. I again call your attention to Footnote 9 and note that to my knowledge DHS has not even listed EMP among the strategic disaster scenarios against which all emergency managers (federal, state and local) are supposed to prepare[22]. See Footnote 21 that explains Dr. Graham's purpose in his letter to Secretary Perry. Unlike the previous DHS Secretary, Secretary Kelley has stated his support for addressing such EMP and related issues.

Senator Hall certainly understands many of these political challenges, since this is his second try at getting the full Texas Senate to pass needed legislation to harden the Texas Grid—and the Texas legislature meets only every other year. Other states have tried and are trying to pass legislation in various formats to protect their citizens. But so far, most of their efforts have been blocked by a lethargic regulatory, self-supervising regime and lack of leadership at the federal level—in both the legislature and executive branches. And I would add, a lack of knowledge of what needs to be done.

[22] I'd also note that NORTHCOM has refused at least two attempts known to me by the SC Adjutant General's office to permit the National Guard to include EMP in its annual Vigilant Guard exercises. So the National Guard upon which we all depend in major emergencies is unprepared to deal with EMP threats.

In 2013, the first state legislation was initiated by State Representative Andrea Boland and passed in Maine, and I understand the subsequent response has been helpful but limited—inhibited by pushback from the private sector and a lethargic response by Maine's Public Utility Commission. That public record is pertinent for others to exploit. For example, a successful legislative initiative was passed in Virginia, and I understand it is being effectively supported by Dominion Electric—perhaps because Virginia's major military presence has a collective background that appreciates the EMP threat. A number of other states are considering initiatives as well.

WHAT TO DO?

Given these political/bureaucratic difficulties (and others), I concluded several years ago that I would never see major progress in dealing with the EMP existential threat in my lifetime, especially if the current conditions remain. And I could see no prospect for meaningful improvement. So, I decided to try a different approach and work the problem from the "bottom up" . . . literally.

I entered this phase with several biases, based on a lifetime of pertinent experiences, which have survived to this day and which guide my assessments and recommendations.

- I have no confidence that we will ever harden the entire grid, so I believe we have to establish priorities—I give top priority to assuring the safety and viability of our ~100 nuclear power plants that produce about 20-percent of the nation's electricity, and half the electricity of my home state South Carolina. Thus, I believe our top priority is to build protected "islands" around our nuclear power plants[23].
- To assure the viability of the nuclear power plants, we must first assure their cooling water systems are viable in an indefinite grid shutdown to avoid Fukushima-like disasters.
- We must assure that sufficient generating and loading conditions provided by the surrounding "island" in the grid—and linked with other critically important elements of the grid—are available to restart the nuclear power plants—and other power plants, which will shut down to protect themselves if the grid goes down.
- I don't believe anything that isn't regularly tested and subjected to independent critical review—effective design and deployment is not enough; truly effective testing and maintenance are major challenges.
- Accomplishing these objectives requires considerable emergency management cooperation at the local level—without which there is little hope for most citizens who today depend on electricity for life-line services in our "just-in-time" economy.

I approached the Electrical Engineering Department Chairman at my alma mater, Clemson University, and requested information on faculty who might be interested in my concerns and graduates who were employed by Duke Energy—one of the nation's largest companies, if not its largest, with whom I could begin working to address the EMP threat to the grid. I want to make clear I was not selling anything to or for Duke and would not take money from them if they offered it. I just want to cut through the morass described above, and provide hope that my grandkids can survive if we experience an EMP attack. I know that all our citizens want this objective met.

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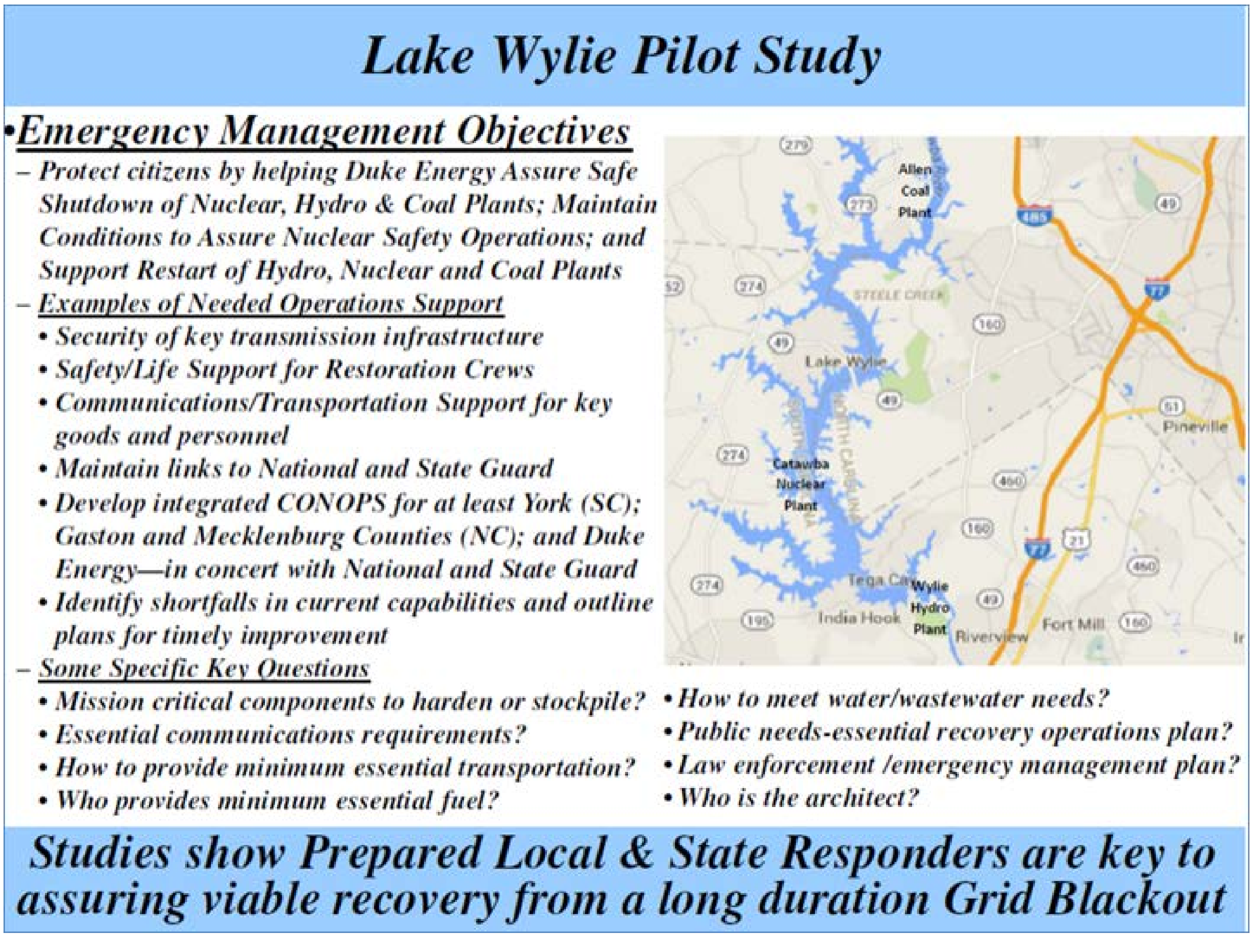
[23] This "Islanding" approach to prioritizing what to harden first is similar to the approach adopted by the DoD in giving top priority to protecting our strategic systems and their supporting command, control and communications systems. This objective was central to our "deterrent" policies of the Cold War. And we hardened little military infrastructure and essentially no critical civil infrastructure beyond assuring that we could meet that objective.

To make a long story short, I developed an excellent relationship with a key professor and several Duke engineers who also are concerned about this threat—and we agreed on how we could proceed with a meaningful "bottoms-up" program to assure the viability of three Duke Energy power plants on Lake Wylie, on the Catawba River that runs between North and South Carolina—and of course key transmission infrastructure that interconnects those power plants and others to their customers. We refer to this project as the "Lake Wylie Pilot Study," briefly summarized in the following chart.



I have now been working for nearly two years with Duke Energy engineers to address how best to assure we can restart the grid after a major blackout—while giving top priority to assuring the safety and viability of our Nuclear Power Plants[24]. Duke Energy's senior management has agreed to share broadly the lessons learned from the Lake Wylie Pilot Study.

In particular, we are working with local and state authorities and citizens to help Duke engineers exploit the most resilient electric power source, the Wylie Hydroelectric Power Plant, to assure availability of electricity to the cooling water pumps at the Catawba Nuclear Power Plant, if its diesel generator fuel is exhausted and can't be replaced. (See the list of "Needed Operations

[24] Along the way, I discovered that Duke Energy was funding related research at several universities and in cooperation with other energy companies. While that research is primarily focused on the cyber threat, EMP concerns will no doubt also receive attention. Recently I learned that Duke plans to invest significant funds to modernize and protect their power systems over the next 10 years, $13 billion in North Carolina (http://www.utilitydive.com/news/duke-energy-to-harden-north-carolinas-power-system-with-13b-initiative/440524/) and $25 billion in the several states in which they have infrastructure http://www.charlotteobserver.com/news/business/article133059044.html .

Support" and "Key Questions" in the above chart.) The Allen Coal Plant in Gaston County, NC also should be available relatively quickly and has a major supply of coal to support operations.

So, at a top level, the key operations of the Duke infrastructure are being considered and with no question Duke Energy intends to assure its power plants are functional after an EMP attack. From my perspective, there would likely be problems with SCADAs, especially those that control natural gas and petroleum pipeline operations, so that is a remaining concern—at least to me.

We are working to assure that electricity gets restored to subscribers around the Lake Wylie "Island" in the grid, especially high priority subscribers like the water-wastewater operations that are not served directly by Duke Energy infrastructure[25]. That service is provided by other utility companies and Electric Cooperatives (CoOps) that maintain important grid infrastructure between Duke Energy, from whom they purchase electricity, and their subscribers. Moreover, Duke Energy engineers need information from these utility companies and CoOps if they are to exploit that set of loading conditions to enable rapid restart of their power plant operations serving the general public throughout York County and beyond.

We are progressing well toward this end—engaging with city, county and state officials to assure (at least in York County, SC and Gaston and Mecklenburg Counties, NC) that the utility companies and CoOps who buy electricity from Duke and distribute it through their own grid infrastructure to their customers/subscribers are prepared to deal with a major grid outage. We seek to assure that Duke Energy's nuclear, hydroelectric and coal power plants serve the local interests—and that the lessons learned are exploited throughout South and North Carolina—and beyond. Our effort should serve as a pattern that can be followed in integrating the activities of the several thousand electric utilities and CoOps that are key to delivering electricity to their subscribers throughout the nation.

We plan to engage with others as we progress—as previously noted, I intend to join forces with Texas Senator Bob Hall and other friends in Texas as they progress with their legislative initiative and related efforts to harden the Texas Grid and especially related to nuclear power plants and associated islands in the overall grid. I also intend to engage other states, particularly Pennsylvania and Illinois. Like South and North Carolina, they rely heavily on electricity from nuclear plants.

I also intend to work closely with the National Guard and the Adjutants General of the United States because of their key roles in disaster emergency management activities[26].

Before we began our Lake Wylie Pilot Study in earnest, my Duke Energy partner engineers got approval from their front office that the lessons learned would not be treated as "Duke Proprietary"—but could be shared with others in the electric power and related sectors. We are working with local and county officials and associated utility companies and other CoOps to

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[25] Water-wastewater operations are perhaps the top priority, especially for urban operations. The June 2016 report by the National Infrastructure Advisory Council (NIAC) http://highfrontier.org/wp-content/uploads/2016/08/NIAC-Water-Sector-Resilience-Final-Report-Recommendations-July-2016.pdf indicates how key services are rapidly lost without water-wastewater services. For example, casualties in hospitals are expected within hours following a loss of water-wastewater support.

[26] While our SC Adjutant General—a Georgia Tech electrical engineering graduate—is on board with our Lake Wylie project, we have not yet engaged our state legislators to seek a supportive legislative initiative. However, SC State Senators and Legislators have indicated to me during the past two years that they would help sponsor such legislation when we are ready. The Duke engineers with whom I am working have cleared our project with their front office and lessons learned will be shared with all when we are ready. I understand from my Duke partners that they are fully engaged in a related NC initiative by their Lt. Governor.

understand how best to assure infrastructure connectivity to enable a Black Start following a major grid shutdown, beginning with the Lake Wylie "Island" in the grid.

South Carolina is one of the few states (joined only by Wisconsin when last I checked) focusing a statewide effort associated with NERC's November GRIDEX-IV national exercise on responding to cyber and physical attack threats. I believe the lessons learned will be helpful in extending, again from the bottom up, our Lake Wylie efforts. Therefore, we are also engaging with several other counties in this national exercise to build the relationships to share our lessons learned.

Note, there are several thousand utility companies and CoOps in the United States—so solving this important problem for that integrated "crazy quilt" distribution system is very complicated.

I have serious doubts that I will see a solution result in my lifetime from a "top-down" federal or state initiative. This is not to argue against such initiatives—which are important at least for consciousness-raising purposes. But I do worry that at best they have been proven to be very inefficient in producing serious progress in actually dealing with a truly existential threat.

I'm excited about our progress in working the problem from the bottom-up thus far—with a particular focus on assuring viable water-wastewater services to local citizens, and will be sharing more information in the future, especially with the lessons learned on how best to deal with the political issues that have for more than a decade confounded our collective progress.

My final comment is a lesson I have learned from my entire career: Effectively designing, deploying and operating any complex system requires a competent "Red Team" with access to all design, deployment and operations information, and which can challenge at the top level all efforts and report findings to the top management[27].

In my opinion, the EMP Commission should be chartered to play that role—indefinitely, and it should report directly to the President through an appropriate White House office hosting secretariat services.

Thank you for your interest and attention.

[27] During my watch as SDI Director (1990-93), I voluntarily sent several hundred million dollars from my five year budget to the Defense Special Weapons Agency (now the Defense Threat Reduction Agency) with no strings attached, except that the funds be spent to develop an independent competent assessment capability that could provide needed independent "Red Team" inputs to me (and my boss, the Secretary of Defense) on our BMD acquisition efforts. My distinct impression is that DTRA's capability and interest is a pale shadow of the DSWA's in that era a quarter century ago. I have no idea whether the key BMD systems developed under acquisition programs that I began (our ground-based interceptors in Alaska and California, our Aegis BMD system, our Patriot System or the THAAD system now being deployed in South Korea—and their associated command, control and communications systems) are confidently hardened against EMP, but without question, they certainly should be.

Testimony of

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Submitted to the

SENATE ENERGY & NATURAL RESOURCES COMMITTEE

For the May 4, 2017 Hearing

"To Examine the Threat Posed by Electromagnetic Pulse and Policy Options to Protect Energy Infrastructure"

Chairman Murkowski, Ranking Member Cantwell, and members of the Committee, thank you for inviting me to testify at the hearing today, "To examine the threat posed by electromagnetic pulse and policy options to protect energy infrastructure and to improve capabilities for adequate system restoration."

My name is Caitlin Durkovich. I had the honor of serving eight years in the National Protection and Programs Directorate at the Department of Homeland Security (DHS), first as the Chief of Staff and from May of 2012 to January 2017, as the Assistant Secretary of Infrastructure Protection. NPPD leads the national effort to protect and enhance the resilience of the nation's physical and cyber infrastructure.

I have transitioned from government to Toffler Associates, a future-focused strategic advisory firm that architects better futures for public and private sector clients around the globe with an unwavering commitment to be the catalyst for change.

Over my nearly twenty-year career in homeland security, I have seen critical infrastructure public-private risk management redefined to address emerging, complex issues from lone offenders to complex mass attacks, cybersecurity grid and GPS resilience, interdependencies, electromagnetic pulse (EMP) and severe geomagnetic disturbances (GMDs), and security-by-design. I have co-chaired several interagency task forces that have integrated the private sector into government strategies, including those that are most relevant today – the *Joint US-Canada*

Strategy for Electric Grid Security and Resilience (December 2016) and *The National Space Weather Strategy* (October 2015).

There is no doubt we live in a dangerous world. State and non-state actors, cyber threats, unbounded disasters, lone offenders, insiders, and promulgators of disinformation are growing in kind and consequence. These threats – and our vulnerabilities to them – transcend political treaties, geographic borders, and corporate lines of business, blurring the lines between public and private accountability and responsibility. It is the private sector, which owns and operates most of our critical infrastructure, that must invest in and manage the risks and often intertwined consequences posed by an increasingly dynamic threat environment.

The energy sector in particular faces a variety of threats and hazards, largely driven by the increasing sophisticated threat actors with intent and capability as well as the interdependencies of the infrastructure systems, including the increasing reliance on digital infrastructure as the electric grid transitions from an analog system to a digital system to improve efficiency. The bottom line is the risk to digital and physical infrastructures has grown and our critical infrastructure is more vulnerable than it was a few decades ago.

My colleagues in government have testified before other committees about how the public-private partnership views EMP, and my time out of government has not changed my understanding of the threat or my perspective; therefore, I will leverage the work of DHS and my colleagues within the DHS Office of Cyber and infrastructure Analysis.

Background on EMP

An EMP is the burst of electromagnetic radiation created, for instance, when a nuclear weapon is detonated or when a non-nuclear EMP weapon is used. EMPs can be high frequency, similar to a flash of lightning, or low frequency, similar to an aurora-induced phenomenon. The consequences of an EMP can range from permanent physical damage to temporary system disruptions, and can result in fires, electric shocks to people and equipment, and critical service outages.

There are two general classes of EMP of concern: (1) Nuclear sources of EMP, such as High altitude EMP (HEMP), and (2) Non-Nuclear sources of EMP (NNEP). HEMP results from a nuclear detonation typically occurring 15 or more miles above the Earth's surface. The extent of HEMP effects depends on several factors including the altitude of the detonation, the weapon yield, and whether it was designed for EMP effects. On the ground, effects may be diminished by the electromagnetic shielding, or "hardening," of assets. A high-altitude burst could blanket the entire continental United States and cause widespread impacts to multiple sectors, including to lifeline sectors, such as the energy and communications. HEMP threat vectors can originate from a missile, such as a sea-launched ballistic missile; a satellite asset; or a relatively low-cost balloon-borne vehicle.

Non-Nuclear EMP (NNEP) can be created by sources, such as Radio Frequency Weapons or Intentional Electromagnetic Interference devices, which are designed to produce sufficient electromagnetic energy to burn out or disrupt electronic components, systems, and networks. NNEP devices can be either electrically-driven, where they create narrowband or wideband microwaves, or explosively-driven, where an explosive is used to compress a magnetic field to generate the pulse. The range of an NNEP is short (typically less than 1 kilometer) and Faraday casings with line filters and surge arresters can mitigate much of the EMP effects.

Potential Impacts to Critical Infrastructure from EMP

We do not fully understand how an EMP event would impact electrical infrastructure, and it is the subject of ongoing analysis. In some of its forms, EMP could cause widespread disruption and serious damage to electronic devices and networks, including those upon which many critical infrastructures rely. There is uncertainty over the magnitude and duration of an electric power outage that may result from an EMP event due to ambiguity regarding the actual damage to electric power assets from an event. Any electric power outage resulting from an EMP event would ultimately depend upon several unknown factors and effects to assets that are challenging to accurately model, making it difficult to provide high-specificity information to electric system planners and system operators. These variables include characteristics such as the EMP device type, the location of the blast, the height of the blast, the yield of the blast, and design and operating parameters of the electric power system subject to the blast. Secondary effects of EMP may harm people through induced fires, electric shocks, and disruptions of transportation and critical support systems, such as those at hospitals or sites like nuclear power plants and chemical facilities.

In the development of *The National Space Weather Strategy*, we recognized that the growing interdependencies of critical infrastructure systems have increased potential vulnerabilities to EMPs and GMDs. Cross sector protection and mitigation efforts to eliminate or reduce EMP and GMD vulnerabilities are essential components of national preparedness. Protection focuses on capabilities and actions to eliminate vulnerabilities to EMP, and mitigation focuses on long-term vulnerability reduction and enhancing resilience to disasters. Together, these preparedness missions frame a national effort to reduce vulnerabilities and manage risks associated with EMPs, GMDs, and other unbounded events.

Government and Industry and Collaboration

More than two decades of critical infrastructure programs and policies has fostered unprecedented collaboration between government and industry to mitigate the consequences of low probability, high consequence events, including EMP.

DHS continues to devote resources to address EMP risks, largely in three areas (1) risk assessment and analysis, (2) communication and coordination of threat information, and (3) research and development to mitigate EMP risks. NPPD, the Federal Emergency Management Agency, and the Science and Technology Directorate are working with the critical infrastructure community to ensure it has information to make critical decisions, and can respond to, assist recovery and mitigate the consequences of a potential EMP attack.

My fellow witnesses will testify to the scope of efforts industry is undertaking to continue to improve grid resilience to all-hazards. They range from continued research and development, mutual assistance and spare parts programs, supplemental operating strategies, and full-scale cross sector exercises.

Critical Infrastructure Risk Management

It is important to emphasize, however, that critical infrastructure, including the electric sector, takes a holistic approach to assessing and mitigating risks from not only EMP, but from cyber attacks, physical sabotage, and natural disasters, all of which can result in disruptions to their operations. The partnership between industry and government, which includes information sharing, capability development, training and exercises, and interoperable plans, is even more essential as our Nation continues to face an increasingly complex threat environment.

Conclusion and Recommendations

EMP is one of many threats to the functions, systems, and networks that underpin our national security, economic prosperity, and American way of life. From cyber espionage and sabotage, to the convergence of cyber and physical systems, to insider threats, and to EMPs and GMDs, owners and operators of critical infrastructure have an obligation to manage these persistent threats. However, the solution requires a whole of community effort that is focused not on one threat but on a broad range of threats. These challenges demand industry and government work together to both develop mitigation plans and to invest in a modern and secure infrastructure that is resilient to the threats of today and tomorrow.

You can help by continuing to support national programs that strengthen public-private collaboration and enable the critical infrastructure community to efficiently and effectively manage the complex risk environment, and by continuing to advocate for a secure and resilient critical infrastructure.

Chairman Murkowski, Ranking Member Cantwell, and members of the Committee, thank you again for the opportunity to appear before you today. I look forward to your questions.

Written Testimony

Hearing of the U.S. Senate Energy and Natural Resources Committee

Robin E. Manning
Vice President, Transmission and Distribution
Electric Power Research Institute

"Hearing to examine the threat posed by electromagnetic pulse and policy options to protect energy infrastructure and to improve capabilities for adequate system restoration"

May 4, 2017

The Electric Power Research Institute (EPRI) conducts research and development relating to the generation, delivery, and use of electricity for the benefit of the public. An independent, non-profit organization, EPRI brings together its scientists and engineers, as well as experts from academia and industry, to help address challenges in electricity, including reliability, efficiency, affordability, health, safety, and the environment. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 30 countries.

The subject of today's testimony is EPRI's research efforts related to electromagnetic pulse (EMP) events, including naturally occurring geomagnetic disturbances (GMD) as well as electromagnetic pulse (EMP) events, specifically high altitude EMP, or HEMP. EPRI has been researching GMD for many years with significant applications now implemented across the electric industry. Implications and solutions for EMP and HEMP are less understood. Much of the available information is not specifically applied to electric utilities, making it very difficult for utilities and regulators to understand effective options for protecting energy infrastructure. This testimony provides an overview of EPRI's research activities related to GMD, and a more detailed description of our EMP research efforts as we seek to better inform the issue with a firm technical basis for decision making.

GMD Research

During geomagnetic disturbance (GMD) events, magnetic field variations at the earth's surface drive low-frequency electric currents along transmission lines and through transformer windings to ground. These geomagnetically induced currents (GIC) cause half-cycle saturation of transformers leading to harmonic generation, increased reactive power losses, and heating of transformer windings and structural components. These effects are real, and have been observed in the past. For example, during the March 1989 geomagnetic storm, Hydro-Quebec experienced a blackout resulting from the effects of GMD-related harmonics, and a generator step-up unit (GSU) at Salem Nuclear Power Plant in New Jersey was damaged from resulting hotspot heating. Several other effects were observed in the United States and Canada, for example tripping of capacitor banks, but these did not result in any significant reliability impacts[1].

EPRI recognizes the potential impacts of severe GMD events, and has been involved in GMD-related research for nearly four decades[2]. Some of EPRI's research activities in this area include:

- developing sensors and a support network for measuring GIC;
- developing software tools, models and guidelines to assess the impacts of severe GMD events on the bulk-power system;
- improving the fidelity of existing models (e.g. earth conductivity);
- improving understanding of potential impacts of GMD events on bulk-power system components;
- evaluating mitigation options and their application; and
- supporting the development of benchmark GMD events used in assessments.

Because EPRI's research in the GMD area is expansive, only current activities will be addressed.

Geomagnetic Field Monitoring

EPRI currently has a research project underway to install three axis magnetometer sensors between existing magnetic observatories operated by the U.S. Geological Survey (USGS) to improve magnetic field resolution throughout the United States. Measurement data will be used to validate deep earth conductivity models, and improve understanding of local geological factors that can affect the geoelectric field induction process.

SUNBURST Network

The EPRI SUNBURST network is both an organized method for measuring geomagnetically induced currents (GICs) and a source of data for continuing research studying the cause, effects and mitigation of GIC impacts on electrical power systems. While the primary focus of this research is operating the monitoring network, the data collected in this project will be used for feedback into new prediction models that will serve as advance warnings, that is, the NASA Solar Shield project. The SUNBURST project also supports an annual event where relevant scientists from the field of solar phenomena/space weather come together to discuss common issues and concerns related to GICs.

The SUNBURST network consists of a consortium of member utilities where near-real-time continuous monitoring of the GIC flowing in the neutral of large power transformers is performed. Over the last decade, EPRI has accumulated a body of data and experience about correlations between space weather and GIC flows in the grid.

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[1] North American Electric Reliability Corporation (NERC), March 13, 1989 Geomagnetic Disturbance: www.nerc.com/files/1989-quebec-disturbance.pdf

[2] *Investigation of Geomagnetically Induced Currents in the Proposed Winnipeg-Dulluth-Twin Cities 500 kV Transmission Line.* EPRI, Palo Alto, CA: 1981. EL-1949

New GIC Sensor

One of the limitations of measuring GIC using current technology (e.g. SUNBURST) is that the monitoring location must be the neutral of the transformer. Depending on the type of transformer, e.g. an autotransformer, a neutral connected GIC node may not provide the observability necessary to determine the GIC flows that could affect power system operation. To fill this gap, EPRI has recently developed a sensor that is capable of measuring GIC flows in energized conductors. Measurement of GIC in energized AC (alternating current) transmission lines and transformer windings improves observability of the behavior and effects of GIC on the bulk-power system. In addition, GIC flows through interconnections and in some cases, remote transformers can be measured directly. This will lead to developing more effective network boundary models, and closer representation of actual GIC conditions when assessing impact to transformers.

Current Research in Grid Operations & Planning Area

Harmonics studies are an integral part of any GMD vulnerability assessment, and as such, are a key component of related reliability and planning assessments and associated regulatory requirements, e.g. NERC TPL-007-1 standard. However, commercially-available software tools or industry guidelines necessary to perform such assessments are limited. To fill this gap, EPRI is developing an open source software tool that can be used to perform GMD-related harmonics studies. Additionally, guidelines for performing assessments to determine the potential impacts of GMD-related harmonics on the bulk-power system are being developed.

EMP Research

Electromagnetic pulse (EMP) attacks and geomagnetic disturbance (GMD) events are often discussed together when evaluating potential impacts on the bulk-power system and approaches for improving system resiliency. While both events are considered high-impact low-frequency (HILF) events (along with physical attacks, severe storms, earthquakes, and other similar events), there are very important differences that should be considered when evaluating resiliency improvement priorities and investment decisions.

The high-altitude detonation of a nuclear weapon can generate a large electromagnetic pulse (referred to as a high-altitude EMP or HEMP) that is comprised of three components: E1, E2 and E3. Depending on weapon yield and height of burst the resulting EMP can impact large geographical areas such as the size of an electrical interconnection. The early-time pulse, E1, refers to a nearly instantaneous (rise times are on the order of 2.5 nanoseconds or 2.5 billionths of a second) – large magnitude (50 kV/m) pulse that can result in damage to electronic components and electric infrastructure. The intermediate-time pulse or E2, refers to the short duration pulse which has characteristics similar to lightning although the magnitude of E2 is much lower (~ 0.1 kV/m) and the way in which it couples into electric infrastructure is different. The latter component, magnetohydrodynamic electromagnetic pulse (MHD-EMP) or simply E3 is similar to a severe GMD event, and can drive low frequency, geomagnetically-induced currents (GIC) in transmission lines and power transformers. However, there are two key differences between E3 and GMD. First, E3 from a single high-altitude detonation would not generate planetary-scale effects like a severe GMD event can. Secondly, the magnitude and duration of E3 are significantly different. The magnitude of E3 can be much higher than that of a severe GMD event; however, the duration of E3 is much shorter lasting only a few minutes as compared with days in the case of a severe GMD event. As with severe GMD events, potential impacts from E3 range from voltage collapse to increased hotspot heating in bulk-power transformers.

EMP Research Project Description

HEMP events are a growing concern in the energy business. While the industry has worked to develop effective responses to GMD, little definitive work has centered on the effects of a HEMP attack. Numerous constituencies are pressing to ensure the electric power system is more resilient to a large HEMP event, but technical information is inconsistent and options to increase resilience through hardening and recovery are not well-defined. Some proposed approaches are high-cost and lack the technical basis to substantiate their viability. To fill this gap, EPRI initiated a three-year research project in April 2016, currently with financial support from fifty-six electric utilities, to improve understanding of the potential impacts of HEMP on the bulk-power system and develop cost-effective mitigation options. The financial support of EPRI's members demonstrates the importance to them of providing scientific and technical analysis of this issue for the benefit of the public.

As a part of this research project EPRI is collaborating closely with the U.S. Department of Energy (DOE), national laboratories, and the U.S. Department of Defense (DoD).

The EPRI EMP project is comprised of 7 tasks which are as follows.

<u>Task 1 –HEMP Threat Characterization</u>

As a part of the threat characterization task, we are:

- identifying the state of knowledge of unclassified HEMP research,
- identifying conservative (bounding) HEMP waveforms (magnitude, spatial and time dependent characteristics, etc.) that can be used to assess the potential impacts on bulk-power system components, and
- investigating the physics of HEMP propagation and coupling to power system infrastructure.

As a part of this research, all three components of the HEMP environment are being evaluated, i.e., E1, E2, and E3.

In September 2016, EPRI released its first report[3] associated with this task which is a compendium describing the state of knowledge of HEMP research that is relevant to the electric

[3] *High-Altitude Electromagnetic Pulse Effects on Bulk-Power Systems: State of Knowledge and Research Needs.* EPRI, Palo Alto, CA: 2016. 3002008999.

power industry as well as a suite of unclassified HEMP environments that can be used in power system assessments.

We are currently developing models to simulate coupling of E1/E2 into transmission infrastructure (substation bus work, control cables, control houses, etc.) and are performing an analysis of a transmission substation to determine impacts of E1/E2 on equipment. Modeling results will also be used to inform equipment testing and mitigation efforts. Simulation work has begun and will continue into 2018. EPRI is currently working with Lawrence Livermore National Laboratory (LLNL) to further research in this area.

Additionally, an important component of this research is to develop tools that utilities can use to perform their own assessments. To that end, EPRI is developing software tools and modeling guidelines that can be used by utilities to simulate the coupling of an E1 pulse into overhead and underground conductors and/or control cables. The beta version of the overhead conductor coupling tool is expected to be finished by the fourth quarter of 2017.

Task 2 – Electric Infrastructure EMP Vulnerability

This task is identifying the vulnerability of transmission systems and support assets (protection and control systems, communications, SCADA, cables, transformers, insulators, etc.) exposed to the HEMP threat defined in Task 1 – HEMP Threat Characterization by performing laboratory tests. To facilitate high-volume EMP testing of components, EPRI is building two EMP test labs and updating our high-voltage test lab in Lenox, MA to test systems and components by subjecting them to synthetic EMP pulses (E1). Equipment testing will include both radiated and conducted transients. Testing of protection and control (P&C) systems to determine impacts of E1 is initial priority. Testing is expected to begin by the second quarter of 2017 with initial results possible by the end of the year.

In addition to performing tests internally, EPRI is also partnering with Sandia National Laboratory and Little Mountain Test Facility to perform additional E1 testing of P&C equipment.

Task 3 – Electric Infrastructure Impacts

This task is assessing the potential impacts of a HEMP attack on the bulk-power system by combining the modeling results of Task 1 with the equipment testing results of Task 2. Assessment techniques, models and tools for assessing the impacts of a HEMP attack are also being developed.

The first of many studies has been completed, and will be described in more detail later in this testimony. A report[4] assessing the potential effects of E3 on U.S. bulk-power transformers was released in February 2017. A companion report assessing the potential impacts of E3 on the stability of the bulk-power system is expected to be finished by the third quarter of 2017.

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[4] *Magnetohydrodynamic Electromagnetic Pulse Assessment of the Continental U.S. Electric Grid: Geomagnetically Induced Current and Transformer Thermal Analysis.* EPRI, Palo Alto, CA:2017. 3002009001

The results of the first E1 threat assessment are expected by the end of the year.

<u>Task 4 – Mitigation, Hardening and Recovery</u>

This task is assessing various mitigation and hardening approaches that can be employed to reduce the impacts of HEMP on bulk-power system reliability. Potential unintended consequences of various mitigation and hardening strategies are being evaluated. Enhanced recovery procedures/plans are being developed.

As an initial step, EPRI is developing interim guidance on hardening substations using information provided in relevant IEC[5] and military standards. This is only a first step, and EPRI is not recommending utilities harden to these standards. Future research efforts aim to develop cost-effective hardening and mitigation solutions that are relevant to electric power infrastructure. Interim guidance is expected to be completed and made available to project members by the third quarter of 2017.

<u>Task 5 – Risk-based Decision Support</u>

This task is developing methodologies and tools to support risk-informed decisions regarding the implementation of HEMP hardening and mitigation measures. A framework for assessing the relative benefits of various hardening and mitigation approaches will be developed. Support tools designed to aid in decision making will be developed as a part of this task.

<u>Task 6 – Trial Implementation</u>

Once hardening measures have been identified, supporting member utilities will have the opportunity to evaluate implementation on aspects of their systems. This task will develop a collection of leading industry practices with regards to HEMP mitigation and hardening. Applications of various assessment techniques and mitigation options will be catalogued, and the effectiveness and lessons learned will be communicated.

<u>Task 7 – Project Member and Stakeholder Communication</u>

An important aspect of this research project is communicating the results to our supporting members and stakeholders as appropriate. This task is developing communications to inform of the background and potential impacts of HEMP, and appropriately share new learning in a timely manner.

February, 2017 Report: E3 Assessment of the Continental U.S. Electric Grid

GIC generated by E3 resulting from a HEMP attack can cause additional hotspot heating in windings and structural parts of bulk-power transformers. If heating is severe enough, it can cause damage to the transformer. The loss of hundreds of bulk-power transformers could create an environment where system recovery is not possible in a timely manner resulting in long-term

[5] IEC is the International Electrotechnology Commission – an international standards organization

blackout. Thus, one of the first steps in this three-year research project was to evaluate the potential impacts of E3 on bulk-power transformers.

Past research performed by Oak Ridge National Laboratories (ORNL) during the mid-late 1980's through early 1990's and late 2000's evaluated the potential impacts of E3 on bulk-power transformers; however, the results of the ORNL research had conflicting conclusions. Earlier ORNL research[6] concluded that E3 would not result in significant damage to bulk-power transformers while a later research report[7] concluded that transformer damage was likely, and that up to 100 transformers could be damaged depending on the target location.

The purpose of the EPRI study was to determine, using advanced transformer models that were not available at the time of the ORNL research, whether or not a significant number (hundreds) of bulk-power transformers would experience thermal damage from a single E3 event. More simply, the study sought to answer the question, "if a HEMP attack occurred, would there be enough bulk-power transformers left to facilitate system recovery?"

The fundamental approach to the EPRI study was similar to that adopted by the North American Electric Reliability Corporation (NERC) to assess the potential impacts of severe geomagnetic disturbance (GMD) events on bulk-power transformers. First, the electric field environment necessary for calculating GIC flows was identified and a direct current model of the interconnection-wide system was assembled. For this study, a publicly available E3 environment along with a model of the United States bulk electric system was used to calculate the GIC flows in the transmission system that would result from a single, high-altitude detonation over the continental United States (CONUS). GIC calculations were then performed assuming weapon detonation over 11 separate locations in the CONUS. The resulting time-series GIC flows were then used to compute the time-series hotspot temperature of each bulk-power system transformer included in the interconnection-wide assessment using physically-based transformer models. The maximum instantaneous hotspot temperatures were then evaluated against conservative temperature limits that were based on an assumed condition-based GIC susceptibility category of the entire transformer fleet. The number of transformers that were identified as exceeding the specified temperature limits were then combined with the probabilities of a given transformer being in one of the three specified categories to estimate the expected number of bulk-power transformers to be at potential risk of thermal damage. Additionally, the potential for thermal damage caused by circulating harmonic currents in the tertiary windings of large autotransformers was also evaluated.

The EPRI study found that although a significant number of transformers (hundreds to thousands) could experience GIC flows greater than the 75 amps/phase screening criteria adopted from NERC TPL-007-1, only a small number (3 to 14 depending on the target location evaluated) of these transformers were found to be at potential risk of thermal damage. In addition, the at-risk transformers were found to be geographically dispersed.

[6] Electromagnetic Pulse Research on Electric Power Systems: Program Summary and Recommendations. Oak Ridge National Laboratories, Oak Ridge, TN: 1993. ORNL-6708.

[7] Meta-R-321, The Late-Time (E3) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid. Metatech Corporation, January 2010.

The results of this study agree with earlier work performed by ORNL which indicate that the failure of a large number (hundreds) of bulk-power transformers from E3 is unlikely. The assessment results can be used to help quantify the overall risk of E3 impacting the bulk-power system (interconnection-level assessment), but they should not be interpreted to indicate E3 will not affect bulk-power reliability since the potential for widespread outages due to voltage collapse or the synergistic effects of E1, E2 and E3 are still being investigated. Additionally, because of the number of conservative assumptions that were required due to the lack of asset specific data, the results should not be used to inform investment decisions at individual utilities.

A companion study to the GIC and transformer thermal assessment, an analysis determining the potential for voltage collapse resulting from E3, is expected to be completed by the third quarter of 2017. Future research will be aimed at improving the assessment process to include the synergistic effects of E1, E2 and E3.

Concluding Remarks

The potential impacts of GMD and HEMP are real; however, evaluating the effects of such events on existing and future power grid infrastructure requires concrete, scientifically-based analysis. Once the true impacts are known, including the potential unintended consequences of mitigation options, cost effective mitigation and/or recovery options can be developed and employed.

The recent E3 assessment of the US bulk-power transformer fleet is merely a first step in a series of studies aimed at informing the electric utility industry of the potential impacts of HEMP on the bulk-power system. Although the results of this assessment indicate that E3 from a single high-altitude detonation would have marginal effect on bulk-power transformers, the results should not be interpreted as indicating that HEMP will not affect bulk-power system reliability. More research is needed to determine the impacts of E1 on bulk-power system assets, and more importantly, the ability to accurately capture, through modeling and analysis, the synergistic effects of E1, E2 and E3 is needed to assess the true impact of HEMP on the grid and develop cost-effective mitigation options.

EPRI is committed to developing science-based solutions to these difficult problems, and offers technical leadership and support to the electricity sector, public policymakers, and other stakeholders to enable safe, reliable, affordable, and environmentally responsible electricity to the people of the United States.

Supplemental Document to the Testimony of

KEVIN WAILES

Chief Executive Officer, Lincoln Electric System

On Behalf of the American Public Power Association

Submitted to the

SENATE ENERGY & NATURAL RESOURCES COMMITTEE

For the May 4, 2017, Hearing

"To Examine the Threat Posed by Electromagnetic Pulse and Policy Options to Protect Energy Infrastructure"

Exercises

The electric sector plans and regularly exercises for a variety of emergency situations that could impact their ability to provide electricity. The industry participates in many incident response exercises, including five national-level exercises since November 2015.

I. **GridEx III** *(NERC, November 2015)* gathered more than 360 organizations and 4,400 participants from industry, government agencies, and partners in Canada and Mexico. GridEX III also included an executive tabletop exercise where 32 electric sector executives and senior U.S. government officials worked through incident response protocols to address widespread outages.
II. **Clear Path IV** *(DOE, April 2016)* convened 200 participants from the oil and gas and electric power industries and federal and state officials to test response and restoration protocols to a catastrophic simulated earthquake and tsunami in the Pacific Northwest.
III. **Cascadia Rising** *(FEMA, June 2016)* was a three-day exercise that tested first responders and government emergency personnel responders and government emergency personnel responses in the immediate aftermath of a significant earthquake.
IV. **Cyber Guard** *(DOD/NSA, June 2016)* was a two-week exercise that tested the response capabilities of 1,000 energy, IT, transportation, and government experts to a major cyber-attack.
V. **Joint Financial Services – Electric Sector Cyber Exercise** *(Treasury, August 2016)* examined incident response capabilities and interdependencies between the two sectors.

Spare Equipment Programs

Electric companies regularly share transformers and other equipment to improve grid resilience from a range of threats. There are multiple spare transformer initiatives:

I. **Spare Transformer Equipment Program (STEP) -** In 2006, federal energy regulators approved the Spare Transformer Equipment Program (STEP), an electric industry program that strengthens the sector's ability to restore the nation's transmission system more quickly in the event of a terrorist attack. STEP represents a coordinated approach to increasing the electric power industry's inventory of spare transformers and streamlining the process of transferring those transformers to affected utilities in the event of a transmission outage caused by a terrorist attack.

Under the program, each participating electric utility is required to maintain and, if necessary, acquire a specific number of transformers. STEP requires each participating utility to sell its spare transformers to any other participating utility that suffers a "triggering event," defined as an act of terrorism that destroys or disables one or more substations and results in the declared state of emergency by the President of the United States.

Any investor-owned, government-owned, or rural electric cooperative utility in the United States or Canada may participate in the program. Currently over 50 utilities are members.

II. **SpareConnect** - The SpareConnect program provides an additional mechanism for Bulk Power System (BPS) asset owners and operators to network with other SpareConnect participants concerning the possible sharing of transmission and generation step-up (GSU) transformers and related equipment, including bushings, fans and auxiliary components. SpareConnect establishes a confidential, unified platform for the entire electric industry to communicate equipment needs in the event of an emergency or other non-routine failure.

SpareConnect complements existing programs, such as the Spare Transformer Equipment Program (STEP) and voluntary mutual assistance programs, by establishing an additional, trusted network of participants who are uniquely capable of providing assistance concerning equipment availability and technical resources. SpareConnect does not create or manage a central database of spare equipment. Instead, SpareConnect provides decentralized access to points of contact at power companies so that, in the event of an emergency, SpareConnect participants are able to connect quickly with other participants in affected voltage classes. SpareConnect does not impose any obligation on participants to provide any information or to make any particular piece of equipment available. Once connected, those SpareConnect participants who are interested in providing additional information or sharing equipment work directly and privately with each other on the specific terms and conditions of any potential equipment sale or other transaction.

As of March 27, 2017, SpareConnect has 129 member utilities. Seven of the municipal utility members are joint action agencies that participate on behalf of themselves and their 176 municipally-owned utilities. Generation & Transmission (G&T) cooperatives within SpareConnect participate on behalf of 180 distribution cooperative systems.

III. **Grid Assurance –** Launched in 2016 by six large electric utility companies, Grid Assurance is an independent company created to enhance grid resiliency by giving electric transmission owners faster access to long-lead time critical equipment necessary to recover from catastrophic events that could impact the nation’s electric grid. More information is available at http://www.gridassurance.com/#IndustryDriven