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PROTECTING THE ELECTRIC GRID FROM THE POTENTIAL THREATS OF SOLAR STORMS AND ELECTROMAGNETIC PULSE

HEARING

BEFORE THE

COMMITTEE ON HOMELAND SECURITY AND GOVERNMENTAL AFFAIRS UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

FIRST SESSION

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WEDNESDAY, JULY 22, 2015

U.S. SENATE,
COMMITTEE ON HOMELAND SECURITY
AND GOVERNMENTAL AFFAIRS,
Washington, DC.

The Committee met, pursuant to notice, at 10:01 a.m., in room SD–342, Dirksen Senate Office Building, Hon. Ron Johnson, Chairman of the Committee, presiding.

Present: Senators Johnson, Ayotte, Ernst, Sasse, Carper, McCaskill, and Peters.

OPENING STATEMENT OF CHAIRMAN JOHNSON

Chairman JOHNSON. Now that I have my cup of coffee, this hearing will come to order. Senator Carper will be a little bit late, so he told me that I could start the hearing without him.

Let me first welcome our witnesses. Thank you for your thoughtful testimony. I have read it all. I hope every Committee Member has read it all. I hope everybody in the audience has, and I would encourage members of the public to read this testimony and pay attention to this hearing.

I was first made aware of the potential threat of electromagnetic pulse (EMP), disruptions to our electrical grid and geomagnetic disturbances (GMD) well before I ever became a United States Senator. But I think like most members of the public, it is one of those scary things that is, "Ah, that is just science fiction. What are the chances of that?"

When I became a United States Senator, I was briefed by a couple gentlemen who gave me a booklet that I read that made me pretty concerned. This was probably a couple of years ago, and I started talking to other Members, and a lot of those Members never really even heard of this threat.

I have raised this in secure briefings with members of the Department of Homeland Security (DHS), and I have been told, "OK, we are on that. We are looking into it."

But the fact of the matter is that this was first made public and declassified in 2004, and we had a congressional commission on that. And then we had another commission in 2008, and the dangers posed by EMP and GMD have been well known really for decades but made public now for over 10 years, and we literally have not done anything.

So the purpose of this hearing is to basically stop and pull our head out of the sand, and start paying attention to this very real threat. We are going to be debating a nuclear deal with the State of Iran. We already know we have North Korea with both nuclear weapon capability and ballistic missile technology, and that ballistic missile technology is improving in North Korea.

We know that Iran has those exact same ambitions, and I guess now we have a deal that is going to end an embargo on their ballistic missile technology. There are satellites that are orbiting overhead that could potentially deliver a nuclear explosion that would cause something like this. So this is a threat that is real and that we need to acknowledge.

Now, as I was made aware of this and I started talking to colleagues, a lot of time people's opinion of this was marginalized by, "Well, those are just lobbyists that want to sell the Federal Government some protections." I think we need to keep our eyes open for that type of conflict. But it is no reason to not be addressing this and taking a look in a very serious fashion.

So today we have I think, a good panel of witnesses, starting with Ambassador James Woolsey and Joseph McClelland and Richard Garwin and Chris Currie and Bridgette Bourge—am I pronouncing that correctly?

Ms. BOURGE. Yes, Senator.

Chairman JOHNSON. That is actually unusual that I get it right the first time.—some people that will give us the truth and give us the information on this. So I am looking forward to your testimony. When Senator Carper gets here, we will give him an opportunity to make an opening statement as well, but let us just start by maintaining the tradition of this Committee, which is that we do swear witnesses in. So if you would all rise and raise your right hand. Do you swear that the testimony you will give before this Committee will be the truth, the whole truth, and nothing but the truth, so help you, God?

Mr. WOOLSEY. I do.

Mr. MCCLELLAND. I do.

Mr. GARWIN. I do.

Mr. CURRIE. I do.

Ms. BOURGE. I do.

Chairman JOHNSON. Thank you. Please sit.

Our first witness will be Ambassador James Woolsey. Ambassador Woolsey is the former Director of Central Intelligence and Ambassador to and chief negotiator for the Conventional Forces in Europe Treaty from 1989 to 1991. He is currently the Chairman of the Foundation for Defense of Democracies and is a venture partner with Lux Capital Management. Ambassador Woolsey.

TESTIMONY OF THE HONORABLE R. JAMES WOOLSEY,[1] FORMER DIRECTOR OF CENTRAL INTELLIGENCE, AND CHAIRMAN, FOUNDATION FOR DEFENSE OF DEMOCRACIES; ACCOMPANIED BY PETER VINCENT PRY, PH.D., EXECUTIVE DIRECTOR OF THE TASK FORCE ON NATIONAL HOMELAND SECURITY

Mr. WOOLSEY. Thank you, Mr. Chairman. In the interest of our 6-minute limit, I will summarize quickly several major points.

First of all, the Earth has been being bombarded by electromagnetic pulses for about 4½ billion years, so in one sense, this is not a new issue. And I am not going to get into the details of the difference between the different wavelengths from electromagnetic pulses versus those created by the Sun and the like, but will generalize more in the interest of time.

We have a very serious problem with exactly what you described: lack of willingness to admit or understand at the beginning that this could be as serious as it is given how horrible it is. People tend to want to shove those types of issues aside.

But, in fact, there are ways in which electromagnetic pulse threats are more serious than a conventional version of a nuclear threat. For example, deterrence may not work at all with respect to electromagnetic pulse. The reason is we may not know where the pulse came from. If everything goes dark, it may be a solar event, and it may be North Korea.

Furthermore, a satellite can be launched into orbit with a southern trajectory, so it misses, at least initially, all of our radars and other sensors that are focused north. And, second, it could be launched—a Scud with a warhead could be launched from a freighter off one of our coasts. We recently had a North Korean freighter picked up by the Panamanians that had two air defense missiles in it, each capable of putting something into orbit.

So we have a very serious problem from the point of view of deterring particularly a country such as Iran or North Korea that is not playing by anywhere close to the standards of rationality that one would see even in, let us say, China or Russia when we are having tense relations with one another.

So I think that is the first and biggest problem. We do not just have a probability issue the way one would have if we were only worried about the solar EMP events. That could be bad enough because we are due for a very large pulse event. The last one occurred over a century and a half ago, and we are due for another. But that could come anytime or not come for some time.

The decision by a North Korean leader or an Iranian leader that it is time to destroy the electric grid of the United States is a different matter. We do not know what they are going to do and when. People say, "Well, they are not crazy." But sometimes individual government leaders such as Adolf Hitler are mad north by northwest. They have horrible objectives, and they pursue them very diligently. The objectives are not something any of us would sympathize with.

The same could well be true of an Iranian missile, which they have now, and an Iranian nuclear weapon, which I think even

[1] The prepared statement of Ambassador Woolsey appears in the Appendix on page 49.

under this agreement they are likely to have or be able to have within months to perhaps a year or two.

The use of electromagnetic pulse has been embodied in writings in the East, Russian and Chinese particularly. I would call everybody's attention to the work of the Russian General Vladimir Slipchenko in his military textbooks which focus on EMP together with cyber as the new mode of warfare. An EMP for the North Korean, Iranian, Russian, and Chinese point of view is part of cyber and a particularly deadly part.

There have been a number of efforts for us to find some way to take positive steps to do something about electromagnetic pulse, whether from a nuclear weapon or from the sun, and they have all been thwarted. Washington is completely dysfunctional on this issue and has been for some time. The amount of money involved is relatively small by infrastructure need standards. According to the EMP Commission, about $2 billion, about what we give in foreign aid to Pakistan every year for dealing with the essentials of the electric grid, $10 to 20 billion, according to the Commission, would protect all of the critical infrastructures from nuclear EMP attack.

From the point of view of the cost of improvements in our infrastructures that are badly needed, that is not a great deal of money. But so far the resistance in the North American Electrical Reliability Corporation (NERC), and in industry has been solid and total. They have been able to prevent steps by individual States that have wanted to take action, and they have done everything they possibly can to keep the Critical Infrastructure Protection Act (CIPA) and the reestablishment of the congressional EMP Commission and the SHIELD and GRID Acts all bottled up and not being able to be passed by the Congress.

One, perhaps two pointed observations by Texas State Senator Robert Hall, a former Air Force colonel and himself an EMP expert, characterizes the behavior of the electric utilities and their lobbyists on this matter, Mr. Chairman, as "equivalent to treason."

Thank you.

Chairman JOHNSON. Thank you, Ambassador Woolsey.

Our next witness will be Joseph McClelland. Mr. McClelland is the Director of the Office of Energy Infrastructure Security (OEIS) at the Federal Energy Regulatory Commission (FERC). His office provides leadership, expertise, and assistance to identify, communicate, and seek comprehensive solutions to potential risks to FERC-regulated facilities from cyber attacks and physical threats such as electromagnetic pulses. Mr. McClelland.

TESTIMONY OF JOSEPH MCCLELLAND,[1] DIRECTOR, OFFICE OF ENERGY INFRASTRUCTURE SECURITY, FEDERAL ENERGY REGULATORY COMMISSION

Mr. MCCLELLAND. Thank you, Chairman Johnson, for the privilege to appear before you today to discuss threats to the electric grid in the United States. In the interest of time and pursuant to your request, I will skip over the section that details the E1, E2, and E3 threats.

[1] The prepared statement of Mr. McClelland appears in the Appendix on page 62.

My name is Joe McClelland, and I am the Director of the Office of Energy Infrastructure Security at the Federal Energy Regulatory Commission. I am here today as a Commission staff witness, and my remarks do not necessarily represent the views of the Commission or any individual Commissioner.

Under Section 215 of the Federal Power Act, the Commission is entrusted with the responsibility to approve and enforce mandatory reliability standards for the Nation's bulk power system. These standards are developed and proposed by the North American Electrical Reliability Corporation.

Section 215 of the Federal Power Act provides a statutory framework for the development of reliability standards for the bulk power system. However, the nature of a national security threat by entities intent on attacking the United States through its electric grid stands in stark contrast to other major reliability events that have caused blackouts and reliability failures in the past. Widespread disruption of electric service can quickly undermine the U.S. Government, its military, and the economy, as well as endanger the health and safety of millions of its citizens.

Therefore, to provide a significantly more agile and focused approach to these growing cyber and physical security threats, the Commission established our office in late 2012. Our office's mission includes responses to geomagnetic disturbances and electromagnetic pulses.

Just briefly, in 2001 Congress established a Commission to assess and report on the threat from EMP. In 2004 and again in 2008, the Commission issued reports on these threats. One of the key findings in the reports was that a single EMP attack could seriously degrade or shut down a large part of the electric power grid. Depending upon the attack, significant parts of electric infrastructure could be "out of service for periods measured in months to a year or more." And some would say that is optimistic.

In order to better understand and quantify the effect of EMP and GMD on the power grid, FERC staff, the Department of Energy (DOE), and the Department of Homeland Security, all three agencies, sponsored a single study conducted by the Oak Ridge National Laboratory in 2010. The results of the study support the general conclusion of prior studies that EMP and GMD events pose substantial risk to equipment and operation of the Nation's electric grid and under extreme conditions could result in major long-term electrical outages. Unlike EMP attacks that are dependent upon the capability and intent of an attacker, GMD disturbances are inevitable with only the timing and magnitude subject to variability. The Oak Ridge study assessed a solar storm that occurred in May 1921, which has been termed a 1-in-100-year event, and applied it to today's electric grid. The study concluded that such a storm could damage or destroy over 300 high-voltage electric grid transformers and interrupt service to 130 million people with some outages lasting for a period of years.

To help address these matters, the Commission has used both regulatory and collaborative actions.

Under its regulator authority, the Commission ordered NERC to develop two GMD reliability standards for the bulk power system,

requiring new operational procedures and vulnerability assessments.

Under its collaborative programs, the Commission actively participates with Federal agencies and industry members to establish action plans, develop risk assessments that identify key energy facilities, and prioritize best practices that exceed regulatory requirements at those facilities for cyber and physical security matters, including both GMD and EMP.

In addition, the Commission continues to facilitate threat briefings to industry members and cooperate with our international partners to compare ongoing initiatives.

Internationally, over a dozen nations have GMD and/or EMP programs in place or are in the early stages of addressing or examining the impacts of GMD and EMP. For the United States, although GMD baseline standards and some best practices are being established for portions of the electric grid, few entities have taken steps to address EMP on their systems.

In conclusion, these types of threats pose a serious risk to the electric grid and its supporting infrastructures that serve our Nation.

Thank you for the opportunity to be here today, and I would be delighted to answer any questions you have.

Chairman JOHNSON. Thank you, Mr. McClelland.

Our next witness is Dr. Richard Garwin. Dr. Garwin is a Fellow Emeritus at the IBM Thomas J. Watson Research Center, testifying in his personal capacity. He brings significant experience on issues related to electromagnetic pulse. In what is now the Los Alamos Laboratory, he outlined the first design for a hydrogen bomb and wrote the first paper on the electromagnetic pulse from nuclear explosions in the atmosphere. He has served as an adviser to the Federal Government for decades on national security issues, including by serving on the JASON Defense Advisory Board. He is a member of the National Academies of Science, Engineering, and Medicine, among other organizations, and he has received the Enrico Fermi Award, the R.V. Jones Award for Scientific Intelligence, and the National Medal of Science.

Dr. Garwin, when we met earlier, I remembered reading a briefing that Enrico Fermi referred to you as one of the only true geniuses he had ever met, so I think that is pretty good praise from somebody that is also a genius. We are looking forward to your testimony. Dr. Garwin.

TESTIMONY OF RICHARD L. GARWIN, PH.D.,[1] FELLOW EMERITUS, IBM THOMAS J. WATSON RESEARCH CENTER

Dr. GARWIN. Thank you, Mr. Chairman. Actually, Ambassador Woolsey created the R.V. Jones Award, which was later awarded to me.

The spectacular images of Pluto this week from the National Aeronautics and Space Administration (NASA) New Horizons probe provoked great interest in our solar system. But our solar system is a matter for concern, as well. The 1,200 people injured in February 2013 at Chelyabinsk, Russia, from a bolide—a meteor—

[1] The prepared statement of Dr. Garwin appears in the Appendix on page 69.

brought substantial focus on low-probability, high-consequence events. Among these are particularly intense magnetic storms from space—weather events or coronal mass ejections from the Sun, possibly even more intense than the 1859 Carrington Event in the pre-electric grid era.

Another potentially great impact on the electrical grid and modern society is the electromagnetic pulse from high-altitude nuclear explosions, on the order of 100 kilometers or more above the Earth's surface.

The United States has been a leader in long-distance transmission of electrical power, but its system differs in characteristics, management, and organization from those of other advanced States. Nevertheless, there is much to be learned from and by the United States in working to make our electrical grid robust and economical in the modern era of technological threats and opportunities.

I begin with my recommendations to ease and essentially solve the severe problem posed by geomagnetic storms induced by space weather—specifically by the routine ejection from the sun of enormous blocks of plasma that travel out within the solar system and reach the Earth typically in a couple of days. Most of these coronal mass ejections do not reach the Earth. They go in other directions. When they do reach the Earth, they cause displays of the Northern Lights and Southern Lights, and, more importantly, the magnetized plasma and its incorporated magnetic field merge with the magnetic field of the Earth and change it by a relatively small amount, which, however, can create large currents on long electrical conductors such as pipelines, telegraph wires in the old days, and the electrical power transmission system—the Bulk Power System.

Very serious consequences are estimated for such an event of a magnitude that can be expected to occur at random once per century.

I emphasize that a once-per-century event might occur next week; it has a probability of 10 percent of occurring within the next 10 years—a time in which we can and should take measures to reduce and essentially eliminate its impact on the Bulk Power System of the United States. But events expected to occur once in 20 years can cause significant damage and disruption.

My recommendations regarding the Bulk Power System: Missing in Federal policy and practice is a program to:

One, train and equip utility and transmission operators to bring down within seconds—that is, to switch off—transmission lines that are at risk of being damaged;

Two, implement "rapid islanding" of the grid, to maintain a large fraction of the power consumers in operation by the use of whatever island—that is, local—generation capacity exists; this also facilitates restoring the Bulk Power System to operation, in contrast with a so-called black start.

Three, fit transmission lines on a priority basis with "neutral current-blocking devices"—capacitors—in the common neutral-to-ground link of the three-phase transformers of extra-high-voltage transmission systems at one end of the line—whether three-phase transformers or three single-phase transformers. Where trans-

formers at both ends are autotransformers, this may not be possible, in which case series-blocking capacitors in the power lines themselves should be installed and could be kept shorted until an EMP event is recognized, or a geomagnetic storm.

Four, alert grid operators and others to a high-altitude nuclear explosion within thousandths of a second of the event (by detection of the unambiguous very brief E1 pulse).

In my supplemental testimony submitted for the record, I provide support for these recommendations and explain why they would largely and immediately also eliminate long-lasting damage to the extra-high-voltage transmissions system that might otherwise result from a high-altitude nuclear explosion.

So if we solve the problem that is sure to arise from space weather and geomagnetic storm, we will solve the long-distance transmission problem from high-altitude nuclear explosions, which may or may not arise.

Those are also deterrable if they are from a place like North Korea or Iran, and, it is better to plan to deter them by means of our projected response, as well as to prevent damage from their happening. But those are two arms of the response.

I should say that in 2011 I was a co-author of a study by the JASON group, "Impacts of Severe Space Weather on the Electric Grid," and on pages 3 to 5 of that report, there are recommendations that include the ones I am giving now.

Also, interestingly, there is the so-called E–PRO Handbook, the electric protection handbook, Executive Summary 2014 and International E–PRO Report of September 2013. That specifically advocates geomagnetic storm-induced current blockers, the neutral current ground interruptors, series capacitance in lines, reducing transformer loads, and real-time threshold-based transformer protection.

Finally, I say that series-blocking capacitors in the power lines themselves are poorly understood. These are small devices, not like the enormous fields of transformers, of capacitors that are deployed for power—factor correction. But it is a little difficult to understand them because they have to be bigger in capacitance but smaller by a factor of 100 or 30 altogether because they have less energy storage, less mega-volt ampere ratings than the power factor correction. But maybe as a result of this hearing, they will get more attention.

Thank you.

Chairman JOHNSON. Thank you, Dr. Garwin. And that obviously is the purpose of this hearing.

Our next witness is Mr. Chris Currie. Mr. Currie is a Director of the Government Accountability Office (GAO), where he leads the agency's work in evaluating emergency management, national preparedness, and critical infrastructure protection issues. In this role, Chris has led reviews of numerous Federal programs and efforts to prevent, plan for, and respond to natural and manmade disasters and terrorist attacks. Mr. Currie.

TESTIMONY OF CHRISTOPHER P. CURRIE,[1] DIRECTOR, HOMELAND SECURITY AND JUSTICE, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Mr. CURRIE. Thank you, Chairman Johnson and Ranking Member Carper and other Members that are here today. We appreciate the opportunity to be here today and testify.

Within the United States there are 16 critical infrastructure sectors, for example, water, transportation systems, agriculture, and, of course, energy. The energy sector ties all of these sectors together, and without it, the others just cannot function. This makes protecting it a national security priority. So I think the others on the panel have done a really good job of setting up the EMP and the solar weather threat. Both could cause power outages across large parts of the country for a long period of time.

That threat was so great that Congress established a whole Commission on EMP in 2001, which issued reports in 2004 and 2008, and had many recommendations.

GAO is currently evaluating the Department of Homeland Security's efforts to address EMP threats and electromagnetic threats in general, and today I would like to share our preliminary findings in two areas: the first is the extent to which DHS has addressed the 2008 EMP Commission recommendations; and the second is DHS' efforts to coordinate with other Federal agencies and industry stakeholders to mitigate risks to the electric grid.

So far, we have found that DHS has taken some actions to mitigate the threats to the grid. These include developing mitigation projects and planning for the consequences of an event like an EMP, among other things. So two quick examples of these actions are:

DHS is developing an R&D prototype transformer that would allow utilities to replace critical large transformers within a week, as opposed to the months it could take now, and it is currently testing that.

Also, for example, the Federal Emergency Management Agency (FEMA) is developing a specific Incident Annex to deal with a long-term power outage, and while this is not specific to electromagnetic threats, this plan would address one of the biggest side effects of an EMP or solar event.

In regard to coordination, we have found so far that DHS has coordinated with stakeholders to address some but not all risks to the electric grid. Some of these actions address electromagnetic threats. For example, DHS participates in interagency working groups that are designed to prepare and respond to space weather events. However, our preliminary work shows that DHS has not fully coordinated with stakeholders in areas like sharing threat information, identifying key infrastructure assets, and identifying research priorities, just as examples.

So, for example, within those areas, energy industry officials told us that they lack sufficient threat information to determine if they should take actions to mitigate against an EMP. They also said that this information would help them justify these investments to their management and shareholders. And this is similar to our past

[1] The prepared statement of Mr. Currie appears in the Appendix on page 77.

work and recommendations related to cyber threats. In that work, we found that Federal agencies' efforts to share information did not always meet industry expectations, in part because of restrictions on information that can be shared. And DHS has since taken steps to implement those recommendations in that area, including granting security clearances and establishing a secure mechanism to share cyber threat information.

In another example, we have found that DHS and the Department of Energy have not identified the most critical energy substations and transformers on the grid. This was a key recommendation of the EMP Commission, and this information would help prioritize investments to mitigate against the largest vulnerabilities.

There are a couple final and overarching points I would like to make based on our work.

First, while DHS has taken some actions, as I have mentioned, there has been no integrated effort to address the EMP Commission recommendations. In fact, we have seen some confusion within DHS about who is responsible for taking lead on this.

Second, although DHS is not required by law to implement the Commission's recommendations, many of the recommendations align with responsibilities that DHS and DOE already have for protecting critical infrastructure and coordinating these efforts, such as under the National Infrastructure Protection Plan. For example, DHS and DOE have not identified roles and responsibilities for addressing electromagnetic impacts to the grid.

As we complete our review, we will continue to evaluate the extent that DHS has implemented the EMP Commission recommendations and determine where specific coordination efforts could be improved, and we expect to issue our final report later this year.

This completes my prepared remarks, and I would be happy to answer any questions you have.

Chairman JOHNSON. Thank you, Mr. Currie.

Our final witness is Ms. Bridgette Bourge. Ms. Bourge is a senior principal for legislative affairs at the National Rural Electric Cooperative Association (NRECA), where she leads the work on homeland security policy issues. She previously served as a consultant to the Department of Homeland Security on critical infrastructure issues. Ms. Bourge.

TESTIMONY OF BRIDGETTE BOURGE,[1] SENIOR PRINCIPAL, LEGISLATIVE AFFAIRS, NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION

Ms. BOURGE. Thank you. It is an honor to be here to testify today on behalf of the industry about the threat of solar storms and electromagnetic pulses on the bulk power system.

As the Chairman mentioned, I do work for the National Rural Electric Cooperative Association. I advocate for best security practices that recognize the reality of the threat environments on behalf of a service organization that serves over 900 not-for-profit

[1] The prepared statement of Ms. Bourge appears in the Appendix on page 97.

electric utilities providing reliable power to over 42 million people in 47 States.

As member-owned, not-for-profit utilities, electric cooperatives focus on providing reliable electricity at the lowest reasonable cost. Anything that undermines that mandate undermines our members. Our member owners bear every cost. There is never any debate over whether a proposed project benefits cooperative stakeholders or cooperative customers. They are one and the same.

I am not going to get into defining EMPs or GMDs. I think we have gone into that quite a bit here. I do want to stress, though, that we are a little concerned that there is some misinformation out there that fails to reflect the reality and factual danger of either phenomenon. These two are entirely separate threats, both in nature and in execution, with different causations and impacts. Yet they are, nevertheless, regularly conflated as the same.

GMDs are common, relatively common natural events that can result from a solar storm. We actually had a few weeks ago a 3-day occurrence of GMDs at a G3 level. You saw no impact from the bulk power system. You felt nothing from that. We have standards and processes in place to address the GMDs at those levels.

As you heard from Mr. McClelland, we are in the process of waiting on an additional set of standards that will help us plan for the 100-year event scenario. So industry does address the GMD. We are aware of that issue and highly engaged on that issue, and we are continuing to address that issue.

Electromagnetic pulses from a nuclear detonation are a little different, from our perspective. They require a different technology solution. They also require different planning, different mitigation, different preparation. I would actually like to read from the EMP Commission here where it says, "It is not practical to try to protect the entire electrical power system or even all high-value components from damage by an EMP event. There are too many components of too many different types, manufacturers, ages, and designs. The cost and time would be prohibitive. Widespread collapse of the electrical power system in the area affected by EMP is virtually inevitable after a broad geographic EMP attack, with even a modest number of unprotected components."

So basically the EMP Commission even had the same view of protecting the grid will not guarantee the grid stays up. So we have to look at this, separate the issues. A GMD is a solar storm. It is something we do work on, we do address.

EMPs are something we also address through policy and planning, not so much through the technology solution, because we do not see it as something we can guarantee survival on. We do try to protect it, and we do want to look toward planning scenarios so that we can recover from it. When you hear people talk about spare transformers, that is an idea that we think is very valuable and should be looked at most certainly. And you see some bills actually over in the House proposing that type of concept, and the Department of Energy, I believe, just recently put out a request for information on how they might be able to do such a thing. That is an area of focus where industry thinks that we would be very beneficial to turn toward.

We have to remember when you are conflating the EMPs and GMDs, you have the chance of impacting existing standards, existing processes, existing mitigation efforts. GMDs are something that impacts the electric grid. It is something that impacts communications systems. EMPs are something that impacts all critical infrastructure. If you have a microprocessor, more than likely you are going to feel an impact. You are going to have an impact on our hospitals, on our transportation, on our fuel lines. These are interdependent critical infrastructures. They rely on us, but we also rely on them. If we have no fuel, if we have no water to cool, we will not function.

So when you say everyone else needs electricity to work, electricity needs others to work as well. So simply finding a way to harden a grid that will, per the EMP Commission, still likely come down, when no one else is hardened, when we still will fail because there are no protections anywhere else does not seem like the best focus of our energy and time. We want to focus on that recovery scenario for the low-likelihood, high-impact events like an EMP, which we do see as distinctly different than the GMD.

That is the conclusion of my testimony. If anyone has any questions, I would be happy to answer them.

Chairman JOHNSON. Thank you, Ms. Bourge.

I will start the questioning, but before I start the clock, I did a pretty good job of convincing all the panel members not to describe E1, E2, E3, and GMD, so nobody did. So I guess what I would like to do is I think Mr. McClelland might be the best person to, please just kind of walk us through really what we are talking about here, because it is, EMP is different from the GMD, although there are certainly similarities in terms of some of the effects on some of it. So if you would just kind of educate us on that, and then I will start asking questions.

Mr. MCCLELLAND. Sure. Mr. Chairman, I will read, because I have summarized it very succinctly, and I think comprehensively. So within a paragraph, I think I can address it here at your request.

Chairman JOHNSON. Thank you.

Mr. MCCLELLAND. GMD and EMP events are generated either from naturally occurring or manmade causes. In the case of geomagnetic disturbances, or GMDs, solar magnetic disturbances periodically disrupt the Earth's magnetic field, which in turn can induce currents on the electric grid that can damage or destroy key transformers over a large geographic area.

Regarding manmade events, EMPs can be generated by devices that range from small, portable, battery-powered units through missiles equipped with nuclear warheads. In the case of the former—the battery-powered units—the equipment is readily 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. The EMP generated during the detonation of a nuclear device is far more encompassing and generates three distinct effects: a short high energy radio-frequency-type burst called E1 that destroys electronics; a slightly longer burst that is similar to lightning termed E2; and a final effect termed E3 that is similar in character and effect to the GMD targeting the

same equipment including key transformers. Any of these effects can cause voltage problems and instability on the electric grid, which can lead to prolonged wide-area blackouts.

So the key distinction between the two, geomagnetic disturbances and we will go with the nuclear because it covers the range—the nuclear EMP is that nuclear EMP generates two other effects: E1, which damages and destroys electronics; E2, which is similar to lightning, and the common belief in the community is that E2 has been mitigated or is readily mitigated by the lightning practices of the utilities today; and then E3, which is a longer-term effect which generates those geomagnetically induced type currents that destroy key pieces of transformers.

So if you mitigate against GMD, you have mitigated really against everything but E1, the E1 effect from a nuclear detonation.

Chairman JOHNSON. Let me just ask the open question: Does anybody disagree with that basic description? Or would you want to tweak it in some way? Ambassador Woolsey.

Mr. WOOLSEY. I do not disagree. Most of what I know about these issues I have learned from Joe McClelland. But I want to stress that the EMP Commission did not—repeat, not—conclude that it is futile to protect the grid. The Commission recommended protecting the grid in such a way that it would fail gracefully, essentially, so it could be quickly recovered. But the industry across the board has gotten very, very good at pointing the finger at other parts——

Chairman JOHNSON. And, again, we will get into that discussion.

Mr. WOOLSEY. All right.

Chairman JOHNSON. Again, right now I just want to lay the predicate in terms of this is what we are talking about.

Mr. WOOLSEY. Got it.

Chairman JOHNSON. E1, E2, E3, EMP versus GMD, and GMD and EMP with the E3 that is a similar effect. OK. I just wanted to get—and I also did want to—you talked about a G3 level happening all the time. What would be the level of the 100-year event or the Carrington Effect? What is that on the scale? Anybody?

Mr. MCCLELLAND. That is going to be like a K8, K9 effect, and we have not seen one. So we have not seen a 1921 level effect. We have seen two others, and they are very interesting. One is in 1989. We saw about a half of a 1921 event, and it collapsed the grid of Canada. The Quebec grid collapsed very quickly. We also saw a fraction of that event in South Africa in October 2003 that destroyed over 12 large bulk power system transformers. It was very small, so it did not collapse the grid, but it was off for a prolonged period of time, destroyed that critical equipment at a very low level.

Chairman JOHNSON. OK. So you had the Carrington Effect, which was, what, 1859?

Mr. MCCLELLAND. 1859.

Chairman JOHNSON. And that in this G-scale would be a G8 or G9?

Mr. MCCLELLAND. Well, I would say K9.

Chairman JOHNSON. OK, K9. Again, not that this really means anything to anybody, but it just kind of gives order of magnitude. So you had the Carrington Effect, which was kind of once in a cen-

tury, but that has been 150 years. Then we had the 1921 event, what would that have been on that scale?

Mr. MCCLELLAND. I have the nanoteslas, but as far as relating it to the K-factor, I am sorry, I would not be able to answer that question here.

Chairman JOHNSON. Way more than a G3, though?

Mr. MCCLELLAND. Yes.

Chairman JOHNSON. How about on a scale of 1 to 10? I am just trying to get some sort of idea of the magnitude of these things, from a Carrington to what we are seeing, almost background noise, but this is happening all the time. And we have all seen disruptions to TV signals, satellite signals, that type of thing, but kind of the minor annoyances.

I think it is also true that Lloyd's of London says that on average there is about $2 billion worth of damage from these G3 types of effects annually.

Again, so Carrington was massive; 1921 was not quite as massive as the Carrington Effect. Correct?

Mr. MCCLELLAND. Right.

Chairman JOHNSON. The next one was in Canada?

Mr. MCCLELLAND. Yes, in 1989.

Chairman JOHNSON. In 1989. Do you have that on a scale?

Mr. MCCLELLAND. I do. I can pull it up for you. If the 1921 event was 5,000 nanoteslas, the Canadian event was about 1,100 or 1,200 nanoteslas, so about a fifth. I would say about a fifth.

Chairman JOHNSON. It was a fifth of the 1921 event, and it shut down all of Canada's electrical grid?

Mr. MCCLELLAND. It shut down Hydroelectric of Quebec, the entire Quebec grid, shut down in 93 seconds; 6 million customers were out of power for about 10 hours. The estimated cost, I have heard cost estimates of $1 to $2 billion, but very minor equipment damage. So they were able to restore very quickly, but still the cost was very significant.

Chairman JOHNSON. But a fifth the size of the 1921 event, which smaller than or less intense than the Carrington Effect.

Mr. MCCLELLAND. Right.

Chairman JOHNSON. And then the last one was, you said, in South Africa?

Mr. MCCLELLAND. Right. That was the South African event. Again, in orders of magnitude, that was probably about half to a quarter of the Canadian event. It was a very low level event, but it stayed on for a period of days. The grid did not collapse. It did not cause consumption, overconsumption, reactive power flow. So the grid stayed on. Equipment saw prolonged exposure to this event, and months later, over a period of months, 12 transformers were lost due to that event.

Chairman JOHNSON. Then it was true that in 2012 there was a coronal discharge or a solar flare, whatever we want to call it, that was pretty massive. Dr. Garwin, can you comment on that?

Mr. GARWIN. No.

Chairman JOHNSON. OK.

Mr. GARWIN. Some of these things are not really on an appropriate scale because, activity on the Sun is not necessarily reflected in a geomagnetic event on the Earth. It depends on the polarity of

the plasma that is ejected. And many of the things that happen on the Sun are spectacular, but their coronal mass ejections go in different directions.

Chairman JOHNSON. OK. I saw a satellite picture of us missing this by about 9 days. Anybody know anything about this and can comment on it? Ambassador Woolsey.

Mr. WOOLSEY. I just got tipped from my friend who is the Chairman or the Staff Director of the EMP Commission, and he tells me that on July 23, 2012, there was a Carrington-level event. It missed us by 3 days.

Mr. GARWIN. That means it just went off in a different direction.

Chairman JOHNSON. Correct, but had the Earth been in its—had it affected the Earth, it is going to only—does it only affect the side facing the Earth?

Mr. GARWIN. No, the entire Earth, especially the polar regions, but even down into the mid-latitudes Carrington—the only long wires in those days were telegraph wires.

Chairman JOHNSON. Right.

Mr. GARWIN. So no grid to bring down, no pipelines, but it did play havoc with telegraph wires, burned up some telegraph offices, and it would be much worse. It would collapse societies. But if the transformers are off, they are not damaged, and so the worst that would happen, if you take proper preparations, is that you would have to turn off transformers which have not been sufficiently mitigated. But the ones that have been mitigated or which do not have the connections that make them vulnerable—so-called Y connections instead are delta connections, which work just as well—those are immune to geomagnetic storms.

Chairman JOHNSON. Go ahead.

Mr. MCCLELLAND. I am sorry, Mr. Chairman. To answer your question, because I do have the numbers here, the July 2012 event was about a quarter or about 25 percent of the size of the 1921 event. The 1989 event that collapsed the Quebec grid was about a tenth of the size of the 1921 event. And the event is called "the Halloween Storm of 2003 for South Africa." That was about a 50th of the size of the 1921 event. And I do have those numbers and can provide that information.

Chairman JOHNSON. But, again, the granddaddy of them all was the Carrington in terms of our history that we have witnessed. Do you have any kind of relationship to that?

Mr. MCCLELLAND. I am sorry. I do not have that information.

Chairman JOHNSON. But bigger than 1921?

Mr. MCCLELLAND. Yes, bigger.

Chairman JOHNSON. Ambassador Woolsey.

Mr. WOOLSEY. Joe or Dick could correct me if I am wrong, but 1921 affected, I think, North America only; whereas, the Carrington Event of 1859 affected the entire world.

Chairman JOHNSON. OK. Ms. Bourge, again you are making a distinction between EMP and GMD and to a certain extent implying that, boy, there is just not much we can do about EMPs, so, you know——

Ms. BOURGE. Well, I certainly do not mean to be implying there is not much we can do about EMPs. I think planning and talking at a national level across the critical infrastructure in identifying

interdependencies, figuring out where government can help industry and where industry can help industry and what are the most logical ways to go about addressing this low-likelihood, high-impact situation, as we would with many others. Whenever you are talking about a catastrophic situation, sometimes protection and mitigation has to be looked at, but so does recovery. And you have to balance how much effort should be put on ahead of time and how much effort should be put on that recovery situation instead.

Chairman JOHNSON. Dr. Garwin, you have made four recommendations. Have you ever seen any kind of cost estimate of what it would cost to implement your recommendations?

Mr. GARWIN. The EMP Commission has those $2 billion. They do not exactly align with these recommendations. But the neutral current-blocking device which solves the problem on the EHB, the bulk transmission system, those might cost about $100,000 per transformer. That is cheap compared with the several million dollars per transformer, and it is very cheap compared with the damages that would be avoided.

Chairman JOHNSON. Do you know how many transformers would have to be protected?

Mr. GARWIN. A couple hundred in a priority——

Chairman JOHNSON. Literally, $100,000 times a couple hundred?

Mr. GARWIN. Yes, that is right. You know, $100,000, that is——

Chairman JOHNSON. That does not even show up in the Federal budget. That is pocket change.

Mr. GARWIN. Right. But we do not have the census. We do not have from the transmission companies the details as to which transformers are most vulnerable, so we do not know where to start.

Chairman JOHNSON. So we have not even done that, which 200 transformers should have $100,000 worth of protection?

Mr. GARWIN. Yes, and there are some that will not help because they are autotransformers, and so you cannot separate their ground——

Chairman JOHNSON. Mr. McClelland, you——

Mr. MCCLELLAND. I am sorry. I guess it really does depend—the substation number does depend on the outcome that one is pursuing. If it is grid stability and continuity, then it is a small, relatively small number of substations. So 55,000 critical substations, as Dr. Garwin has indicated, would number in the hundreds. If, however, it is to preserve the integrity of the Department of Defense or the offsite power supply to nuclear power stations, then criticality of load becomes an important issue. In that case, you may escalate from a few hundred to a thousand or more substations.

In addition, it is important to state that Dr. Garwin I think focused on just one aspect, geomagnetic disturbance. Electromagnetic pulse requires E1 hardening, too, and——

Chairman JOHNSON. I understand. So the point being is let us not make perfect the enemy of the good. Let us not sit back and go, "Well, if you cannot protect everything, protect nothing." Let us start protecting things.

Mr. MCCLELLAND. Right.

Chairman JOHNSON. Literally, $100,000 times 200, was it? What is the math on that? I made a mistake earlier. I need a calculator. It is not much.

Somebody described the Commission is established, starting in 2004 when we declassified what we knew dating back to the 1960s, right, when we were doing nuclear testing and we realized, whoa, something pretty strange is happening or something pretty damaging, and we classified that. We declassified in 2004, correct? And we set up a Commission—this is for Dr. Garwin.

Mr. GARWIN. No. It was long before. It was recognized in 1962 by a high-altitude nuclear test. It was explained a couple years later, never was classified. The only thing that is classified is the details of the construction of the nuclear weapons that caused this.

Chairman JOHNSON. So it was just ignored. It was something pretty scary, and we did not want to acknowledge it, so we put our head in the sand, and our head is still in the sand, by and large.

Mr. GARWIN. Well, people tried and, of course——

Chairman JOHNSON. I am not blaming you. I am just saying that is the position——

Mr. GARWIN [continuing]. And the EMP Commission has been trying, but here is what the EMP Commission said, if you look on page 6 of my submittal for the record. So E1, this very sharp pulse that has no counterpart in a natural phenomenon, does not affect people, no direct harm to humans or animals, gasoline-fueled automobiles, 3 stopped running out of 37, but all restarted without incident, and then, in particular, the electrical grid.

But Ms. Bourge is right. The country runs on other than electricity, and so you have to protect more than the electrical grid. But our subject is the electrical grid, and to protect the electrical grid even against E1 is not the big problem that protecting all of society is.

So electromagnetic relays that send current and voltage were immune to E1, and the electronic protective relays, they were the toughest devices tested, and they could be even tougher, according to the EMP Commission, with minor filtering on them.

So it is something that is doable, is to protect the bulk power system not only against the geomagnetic storms and against E3 from high-altitude nuclear explosions, but also against E1. That would not solve the problem of society because we depend upon a lot of other things. And if all of our furnaces and water pumps and so on go out because of the personal computer type things that are used in them, that is a bad day.

Chairman JOHNSON. But we can protect ourselves against something like the Carrington Effect, the 1921 effect, and we can do that for a relatively low cost. And, again, it is something that has a 10 to 12 percent probability of happening every decade, and we escaped something massive by a couple days in 2012. Am I stating that correctly?

Mr. MCCLELLAND. Yes.

Mr. WOOLSEY. Yes.

[Witnesses nod in agreement.]

Chairman JOHNSON. So, again, let us go back to 2008, and I want to start with you, Mr. Currie. I am going to go through Recommendations A through O of the 2008 EMP Commission, and I

really want just a simple yes or no on these. Have we done this? OK? Do we understand the system network level vulnerabilities, including cascading effects? Do we understand that? Has DHS done that?

Mr. CURRIE. No, DHS has not done that.

Chairman JOHNSON. So we do not even understand the system or network level vulnerabilities, including cascading effects?

Mr. CURRIE. Not for geomagnetic threats. No, DHS has not done that.

Chairman JOHNSON. OK. Well, that was the first recommendation. So, again, this is in 2008, and now it is 2015, and I can actually do that math in my head. That is 7 years. OK.

B, Evaluate and implement quick fixes.

Mr. CURRIE. They are evaluating some quick fixes, like the project I mentioned, the transformer quick fix project, and that is——

Chairman JOHNSON. So do you think seven—I am not beating up on you. Seven years later, that is not exactly a quick evaluation of a quick fix, is it?

Mr. CURRIE. Right.

Chairman JOHNSON. So we still have not done that. We are kind of evaluating it. Seven years to evaluate a quick fix that could cost minimal dollars, that would go a long way toward protecting the absolute critical substations and transformers of an effect that we know will happen again with 100 percent certainty, right, Dr. Garwin? We will be hit by one of these solar flares with 100 percent certainty?

Mr. GARWIN. Right.

Chairman JOHNSON. Sometime in the future.

Mr. GARWIN. Right.

Chairman JOHNSON. We have known about this publicly since 2004. In 2008, these recommendations. Seven years later, we have virtually done nothing in terms of some quick fixes that would cost $100,000 per transformer—when, by the way, we spent $800 billion in 2009 and 2010 on a stimulus package looking for shovel-ready projects. This would have been a pretty good shovel-ready project, wouldn't it?

Mr. GARWIN. Well, the criterion was too severe because it takes longer than a year to go from something which is there actually to get it running. You have all that planning and budgeting, and it should have lasted longer, and we should have fixed our infrastructure more widely.

Mr. CURRIE. Senator Johnson, can I mention one thing?

Chairman JOHNSON. Sure, Mr. Currie.

Mr. CURRIE. One of the things that makes it hard—and this has made our work really hard—is there is no one at DHS that sort of line by line tracks what efforts coincide with these recommendations.

Chairman JOHNSON. No, I will stipulate the dysfunction with government, OK? And, again, we are describing dysfunction. This is a serious threat; 100 percent certainty this will happen, and we have done nothing, having known about this publicly since 2004, we have done nothing. We have spent minimal amounts of dollars on a quick fix to protect a big chunk of our iron structure. Not per-

fect, not protecting everything, but just doing the bare minimum, we have done nothing.

Let me go on. C, have we developed national and regional restoration plans? Yes or no.

Mr. CURRIE. According to our work, DHS has not done that. There may have been discussions about that in the Sector Coordinating Council.

Chairman JOHNSON. So 7 years later, we have not developed national and regional restoration plans.

By the way, if anybody wants to challenge this, pipe in. We have plenty of time. I am the only questioner, which is kind of nice.

Ms. BOURGE. Chairman Johnson——

Chairman JOHNSON. I wish every member of the Committee were here to hear this, though. It is unfortunate they are not. But, again, if anybody wants to challenge this, step in. Do you want to say—have we developed a national or regional restoration plan?

Ms. BOURGE. Actually, I want to go one back from there. I want to talk about whether or not we have done nothing, because I think the issue got a little conflated here on the EMP versus GMD. Industry has done things on GMDs. We have standards implemented. We are in the process of pending approval from FERC on a second set of standards to build toward the 100-year event.

Chairman JOHNSON. Have we installed anything? Have we actually protected anything? So industry, great, God bless you, I love industry. So industry has done some studying. The government has not.

Ms. BOURGE. I could not say what DHS has done specifically or not.

Chairman JOHNSON. That is why we have GAO here, and he said government has not done anything. So God bless industry. I am glad you are moving forward. We should start installing some of these things.

D, have we assured the availability of replacement equipment. Have we done that?

Mr. CURRIE. No. It is being researched, but there is no assurance.

Chairman JOHNSON. Ah, research. Love research. Some of these transformers are 2 years out in terms of lead time, correct?

Mr. WOOLSEY. Yes.

Chairman JOHNSON. Two years out.

Mr. WOOLSEY. And the last time I looked, Mr. Chairman, they were made only in—the big ones, only in South Korea and Germany.

Chairman JOHNSON. So anybody with a brain in their head looking at this would go, what we ought to do—again, we are going to spend $800 billion looking for shovel-ready projects and shovel about $2 billion into some replacement transformers and just keeping the spare parts. Wouldn't that have been a rational response, take $2 billion and buy a bunch of transformers and store them so that we can restore power from that——

Mr. WOOLSEY. Some transformers are not fungible. You cannot just take one and put—but people here who know more about that——

Chairman JOHNSON. That would, of course, require some research and some planning, which we did not do that either. So let me keep going on.

Mr. GARWIN. As they say, the good is the enemy of——

Chairman JOHNSON. No. The perfect is the enemy of the good, I know. And just government does not work, and I think this is pretty obvious.

Mr. GARWIN. You can make replacement transformers that are modular and stack them up, and that is a good way to do it. But it is very difficult to get people to agree on a particular course. And in industry and commerce, you have competition, so people buy what is most effective and what——

Chairman JOHNSON. Right, and, of course, the point of this hearing is to lay bare how ridiculous it is that we have done nothing, and we have let the perfect be the enemy of the good, and we have allowed governmental dysfunction to prevent us from even doing the basic first little quick fixes to begin protecting our critical infrastructure. That is the purpose of this hearing.

Let me go on. E, assure availability of critical communications channels. Have we done that, Mr. Currie?

Mr. CURRIE. So we focus on the energy sector, and one thing that was not mentioned is that the EMP Commission report actually covered other sectors, like telecommunications and banking and finance and raised threats in those areas, too. I do not have knowledge of the communications area.

Chairman JOHNSON. Well, again, and I agree with your assessment in your testimony, too. We have 16 critical infrastructures, and they all depend on energy. So, again, we are trying to prioritize what you are trying to address—again, not going to solve all of them. In other words, do nothing, so try and start solving something. The top priority would be protect our electrical infrastructure, correct?

F, expand and extend emergency power supplies. Have we done that?

Mr. CURRIE. That is not something we have looked at as DHS because they would not be responsible.

Chairman JOHNSON. I will take that as a no.

Extend black start capability.

Mr. CURRIE. It is something that they have looked at as their research and development for installing these transformers that can be easily replaced, but I am not aware of——

Chairman JOHNSON. So looked at it. Then that would be what we would have to do. Pre-purchasing some of these replacement transformers is really what we are talking about, right? And getting those in a position so that we do not have to rely on transportation to put them in service. Mr. McClelland.

Mr. MCCLELLAND. If you do not mind, Mr. Chairman, I would like to revisit just a couple——

Chairman JOHNSON. Sure.

Mr. MCCLELLAND. Not from the DHS perspective, but from FERC's perspective. Regarding item No. 1, identify critical facilities, the Commission did finish comprehensive network modeling, has identified the most critical substations and nodes on the electric power grid, conveyed that information to the industry, and

then offered assistance. And this is in conjunction with DOE and DHS, so they were our partners on this. We did collaborate, so we have identified those critical nodes, met with the subject matter experts who own and operate those critical nodes, and offered assistance, joint assistance for cybersecurity with DHS and also assistance on both GMD and EMP mitigation procedures and techniques.

We have also collaborated with our partners at the Department of Defense (DOD) to identify mission-critical facilities and essentially perform the same function for our partners at DOD.

So work has been done. I cannot speak to independent efforts by DHS. The work was not specifically driven by GMD and EMP. It was driven in the threat context and used for both cyber GMD and EMP.

On the second item, I do not want to overrepresent it. I think it is important to say that the NERC standards are a baseline approach, so they are a foundational approach. They are certainly not best practices, and they certainly would not represent best practices that the industry could bring to bear. However, NERC did put operating procedures in place so that when they receive alerts and bulletins from the National Oceanic and Atmospheric Administration (NOAA) folks regarding space weather events, they are given an alert, and they can take operational action. That is just operational action, though. It does depend on human beings to actuate procedures in order to protect the system.

There is a second phase of that standard. The second phase of that standard regards a self-assessment by the industry to determine whether or not they need to take protective measures, automatic protective measures against GMD. And the Commission has questioned some of the aspects of that standard in regards to the 1-in-100-year event and the baseline that NERC submitted for the Commission's review.

Chairman JOHNSON. OK. So that is good news. I would have assumed we would have been looking at this. I am sure there is, with all the paper being produced around here, there are some studies. We need to start implementing some protections, though, and prioritizing those things. Ambassador Woolsey.

Mr. WOOLSEY. Mr. Chairman, just one illustration. It takes NERC sometimes quite a while to come up with these standards. In 2003, after the Great Northeast Blackout in Canada—and it started, I think, in Cleveland, with a tree branch touching a wire—NERC undertook a Vegetation Management Plan. It took them slightly over 10 years, until 2013, to come up with that. The United States was engaged in World War II for 3 years and 8 months, so that is essentially three World War II's that it took NERC to figure out what to do with vegetation. I do not know how long it took them to handle a much more complex problem, like, say, squirrels.

Ms. BOURGE. Mr. Chairman, if I could add one thing——

Chairman JOHNSON. Squirrels are a 100 percent probability as well. [Laughter.]

Ms. BOURGE. The NERC process has been changing and growing and establishing itself over the years, and that was more in its infancy. At this point we have gotten better with standards. I am not going to say we are perfect, but we have gotten better in the proc-

ess of getting them done, and for an example, we had a request from FERC to create physical security standards last year, and we did that, I believe, in 82 days.

Chairman JOHNSON. Again, this is a different example, but I know the Centers for Disease Control (CDC) has established standards in case the Ebola virus ever came to the United States, and the first time it happened, we had some young nurses contract Ebola because—again, you can write up standards, but if you do not test it, if you do not actually have the protective gown and equipment in place, the standards, the piece of paper does nothing.

Let me just continue, because I just want to—and, again, anybody can answer this. If it is yes or no or, maybe or partially, let me know.

Prioritize and protect critical nodes. Have we prioritized and protected critical notes? Mr. McClelland.

Mr. MCCLELLAND. The studies that FERC has performed do prioritize the critical nodes for the industry.

Chairman JOHNSON. So we prioritized but no protection.

Mr. MCCLELLAND. No, the protection is voluntary. There is no EMP standard, and the Commission has said on numerous occasions that for national security the standards are not adequate.

Chairman JOHNSON. OK. So, listen, I am somebody who hates overreaching government, overregulation. But let us face it: Voluntary is not working so good. From my standpoint, this is something that needs to be addressed, and if government has to pay for it, again, that is why I go back to the old stimulus, $800 billion, we could have done a lot of protection with just a small little fraction of that, and it is just a shame, it is just unconscionable we did not.

Mr. MCCLELLAND. I can just add to that quickly. We have seen just a handful of utilities move forward with EMP mitigation. One or two have been very proactive. The cost for both GMD and EMP mitigation at those stations is relatively small. It has been 1 to 2 percent—for EMP mitigation included.

Chairman JOHNSON. When the administration in 2009 was looking for those shovel-ready projects, did NERC ever raise its hand and say, "We have one here"?

Mr. MCCLELLAND. I do not know.

Chairman JOHNSON. I wish they would have.

Mr. WOOLSEY. Not to my knowledge, Mr. Chairman.

Mr. GARWIN. There is a generic problem in the government, as evidenced by our late friend Jim Schlesinger when he was Secretary of Defense. They needed a fiscal stimulus, and Schlesinger came up with $5 billion to be spent. He said, "We do not need it for defense, but I am the only one in the government, the only Cabinet Secretary, allowed to have contingency plans for spending money we do not have."

And so we spent that $5 billion on defense. Schlesinger said we did not need it, but it was a good thing to do, according to the administration and the Congress. We ought to have contingency plans lined up for things that we do not have money to do, and you have to be able to say no to them to stay within the budget.

Chairman JOHNSON. Well, again, the purpose of this hearing is to raise this issue, this contingency and a real high—this is not a

contingency. This is an imperative. This is a top priority from my standpoint.

I, Expand and assure intelligent islanding capability. Dr. Garwin, that was part of your testimony. Have we done anything there?

Mr. GARWIN. I do not know.

Chairman JOHNSON. Mr. McClelland.

Mr. MCCLELLAND. I would say not, no.

Chairman JOHNSON. OK. Assure protection of high-value generation assets.

[No response.]

No? Correct? I guess we will just assume no unless somebody wants to—OK.

Assure protection of high-value transmissions assets.

[No response.]

No. Assure sufficient numbers of adequately trained recovery personnel. Have we done that one?

[No response.]

No. Simulate, train, exercise, and test the recovery plan. Have we done that?

[No response.]

No, we have not done that.

Develop and deploy system test standards and equipment.

[No response.]

Have not done that.

The final one, you can all breathe easy now, establish installation standards.

[No response.]

So this is pretty remarkable. From 2008, we had all these recommendations, seems like pretty common-sense recommendations, things that responsible individuals would have hopped right on and said, "This is a problem, this is a threat, this needs to be addressed, this is a priority." And we have virtually done very little. We have done some. We have done some studies. We need to start using those studies.

We are, by the way, going to be introducing a piece of legislation—and I have it here somewhere. Oh, I know. This passed in the House. One of the reasons we are holding this hearing now is I wanted the House to move first. It is called the "Critical Infrastructure Protection Act." To me, this is just bare minimum. And it was amazing to me. Ambassador Woolsey, can you describe the problems we had even passing this in the House? It is going to require DHS to prepare a strategy to protect critical infrastructure against electromagnetic threats.

Mr. WOOLSEY. I think this is the one that go through the House and was stopped in the Senate—Peter Pry has followed the legislation on this more closely, if we can ask him, former Chief of Staff of——

Chairman JOHNSON. Sure. Why don't you come forward? I will let you provide the information without being sworn in.

Mr. WOOLSEY. Progress, particularly in the House, of CIPA.

Mr. PRY. Well, it was passed in the House, but like in the last week of the last Congress. It passed unanimously, as a matter of fact, but we just ran out of time. I think the bills you are thinking

about are the SHIELD Act and the GRID Act which were held up for years in the House Energy and Commerce Committee. One of them, the GRID Act, did pass the House unanimously in 2010, and it came over to the Senate. But one Senator anonymously put a hold on the bill, and then it died. And that is the closest we came.

Chairman JOHNSON. I actually was going to get to the SHIELD and GRID Acts. Right now we are just talking about CIPA, because I think the House—is it Homeland Security?—has actually reported out of Committee, and hopefully the House will pass it. And I want to bring this up and report it out of our Committee as well, and it is one of the reasons I held this hearing, was to get Committee support for just a bare minimum. Again, this is sort of a study as well. But we need to move past studies as quickly as possible and develop a strategy and start implementing it real quick. And I think some of these things we are talking about here, the $100,000 for some of these critical transformers, I do not think we need a strategy or a study. I think we should just do it, quite honestly. I will amend this bill to authorize the dollars to do just that.

Mr. GARWIN. One problem is that some of these remedies are so cheap, so that is the reproduction cost. But the design, the test, that costs really a lot of money, and then you put it into production. But you have to decide what it is you put into production. So that is why there has not been a lot of supply-industry interest in this, because the market is not all that big.

Chairman JOHNSON. Mr. Currie, do you want a quick——

Mr. CURRIE. Yes, sir. On the cost issue, one of the things that we are looking at—when we talk about this, we tend to talk about just replacing existing equipment now. Another option that is easier and cheaper is, as you redesign systems, as they need natural replacement, that you consider hardening in this, too, which can be cheaper and easier to do as well.

Chairman JOHNSON. That is fine. But, again, that is replacing. That is further out in the future. Let us take a look at what we have now. Let us address that. Let us offer some protection now.

I think I will yield back my time remaining, my 7 minutes here. [Laughter.]

Senator CARPER. I will say you have made the most of it.

Chairman JOHNSON. I have it right here. It says all 7 minutes, so I have not even begun.

I will say I wish we have had really good attendance at these hearings, and this is probably the least attended hearing, and it is unfortunate. I will ask——

Senator CARPER. They are all waiting in the anteroom until you finish.

Chairman JOHNSON. I will ask that you review what has already been stated here, Senator Carper. This is unbelievable. It is just unbelievable. So if you have an opening statement, I am happy to have you make it now. But I really want you to review the testimony, and I want you to review the initial questioning here, and what we have not done is pretty jaw-dropping and how little it is going to cost to just offer some basic protection, this is something we need to prioritize. We need to get moving on this now. But why don't you make your opening statement? Then we will continue on with questions.

OPENING STATEMENT OF SENATOR CARPER

Senator CARPER. OK. Thanks. I apologize to our witnesses. First, my train was running about an hour and a half late. That is enough of a trouble. And the Northeast corridor was shut down for a while. And I got here, and I got distracted on another big issue that we are facing in the Senate today. But, Mr. Chairman, thanks very much for holding this hearing, and thanks to our witnesses as well for joining us.

Threats to the homeland have evolved, as we all know, considerably over the last 15 years. In the months after 9/11, the most pressing threat to our homeland came from al-Qaeda terrorists planning attacks from remote caves in Afghanistan. Today the terror threat has become far more diverse.

Some terror groups are still seeking sophisticated attacks against high-profile targets. Other groups, such as the Islamic State of Iraq and Syria (ISIS), are attempting to inspire extremists all over the world—including right here in the United States—to carry out simple attacks within their own communities, sometimes lethal attacks.

We are also being attacked daily in cyberspace. In many ways, we are dealing with an epidemic of online theft and fraud. This epidemic is growing at an alarming rate and touches many of the people in this room, including on this side of the dais, as attacks become more sophisticated and more disruptive.

And the challenges we faced with the recent Ebola outbreak and our ongoing efforts to counter the spread of avian influenza remind us that threats to our homeland are not just manmade. To address these evolving threats, we must always look to stay at least one step ahead of the bad guys or, in some cases, Mother Nature.

At the same time, we have to reluctantly accept the reality that our Nation cannot protect against every threat, or potential threat, out there. Though we should always strive for perfection, we simply do not have the resources to achieve 100 percent security all of the time. I know that, and I think we all recognize that. That is why it is so critical that we prioritize our homeland defenses. We must focus on those threats that our experience and intelligence tell us are most likely to occur and would have the gravest effects if, God forbid, they should become a reality.

Today's hearing gives us an opportunity to assess two different potential threats to our electrical grid: man-made electromagnetic pulses, and geomagnetic disturbances caused by space weather.

Each of these threats poses some degree of risk to our communities. That much is clear. Our job, however, is to assess that risk and figure out where these threats rank in the spectrum of everything else that our country faces. For example, we must determine how likely electro-and geomagnetic threats are to occur given our existing preparations and deterrents. And if they were to occur, how would they impact our homeland?

The answers to these basic questions become all the more important and urgent amid the horrific reminders of the existing challenges we already do face from domestic terrorism and homegrown violent extremism in our own communities—attacks like those that occurred recently in Chattanooga and in Charleston.

I hope today we can make some progress on this front and that our witnesses can provide us with a clear-eyed assessment of these threats. I look forward to questioning, but I am going to yield on my questions to Senator Ernst and Senator Ayotte and then maybe pick up the chance to ask my own questions in a few minutes.

Thank you.

Chairman JOHNSON. Thank you, Senator Carper. Senator Ernst.

OPENING STATEMENT OF SENATOR ERNST

Senator ERNST. Thank you, Mr. Chairman, and thank you, Ranking Member Carper.

I would like to start, of course, with a discussion. I know the DOD was brought up earlier—and, first, I apologize. I want to thank all of you for being here today as well. I know many of us are dashing from meeting to meeting. But the DOD was brought up as far as our military is concerned, so, Director Woolsey, I would like to direct this to you first. I am interested in your thoughts on the potential impact of whether it is a natural or man-made EMP on our military capabilities, and if you could I guess detail or general observation, either, on where we are most vulnerable and how we should prioritize our efforts to harden these areas in our military and mitigate some of the threats that have been discussed here today.

Mr. WOOLSEY. Well, 99 percent of—maybe it is like 97 percent of the military are on the grid. That is where they get their power.

Senator ERNST. Correct.

Mr. WOOLSEY. I think in California there is one hot water steam facility, but that is it. So since we have 16 critical infrastructure and they all in one way or another depend on electricity, although electricity depends on them—they are interacting. But if the grid goes down, there is no special arrangement for the military. They are hungry and thirsty just like everybody else. And so in a real crisis one might look to the National Guard or whatever to maintain order. They are going to be worried about their families starving and not having water just like everybody else.

So we have a very fundamental problem that the infrastructure at least in this country is essentially completely integrated, and one good thing is that Defense often has less difficulty making decisions and moving out, and sometimes they have a bit of extra money, so sometimes if you have a cooperative arrangement between Defense and other parts of the government, and particularly on something like this, Defense could kind of take the lead, particularly in areas like the corridor in the middle of Texas, which has several major military bases on it as well as several cities. And it would be a way to move out relatively quickly, perhaps, on getting some of these changes to the transformers and the rest that we have been talking about here.

Senator ERNST. So you would say they would be a priority; they would need to be a priority.

Mr. WOOLSEY. Absolutely, but, I mean, hospitals are going to be a priority because they will not have electricity, et cetera, et cetera. The military would certainly be front and center.

Senator ERNST. Certainly. And do you believe that we could adequately protect our installations here? What about post bases that we have overseas?

Mr. WOOLSEY. Well, there are different threats, both for geomagnetic—except for the really huge Carrington Effect 1859 event, the events like even the railroad one of 1921 occur only over part of the Earth. So if something like that hit us, unless it was a gigantic Carrington event, it might well not hit our bases in other parts of the world. And if they were hit, then they might not be in the United States.

But whether it is in Britain or Germany or here, we cannot assume that our military is going to have electricity and power and function any different really than the rest of society. They are going to depend on British transformers in Britain.

Senator ERNST. Based on those host countries.

Mr. WOOLSEY. Yes, I am sure they have generators and fuel that will last for 2 or 3 days or something like that, like a lot of businesses do. But we are used to planning for weather-caused outages, which will last 2, 3, or 4, maximum 4 or 5, let us say, days. And that is not what this would be. This would be an outage for a very long time.

Senator ERNST. OK. Mr. McClelland, I think you had some information.

Mr. MCCLELLAND. I do. In 2008—and, actually, Mr. Woolsey was a part of this initiative. It was the Defense Science Board Task Force that wrote a report in February 2008 called "More Fight, Less Fuel." The primary objective of that task force, as I remember, was to evaluate battlefield needs and dependency on fuel. They inadvertently found, however, they came up with two primary determinations. The second was very serious and was a surprise, and I would just like to read an excerpt from the memorandum from Dr. Schlesinger.

Senator ERNST. Please.

Mr. MCCLELLAND. He said, "The task force concluded that DOD has two primary energy challenges," and this is the second: "Military installations are almost completely dependent on a fragile and vulnerable commercial power grid, placing critical military and homeland defense missions at an unacceptable risk of extended outages."

And so that report went on then to detail the findings as well as recommendations to help correct that circumstance.

Senator ERNST. So in your assessment then, it would be important that not only are we ensuring our troops are prepared for war, but also that they would be prepared in situations like this to make sure we can eventually step up into military operations.

Mr. MCCLELLAND. Absolutely.

Senator ERNST. OK. Thank you very much. I have very little time remaining, but I do want to thank all of you for participating today.

Thank you, Mr. Chairman.

Chairman JOHNSON. Thank you, Senator. I will use your time, because we have not adequately described this.

Ambassador Woolsey, you said "a very long time." Lay out exactly what would happen in a massive GMD or an EMP. Lay it out.

Describe what this is going to look like. This is not a 2-week or a 3-week power outage. Talk about the electrical grid going down and everything shuts down.

Mr. WOOLSEY. Well, I will take a quick stab at it and then lateral it to Joe and Dick, if they want to add, because they both know a great deal about this issue—more than I, really.

You have the short wavelength effects that operate line of sight, so if you——

Mr. GARWIN. Short time.

Mr. WOOLSEY. Short time.

Chairman JOHNSON. I really do not want to impinge too much on Senator Ayotte's time here. Kind of get by the technical aspects to now the grid is down.

Mr. WOOLSEY. All right.

Chairman JOHNSON. And just describe what happens to society when the grid is down for—you said "a very long time." We are talking a year or two, because we cannot get these transformers.

Mr. WOOLSEY. It is briefly dealt with in the Commission report of 2008, and there are essentially two estimates on how many people would die from hunger, from starvation, from lack of water, and from social disruption. One estimate is that within a year or so, two-thirds of the United States population would die. The other estimate is that within a year or so, 90 percent of the U.S. population would die. We are talking about total devastation. We are not talking about just a regular catastrophe.

Chairman JOHNSON. I think that made the point. Senator Ayotte.

OPENING STATEMENT OF SENATOR AYOTTE

Senator AYOTTE. Thank you, Chairman.

Ambassador, you certainly made the point, which brings me to my question. I serve on the Armed Services Committee as well, and in February, our Director of National Intelligence (DNI) and the Director of the Defense Intelligence Agency (DIA) both testified before the Senate Armed Services Committee regarding worldwide threats. It is our annual worldwide threats hearing. And this was obviously intended to be a comprehensive assessment, yet neither of them even mentioned the EMP threat in their lengthy written testimony provided to the Committee or in the oral testimony.

So, Ambassador Woolsey, what explains this notable silence? If you look at collectively your tremendous experience in so many key positions in our government, how would you assess our awareness about this threat? And do you worry that there is a gap in terms of the intelligence community's (IC) and our overall focus on this devastating threat?

Mr. WOOLSEY. Senator, it is a great question, and it is one of the things that perplexes everybody who looks at this. How could this be such a terrible threat and nobody has paid attention to it for quite a while, sometimes even in DIA and DNI testimony? I think there are two things going on.

First of all, all parts of government and individuals are strapped for cash these days, and so to stick one's neck out in a bureaucratic situation in which you say, "I understand that. That is my agency's responsibility. We will take charge, and here we go," you may find that it is being taken out of your hide. And so you do not have any

real prospect to get added resources to do something, even if the resources are a couple of billion dollars, very small in these terms. So that is, I think, one thing that is going on.

Another is that it has enough of a technological component that people tend to think of it as science fiction. I gave a speech to a group of very distinguished scientists, and one came up afterwards and said, "Come on, Woolsey. You cannot mean this. Newt Gingrich writes novels about this." I said, "Well, Tolstoy wrote a novel about the war in Europe in Napoleonic times. It did not mean it did not happen."

But people get into the mode of thinking that this is so horrible if it goes the way it might—and there are books, there are good sort of dystopian books—one called "One Second After"—about this, and so people get into not wanting to think about it, not wanting to worry about it because it is too terrible.

I think that those two phenomena—and, finally, we kind of first knew about this—and, Dick, correct me if I am wrong—as a result of the atmospheric or high-altitude nuclear test just before the Atmospheric Test Ban Treaty came into effect, we and the Russians. And we dealt with the problem from the point of view of protecting the Strategic Air Command's assets, bombers, radar aircraft, and so on. But everybody kind of thought of it as, well, this is one thing that would be terrible if we had a nuclear war with the Soviets, so it is kind of a lesser included case. And the problem is that it is not now a lesser included case. If Iran gets one nuclear weapon, relatively primitive, just like what we dropped on Hiroshima, and can put it into a simple launcher, a Scud—they give Scuds to the Houthis in Yemen—a Scud and put it into orbit at, say, 100 kilometers, which is the easiest thing to do in space, the first thing we did, the first thing the Russians did, launch a little satellite into space. They get into space, and it is low-Earth orbit, and it is going around the Earth a couple of times a day or so, it crosses the United States. If you have that up there and you are the Iranians and that morning you wake up and think you really mean the "death to America" business, then you can pickle it off and go, "Boom," and knock out the American grid.

It is not just a lesser included case of strategic—and, by the way, the Iranians are rather good at deception. They might try to make it look like it was North Korea or something.

Senator AYOTTE. And North Korea otherwise could do it.

Mr. WOOLSEY. North Korea otherwise could do it.

Senator AYOTTE. They are not know for——

Mr. WOOLSEY. Try to make it look like it is Iran.

Senator AYOTTE [continuing]. Really rational leaders all the time.

Mr. WOOLSEY. So there are several factors, but when you put them all together, the government—and I guess finally with respect to electricity, the functions of government with respect to the electric grid, particularly after it was in part—competition introduced into it around 2000—is you have FERC, you have NERC, you have State authorities, you have different kinds of ownership practices in industry. You have chaos from the point of view of trying to have anybody in charge of a coherent policy. There is only one person, I think, who can set this priority for the Nation and

get people going, and that would be the President of the United States.

Senator AYOTTE. And from what I hear from your testimony, you would say that it is very important that the President do that, whether it is this President or the next President, but as soon as possible.

Mr. WOOLSEY. I absolutely think as soon as possible, because even if you are willing to hope that things will work out OK with North Korea and with other nuclear powers that could orbit a satellite, Iran is explicitly genocidal with respect to both us and Israel, and they are, I think, months maybe—I hope years, but quite possibly months away from having a nuclear weapon.

Senator AYOTTE. Well, and, of course, under the agreement that has been released, the U.N. Resolution against intercontinental ballistic missiles (ICBM) and their missile program will be lifted in 8 years, but the intelligence estimates have been that they would have ICBM capability this year, is what we have heard. So we know that, yes, the Scud would be the more primitive form, but they are also working on more advanced forms that could deliver these types of weapons and could have the same effect.

Mr. WOOLSEY. Absolutely right. And the thing that is a problem here is that this is easier, an EMP shot is easier than launching a long-range missile at a target on the Earth. The shooter does not have to worry about reentry, does not have to worry about accuracy, none of that. They just need to get into orbit and detonate when the orbit takes the satellite over the United States.

Senator AYOTTE. Well, I want to thank all of you for being here. I did not get to a question which I will submit for the record, but there is some really important work being done on this issue at the University of New Hampshire (UNH), and they are actually a leader in the field of heliophysics and researching this area, and also the impact of actually building space aircraft instruments to predict and detect solar eruptions, but also other types of events are important that we have referenced today. So I am going to submit a question for that, and I want to give UNH a shout-out for their important work on this.

And I think this is a wakeup call, Mr. Chairman, for important work we could do on this Committee to really raise the attention level of what would be a devastating impact on our country. So I thank you all for being here.

Chairman JOHNSON. Thank you, Senator. It definitely is a wakeup call, although the wakeup call was first broadcast in 2004, then 2008. And, by the way, I did do a quick calculation using my iPhone here: 200 critical transformers at $100,000 would be $20 million. That is it, $20 million and we would go a long way toward at least protecting a good chunk of our electrical grid.

Mr. WOOLSEY. About a third of a fighter aircraft.

Chairman JOHNSON. $20 million, that is it. We are going to include that on our CIPA bill.

Mr. GARWIN. Could I reduce some confusion here, perhaps?

Chairman JOHNSON. Sure.

Mr. GARWIN. Jim Woolsey and I worked together in 1998 on the Missile Threat Commission, and we said there it is not only the ICBMs but it is short-range missiles, cruise missiles, or ballistic

missiles from freighters that could threaten the United States. Now, some people do not like to hear that because they like to build defenses against ICBMs, and it is hard to defend against these little things—even harder to defend against ones that do not have to actually reenter but could detonate over the United States.

However, never mind radars. We do see every launch of a significant ballistic missile, even Scuds, with the warning satellites. And so we know where it is fired from. If it is a long-range missile fired from Iran or North Korea, we know. There are easier ways for those countries to commit suicide than to send a nuclear weapon to do EMP that does not kill anybody directly but may kill tens of millions of people indirectly.

But among those would be many Iranians and North Koreans, and, one ought to say that, in my opinion.

Chairman JOHNSON. Well, thank you, Dr. Garwin. Senator Carper.

Senator CARPER. Thanks again, everybody.

I think I would like to start off my first question with Mr. Currie—thank you for being here—and Dr. Garwin. Here is my question: We have heard about high-altitude nuclear detonations and the EMP threat that they could pose. Where do manmade EMP threats rank in the spectrum of all homeland threats? Do you want to take a shot at that, Mr. Currie?

Mr. CURRIE. Yes, sir. Thank you for the question.

So that is the responsibility of DHS to assess those types of threats, and one of the things we found in our work is that DHS has not done that. They have not sort of incorporated the EMP or geomagnetic threat into their assessments yet. And there has been some confusion at DHS, too. When we asked them the question of who is responsible for doing that, there has been some confusion around who is supposed to do that.

Senator CARPER. OK. Dr. Garwin.

Mr. GARWIN. Nuclear weapons are not very widely available, and to add to that, the capability of launching them over the United States is also not something they find in the ordinary terrorist cell. So that is a blessing.

The suitcase battery-operated EMP generators, they can cause damage at a substation, but there are a lot of other ways to cause damage at a substation by shooting the transformer——

Senator CARPER. We saw that near San Jose. I saw it with my own eyes.

Mr. GARWIN. Yes. Or, for instance——

Senator CARPER. Metcalf.

Mr. GARWIN [continuing]. Nuclear power plants. You use a little bit of explosives on the towers, and you bring down all the offsite power. That is why nuclear power plants have backup diesels, and we have taken that much more seriously after the Fukushima Daiichi meltdowns. But it took awhile to realize that the U.S. plants did not have sufficient battery capacity, did not have sufficient protection of their diesels.

So the high-altitude nuclear explosion EMP threat is real. It is very special. We have many other problems of homeland security: disease spread by terrorists, for instance, as was mentioned; many other problems; widespread just shooting in marketplaces, which is

endemic in the rest of the world—fortunately, not so common here; bringing down the commercial aviation sector by various means. So Homeland Security has a lot of things to think about.

Senator CARPER. I like to say it is a busy neighborhood.

Mr. GARWIN. And EMP, we should fix the E3 threat. We should fix the solar storm threat. And then we should move on and do the E1 hardening and tell people that they are going to be out of business if such a thing happens, and that is an unnecessary vulnerability of the country.

Senator CARPER. Ms. Bourge, do you want to comment on what Mr. Currie and Dr. Garwin just said, please?

Ms. BOURGE. Thank you, Senator. What I would add to that is that the EMP threat is a lower-likelihood threat, but it is one of the highest-impact threats that you can find out there. And I think that is one reason that even though it is a very low likelihood, it is a very important issue, and a lot of people talk about it. Maybe not as many as should, and hopefully we are moving toward getting to public-private partnerships across the infrastructures to do so. But for now, it is a low-risk, high-impact threat. And as industry, we address those type of threats in a defense-in-depth approach, and so we take into consideration all threats, but then we do have to also factor in the likelihood, the ability to protect against it, the cost and impact on the consumers, and many other considerations as we are doing that to decide which threats we are going to address which ways. And so just because it is a low likelihood does not mean we do not think about it, but it means that it is one of the ones that is not the first that we are fixing.

Senator CARPER. All right. My followup to you, if I could, we have heard today that it could take as little as $20 million to upgrade 200 transformers in the United States. Would you like to address that number or that assertion?

Ms. BOURGE. So I have heard that number before in the past. Usually, I have heard it in reference to——

Senator CARPER. Do you have any idea how many transformers there are in the country? I do not know. Roughly. Are there 100,000? Are there 50,000?

Ms. BOURGE. I believe you are looking at around 20,000 of the major transformers.

Senator CARPER. Major.

Ms. BOURGE. But I would have to confirm that number.

Senator CARPER. OK.

Ms. BOURGE. Joe might be able to——

Mr. GARWIN. I think there are only about 700 extremely high voltage (EHV) transformers, the ones that carry power over many hundreds of kilometers at voltages above 500,000 volts.

Senator CARPER. OK.

Mr. GARWIN. Those are the primary ones that would be damaged and should be protected.

Senator CARPER. All right. Good. Thanks.

Mr. GARWIN. But the $20 million that is the reproduction cost.

Senator CARPER. The what?

Mr. GARWIN. The cost of building these things once you decide what it is and you do all of the homologation—that is, you make sure it is suitable, it passes all the requirements of the various

councils that are involved, and that is a good many million dollars before you get the first one. Now, some of that work has been done in Ontario Hydro and elsewhere.

Senator CARPER. We interrupted what you were saying, Ms. Bourge. Do you want to finish? I do not want to be rude.

Ms. BOURGE. Oh, no. No worries at all. I believe I had actually pretty much finished all my statement.

Senator CARPER. OK. Let me go back and ask a followup to my first question, Mr. Currie, to you and Dr. Garwin. How likely is it that a country, like Russia, like China, like North Korea, would detonate a nuclear weapon in the atmosphere above the United States? Do we have any deterrence in place to the launching of a high-altitude nuclear blast?

Mr. CURRIE. Sir, from a GAO perspective, I do not know the answer to that. We have done some work, a couple of years ago on DOD's efforts, the Department of Defense's efforts to mitigate against this and plan for this, and that is completely classified. So we would be happy to give that report to you or your staff.

Senator CARPER. OK. That would be good. Thanks.

Dr. Garwin, do you have any—first of all——

Mr. GARWIN. There are two aspects to what Ms. Bourge mentioned.

Senator CARPER. OK.

Mr. GARWIN. She said explicitly what would be the cost to the American public, the consumer, of such an event if it happened, and we do not really know that. We need many more and more precise and more public estimates of that. Then anybody can supply the probability, which is not really a probability because it is affected by people's decisionmaking process, and in the case of China and Russia, that is deterrable. We would deter that. This is not something that they could do lightly without realizing that they would suffer nuclear response, not just high-altitude EMP. So it would be very bad for their militaries, and you might say that could cause all-out war. So it could. And it would not help to put the blame on the one who started it. We have to think these things through.

So what is the probability? Difficult to answer.

Senator CARPER. All right. Thanks.

Mr. Chairman, my time has expired. I know you went on for a while, and I would like to go on—not for that long but for a while. Is that OK?

Chairman JOHNSON. Can I come back to you? I just want to clarify a few things.

Senator CARPER. Sure.

Chairman JOHNSON. Dr. Garwin, 700 total transformers that are kind of the critical ones, the long term; $100,000, that would be $70 million. Again, that does not even show up as a rounding error in the Federal budget. We are talking about $70 million. But I did want to ask you a question. Are those capacitors that you are recommending already designed? Or is that something that would have to be developed?

Mr. GARWIN. The neutral current-blocking devices exist. They have been tried. A company, Emprimus, is offering them for sale. Who knows how much they are charging for it? I think that you

can use one device on several transformers, and that is where this $100,000 or $150,000 per transformer comes from.

The series blocking capacitors in the power lines themselves, those have not been designed. Those are also of the same order of cost. It depends whether you put them in substations on fiberglass stands, whether you actually hang them on the lines, what kind of control systems you put around them so that they do not cause any power problems when there is no electromagnetic pulse or solar storm.

So those have not been designed. I wish to call attention to the fact that they exist. It is hard for an electrical engineer even to get her mind around the fact that you make a great big value of a capacitance, a lot of millifarads. And it still costs less than the ones that we are accustomed to having because the voltage across them is lower.

Chairman JOHNSON. So, again, these are estimates. I am just trying to get a feel for how much we are talking about, how much of the electrical grid would it protect, and how quickly could we actually install these things. As a business guy, that would be my first questions. How much is it going to cost? How quickly could we install them, in what kind of phasing? And, how much development really has to occur on this? Anybody else can jump in.

Mr. GARWIN. You could do it in a couple of years.

Chairman JOHNSON. But could you start installing some of these things tomorrow?

Mr. GARWIN. Yes, you could install neutral current-blocking devices. You could have some military base at the end of a long transmission line, install series-blocking capacitors. Yes, you could go ahead, and if it did not work, you would take it out of service. But you need to do analyses of the stability of the networks, electrical stability of the networks, and then you need to have competition to perfect these things. But, yes, you could get a good ways within a couple of years.

Chairman JOHNSON. So, again, for this not even pocket change to the Federal Government, would this make sense for us to quickly authorize just a bare minimum level of protection, authorize, $20 to $70 million—again, no need to ask for an offset for that small amount—start installing these things, maybe they are not perfect, we can always upgrade them. And I guess I want to ask you, Mr. McClelland, and you, Ms. Bourge, is that something that we could support and get done and do it tomorrow? We will do other strategies. We will do other reports. But is this something we could do tomorrow, get that in motion so we can start installing these things as quickly as possible? Mr. McClelland.

Mr. MCCLELLAND. I would say yes. I would also make a recommendation that we stay flexible. Neutral blocking may not be the only solution. It may not be a good fit for that particular site, and you will hear that from industry members that evaluate their——

Chairman JOHNSON. But if we are paying for it——

Mr. MCCLELLAND. Right.

Chairman JOHNSON. I mean, is there going to be much reason for them to squawk?

Mr. MCCLELLAND. No. And I would even say that there may be cheaper solutions, so instead of a neutral blocker, you could trip the transformer off.

And just to put one other item in context, if you will allow me, the 1989 Quebec event, there was virtually no equipment damage, 10 hours of off time for the grid, cost between $1 to $2 billion. If you work backward and if you just inflate the cost to half a million dollars, you are equivalent then to $1 billion, the lower end of that cost for that relatively benign event, versus a much more severe event that is inevitable.

Chairman JOHNSON. Again, so what I am going to try and convince our Ranking Member is to join me in authorizing up to $100 million to quickly install these as a first step. Could you do these things in a series? Again, we are talking about such a minimal expenditure with such a great risk. And, by the way, we do know GMD, it is 100 percent certainty that this will occur. Maybe not tomorrow, 10 percent every decade, but it will occur. It is 100 percent. And so we need to protect ourselves against that.

Ms. Bourge, would industry have any problems if we authorized spending the money to install these types of controls, realizing they are not perfect and there may be better solutions, lower-cost solutions in the future, but let us at least do this minimal amount now and continue to look at this in the future?

Ms. BOURGE. I think the overall concept would not be so concerning, but there would be some concerns about the flexibility of what type of technology solutions are going to be applied and where we are applying, because the longitude or the closeness to water, things like that impact what type of protections are best recommended for an individual facility.

So I am not sure if we would be comfortable with the idea of it just being a mandate, here is the money, but you need to install this specific technology on every part of the system; so much as here is some money, work together with DOE, figure out how best to install it——

Chairman JOHNSON. OK. Happy to provide that flexibility, but I want to get the thing moving. So I do not want to say, well, until we have it all designed and we know exactly what we are going to put on all 700, we are going to do nothing. Let us take a look at if there are 500 which are pretty obvious, let us get the things installed. And it may not be perfect, and we will come back and authorize a better solution. Mr. Currie.

Mr. CURRIE. Yes, sir. I will say one thing that could be a stumbling block, again, is this prioritization of the most high risk places or transformers, and it sounds like FERC has some efforts ongoing. Based on our work at DHS, we have not seen anything that has really fleshed that out yet or any entity at DHS that really knows that information. So that would be critical before you could ever figure out how to spend money.

Chairman JOHNSON. But, again, FERC, you have done a fair amount—you have already done some studies, so you think this could be implemented pretty rapidly. So I will come to you guys, and I will leave DHS out of this for the time being, because you are little more prepared, or I will ask you to give the information

to DHS. What a concept. We can actually get these things done. Senator Carper.

Senator CARPER. Thanks, Mr. Chairman.

Again, another question, if I could, for Ms. Bourge, and maybe, Dr. Garwin, you take a swing at this one as well. A fellow named Yousaf Butt—I think that is the correct pronunciation—a nuclear physicist and former researcher with the Harvard-Smithsonian Center for Astrophysics, recently wrote the following—this is what he wrote. He said, "If terrorists want to do something serious, they will use a weapon of mass destruction—not mass disruption. They do not want to depend on complicated secondary effects in which the physics is not very clear." That is what he said.

Let me just ask, is a high-altitude nuclear EMP a weapon of mass destruction or a weapon of mass disruption? If you believe it is a weapon of mass disruption, do you agree with Dr. Butt's statement? Ms. Bourge, please.

Ms. BOURGE. It is most definitely mass disruption when you are talking about a high-altitude nuclear EMP. The reason someone would detonate a nuclear bomb or device in the air like that is for the EMP effect. Otherwise, they are going to do a ground detonation.

From our perspective, we tend to see it from a risk scenario. The most likely scenario is that a nuclear bomb would be detonated on the ground, not in the air, because a nation state would be doing an act of war. A terrorist is also going to be trying to kill as well as cause terror. So you would have some groups that would do a high-altitude detonation, but their intent has to be that mass panic, that mass destruction, without the mass casualties immediately.

Senator CARPER. OK. Again, Dr. Garwin, I will quote Dr. Butt again. He said, "If terrorists want to do something serious, they will use a weapon of mass destruction—not mass disruption." Then he went on to say, "They do not want to depend on complicated secondary effects in which the physics is not very clear."

Mr. GARWIN. He asserts a better understanding of terrorists than I have. Yes, having a nuclear weapon, exploding it at ground level in a city, I have written about that a lot. That is a real problem. It is a lot easier to do, really, than sending it up without killing anybody immediately. But you will kill lots of people.

Now, a first-generation nuclear weapon produces a very significant E1 and destroys all kinds of electronics. It does not do very much for the E3, that is, the geomagnetic storm-like pulse. But it will kill a lot of people, not instantly, and, that is up to the terrorists' taste. It is easier for them, in my opinion, to detonate a nuclear weapon in a city. But that does not mean we should not protect against the other.

Senator CARPER. I have several other questions. If you would, just bear with me, please. A question on predicting space weather, if we could, and I do not know if this is a fair question to ask of you, Ms. Bourge, but I will start with you if I could.

When it comes to space weather-generated geomagnetic disturbances, it appears that our ability to predict the intensity of solar flares and their impact on Earth is critical to mitigating the impacts to the electrical grid. Ms. Bourge, could you and maybe Dr.

Garwin take this question for me? Can you address if the United States is doing a good job at predicting space weather events?

Ms. BOURGE. From the electric industry——

Senator CARPER. Microphone.

Ms. BOURGE. From the electric industry perspective, I would say that the United States is doing a pretty good job of predicting space events. We do get early alerts so that we are able to take protective action for our systems in the higher latitudes. That sometimes will mean turning off a system because we got that alert from the government in time.

Senator CARPER. Is it a couple of days? Is it hours?

Ms. BOURGE. So it depends on the size of the storm. Usually, it takes about 16 hours to, I think, 36 hours, if I recall correctly, for the storm to impact the Earth from when it first happened on the Sun, and we usually get close to that for type of a heads up. But you could have a shorter time period as well. But as long as we have enough time to have our operators respond, that works. And so that is a very important issue from our perspective, because unlike the EMP threat, the GMD threat we do get that early warning. We do know for sure. The military is not going to call us if they are tracking a nuke, most likely. But we do get a heads up when a GMD is heading our way. We know what level we are expecting. We know what region is likely to have the most impact, and we can take protective measures for our system.

Senator CARPER. What kind of protective measures would you take in those instances?

Ms. BOURGE. So in some cases, we already have existing technology on the systems at the higher latitudes to protect against GMDs. They are often called "chokes."

Senator CARPER. Chokes?

Ms. BOURGE. Chokes.

Senator CARPER. Like a chokehold.

Ms. BOURGE. Like a chokehold, because basically that is what it is doing to the current. It is trying to limit its ability to impact the system.

And then we also have that early warning system. That is a big part of protection against a GMD, just knowing that it is coming, knowing what time you are expecting it so you can protect your system, and if need be, shut it off so it does not get hurt.

Senator CARPER. And if you get like a warning of 12, 18 hours, that is enough time to shut down?

Ms. BOURGE. That is enough time. We always would love more time. The more time you have for things, the better. But that is a good window. I would caution that these are programs that are sponsored by government dollars. It is satellites that are out in space monitoring space weather for us. And it is very important as we move forward in the years that we do not consider removing these technologies from NOAA's suite of technologies and availabilities that they have.

Senator CARPER. Dr. Garwin, do you agree with anything that Ms. Bourge just said?

Mr. GARWIN. Quite a lot. We do not get very good warning. We see these things on the sun, and 24 or 36 hours later we may or may not have a severe geomagnetic storm on the Earth. A real

warning of about 40 minutes comes from an ACE satellite or now the DSCOVR satellite on the Earth-Sun line off at a million and a half miles from the Earth out of 93 million miles to the Sun. Forty minutes is sort of short to change from economic dispatch where you send the electricity in the cheapest way to robust dispatch, which may do some good so that the lines are less heavily loaded and more generators are operating, so if one line goes out, another one can take over.

We could have, as in the 2011 report, some so-called quasi-satellites that would be out at 15 million miles. You cannot station them there. You have to have a whole swarm of them. But they can be tiny things, and that would extend from 40 minutes to about 7 hours and give you really better actionable intelligence.

Senator CARPER. OK.

Mr. GARWIN. So that would be a good thing. It really would not cost very much. Nobody that I know is planning for it.

Senator CARPER. All right. Thank you. And one last question, if I could, for Mr. Currie. Mr. Currie, the EMP Commission issued its recommendations several years ago, and I think those have been discussed at least to some degree here today. As I understand it, GAO is working to assess whether the Department of Homeland Security has implemented the EMP Commission's recommendations. Here is my question: Is DHS required to implement the EMP Commission's recommendations? That is one. Second, have any of the EMP Commission's recommendations been codified in statute? Go ahead and answer those first. Is DHS required to implement the EMP Commission's recommendations? And, two, have any of the EMP Commission's recommendations been codified in statute? Just do those first. And then I have one more followup.

Mr. CURRIE. Sure. No, I am not aware of any law that requires DHS to implement the recommendations.

Senator CARPER. Have any of the Commission's recommendations been codified in statute yet?

Mr. CURRIE. Not that we have seen.

Senator CARPER. OK. Last question: Did the EMP Commission recommend that any other department or agency take action?

Mr. CURRIE. Absolutely. The Department of Energy was a big part of the EMP Commission report, too, and they were to work either independently or with DHS to implement the recommendations, too. And that is the same structure for protecting critical infrastructure across the country. DHS has the lead in coordinating, and they work with the sector-specific agency. For energy, it is DOE. But that applies to all sectors, too. So it is a partnership.

Senator CARPER. OK. I want to, if I could just in a closing statement, thank each of you for coming today, for your preparation, and for your responses to questions.

In the last Congress—I call him the wingman while I was chairing this Committee, was Tom Coburn of Oklahoma, Dr. Coburn, a House Member, a physician, a successful business person, and a valued member of this Committee and this body. And we were encouraged at one point in time—at several points in time in the last Congress to hold hearings and to delve deeper into this issue. And I recall him as a Congressman, he is one of those persons who—for those of you who know him—was already free to

speak his mind. And one of our colleagues used to say of Tom, whom I love dearly, he would say, "Dr. Coburn is sometimes mistaken but never uncertain." That is what he would always say. But he was oftentimes right.

We once had a conversation about this issue. I think he described this issue as "hokum." That is a word we sometimes use in Delaware. Again, going back to the characterization one of our colleagues used to have of Tom, I do not know if this is hokum or not. I think we have some pretty smart people here that are before us and who have the interests of our Nation at heart, have brought their concerns to us, and we should certainly be attentive to those. I know this is an issue that is especially important to our Chairman, so it is sure to get some attention. But I know just about enough to be dangerous on this subject, and I did not know that much before we started planning for this hearing, so I have learned a bit, and I have more to learn.

But among other things, I know a little bit about cyber attacks. I know a little bit about cybersecurity. I know a little bit about data breaches. In fact, I have learned a lot. I remember a couple years ago when there was an article several years ago in the press that said I was the expert in the Senate on cybersecurity. And I turned to a member of my staff, and I said, "Imagine that. I am an expert now in cybersecurity now that I am the Chairman of the Committee." And my staff person said, "In the land of the blind, the one-eyed man is king." So for me not to get carried away with being deemed an expert in that.

But I know a fair amount about those. I also know I am a retired naval flight officer (NFO), retired Navy captain, and spend a fair amount of time thinking about wars and being involved in one and worried about our homeland security and a lot of levels, including lone-wolf attacks—and those are not lone-wolf attacks—including avian influenza, Ebola. It is a wild and crazy world that we live in today, and we need to be able to sort of assess these risks, and to the extent that we have resources, people and other resources to push toward these risks, what we need to do is make sure that we are adjusting our resources that we have, can commit, are committing to the level of risk, and that we always keep that in mind.

All right. Mr. Chairman, thanks so much for bringing this together and to all of you for joining us today.

Chairman JOHNSON. Thank you, Senator Carper.

I just have two quick questions. Then I will give everybody a chance, if you have another comment you want to make, to do that. First of all, does anybody on the panel think the threats from EMP and GMD is "hokum"? Anybody?

Ms. BOURGE. I just have to admit I do not know the word. [Laughter.]

Chairman JOHNSON. Hooey. Science fiction. Fanciful. Like not a problem.

Ms. BOURGE. I would not agree that it is imaginative or movie scenario only. It is a definite potential threat. I just would not agree that it is the most vital threat against our electric infrastructure.

Chairman JOHNSON. OK. It is a real threat.

Second, we were talking about one of the solutions would be basically shutdown—with early warning, shutdown. Correct?

Ms. BOURGE. For a GMD.

Chairman JOHNSON. Now, we have a massive solar flare, space weather like a Carrington Effect. You would have to shut down everything, correct? Dr. Garwin.

Mr. GARWIN. You can wait, but we do not have the instrumentation right now to give you the information. We have to look at the individual transformers, listen to the noise they make, measure their ground currents, and in order not to shut them down unnecessarily, use the magnetometers. China has a much better display, deployment of National Science Foundation magnetometers than we have here.

Chairman JOHNSON. But, again, that is making the decision based on what the extent of the solar discharge would be if it was massive, like a Carrington.

Mr. GARWIN. Well, we might——

Chairman JOHNSON. You would have to shut it down then, correct?

Mr. GARWIN. With no protection deployed, yes, we could and should do that.

Chairman JOHNSON. And for how long? How long do these space weather effects——

Mr. GARWIN. Some of them are a few days.

Chairman JOHNSON. Which means you would have to—because we do not have protection, we have not installed the capacitors——

Mr. GARWIN. Yes.

Chairman JOHNSON [continuing]. The only solution we have right now, the only protection would be early warning, and on something massive, complete shutdown of our electrical grid to save it.

Mr. GARWIN. Well, the North American Electric Reliability Corporation, argues that you do not have to plan for a shutdown. The grid is so vulnerable that it will shut itself down.

Chairman JOHNSON. That is not very comforting, and it could shut down for a couple years. Ambassador Woolsey.

Mr. WOOLSEY. Mr. Chairman, I just want to make one point on this issue of whether this is a low-probability, high-risk problem. There is more than one kind of probability. I sometimes talk about whether you are dealing with a malignant or malevolent problem—a malignant problem being something that is natural and it may metastasize, it may be terrible, it may be awful—Ebola. But it is random in the sense that it is only influenced by nature. Whereas, a malevolent one is one where there is somebody on the other side actually planning to try to kill you, and you cannot really assign a probability to that. All you can do is try to understand their culture. A lot of people would not have thought in 1929 that within a decade we would be into World War II with the Nazis in control of Germany and the rest.

But I want to read two sentences from an Iranian publication: "Once you confuse the enemy communication network, you can also disrupt the work of the enemy command and decisionmaking center. Even worse, today when you disable a country's military high command through disruption of communications, you will, in effect, disrupt all the affairs of that country. If the world's industrial

countries fail to devise effective ways to defend themselves against dangerous electronic assaults, then they will disintegrate within a few years. American soldiers would not be able to find food to eat, nor would they be able to fire a single shot." That is the Iranian magazine Nashriyeh-e Siasi, 17 years ago, in 1998. Their strategists have been following and analyzing General Slipchenko's work, which I mentioned. That is not something to which one can assign a random probability. If these guys get in control, a launch under some circumstances could be possible.

Chairman JOHNSON. Again, that was 17 years ago, and they have been pretty patient. And now we have a deal that I believe will allow them to become a nuclear power with ballistic missile technology.

Mr. WOOLSEY. Yes.

Chairman JOHNSON. And this is in their military planning and strategy, as well as—and I would refer everybody to your testimony. You have a number of statements from military planners in Russia and China and North Korea.

Mr. WOOLSEY. Yes.

Chairman JOHNSON. Again, fully aware of this real threat—not hokum. A real threat.

Mr. WOOLSEY. Yes.

Chairman JOHNSON. Again, this is not like, "Oh, nobody has thought about this." No, people have thought about it, and they are planning for it, and they are giving themselves the capability to implement it.

Mr. WOOLSEY. And the South Koreans are not getting bogged down in probabilities. They are toughening their grid because they have North Korea to deal with.

Chairman JOHNSON. And we have known absolutely this for decades, publicly since at least 2004 with these EMP Commissions, and we have done virtually nothing.

Mr. WOOLSEY. Absolutely.

Chairman JOHNSON. When we can do something, and it does not cost very much—not perfect, but we can spend a few million dollars—millions. We are not talking billions. We are talking millions, and we could go a long way toward providing some pretty significant protection.

Chairman JOHNSON. OK.

Mr. GARWIN. I will agree with that. I disagree with Jim Woolsey's characterization. It sounds like, not only 17 years ago. It sound like Sun-Tzu.

Mr. WOOLSEY. It does. Sun-Tzu could have written that if he had known about EMP.

Chairman JOHNSON. But he was not aware of nuclear weapons.

Final comments, we will start with you, Ms. Bourge.

Ms. BOURGE. I just want to remind you that we do need to look at these issues as separate, GMDs and EMPs. I hear a lot of conflation, and I understand the reason why, because of that E3 component. But one thing I do not think was clear when we defined that out initially was it was defined as E3 component is similar to a severe GMD storm. That is not identical. That is similar. So there has been some disagreement, and there is a desire to have some research to see just how well does the GMD protections that

we do utilize in some parts of the country currently, how well do those actually protect against an EMP? And so I am not sure if industry would agree that by putting on the technology solution that is being put forth here or the ones we already utilize in some parts of the industry, if that would actually solve the EMP threat.

Chairman JOHNSON. And that is fine, but let us at least protect ourselves from GMD in a more robust fashion where it does not cost very much. And, again, my proposal would actually have the government pay for it, and we just need cooperation.

Ms. BOURGE. Well, we certainly——

Chairman JOHNSON. Trust me, now I am all about let us not grow the Federal Government, let us not overregulate. I mean, I am your ally from that one still. So, again, kind of work with us on this. I would appreciate it. Mr. Currie.

Mr. CURRIE. Yes, sir. Well, as I said in my opening statement, I think it is really difficult to fully assess the risks of this or prioritize investments and security when it is not clear who has the lead role, and that is one of the big themes that we have found—is that DHS has the lead role for critical infrastructure protection, but has not identified different roles and responsibilities for electromagnetic threats.

Chairman JOHNSON. So that would be something our Committee could potentially help define in legislation. Dr. Garwin.

Mr. GARWIN. Let me pass right now.

Chairman JOHNSON. Sure. Mr. McClelland.

Mr. MCCLELLAND. Just one quick clarification. An EMP event and a GMD event would be events of mass destruction. The EMP Commission was very clear about the electronics and the transformers and the lead times associated with those systems as well as the other systems, the other infrastructure types that would be affected. A recovery would not be easy. In many cases, the generators are specifically and custom-built. They have transformers that are custom-built for their installation. So stockpiling those transformers and then replacing them after the effect is simply not a feasible solution.

Chairman JOHNSON. OK. Ambassador Woolsey.

Mr. WOOLSEY. Mr. Chairman, I want to thank you for holding this hearing and say that anything I can do in the future to help you in these efforts. After several years of Peter and I and others who are interested in this issue feeling like we are beating our heads against a wall, it is great to have a Chairman and a Committee that is taking us seriously.

Chairman JOHNSON. I understand what that feels like, by the way. [Laughter.]

Mr. WOOLSEY. Anyway, I just want to say thank you.

Chairman JOHNSON. OK. Well, again, thank you for your work on this. Dr. Garwin.

Mr. GARWIN. OK. My summary is a small point, and in my analyses, E3 from a high-altitude nuclear explosion is easier to correct, to mitigate, than a geomagnetic storm because it is over in a minute or so, and you are going to shut down, generators are still spinning, easier to get back up.

Chairman JOHNSON. Can you shut down quickly enough in an EMP, though? Doesn't that require microseconds?

Mr. GARWIN. No. The E3 does not cause damage for seconds or more because it is the power that is flowing in the transformers that can no longer resist the voltage——

Chairman JOHNSON. But you need automatic trips. I mean, you are going to have to have some kind of detection in mind——

Mr. GARWIN. I agree with you, and you would have absolute certainty if you put in this warning system that I recommend, government-operated, high-altitude nuclear explosion went off, never went off before, and take measures to protect your system. Then milliseconds, seconds, those would be fine for protecting the transformers. Of course, other things may have been lost due to the E1 pulse.

Chairman JOHNSON. OK. Well, again, I just want to thank all of you for your time, your thoughtful testimony, your answers to my questions, all of our questions. I hate to call this a "first step," but I guess we are kind of at that stage where, at least for this Committee, for the U.S. Senate, this is kind of a first step. Maybe we have had a number of first steps. It cannot be the last step. So I am going to aggressively pursue this, provide it the type of public attention I think it deserves, and hopefully the thoughtful evaluation so we can start moving forward. Let us do the easy things first, not perfect, but let us start offering and implementing some protections as we continue to study this, as we develop a longer-term strategy that is certainly more encompassing.

So, with that, this hearing record will remain open for 15 days until August 6 at 5 p.m. for the submission of statements and questions for the record.

This hearing is adjourned.

[Whereupon, at 12:12 p.m., the Committee was adjourned.]

APPENDIX

Opening Statement of Chairman Ron Johnson
"Protecting the Electric Grid from the Potential Threats of Solar Weather and Electromagnetic Pulse"
July 22, 2015

As prepared for delivery:

Good morning. Thank you all for joining us today. We will be looking at an issue that I believe is vital to national security—the extent to which the electric grid may be vulnerable to the threats of solar weather or a high-altitude electromagnetic pulse.

When it comes to critical infrastructure, there are several key sectors, often called the "lifelines," that essentially undergird and support all other sectors. The energy sector is one of these crucial lifelines. Without it, the other sectors would cease to function. Our economy, our livelihoods and our ability to defend ourselves would be crushed.

Protecting the electric grid is a monumental challenge, and the threats facing it are many and varied. The grid's physical infrastructure is necessarily spread throughout the nation and often cannot be protected from severe weather, sabotage or vandalism. Likewise, utilities themselves are encountering an enormous task in protecting their computer networks and fighting off cyberattacks.

We also know that the potential consequence of any attack or event on the grid is very high. In a real-life example, in 2003, a cascading failure across the grid in the Northeast left almost 50 million people without power, many for days. One federal study identified nine critical substations that could be disabled and potentially bring down the entire U.S. grid for more than 18 months.

The threats of solar weather and high-altitude electromagnetic pulse are unique in that they can affect a vast region of the country. They may damage assets on the grid that are expensive, difficult and time-consuming to replace.

It is my goal that this hearing enable us to define the problem--that is, to identify how significant these threats are to our electric grid and our nation. We need to understand how ready our nation is for these threats, and we need to evaluate potential opportunities to mitigate them.

Several reports over the last decade have highlighted just how bad these electromagnetic threats could be. While we want to avoid fear-mongering, we don't want to take these issues lightly.

One study estimated severe solar weather could leave as many as 130 million people without power for years. Similarly, the EMP Commission estimated that 90% of the U.S. population could die as a result of the consequences of a high-altitude electromagnetic pulse. The electromagnetic pulse of a nuclear blast 300 miles above the U.S. could potentially reach the entire country.

While these numbers may be worst-case projections, we need to be sure we are adequately studying these threats and prioritizing them against others. It is not enough to hope they never occur.

There are opportunities for protecting the electric grid from these threats, but they are costly. The EMP Commission, for example, projected that hardening the grid could cost $2 billion. Compared to the likely economic impact of one of these events, these costs may well be worth it.

That being said, this hearing is not one in which we are exploring ways we can place stronger regulations on industry. After 31 years in manufacturing before I came to the Senate, I understand that the level of regulation on businesses already is burdensome and has serious negative unintended consequences. I hope to see industry and government working together to meet the common challenges facing critical infrastructure.

Our witness panel is well equipped to handle these questions today, bringing vast experience and study of these issues to bear. Thank you all for joining us, and I look forward to your testimony.

Statement of Ranking Member Thomas R. Carper
"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"
July 22, 2015

As prepared for delivery:

Threats to the homeland have evolved considerably over the past 15 years. In the months after 9/11, the most pressing threat to the homeland came from Al-Qaeda terrorists planning attacks from remote caves in Afghanistan. Today, the terror threat has become far more diverse.

Some terror groups are still seeking sophisticated attacks against high profile targets. Other groups, such as ISIS, are attempting to inspire extremists all over the world – including here in the United States – to carry out simple attacks within their own communities.

We are also being attacked daily in cyberspace. In many ways, we are dealing with an epidemic of online theft and fraud. This epidemic is growing at an alarming rate, as attacks become more sophisticated and disruptive.

And the challenges we faced with the recent global Ebola outbreak and our ongoing efforts to counter the spread of avian influenza remind us that threats to the homeland aren't just man-made. To address these evolving threats, we must always look to stay at least one step ahead of the bad guys, or in some cases, Mother Nature.

At the same time, we have to reluctantly accept the reality that our nation cannot protect against every threat, or potential threat, out there. Though we should always strive for perfection, we simply do not have the resources to achieve 100 percent security all of the time. That is why it is so critical that we prioritize our homeland defenses. We must focus on those threats that our experience and intelligence tell us are most likely to occur, and would have the gravest impact if, God forbid, they became a reality.

Today's hearing gives us an opportunity to assess two different potential threats to our electrical grid—man-made electromagnetic pulses, or 'EMPs,' and geomagnetic disturbances caused by space weather.

Each of these threats poses some degree of risk to our communities – that much is clear. Our job, however, is to assess that risk and figure out where these threats rank in the spectrum of everything else our country faces. For example, we must determine how likely electro and geomagnetic threats are to occur given our existing preparations and deterrents. And if they were to occur, how they could impact the homeland?

Answers to these basic questions become all the more important and urgent amid the horrific reminders of the existing challenges we face from domestic terrorism and homegrown violent extremism in our own communities —attacks like those that occurred recently in Chattanooga and Charleston.

I hope today we can make some progress on this front, and that our witnesses can provide us with a clear-eyed assessment of these threats. I look forward to an informative hearing.

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Senate Testimony

Heading Toward An EMP Catastrophe*

Ambassador R. James Woolsey
Chairman, Foundation for Defense of Democracies
Former Director of Central Intelligence

Senate Homeland Security and Governmental Affairs Committee

Washington, DC
July 22, 2015

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For over a decade now, since the Congressional EMP Commission delivered its first report to Congress eleven years ago in July of 2004, various Senate and House committees have heard from numerous scientific and strategic experts the consensus view that natural and manmade electromagnetic pulse (EMP) is an existential threat to the survival of the American people, that EMP is a clear and present danger, and that something must be done to protect the electric grid and other life sustaining critical infrastructures--immediately.

Yet this counsel and the cost-effective solutions proposed to the looming EMP threat have been ignored. Continued inaction by Washington will make inevitable a natural or manmade EMP catastrophe that, as the Congressional EMP Commission warned, could kill up to 90 percent of the national population through starvation, disease, and societal collapse.

Indeed, some actions taken by the Congress, the White House, and the federal bureaucracy are impeding solutions, making the nation more vulnerable, and helping the arrival of an EMP catastrophe. More about that later.

Why has Washington failed to act against the EMP threat? A big part of the problem is that policymakers and the public still fail to understand that EMP, and the catastrophic consequences of an EMP event, are not science fiction.

The EMP threat is as real as the Sun and as inevitable as a solar flare.

The EMP threat is as real as nuclear threats from Russia, China, North Korea, and Iran. Nuclear EMP attack is part of the military doctrines, plans and exercises of all of these nations for a revolutionary new way of warfare that focuses on attacking electric grids and civilian critical infrastructures--what they call Total Information Warfare or No Contact Wars, and what some western analysts call Cybergeddon or Blackout Wars.

The nuclear EMP threat is as real as North Korea's KSM-3 satellite, that regularly orbits over the U.S. on the optimum trajectory and altitude to evade our National Missile Defenses and, if the KSM-3 were a nuclear warhead, to place an EMP field over all 48 contiguous United States.

The EMP threat is as real as non-nuclear radiofrequency weapons that have already been used by terrorists and criminals in Europe and Asia, and no doubt will sooner or later be used here against America.

A Clear And Present Danger

EMP, while still inadequately understood by policymakers and the general public, has been the subject of numerous major scientific and strategic studies. All of these warn by consensus that a natural or nuclear EMP, in the words of the Congressional EMP Commission, "Is one of a small number of threats that has the potential to hold our society seriously at risk" and "Is capable of causing catastrophe for the nation." Such is

the warning not only of the Congressional EMP Commission, but of studies by the Congressional Strategic Posture Commission, the National Academy of Sciences, the Department of Energy, the National Intelligence Council, a U.S. Federal Energy Regulatory Commission report coordinated with the Department of Defense and Oak Ridge National Laboratory, and numerous other reports.

Yet a recent Wall Street Journal article (May 1, 2015) on NORAD moving back into Cheyenne Mountain and spending $700 million to further harden the mountain against a nuclear EMP attack from North Korea, received hundreds of comments from shocked readers, half of whom still think that EMP is science fiction.

Nuclear EMP. We know that EMP is not science fiction but an existential threat that would have catastrophic consequences for our society because of high-altitude nuclear tests by the U.S. and Russia during the early Cold War, decades of underground nuclear testing, and over 50 years of tests using EMP simulators. For example, in 1961 and 1962, the USSR conducted several EMP tests in Kazakhstan above its own territory, deliberately destroying the electric grid and other critical infrastructures over an area larger than Western Europe. The Congressional EMP Commission based its threat assessment partially on using EMP simulators to test modern electronics--which the Commission found are over one million times more vulnerable than the electronics of the 1960s.

One prominent myth is that a sophisticated, high-yield, thermonuclear weapon is needed to make a nuclear EMP attack. In fact, the Congressional EMP Commission found that virtually any nuclear weapon--even a primitive, low-yield atomic bomb such as terrorists might build--would suffice. The U.S. electric grid and other civilian critical infrastructures--for example, communications, transportation, banking and finance, food and water--have never been hardened to survive EMP. The nation has 18 critical infrastructures--all 17 others depend upon the electric grid.

Another big myth is that a sophisticated long-range missile is needed to deliver an EMP attack. The iconic EMP attack detonates a single warhead about 300 kilometers high over the center of the U.S., generating an EMP field over all 48 contiguous United States.

However, any warhead detonated 30 kilometers high anywhere over the eastern half of the U.S. would collapse the Eastern Grid. The Eastern Grid generates 75 percent of U.S. electricity and supports most of the national population. Such an attack could be made by a short-range Scud missile launched off a freighter, by a jet fighter or small private jet doing a zoom climb, or even by a meteorological balloon.

According to a February 2015 article by President Ronald Reagan's national security brain trust--Dr. William Graham who was Reagan's Science Advisor and ran NASA, Ambassador Henry Cooper who was Director of the Strategic Defense Initiative, and Fritz Ermarth who was Chairman of the National Intelligence Council--North Korea and Iran have both practiced the iconic nuclear EMP attack against the United States. Both nations have orbited satellites on south polar trajectories that evade U.S. early warning

radars and National Missile Defenses. North Korea and Iran have both orbited satellites at altitudes that, if the satellites were nuclear warheads, would place an EMP field over all 48 contiguous United States.

Dr. Graham and his colleagues in their article warn that Iran should already even be regarded as having nuclear weapons and missiles capable of making an EMP attack against the U.S., or against any nation on Earth.

North Korea and Iran have also apparently practiced making a nuclear EMP attack using a short-range missile launched off a freighter. Such an attack could be conducted anonymously to escape U.S. retaliation--thus defeating nuclear deterrence.

Natural EMP. We know that natural EMP from the Sun is real. Coronal mass ejections traveling over one million miles per hour strike the Earth's magnetosphere, generating geomagnetic storms every year. Usually these geo-storms are confined to nations at high northern latitudes and are not powerful enough to have catastrophic consequences. In 1989, the Hydro-Quebec Storm blacked-out half of Canada for a day causing economic losses amounting to billions of dollars.

However, we are most concerned about the rare solar super-storm, like the 1921 Railroad Storm, which happened before American civilization became dependent for survival upon electricity and the electric grid. The National Academy of Sciences estimates that if the Railroad Storm were to recur today, there would be a nationwide blackout with recovery requiring 4-10 years, if recovery is possible at all.

The most powerful geomagnetic storm on record is the 1859 Carrington Event. Estimates are that Carrington was about 10 times more powerful than the 1921 Railroad Storm and 100 times more powerful than the 1989 Hydro-Quebec Storm. The Carrington Event was a worldwide phenomenon, causing forest fires from flaring telegraph lines, burning telegraph stations, and destroying the just laid intercontinental telegraph cable at the bottom of the Atlantic Ocean.

If a solar super-storm like the Carrington Event recurred today, it would collapse electric grids and life-sustaining critical infrastructures worldwide, putting at risk the lives of billions.

NASA in July 2014 reported that two years earlier, on July 23, 2012 , the Earth narrowly escaped another Carrington Event. A Carrington-class coronal mass ejection crossed the path of the Earth, missing our planet by just three days. NASA assesses that the resulting geomagnetic storm would have had catastrophic consequences worldwide.

We are overdue for recurrence of another Carrington Event. The NASA report estimates that likelihood of such a geomagnetic super-storm is 12 percent per decade. This virtually guarantees that Earth will experience a catastrophic geomagnetic super-storm within our lifetimes or that of our children.

Radio-Frequency Weapons (RFWs). Just as nuclear and natural EMP are not science fiction, we also know that the EMP threat from non-nuclear weapons, commonly called Radio-Frequency Weapons, is real. Terrorists, criminals, and even disgruntled individuals have already made localized EMP attacks using RFWs in Europe and Asia. Probably sooner rather than later, the RFW threat will come to America.

RFWs typically are much less powerful than nuclear weapons and much more localized in their effects, usually having a range of one kilometer or less. Reportedly, according to the Wall Street Journal, a study by the U.S. Federal Energy Regulatory Commission warns that a terrorist attack that destroys just 9 key transformer substations could cause a nationwide blackout lasting 18 months.

RFWs offer significant advantages over guns and bombs for attacking the electric grid. The EMP field will cause widespread damage of electronics, so precision targeting is much less necessary. And unlike damage from guns and bombs, an attack by RFWs is much less conspicuous, and may even be misconstrued as an unusual accident arising from faulty components and systemic failure.

Some documented examples of successful attacks using Radio Frequency Weapons, and accidents involving electromagnetic transients, are described in the Department of Defense *Pocket Guide for Security Procedures and Protocols for Mitigating Radio Frequency Threats* (Technical Support Working Group, Directed Energy Technical Office, Dahlgren Naval Surface Warfare Center):

--"In the Netherlands, an individual disrupted a local bank's computer network because he was turned down for a loan. He constructed a Radio Frequency Weapon the size of a briefcase, which he learned how to build from the Internet. Bank officials did not even realize that they had been attacked or what had happened until long after the event."

--"In St. Petersburg, Russia, a criminal robbed a jewelry store by defeating the alarm system with a repetitive RF generator. Its manufacture was no more complicated than assembling a home microwave oven."

--"In Kzlyar, Dagestan, Russia, Chechen rebel commander Salman Raduyev disabled police radio communications using RF transmitters during a raid."

--"In Russia, Chechen rebels used a Radio Frequency Weapon to defeat a Russian security system and gain access to a controlled area."

-- "Radio Frequency Weapons were used in separate incidents against the U.S. Embassy in Moscow to falsely set off alarms and to induce a fire in a sensitive area."

--"March 21-26, 2001, there was a mass failure of keyless remote entry devices on thousands of vehicles in the Bremerton, Washington, area...The failures ended abruptly as federal investigators had nearly isolated the source. The Federal Communications Commission (FCC) concluded that a U.S. Navy presence in the area probably caused the incident, although the Navy disagreed."

--"In 1999, a Robinson R-44 news helicopter nearly crashed when it flew by a high frequency broadcast antenna."

--"In the late 1980s, a large explosion occurred at a 36-inch diameter natural gas pipeline in the Netherlands. A SCADA system, located about one mile from the naval port of Den Helder, was affected by a naval radar. The RF energy from the radar caused the SCADA system to open and close a large gas flow-control valve at the radar scan frequency, resulting in pressure waves that traveled down the pipe and eventually caused the pipeline to explode."

--"In June 1999 in Bellingham, Washington, RF energy from a radar induced a SCADA malfunction that caused a gas pipeline to rupture and explode."

--"In 1967, the *USS Forrestal* was located at Yankee Station off Vietnam. An A4 Skyhawk launched a Zuni rocket across the deck. The subsequent fire took 13 hours to extinguish. 134 people died in the worst U.S. Navy accident since World War II. EMI [Electro-Magnetic Interference] was identified as the probable cause of the Zuni launch."

--North Korea used an Radio Frequency Weapon, purchased from Russia, to attack airliners and impose an "electromagnetic blockade" on air traffic to Seoul, South Korea's capitol. The repeated attacks by RFW also disrupted communications and the operation of automobiles in several South Korean cities in December 2010; March 9, 2011; and April-May 2012 as reported in "Massive GPS Jamming Attack By North Korea" (*GPSWORLD.COM*, May 8, 2012).

All Hazards Strategy. The Congressional EMP Commission recommended an "all hazards" strategy to protect the nation by addressing the worst threat--nuclear EMP attack. Nuclear EMP is worse than natural EMP and the EMP from RFWs because it combines several threats in one. Nuclear EMP has a long-wavelength component like a geomagnetic super-storm, a short-wavelength component like Radio-Frequency Weapons, a mid-wavelength component like lightning--and is potentially more powerful and can do deeper damage than all three.

Thus, protecting the electric grid and other critical infrastructures from nuclear EMP attack will also protect against a Carrington Event and RFWs. Moreover, protecting against nuclear EMP will also protect the grid and other critical infrastructures from the worst over-voltages that may be generated by severe weather, physical sabotage, or cyber-attacks.

EMP--The Ultimate Cyber Weapon

Ignorance of the military doctrines of potential adversaries and a failure of strategic imagination is setting America up for an EMP Pearl Harbor that could easily be avoided--if we would only heed that terrorist sabotage of electric grids and cyber-attacks are early warning indicators. In fact, in the military doctrines, planning, and exercises of Russia, China, North Korea and Iran, nuclear EMP attack is the ultimate weapon in an

all-out cyber operation aimed at defeating nations by blacking-out their electric grids and other critical infrastructures.

For example, Russian General Vladimir Slipchenko in his military textbook *No Contact Wars* describes the combined use of cyber viruses and hacking, physical attacks, non-nuclear EMP weapons, and ultimately nuclear EMP attack against electric grids and critical infrastructures as a new way of warfare that is the greatest Revolution in Military Affairs (RMA) in history. Like Nazi Germany's Blitzkrieg ("Lightning War") Strategy that coordinated airpower, armor, and mobile infantry to achieve strategic and technological surprise that nearly defeated the Allies in World War II, the New Blitzkrieg is, literally and figuratively an electronic "Lightning War" so potentially decisive in its effects that an entire civilization could be overthrown in hours. According to Slipchenko, EMP and the new RMA renders obsolete modern armies, navies and air forces. For the first time in history, small nations or even non-state actors can humble the most advanced nations on Earth.

China's military doctrine sounds an identical theme. According to People's Liberation Army textbook *World War, the Third World War--Total Information Warfare*, written by Shen Weiguang (allegedly the inventor of Information Warfare), "Therefore, China should focus on measures to counter computer viruses, nuclear electromagnetic pulse...and quickly achieve breakthroughs in those technologies...":

With their massive destructiveness, long-range nuclear weapons have combined with highly sophisticated information technology and information warfare under nuclear deterrence....Information war and traditional war have one thing in common, namely that the country which possesses the critical weapons such as atomic bombs will have "first strike" and "second strike retaliation" capabilities....As soon as its computer networks come under attack and are destroyed, the country will slip into a state of paralysis and the lives of its people will ground to a halt. Therefore, China should focus on measures to counter computer viruses, nuclear electromagnetic pulse...and quickly achieve breakthroughs in those technologies in order to equip China without delay with equivalent deterrence that will enable it to stand up to the military powers in the information age and neutralize and check the deterrence of Western powers, including the United States.

Iran in a recently translated military textbook endorses the theories of Russian General Slipchenko and the potentially decisive effects of nuclear EMP attack some 20 times. An Iranian political-military journal, in an article entitled "Electronics To Determine Fate Of Future Wars," states that the key to defeating the United States is EMP attack and that, "If the world's industrial countries fail to devise effective ways to defend themselves against dangerous electronic assaults, then they will disintegrate within a few years.":

Advanced information technology equipment exists which has a very high degree of efficiency in warfare. Among these we can refer to communication and information gathering satellites, pilotless planes, and the digital system....Once you confuse the enemy communication network you can also disrupt the work of the enemy command

and decision-making center. Even worse, today when you disable a country's military high command through disruption of communications you will, in effect, disrupt all the affairs of that country....If the world's industrial countries fail to devise effective ways to defend themselves against dangerous electronic assaults, then they will disintegrate within a few years... American soldiers would not be able to find food to eat nor would they be able to fire a single shot. (Tehran, *Nashriyeh-e Siasi Nezami*, December 1998 - January 1999)

North Korea appears to have practiced the military doctrines described above against the United States--including by simulating a nuclear EMP attack against the U.S. mainland. Following North Korea's third illegal nuclear test in February 2013, North Korean dictator Kim Jong-Un repeatedly threatened to make nuclear missile strikes against the U.S. and its allies. In what was the worst ever nuclear crisis with North Korea, that lasted months, the U.S. responded by beefing-up National Missile Defenses and flying B-2 bombers in exercises just outside the Demilitarized Zone to deter North Korea. On April 9, 2013, North Korea's KSM-3 satellite orbited over the U.S. from a south polar trajectory, that evades U.S. early warning radars and National Missile Defenses, at the near optimum altitude and location to place an EMP field over all 48 contiguous United States. On April 16, 2013, the KSM-3 again orbited over the Washington, D.C.-New York City corridor where, if the satellite contained a nuclear warhead, it could project the peak EMP field over the U.S. political and economic capitals and collapse the Eastern Grid, which generates 75 percent of U.S. electricity. On the same day, parties unknown used AK-47s to attack the Metcalf transformer substation that services San Francisco, the Silicon Valley, and is an important part of the Western Grid. Blackout of the Western Grid, or of just San Francisco, would impede U.S. power projection capabilities against North Korea. In July 2013, a North Korean freighter transited the Gulf of Mexico with two nuclear capable SA-2 missiles in its hold, mounted on their launchers hidden under bags of sugar, discovered only after the freighter tried to return to North Korea through the Panama Canal. Although the missiles were not nuclear armed, they are designed to carry a 10 kiloton warhead, and could execute the EMP Commission's nightmare scenario of an anonymous EMP attack launched off a freighter. All during this period, the U.S. electric grid and other critical infrastructures experienced various kinds of cyber-attacks, as they do every day and continuously.

North Korea appears to have been so bold as to use the nuclear crisis it deliberately initiated to practice against the United States an all-out cyber warfare operation, including computer bugs and hacking, physical sabotage, and nuclear EMP attack.

Just as Nazi Germany practiced the Blitzkrieg in exercises and during the Spanish Civil War (1936-1939), before surprising the Allies in World War II, so terrorists and state actors appear to be practicing now. For example:

--On October 27, 2013, the Knights Templars, a criminal drug cartel, blacked-out Mexico's Michoacan state and its population of 420,000, so they could terrorize the people and paralyze the police. The Knights, cloaked by the blackout, entered towns and villages and publicly executed leaders opposed to the drug trade.

--On June 9, 2014, Al Qaeda in the Arabian Peninsula used mortars and rockets to destroy transmission towers, plunging into darkness all of Yemen, a country of 16 cities and 24 million people. It is the first time in history that terrorists put an entire nation into blackout, and an important U.S. ally, whose government was shortly afterwards overthrown by terrorists allied to Iran.

--In July 2014, according to press reports, a Russian cyber-bug called Dragonfly infected 1,000 electric power-plants in Western Europe and the United States for purposes unknown, possibly to plant logic bombs in power-plant computers to disrupt operations in the future.

--On January 25, 2015, terrorists blacked-out 80 percent of the electric grid in Pakistan, a nation of 185 million people, and a nuclear weapons state.

--On March 31, 2015, most of Turkey's 75 million people experienced a widespread and disruptive blackout, the NATO ally reportedly victimized by a cyber-attack from Iran.

On June 20, 2015, the New York Times reported that administration officials in a classified briefing to Congress on a cyber-attack from China, that stole sensitive U.S. Government data on millions of federal employees, was information warfare "on a scale we've never seen before from a traditional adversary." Yet this and the other ominous threats described above are already forgotten, or relegated to back page news, as policymakers and the public stumble on, seemingly shell-shocked and uncomprehending, to the latest cyber crisis.

We as a nation are not "connecting the dots" through a profound failure of strategic imagination. Like the Allies before the Blitzkrieg of World War II, we are blind to the unprecedented existential threat that is about to befall our civilization--figuratively and literally, from the sky, like lightning.

Washington Dysfunction

The Congressional EMP Commission recommended a plan to protect the national electric grid from nuclear EMP attack, that would also mitigate all lesser threats--including natural EMP, RFWs, cyber bugs and hacking, physical sabotage, and severe weather--for about $2 billion, which is what the U.S. gives away every year in foreign aid to Pakistan. About $10-20 billion would protect all the critical infrastructures from nuclear EMP attack and other threats.

There are other plans that cost much less, and much more, because there are different technologies and strategies for protecting against EMP, and to different levels of risk. Any or all of these plans are commendable. There is no such thing as being over-prepared for an existential threat.

Unfortunately, none of these plans has been implemented. The U.S. electric grid and other civilian critical infrastructures remain utterly vulnerable to EMP because of

lobbying by the electric utilities in Congress, the federal bureaucracy, and the White House.

Lobbying by the electric power industry and their North American Electric Reliability Corporation (NERC) has, so far, thwarted every bill by the U.S. Congress to protect the grid from EMP. For example, in 2010, the House passed unanimously the GRID Act--which was denied a vote in the Senate, because a single Senator on the Energy and Natural Resources Committee put a hold on the bill. If the GRID Act passed in 2010, the national electric grid would already be protected from EMP, a process the EMP Commission estimated would take about 3-5 years.

The SHIELD Act, another bipartisan bill to protect the electric grid, has been stalled in the House Energy and Commerce Committee for years, due to lobbying by the electric utilities.

Even worse, the U.S. Federal Energy Regulatory Commission, which has a too deferential and too cozy relationship with NERC, has approved a NERC proposed standard for protecting the grid from solar storms that has been condemned by the best scientific experts. Dr. William Radasky and John Kappenman, who both served on the Congressional EMP Commission, and other independent experts have written scientific critiques proving that the NERC standard for natural EMP (also called GMD for Geo-Magnetic Disturbance) is based on "junk science" that grossly underestimates the threat from natural EMP.

For example, Kappenman and Radasky, who are among the world's foremost scientific and technical experts on geomagnetic storms and grid vulnerability, warn that NERC's GMD Standard consistently underestimates the natural EMP threat from geo-storms: "When comparing...actual geo-electric fields with NERC model derived geo-electric fields, the comparisons show a systematic under-prediction in all cases of the geo-electric field by the NERC model."

Dr. Radasky, who holds the Lord Kelvin Medal for setting standards for protecting European electronics from natural and nuclear EMP, and John Kappenman, who helped design the ACE satellite upon which industry relies for early warning of geomagnetic storms, conclude that the NERC GMD Standard so badly underestimates the natural EMP threat that "its resulting directives are not valid and need to be corrected." Kappenman and Radasky:

These enormous model errors also call into question many of the foundation findings of the NERC GMD draft standard. The flawed geo-electric field model was used to develop the peak geo-electric field levels of the Benchmark model proposed in the standard. Since this model understates the actual geo-electric field intensity for small storms by a factor of 2 to 5, it would also understate the maximum geo-electric field by similar or perhaps even larger levels. Therefore, the flaw is entirely integrated into the NERC Draft Standard and its resulting directives are not valid and need to be corrected.

The excellent Kappenman-Radasky critique of the NERC GMD Standard represents the consensus view of all the independent observers who participated in the NERC GMD Task Force.

Perhaps most revelatory of U.S. FERC's failures, by approving the NERC GMD Standard that grossly underestimates the natural EMP threat from geo-storms--U.S. FERC abandoned its own much more realistic estimate of the natural EMP threat from geo-storms. It is incomprehensible why U.S. FERC would ignore the findings of its own excellent interagency study, one of the most in depth and meticulous studies of the EMP threat ever performed, that was coordinated with Oak Ridge National Laboratory, the Department of Defense, and the White House.

U.S. FERC's preference for NERC's "junk science" over U.S. FERC's own excellent scientific assessment of the geo-storm threat is indefensible.

The White House has not helped matters by issuing a draft executive order for protecting the national grid from natural EMP--but that trusts NERC and the electric utilities to set the standards.

Nor has the White House or the U.S. FERC challenged NERC's assertion that it has no responsibility to protect the electric grid from nuclear EMP or Radio-Frequency Weapons.

Nor has the White House or the U.S. FERC done anything to prevent NERC and the utilities from misinforming policymakers and the public about the EMP threat and their lack of preparedness to survive and recover from an EMP catastrophe.

Consequently, policymakers in the States who are alarmed by the lack of progress in Washington on EMP preparedness, find themselves seriously disadvantaged in efforts to protect their State electric grids by the utilities and their well-funded lobbyists who falsely claim Washington and the utilities are making great progress partnering on the EMP problem. So far in 2015, State initiatives to protect their electric grids have been defeated by industry lobbyists in Maine, Colorado, and Texas.

Texas State Senator Bob Hall, a former USAF Colonel and himself an EMP expert, characterizes as "equivalent to treason" the behavior of the electric utilities and their lobbyists:

As a Texas State Senator who tried in the 2015 legislative session to get a bill passed to harden the Texas grid against an EMP attack or nature's GMD, I learned firsthand the strong control the electric power company lobby has on elected officials. We did manage to get a weak bill passed in the Senate but the power companies had it killed in the House. A very deceitful document which was carefully designed to mislead legislators was provided by the power company lobbyist to legislators at a critical moment in the process. The document was not just misleading, it actually contained false statements. The EMP/GMD threat is real and it is not "if" but WHEN it will happen. The responsibility for the catastrophic destruction and wide spread death of

Americans which will occur will be on the hands of the executives of the power companies because they know what needs to be done and are refusing to do it. In my opinion power company executives, by refusing to work with the legislature to protect the electrical grid infrastructure are committing an egregious act that is equivalent to treason. I know and understand what I am saying. As a young US Air Force Captain, with a degree in electrical engineering from The Citadel, I was the project officer who led the Air Force/contractor team which designed, developed and installed the modification to "harden" the Minuteman Strategic missile to protect it from an EMP attack. The American people must demand that the power company executives that are hiding the truth stop deceiving the people and immediately begin protecting our electrical grid so that life as we know it today will not end when the terrorist EMP attack comes.

Ironically, while electric power lobbyists are fighting against EMP protection in Washington, Texas, Maine, Colorado and elsewhere, the Iranian news agency MEHR recently reported that Iran is violating international sanctions and going full bore to protect itself from a nuclear EMP attack:

Iranian researchers...have built an Electromagnetic Pulse (EMP) filter that protects country's vital organizations against cyber-attack. Director of Kosar Information and Communication Technology Institute Saeid Rahimi told MNA correspondent that the EMP (Electromagnetic Pulse) filter is one of the country's boycotted products and until now procuring it required considerable costs and various strategies. "But recently Kosar ICT...has managed to domestically manufacture the EMP filter for the very first time in this country," said Rahimi. Noting that the domestic EMP filter has been approved by security authorities, Rahimi added "the EMP filter protects sensitive devices and organizations against electromagnetic pulse and electromagnetic terrorism." He also said the domestic EMP filter has been implemented in a number of vital centers in Iran. (MEHR News Agency, "Iran Builds EMP Filter for 1st Time" June 13, 2015)

What Is To Be Done?

Congress should pass the Critical Infrastructure Protection Act (CIPA), which requires the Department of Homeland Security to adopt a new National Planning Scenario focused on EMP; to develop plans to protect the critical infrastructures; and for emergency managers and first responders to plan and train to protect and recover the nation from an EMP catastrophe. CIPA will enable DHS to draw upon the deep expertise within the Department of Defense and the Intelligence Community to help protect the critical infrastructures from EMP. Do not let the electric power lobby defeat CIPA or weaken its provisions, as they are presently trying to do.

Reestablish the Congressional EMP Commission. The greatest progress was being made when the EMP Commission existed to advance EMP preparedness. Progress stopped when the EMP Commission terminated in 2008. Currently, the struggle to advance national EMP preparedness is being carried on by a handful of patriotic individuals and Non-Government Organizations who have no official standing

and extremely limited resources. Bring back the EMP Commission with its deep expertise to advise Congress, government at all levels, and the private sector on how best to protect the nation, and to serve as a watchdog and leader for national EMP preparedness.

Pass the SHIELD Act or the GRID Act to establish adequate regulatory authority within the U.S. Government to achieve timely protection of the electric grid--and watch U.S. FERC like a hawk to make sure that regulatory authority is exercised.

Include in the National Defense Authorization Act the simple two-sentence provision below, that could rapidly reverse the trend of America's increasing vulnerability to EMP, by directing the Secretary of Defense to help State governments and the electric utilities protect themselves from an EMP catastrophe:

Energy Security For Military Bases And Critical Defense Industries
Whereas 99 percent of the electricity used by CONUS military bases is supplied by the national electric grid; whereas the Department of Defense has testified to Congress that DoD cannot project power overseas or perform its homeland security mission without electric power from the national grid; whereas the Congressional EMP Commission warned that up to 9 of 10 Americans could die from starvation and societal collapse from a nationwide blackout lasting one year; therefore the Secretary of Defense is directed to urge governors, state legislators, public utility commissions of the 50 states, the North American Electric Reliability Corporation (NERC) and the utilities that supply electricity to CONUS military bases and critical defense industries, to protect the electric grid from a high-altitude nuclear electromagnetic pulse (EMP) attack, from natural EMP generated by a solar super-storm and from other EMP threats including radiofrequency weapons, and to help the states, NERC, public utilities commissions, and electric utilities by providing DoD expertise on EMP and other such support and resources as may be necessary to protect the national electric grid from natural and manmade EMP threats. The Secretary of Defense is authorized to spend up to $2 billion in FY2017 to help protect the national electric grid from EMP.

Ambassador R. James Woolsey is former Director of Central Intelligence and is Chairman of the Foundation for Defense of Democracies.

*I am highly indebted to my friend and colleague, Dr. Peter Vincent Pry, who served on the Congressional EMP Commission and is Executive Director of the EMP Task Force on National and Homeland Security, for assistance in drafting this testimony.

Testimony of Joseph McClelland
Director, Office of Energy Infrastructure Security
Federal Energy Regulatory Commission
Before the Committee on Homeland Security
and Governmental Affairs
United States Senate
July 22, 2015

Chairman Johnson, Ranking Member Carper and Members of the Committee:

Thank you for the privilege to appear before you today to discuss threats to the electric grid in the United States. My name is Joe McClelland and I am the Director of the Federal Energy Regulatory Commission's newest office, the Office of Energy Infrastructure Security. I am here today as a Commission staff witness and my remarks do not necessarily represent the views of the Commission or any individual Commissioner.

In the Energy Policy Act of 2005, Congress entrusted the Commission with a major new responsibility to approve and enforce mandatory reliability standards for the Nation's bulk power system. This authority is in section 215 of the Federal Power Act. It is important to note that FERC's jurisdiction and reliability authority under section 215 is limited to the "bulk power system," as defined in the FPA, which excludes Alaska and Hawaii, as well as local distribution systems. Under the section 215 authority, FERC cannot author or modify reliability standards, but must depend upon an Electric Reliability Organization (or ERO) to

perform this task. The Commission certified the North American Electric Reliability Corporation or NERC as the ERO. The ERO develops and proposes reliability standards or modifications for the Commission's review which it can either approve or remand. If the Commission approves a proposed reliability standard, it becomes mandatory in the United States and is applicable to the users, owners and operators of the bulk power system. If the Commission remands a proposed standard, it is sent back to the ERO for further consideration. The Commission is required to give "due weight" to the technical expertise of the ERO when reviewing any of NERC's proposed standards.

Section 215 of the Federal Power Act provides a statutory foundation for the ERO to develop reliability standards for the bulk power system. However, the nature of a national security threat by entities intent on attacking the U.S. by exploiting vulnerabilities in its electric grid using physical or cyber means stands in stark contrast to other major reliability events that have caused regional blackouts and reliability failures in the past, such as events caused by tree trimming practices. Widespread disruption of electric service can quickly undermine the U.S. government, its military, and the economy, as well as endanger the health and safety of millions of citizens. Given the national security dimension to this threat, there may be a need to act quickly to protect the grid in a manner where action is mandatory rather than voluntary while protecting certain sensitive information from public disclosure.

To provide a significantly more agile and focused approach to these growing cyber and physical security threats, the Commission established the Office of Energy Infrastructure Security – or OEIS – in late 2012. Its mission is to provide leadership, expertise and assistance to the Commission, other federal and state agencies and jurisdictional entities in identifying, communicating and seeking comprehensive solutions to significant potential cyber and physical security risks to the energy infrastructure under the Commission's jurisdiction. This includes threats from geomagnetic disturbances (GMDs) and electromagnetic pulses (EMPs). OEIS also assists in the identification of key energy infrastructure facilities for the application of best practices. OEIS has been able to recruit and develop deep subject matter expertise to collaboratively perform its task.

Specific to the subject of this hearing, GMD and EMP events are generated from either naturally occurring or man-made causes. 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. Regarding man-made events, 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. In the case of the former, equipment is readily 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. The EMP generated during the detonation of a nuclear device is far more encompassing and generates three distinct effects, each impacting different types of equipment; a short high energy RF-type burst called E1 that destroys electronics; a slightly longer burst that is similar to lightning termed E2; and a final effect termed E3 that is similar in character and effect to GMD targeting the same equipment including key transformers. Any of these effects can cause voltage problems and instability on the electric grid, which can lead to wide-area blackouts.

In 2001, Congress established a commission to assess and report on the threat from EMP. In 2004 and again in 2008, the commission issued reports on these threats. One of the key findings in the reports was that a single EMP attack could seriously degrade or shut down a large part of the electric power grid. Depending upon the attack, significant parts of the electric infrastructure could be "out of service for periods measured in months to a year or more." It is important to note that effective mitigation against solar geomagnetic disturbances and non-nuclear EMP weaponry can also provide an effective mitigation against the impacts of a high-altitude nuclear detonation.

In order to better understand and quantify the effect of EMP and GMD on the power grid, FERC staff, the Department of Energy and the Department of Homeland Security sponsored a study conducted by the Oak Ridge National Laboratory in 2010. The results of the study support the general conclusion of

prior studies that EMP and GMD events pose substantial risk to equipment and operation of the Nation's electric grid and under extreme conditions could result in major long-term electrical outages. Unlike EMP attacks that are dependent upon the capability and intent of an attacker, GMD disturbances are inevitable with only the timing and magnitude subject to variability. The Oak Ridge study assessed a solar storm that occurred in May 1921, which has been termed a 1-in-100 year event, and applied it to today's electric grid. The study concluded that such a storm could damage or destroy over 300 bulk power system transformers interrupting service to 130 million people with some outages lasting for a period of years.

The Commission has used a two-fold approach to help address the EMP and GMD threats:

1. In response to a Commission Order, NERC has proposed two reliability standards on GMD. The Commission approved the first one, a mandatory reliability standard that requires certain entities to implement operational procedures to mitigate the effects of GMD events. The Commission also has issued an order proposing to approve the second one, a reliability standard proposed by NERC that would establish requirements for certain entities to conduct initial and on-going assessments of the vulnerability of their transmission systems against a

benchmark geomagnetic disturbance. The Commission also proposed certain additional actions.

2. Simultaneous with its regulatory approach, the Commission collaborated with federal agencies and industry members to identify key energy facilities, conduct threat briefings to industry members on both GMD and EMP, assist with the 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.

A few US entities have taken some initial steps to address EMP on their systems, but much work remains. Internationally, the United Kingdom, Norway, Sweden, Finland, Germany, South Korea, Japan, Australia, New Zealand, South Africa, Israel and Saudi Arabia have GMD and/or EMP programs in place or are in the early stages of addressing or examining the impacts of GMD or EMP.

The costs of these initiatives can vary widely depending on factors such as the threshold of protection, the service requirements of the load, the type of equipment that is to be protected, and whether the installation is new or a retrofit.

In conclusion, these types of threats pose a serious risk to the electric grid and its supporting infrastructures that serve our Nation. The Commission is therefore taking both regulatory and collaborative actions to address them.

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

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Prepared testimony for the hearing,
"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"

The spectacular images of Pluto this week from the NASA New Horizons probe provoked great public interest in our solar system. But our solar system is a matter for concern, as well. The 1200 people injured February 15, 2013 at Chelyabinsk, Russia, from a bolide (meteor) brought substantial focus on low-probability, high-consequence events. Among these are particularly intense magnetic storms from space-weather events or coronal mass ejections (CME), possibly even more intense than the 1859 Carrington Event in the pre-electric-grid era

Another potentially great impact on the electrical grid and modern societies is the high-altitude electromagnetic pulse (HEMP) from high-altitude nuclear explosions—HANE—on the order of 100 km or more above the Earth's surface.

The United States has been a leader in long-distance transmission of electrical power, but its system differs in characteristics, management, and organization from those of other advanced states. Nevertheless, there is much to be learned from and by the United States in working to make our electrical grid robust and economical in the modern era of technological threats and opportunities.

I begin with my recommendations to ease and essentially solve the severe problem posed by geomagnetic storms induced by space weather—specifically by the routine ejection from the sun of enormous blocks of plasma that travel out within the solar system and reach the Earth typically in a couple of days[2]. These cause displays of the "Northern Lights" (and Southern Lights as well). More importantly, the magnetized plasma and its incorporated magnetic field merge with the magnetic field of the Earth and change it by a relatively small amount, which, however, can create large currents on long electrical conductors such as pipelines, telegraph wires in the old days, and the electrical power transmission system—the Bulk Power System.

[1] Affiliation given for identification only.
[2] See *"Impacts of Severe Space Weather on the Electric Grid,"* JSR-11-320 of November 2011, sponsored by DHS, of which I was an author—available at https://fas.org/irp/agency/dod/jason/spaceweather.pdf A broad set of recommendations may be viewed on pp. 3-5 of that report.

Very serious consequences are estimated for such an event of a magnitude that can be expected to occur at random once per century, with greater events occurring with lower probability and lesser events more frequently[3].
I emphasize that a "once per century" event might occur next week; it has a probability of 10% of occurring within the next ten years—a time in which we can and should take measures to reduce and essentially eliminate its impact on the Bulk Power System of the United States. But events expected to occur once in 20 years can cause significant damage and disruption.

My recommendations regarding the Bulk Power System[4].

Missing in Federal policy and practice is a program to

1. *train and equip utility and transmission operators to bring down within seconds (switch off) transmission lines that are at risk of being damaged.*
2. *implement "rapid islanding" of the grid, to maintain a large fraction of the power consumers in operation by the use of whatever island generation capacity exists; this also facilitates restoring the Bulk Power System to operation, in contrast with a "black start."*
3. *fit transmission lines on a priority basis with "neutral current blocking devices" (capacitors) in the common neutral-to-ground link of the 3-phase transformers of EHV transmission systems at one end of the line-- whether 3-phase transformers or 3 single-phase transformers. Where transformers at both ends are autotransformers this may not be possible, in which case series-blocking capacitors in the power lines themselves should be installed (even if shorted until an EMP event is recognized).*
4. *alert grid operators and others to a high-altitude nuclear explosion within milliseconds of the event (by detection of the unambiguous very brief E1—pronounced "Ee-one"-- pulse).*

In my supplemental testimony submitted for the record, I provide support for these recommendations and explain why they would largely and immediately also eliminate long-lasting damage to the EHV transmisions system that might otherwise result from a high-altitude nuclear explosion.

** End of prepared oral testimony **

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[3] It is important to understand what can and can not be done to mitigate damage from events that we wish would never happen, as was done in exemplary fashion in the FEMA-sponsored publication *"Key Planning Factors: Response to an Improvised Nuclear Device [explosion] in the National Capital Region"* November 2011, http://www.fas.org/irp/agency/dhs/fema/ncr.pdf

[4] I note that these recommendations are similar to those of the "E-PRO HANDBOOK" Executive Summary 2014 and the INTERNATIONAL E-PRO REPORT of September 2013, e.g.,

GIC current blockers
Series Capacitance
Reducing Transformer Loads
Real-time, Threshold-based Transformer Protection

** Beginning of supplemental Garwin testimony for the record **

Permanent and severe damage to the Bulk Power System occurs largely from the destruction of the extremely high voltage—EHV—transformers that are used to transmit the high-voltage alternating current three-phase power over distances of hundreds of miles. The electricity in our houses, offices, and factories is delivered from the wall plug at a voltage of 120 or 240 V, and large motors, trains, and other system generally consume electrical power at a voltage of some hundreds of volts. But because power is voltage multiplied by current—specifically watts equal volts-times-amperes, and megawatts equals kilovolts-times-kilo-amperes, the only way to transmit electrical power economically over a distance of 100 miles or more is to use a *transformer* to step up the voltage from the convenient generating level of a few thousand volts—kilovolts or kV—to EHV levels exceeding 500 kV.

The Earth's magnetic field changes irregularly over a period of minutes and hours and even days in the course of a geomagnetic storm, and by Faraday's law of magnetic induction produces small voltages in potential electrical circuits—voltages that are totally imperceptible to people and that in our automobiles, homes, or offices are of no concern. But according to Faraday (and this is the principle upon which all electrical motors and transformers are made) the voltage induced is proportional not only to the change of magnetic field per second of time, but to the area of the electrical circuit (and to the number of "turns" of wire around that circuit).

In the case of long-distance power lines that may be 50 meters (164 ft)—above ground, there is a substantial area of the circuit that might be expected to be the height of the power line above the ground, multiplied by the length of the transmission line in hundreds of kilometers. in fact, the area is far greater because, for these slow changes of magnetic field, the voltage around the closed circuit that is composed of the power lines on the transmission towers, and completed by the return of electrical current through the "ground," does not flow along the surface of the Earth. Rather it flows along the higher conductivity regions that are found at depths of 100-200 km or more in regions of the continents overlain by highly insulating crystal and rock such as granite. Much of the geology of eastern Canada and the northeast United States is of this nature, and so the "circuit" area for the changing magnetic field to do its dirty work may be 1000 km long by 100 km high--the size of a small state tipped on its side; the area is not 1000 km by 50m but 2,000 times as large!

The resulting voltage around the one-turn circuit is often expressed as the length of the line multiplied by the "electric field" expressed in volts per kilometer—V/km, and a geo-electric field as small as 5 V/km can cause serious damage because over a line of length 1000 km it would amount to 5,000 V. The particular vulnerability of transformers on the Bulk Power System arises when they are connected on the three-phase line so that the three fat aluminum power cables at the top of the poles enter three separate transformers that are "Y-connected," with their common point connected to a grounding mat or a field of metal stakes driven into the ground. Two such sets of Y-connected transformers at either end of the 1000-km line thus establish a circuit for the geomagnetic storm to induce current.

Despite the fact that EHV transmission occurs at voltages of 500 kV, and we have estimated 5 kV for the voltage due to the geomagnetic storm, the geomagnetic storm voltage is akin to "direct current" like that from a battery, whereas the power carried by the EHV system is alternating current, changing direction (twice) 60 times per second—at 60 hertz (Hz).

Over a period of many seconds or minutes, the dc current drives the transformers into "half-cycle saturation" allowing unprecedented amounts of power to flow from the generators or the source of electrical power, and overheating the copper windings and steel structure of the transformers.

It is essential to understand that geomagnetic storms cause no problems when the transmission systems are de-energized, as they would be following the downing of a transmission tower. Hence the first recommendation.

The second is to avoid collapse of the entire economy—blackout due to the loss of the most vulnerable line from the effect of geomagnetic storm, HANE, sabotage, or other problem. There is a big difference in the recovery time of the electrical power system between the blackout of an area covering many states and eastern Canada, and the loss of EHV transmission lines that only supplement more local generation capacity.

In fact, all but the most intense geomagnetic storm can be countered and Bulk Power Transmission continued if the Y-connected transformers are not connected from their common "neutral" terminal directly to the grounding mat, but instead through a "neutral current blocking device" that is designed to accept for a few minutes or hours steady voltages that could be expected from the 100-year geomagnetic storm. There have been several successful trials of such blocking devices in the United States, Canada, and elsewhere, and they are now offered for sale to the industry.

Their cost is on the order of $100,000 per tranformer[5], but they protect transformers that at a high-power terminal may cost $10 million[6] and can preserve the economy of a million Americans that would otherwise suffer from temporary disruption if the power line needed to be shut off, and severe economic loss and even loss of employment and life if the geomagnetic storm or HANE is allowed to destroy many transformers that would take months or years to replace.

Finally, essentially all transformer damage from a high-altitude nuclear explosion could be avoided by the installation of these blocking devices, or even where no such devices were installed, by manual or automatic shutdown of that EHV line for a minute or so following the detection of a HANE.

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[5] http://www.powerworld.com/files/06Emprimus.pdf

[6] http://energy.gov/sites/prod/files/Large%20Power%20Transformer%20Study%20-%20June%202012_0.pdf A single-phase 500 MW large power transformer is quoted at $4.5 million.

Protection of U.S. society against a high-altitude nuclear explosion.

Such a high-altitude nuclear explosion—HANE—provides disturbances to long-distance power transmission systems by virtue of the high-altitude electromagnetic pulse—HEMP—through mechanisms that are complex and fascinating, but can be understood in broad outline and that have been the subject of much analysis over the decades since they were observed in fragmentary form in 1962.

A nuclear weapon exploded 100 km or so above the surface of the United States or above its shores would have "line of sight" out to 1000 km or so. This applies to a "normal" first-generation nuclear weapon as well as to a megaton-class nuclear explosive such as possessed by the United States, China, and Russia.

The geomagnetic-storm-like effect of a HANE arises from the liberation of large amounts of energy in a small (say one ton) mass of bomb and rocket materials in the weak magnetic field of the Earth. A magnetic bubble, 100-km or more in diameter, forms and is squeezed by the diverging magnetic field—the motion of these field lines in some sense mimics the disturbance formed by the incorporation of a portion of the magnetized plasma from the coronal mass ejection into the Earth's magnetosphere. The details of the resulting magnetic and electric disturbances on Earth are exquisitely complex because the bomb itself, before the expansion can take place, has liberated most of its energy in the form of vast amounts of soft x-rays that increase the ionization at the top of the atmosphere and serve largely to shield against the magnetic field variation from the "bubble" and "heave" of the bomb plasma in the magnetic field of the Earth. The resulting slow component of the electrical field from a HANE is dubbed E3. The time scale is typically ten seconds or more.

As might be suspected, there is an E1, which comes from the prompt gamma rays from the fission process. Within less than a nanosecond of an individual fission, a couple of percent of the energy release is emitted as the equivalent of extremely high voltage x-rays such as those used for radiography and radiotherapy. In a nuclear explosive—warhead or bomb—most of the gamma rays are absorbed, but those high-energy gamma rays that do emerge travel radially from the explosion above the atmosphere, although more might travel up or down or sideways depending upon the detailed internal design of the bomb. The bulk of the gamma rays may emerge over a few-nanosecond interval.

In 1962 the effect of the resulting E1 was observed in Hawaii, 1000 km from the explosion in space of a 1.4 megaton hydrogen bomb at an altitude of 400 km.

In contrast to earlier predictions of a modest electromagnetic pulse from a space nuclear explosion, on the order of 1 V/m at 1000 km[7], the detected EMP in this very fast-time (high frequency) range was of the order of 5,000 V/m, which was unexplained for many months after it

[7] R.L. Garwin, "*Determination of Alpha by Electro-magnetic Means,*" Los Alamos Scientific Lab., Report LAMS-1871, (1954), S-RD.

had been observed, until Los Alamos physicist Conrad Longmire, in preparing for a talk at the Air Force weapons lab in Albuquerque, thought of the mechanism by which such efficient conversion of gamma ray energy to electromagnetic pulse could be achieved.

Although an observder anywhere on Earth within line of sight to the space explosion receives this radio pulse as if it came directly from the explosion itself, it really originates in the upper atmosphere on the line of sight from the bomb to the observer. As the gamma rays produce fast electrons from the molecules of air, the electrons travel initially along the line of sight outward from the bomb, but their paths are *curved* by the weak magnetic field of the Earth. These curved paths radiate, but it seems at first thought impossible that electrons materializing over a path length of 10 km (flight time of 30 microseconds) could add their signals in the nanosecond range, but that is exactly what happens--because the electrons travel at nearly the speed of light, and the gamma rays, which materialize all along this 10 km path, travel at the speed of light in vacuum so that the radio wave is strengthened until the gamma rays are extinguished by absorption in the air atoms.

The result can be the conversion of 10% of the gamma ray energy into electromagnetic pulse, and clever bomb designers can make this pulse even shorter than is natural for an ordinary fission bomb.

However, the EHV transmission system has no special vulnerability to this E1 fast pulse. It was thoroughly addressed and emphasized by the EMP Commission Report of 2008,

Impact of *E1* on critical infrastructure

No mechanism has been identified and there is no experimental or theoretical reason to judge that even the most intense *E1* field will cause direct harm to humans or animals. Furthermore, there is a much shielding of sensitive electronics to electric fields in this range. The EMP Commission arranged for experimental tests of exposure of various kinds of electronics to EMP simulators—specifically *E1*.

Of 37 gasoline-fueled automobiles, 3 stopped running when exposed to simulated *E1*, but all restarted without incident. No effects were observed on cars not running during the EMP exposure. Similar results were obtained for trucks.

With regard to the electrical grid, electromagnetic relays that sense current and voltage by means of the forces produced by their magnetic fields, were immune to E_1. About the more modern electronic relays, the full unclassified 2008 EMPC report, "Critical National Infrastructures" states (p. 40):

> *"Electronic protective relays.* These devices (see figure 2-5) are the essential elements preserving high-value transmission equipment from damage during geomagnetic storms and other modes of grid collapse. Fortunately, these test items were the most robust of any of the electronic devices tested. However, test agencies reported that they are subject

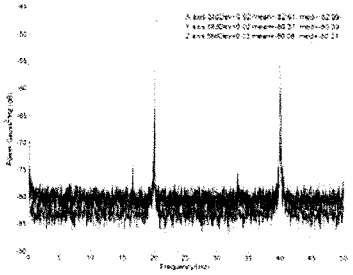
to upset at higher levels of simulated EMP exposure. We believe that altering the deployment configurations can further ameliorate the residual problems."

Thus, relatively simple field retrofits would preserve the electronic protective relays; however, the power grid is imperiled by unnecessarily weak links.

Consumer electronics in operation will suffer upset or damage at E1 fields of some 10kV/m. The EMPC report cites the RS-232 ports of PCs (personal computers) as particularly vulnerable, and PCs are used in the SCADA (systems control and data acquisition) facilities of the electrical grid and other industries, so a robust Bulk Power System will require protective filters on the control computers.

Other nations have taken more seriously improving the resilience of their Bulk Power Systems against geomagnetic storms (and hence E3 from a high-altitude nuclear explosion), as detailed in (4). In this effort there are major technological opportunities to reduce cost of protection and prediction.

One of the substantial lacks in planning and operation to reduce space weather impact on the grid is adequate and continuous magnetic field data, as well as corresponding measurements of GIC. GIC measurements must be obtained from the power transmission companies, and that is in process, but particularly in the United States is bureaucratically difficult. On the other hand, magnetometer data has become easier and cheaper to obtain, as the result of the universal deployment of SmartPhones containing a compass, which is a three-component magnetometer. So here is a reference to and a trace in frequency of the background magnetic noise from anisotropic magneto resistance (AMR) sensor in a typical SmartPhone.



Magnetometer B

These SmartPhones can be programmed to record the magnetic field in an intelligent way, and to transmit it over the Web, either as a typical data call, or via WiFi in case the magnetometer is located close to some facility.

So rather than think of deploying classical magnetometers, one should include the possibility of the SmartPhone magnetometer produced by the millions and correspondingly cheap and robust.

Furthermore, some of the approaches to eliminating geomagnetic-storm-induced current (GIC) are not well appreciated—for instance the use of series capacitors in the three-phase power lines themselves, where blocking the path from transformer "neutral" to ground is not feasible—as in the case of autotransformers. As described in (2), a trio of series blocking capacitors might have only 1% the cost of the series capacitors used for power-factor correction of long lines. The series blocking capacitors could be maintained shorted until potentially harmful GIC was detected, at which time the capacitors could be automatically and gracefully unshorted by silicon controlled rectifiers or other switches operating at the instant the voltage across the capacitor passes through zero.

Can the market provide a more resilient bulk power system?

FERC—the Federal Energy Regulatory Commission—and NERC—the North-American Electric Reliability Corporation—have a complex relationship themselves and with the organizations that generate, transmit, and distribute electric power in the United States and Canada. Thus far, the national interest in a more resilient bulk power system has not resulted in incentives or initiatives that would sufficiently advance that goal. The technical considerations discussed in this paper are important elements, but economic and organizational changes must be sought to result in the adoption of best world-wide practices in the North American Bulk Power System, and to advance beyond those best practices, where it is justified in the national interest.

United States Government Accountability Office

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Testimony
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CRITICAL INFRASTRUCTURE PROTECTION

Preliminary Observations on DHS Efforts to Address Electromagnetic Threats to the Electric Grid

Statement of Christopher P. Currie, Director,
Homeland Security and Justice

GAO-15-692T

GAO Highlights

Highlights of GAO-15-692T, a testimony before the Committee on Homeland Security and Governmental Affairs, U.S. Senate

Why GAO Did This Study

The threat posed by an electromagnetic pulse (EMP) or solar weather event could have a debilitating impact on the nation's critical electrical infrastructure, as well as other key assets that depend on electricity. These events could lead to power outages over broad geographic areas for extended durations. Addressing these risks requires collaboration among multiple government and industry stakeholders; with DHS in the lead role for overall infrastructure protection efforts, working in coordination with DOE.

The EMP Commission, established by statute and comprised of subject matter experts, issued recommendations in 2008 addressing the preparation, protection and recovery of critical infrastructures against a possible EMP attack. The majority of these recommendations were made to DHS and DOE.

This testimony is based on preliminary observations from GAO's ongoing review of DHS's efforts to address electromagnetic threats. Specifically, this testimony addresses the extent to which DHS has: (1) taken action to address recommendations from the 2008 EMP Commission Report and (2) coordinated with other principal federal agencies, such as DOE and industry stakeholders to mitigate risks to the electric grid from electromagnetic threats.

GAO reviewed EMP Commission recommendations and DHS program documents, and interviewed relevant stakeholders who provided insights on key issues and coordination activities with the federal government to address these threats.

View GAO-15-692T. For more information, contact Chris Currie at (404) 679-1875 or curriec@gao.gov.

July 2015

CRITICAL INFRASTRUCTURE PROTECTION

Preliminary Observations on DHS Efforts to Address Electromagnetic Threats to the Electric Grid

What GAO Found

As of July 2015, the Department of Homeland Security (DHS) reported taking several actions that could help address electromagnetic threats to the electric grid. GAO's preliminary analysis of DHS's actions indicates that they generally fell under four categories: (1) developing reports, (2) identifying mitigation efforts, (3) strategy development and planning, and (4) conducting exercises. For example:

- **Impacts of Severe Space Weather on the Electric Grid**. This 2011 report evaluated how previous solar storms have affected electric grids, and identified potential cost-effective mitigation equipment available to protect these grids, among other topics.
- **RecX**. In 2012, DHS Science &Technology partnered with industry to develop a prototype transformer that could significantly reduce the time to transport, install, and energize a transformer to aid recovery from power outages associated with transformer failures from several months to less than one week.

DHS reported its actions were not taken in response to the 2008 recommendations of the *Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack* (EMP Commission). GAO also recognizes that DHS does not have a statutory obligation to specifically address the recommendations, but implementation of them could help mitigate electromagnetic impacts to the electric grid, such as helping to assure the protection of high-value transmission assets. Moreover, GAO's preliminary work suggests that DHS, in conjunction with the Department of Energy (DOE), has not fully addressed a key critical infrastructure protection responsibility—identification of clear internal agency roles and responsibilities related to addressing electromagnetic threats. For example, although DHS recognized one component as the lead for assessing solar weather risks, the component has not yet identified any specific roles related to collecting or analyzing risk information.

DHS has also coordinated with federal and industry stakeholders to address some, but not all risks to the electrical grid since the EMP Commission issued its recommendations. GAO preliminarily identified eight projects in which DHS coordinated with stakeholders to help protect the grid including developing plans to address long term power outages, participation in exercises, and research and development activities. Although these are positive steps, GAO's preliminary work indicates that DHS has not effectively coordinated with stakeholders to identify critical assets or collect necessary risk information, among other responsibilities. GAO will continue to assess the issues in this statement as it completes its work and will issue a report with the final results later this year.

Chairman Johnson, Ranking Member Carper, and Members of the Committee:

Thank you for the opportunity to discuss our work regarding the Department of Homeland Security's (DHS) efforts to address electromagnetic threats to the electric grid. The threat posed by an electromagnetic pulse (EMP) or solar weather event could have a debilitating impact on critical electrical infrastructure and communications systems, as well as other key assets and infrastructure that depend on electric utilities for power. EMP and solar weather events could potentially lead to power outages over broad geographic areas for extended durations, which experts have reported could result in severe economic disruption and significant impacts to public health and safety. Addressing these threats necessitates effective collaboration among multiple government agencies and industry partners and no singular federal program or entity has sole responsibility for addressing electromagnetic threats. However, the National Infrastructure Protection Plan (NIPP) outlines the roles and responsibilities of DHS and applicable sector-specific agencies for each of the 16 critical infrastructure sectors.[1] Within the NIPP framework, DHS has the lead role in coordinating the overall federal effort to promote the security and resilience of the nation's critical infrastructure. For the energy sector, which includes critical electrical infrastructure, the Department of Energy (DOE) is the sector-specific agency and shares responsibility with DHS.

In April 2008, the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack (EMP Commission) issued a report which included recommendations addressing the preparation, protection and recovery of U.S. critical infrastructures against a possible EMP

[1]See DHS, *National Infrastructure Protection Plan, Partnering for Critical Infrastructure Security and Resilience* (Washington, D.C.: December 2013). Sector-specific agencies are the federal departments and agencies responsible for providing institutional knowledge and specialized expertise, as well as leading, facilitating, or supporting the security and resilience programs and associated activities of its designated critical infrastructure sector in the all- hazards environment.

attack.[2] The majority of these recommendations were made to DHS and to DOE. (See Appendix I for a summary of the 2008 EMP Commission recommendations addressing electrical infrastructure.)

My statement today is based on preliminary observations and analyses from our ongoing review of DHS's efforts to address electromagnetic threats.[3] Specifically, I will be discussing the extent to which DHS has: (1) taken actions to address recommendations from the 2008 EMP Commission Report, and (2) coordinated with other principal federal agencies and industry stakeholders to mitigate risks to the electric grid from electromagnetic threats.

To perform our ongoing work, we reviewed EMP Commission information and recommendations, as well as applicable laws and directives related to DHS's critical infrastructure protection responsibilities. To assess DHS actions to address electromagnetic threats, we reviewed DHS program documents, research reports, applicable risk assessments, and other supporting documentation such as program briefings and after action reports. Additional information on DHS coordination efforts was collected through interviews with multiple DHS components and other principal federal agencies addressing electromagnetic threats, as well as industry associations, subject matter experts from research organizations, product manufacturers, and electric utility operators. The non-federal entities we interviewed were identified, by federal officials and through our

[2]Established pursuant to the fiscal year 2001 National Defense Authorization Act, the EMP Commission was responsible for assessing: 1) the nature and magnitude of potential high-altitude EMP threats to the United States; 2) the vulnerability of U.S. military and civilian systems to an EMP attack in terms of emergency preparedness; 3) the capability of the U.S. to repair and recover from damage inflicted by an EMP attack; and 4) the feasibility and cost of hardening select military and civilian systems against EMP attack. See Pub. L. No. 106-398, §§ 1401-09, 114 Stat. 1654, 1654A-345-348 (2000). See also Pub. L. No. 109-163, § 1052, 119 Stat. 3136, 3434-35 (2006) (reestablishing the EMP Commission to continue its efforts to monitor, investigate, make recommendations, and report to Congress on the evolving threat to the U.S. in the event of an EMP attack resulting from the detonation of a nuclear weapon or weapons at high altitude). See also Pub. L. No. 110-181, Div. A, § 1075 122 Stat. 3, 333 (2008) (providing, among other things, that the Commission and the Secretary of Homeland Security shall jointly ensure that the work of the Commission with respect to EMP attack on electricity infrastructure, and protection against such attack, is coordinated with DHS efforts on such matters).

[3]We are conducting this work at the request of the Senate Committee on Homeland Security and Governmental Affairs and the House Committee on Homeland Security. Two individual Members of Congress are also requesters for this work.

background research, as key stakeholders and subject matter experts within the electrical sector. While we intend to conduct additional interviews with industry stakeholders and researchers as part of our ongoing review, we believe the meetings conducted to date provided valuable insights regarding key issues and applicable coordination activities with the federal government to address electromagnetic threats.

We are conducting the work on which this statement is based in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe the evidence obtained provides a reasonable basis for our preliminary findings and conclusions based on our audit objectives.

Background

An EMP is a burst of high power electromagnetic radiation resulting from the detonation of nuclear and non-nuclear devices that are designed to intentionally disrupt or destroy electronic equipment. EMP events may be further categorized into a number of different types, based on their specific source of initiation. The threat focused on primarily by the EMP Commission is the high-altitude EMP (HEMP). A HEMP event is caused by the detonation of a nuclear device at a high-altitude, about 40 to 400 kilometers, above the Earth's atmosphere.[4] A HEMP attack is not intended to cause direct physical impacts at the Earth's surface, such as injury or damage directly from heat or blast, but instead interacts with the atmosphere to create an intense electromagnetic energy field that can overload computer circuitry and could cause significant damage to critical electrical infrastructure.

[4]EMP events may also be initiated by other means. A *Source Region EMP* (in this context) is an electromagnetic pulse created when a nuclear weapon detonates at low altitude (surface or near-surface detonation). The electromagnetic field is small compared to that from HEMP and it affects a smaller geographic area. A *System Generated EMP* occurs when a nuclear weapon detonates above the atmosphere and sends out damaging x-rays that strike space systems, such as satellites. A *Non-Nuclear EMP* is a product of radio frequency weapons, which are devices that produce electromagnetic energy to burn out or disrupt components, systems, and networks. In addition, an intentional electromagnetic interference (IEMI) is the non-explosive, non-nuclear intentional generation of intense electromagnetic fields, which are directed to a target by an antenna. The electromagnetic fields are used to purposefully disrupt or confuse the targeted electronics.

In addition to manmade EMPs, naturally occurring solar weather events can also cause related electromagnetic impacts that can adversely affect components of the commercial electric grid. This type of event is commonly referred to as a geomagnetic disturbance (GMD).[5] In 1989, a GMD caused wide-scale impacts on the Hydro-Quebec power system in Canada which caused the electric grid to collapse within 92 seconds and left six million customers without power for 9 hours. As noted in Presidential Policy Directive 21 (PPD-21), energy sector infrastructure is uniquely critical due to the enabling functions it provides to other critical infrastructure sectors.[6] Given this interdependency, an EMP or major GMD event that disrupts the electric grid could also result in potential cascading impacts on fuel distribution, transportation systems, food and water supplies, and communications and equipment for emergency services, as well as other communication systems which utilize the civilian infrastructure. PPD-21 also recognizes that DHS has numerous responsibilities to protect critical infrastructure, including such things as analyzing threats to, vulnerabilities of, and potential consequences from all hazards on critical infrastructure.

Within DHS, the National Protection and Programs Directorate (NPPD) is responsible for working with public and industry infrastructure partners and leads the coordinated national effort to mitigate risk to the nation's infrastructure through the development and implementation of the infrastructure protection program. NPPD has two principal offices with responsibilities to facilitate protection of critical infrastructure that could be at risk from EMP and GMD events—the Office of Infrastructure Protection (IP) and the Office of Cyber Security and Communications (CS&C). In addition, DHS's Federal Emergency Management Agency (FEMA) and Science and Technology Directorate (S&T) have roles related to addressing potential impacts to the electric grid, which could include EMP and GMD threats.

[5]According to the National Oceanic and Atmospheric Administration's (NOAA) Space Weather Prediction Center, a GMD event is a major disturbance of the Earth's magnetosphere that occurs when there is an exchange of energy from the solar wind into the space environment surrounding Earth. In addition, larger GMD's are generally associated with solar coronal mass ejections (CME), which are explosions of magnetic field and plasma from the Sun's corona. A CME moves outward from the sun through solar wind to reach Earth within 18-96 hours, roughly 1-4 days after a CME.

[6]Presidential Policy Directive/PPD-21—*Critical Infrastructure Security and Resilience* (Feb. 12, 2013).

DOE also has a significant role as the sector-specific agency for the energy sector, which includes critical infrastructure and key resources related to electricity. For example, DOE is responsible for developing an Energy Sector Specific Plan—in collaboration with other stakeholders, including DHS—that applies the NIPP risk management model to critical infrastructure and key resources within the sector. Within DOE, the Office of Electricity Delivery and Energy Reliability leads national efforts to increase the security and reliability of the energy infrastructure and facilitate recovery from disruptions to the energy supply. DOE national laboratories also provide research support and technical expertise to federal and industry stakeholders regarding EMP and GMD impacts.

Other principal federal agencies working to address the threat of EMP and GMD include the Department of Defense (DOD) and the Federal Energy Regulatory Commission (FERC), as well as the National Oceanic and Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA).[7]

Electrical infrastructure is primarily operated by private industry which owns approximately 85 percent of the nation's critical electrical infrastructure. Industry entities are represented, in part, through membership in industry associations such as the American Public Power Association and the Edison Electric Institute. The North American Electric Reliability Corporation (NERC) also serves as the delegated authority to regulate the protection and improvement of the reliability and security of the electrical infrastructure.[8]

[7]FERC is an independent federal agency that regulates the interstate transmission of electricity, natural gas, and oil, and oversees the reliability of high-voltage interstate transmission systems, among other responsibilities. NOAA operates the Space Weather Prediction Center – a 24/7 space weather monitoring facility that provides alerts and warnings to applicable federal entities, emergency management personnel, and other affected parties, including operators of electric utilities.

[8]The North American Electric Reliability Corporation is a not-for-profit international regulatory organization whose mission is to ensure the reliability of the bulk power system in North America and is subject to oversight by FERC and governmental authorities in Canada.

Preliminary Findings Indicate that DHS Actions to Address Electromagnetic Threats were Conducted Independently of the EMP Commission Recommendations

As of July 2015, DHS reported taking several actions that could help address electromagnetic threats to the electric grid, but these efforts were conducted independently of the 2008 EMP Commission recommendations. Our preliminary analysis of DHS's actions indicates that they generally fell under four categories of effort: (1) developing reports, (2) identifying mitigation efforts, (3) strategy development and planning, and (4) conducting training exercises.

Developing Reports

Since 2008, DHS has produced three reports that specifically address electromagnetic threats to the electric grid. Below is a summary of each report.

- ***Electromagnetic Pulse Impacts on Extra High Voltage Power Transformers.***[9] This 2010 report analyzed the potential impact of an EMP on extra high voltage transformers—focusing primarily on transformer equipment designs and identifying specific mitigation efforts such as blocking devices that minimize the impact of geomagnetically induced currents (GIC) on the electric grid.[10] The report concluded that the similarity of EMP effects, regardless of source, indicates that geomagnetic storms provide a useful basis for transformer impact analysis and that selective installation of blocking devices would minimize the impacts of GIC on transformers, among other findings.

- ***Impacts of Severe Space Weather on the Electric Grid.***[11] This 2011 report assessed the impacts of space weather on the electric

[9]Department of Homeland Security, *Electromagnetic Pulse (EMP) Impacts on Extra High Voltage Power Transformers, Rev. 2*, April 2010.

[10]GIC are electric currents induced on a power system caused by fluctuations in the earth's magnetic field. Large-scale fluctuations in the earth's magnetic field that cause damaging GIC are usually caused by solar storms.

[11]MITRE, *Impacts of Severe Space Weather on the Electric Grid*, JSR-11-320 (McLean, VA: November 2011).

grid, seeking to understand how previous solar storms have affected some power grids, and what cost-effective mitigation efforts are available to protect the electric grid, among other topics. Some of the key findings and recommendations include the need for a rigorous risk assessment to determine how plausible a worse-case scenario may be and additional research to better understand how transformers may be impacted by electromagnetic threats. This report also recommended installation of blocking devices to minimize the impacts of GIC.

- ***Sector Resilience Report: Electric Power Delivery.***[12] This 2014 report summarizes an analysis of key electric power dependencies and interdependencies, such as communications, transportation, and other lifeline infrastructure systems. The report included an assessment of, and best practices for, improving infrastructure resilience such as: modeling to identify potential vulnerabilities, conducting a cost-benefit analysis of alternative, technology-based options, and installing protective measures and hardening at-risk equipment, among others.

Identifying Mitigation Efforts

DHS identified two specific efforts implemented since 2008 that could help to mitigate electromagnetic impacts to the electric grid. They are: (1) Recovery Transformer Project (RecX), and (2) Cyber Emergency Response Team.

- **RecX.** In 2012, S&T partnered with industry to develop a prototype transformer that could significantly reduce the time to transport, install, and energize a transformer to aid recovery from power outages associated with transformer failures from several months to less than one week. S&T, along with industry partners, demonstrated the RecX prototype for 2.5 years, ending in September 2014. DHS reported that RecX proved to be successful in an operational environment and has the capacity to reduce the impact of power outages.

- **Cyber Emergency Response Team.** CS&C operates the Industrial Control Systems-Cyber Emergency Response Team to assist critical infrastructure owners in the 16 sectors, including the energy sector, to

[12]Department of Homeland Security, *Sector Resilience Report: Electric Power Delivery*, June 11, 2014.

improve overall cybersecurity posture of their control systems.[13] Industrial control systems are among the types of critical electrical infrastructure that could be impacted in the event of an EMP attack.

Strategy Development and Planning

DHS has taken actions to support the development of two key strategies and plans that could help to address electromagnetic threats. These include areas: 1) Power Outage Incident Annex, and 2) the National Space Weather Strategy.

- ***Power Outage Incident Annex.*** In 2014, FEMA began developing a Power Outage Incident Annex (incident annex) to provide incident-specific information, which supplements the National Response Framework.[14] According to FEMA officials, the incident annex will describe the process and organizational constructs that the federal government will utilize to respond to and recover from loss of power resulting from deliberate acts of terrorism or natural disasters. Among other tasks, the incident annex is designed to identify key federal government capabilities and resources, prioritize core capabilities, and outline response and recovery resource requirements. FEMA officials reported that the incident annex is scheduled to be completed by October 2015.

- ***National Space Weather Strategy.*** In collaboration with the White House Office of Science and Technology Policy and NOAA, DHS has been working since 2014 to help develop a National Space Weather Strategy. As a co-chair of the Space Weather Operations, Research and Mitigation Task Force, DHS is in the process of developing a strategy to achieve several goals, including efforts to establish benchmarks for space weather events, improve protection and mitigation efforts, and improve assessment, modeling, and prediction of impacts on critical infrastructure, among other goals. According to officials at S&T, a draft of the National Space Weather Strategy is

[13]Industrial control system is a general term that encompasses several types of control systems, including Supervisory Control and Data Acquisitions (SCADA) systems. SCADA systems are used extensively in critical infrastructure applications such as electrical transmission and distribution, water management, and oil and gas pipelines.

[14]The National Response Framework is a guide to how the nation responds to disasters and emergencies of all types and describes the principles, roles and responsibilities, and coordinating structures for delivering the core capabilities required to save lives, protect property and the environment, stabilize communities, and meet basic human needs following an incident.

currently being updated to incorporate stakeholder comments and is scheduled to be completed in September 2015.

Conducting Training Exercises

DHS has also conducted two training exercises that could help address the potential impact of power outages caused by electromagnetic events, GridEx II and Eagle Horizon.[15]

- ***GridEx II.*** In November 2013, DHS, along with the Federal Bureau of Investigation, DOE, and other relevant government agencies, participated in an industry-wide exercise assessing the readiness of the electricity industry to respond to a physical or cyber attack on the bulk power system. The key goals of GridEx II were to review existing command, control, and communication plans and tools, incorporate lessons learned from a previous exercise, and to identify potential improvements in cyber and physical security plans and programs. Upon completing the exercises, participants identified key lessons learned, which included the need for enhanced information sharing, and clarification of roles and responsibilities during a physical or cyber attack.

- ***Eagle Horizon.*** Since 2004, FEMA has conducted a mandatory, annual continuity exercise for all federal executive branch departments and agencies to ensure the preservation and continuing performance of essential functions. Key objectives of the training exercise include: assessing the implementation of continuity plans, demonstrating communication capabilities, and examining broader national continuity capabilities with state, local, and private sector partners.

For our ongoing review, DHS did not identify its actions as specifically responsive to the EMP Commission's recommendations; nonetheless, some of the actions DHS has taken since 2008 could help to mitigate some electromagnetic impacts to the electric grid. For example, the three identified reports provide some insights on how the electric grid may be

[15]In commenting on information contained in a draft of this statement, an official with S&T noted that DHS participated in a third exercise addressing risks to the electric grid – Secure Grid 2011. According to this official, the exercise was conducted at National Defense University, was jointly funded by DHS, DOD, and DOE, and included participation with multiple federal agencies and industry representatives. Our ongoing work will review information on this exercise which DHS had not previously identified as an EMP-related action.

impacted by electromagnetic threats. Additionally, the RecX project provided a functional prototype that may facilitate industry efforts to further develop more mobile transformers and assist with recovery efforts in the event of an electromagnetic attack on the electric grid. Similarly, DHS planning efforts to develop the power outage incident annex and space weather strategy are also steps that could help to mitigate the negative effects of an electromagnetic threat to the electric grid by improving critical planning and response efforts.

While DHS has taken several positive steps to address electromagnetic threats to the electric grid since the EMP Commission issued its recommendations in 2008, our preliminary analysis indicates that these actions may fall short of the expectations for DHS regarding overall responsibilities to oversee and coordinate national efforts to protect critical electrical infrastructure, consistent with PPD-21 and the NIPP. For example, DHS's efforts to clearly identify agency roles and responsibilities to date have been limited. Specifically, DHS has had difficulty identifying the relevant DHS components, officials, or ongoing internal DHS activities with an EMP nexus. For example, DHS officials were unable to determine internally which component would serve as the lead—S&T or NPPD—in regards to addressing EMP threats. In addition, NPPD has not yet identified its specific roles and activities in addressing electromagnetic threats even though it has been identified by the DHS Office of Policy as the proposed risk analysis "owner" relative to space weather threats.[16]

We recognize that DHS does not have a statutory obligation to address the specific recommendations of the EMP Commission and many of these recommendations were also directed to DOE. Nevertheless, we believe that implementation of them could help mitigate electromagnetic impacts to the electric grid, such as helping to assure the protection of high-value transmission assets. Moreover, PPD-21 articulates DHS's roles and responsibilities to safeguard the nation's critical infrastructure,

[16]According to the DHS Office of Policy, space weather has been included as an identified risk event since the initial Strategic National Risk Assessment was conducted in 2011, and more recently was included in the Homeland Security National Risk Characterization, which serves to identify the specific natural hazards to be assessed as part of the 2014 Quadrennial Homeland Security Review (QHSR). Every four years the Secretary is to complete a QHSR—a comprehensive examination of the homeland security strategy of the nation that is to include recommendations regarding the long-term strategy and priorities of the nation for homeland security and guidance on the programs, assets, capabilities, budget, policies and authorities of the department. See 6 U.S.C. § 347.

which are consistent with such recommendations. For example, PPD-21 states that DHS, in carrying out its responsibilities under the Homeland Security Act of 2002, as amended, is to, among other things, evaluate national capabilities, opportunities, and challenges in protecting critical infrastructure; analyze threats to, vulnerabilities of, and potential consequences from all hazards on critical infrastructure; identify security and resilience functions that are necessary for effective stakeholder engagement with all critical infrastructure sectors; integrate and coordinate federal cross-sector security and resilience activities; and identify and analyze key interdependencies among critical infrastructure sectors. Moreover, PPD-21 calls for DHS to specifically consider sector dependencies on energy and communications systems, and identify pre-event and mitigation measures or alternate capabilities during disruptions to those systems in updating the NIPP. To date, our preliminary analysis suggests that DHS has not fully addressed some key responsibilities related to effectively preparing for and responding to electromagnetic threats to the electric grid, in conjunction with DOE as the sector-specific agency for the energy sector, which is responsible for critical electrical infrastructure. Specifically, DHS did not identify any efforts it conducted to support the identification of key electrical infrastructure assets or assess cross-sector dependencies on these assets, for which DHS would be expected to play a key role. According to officials within NPPD and the DHS Office of Policy, factors such as competing priorities and a focus on all hazards may contribute to limited efforts being taken by DHS to specifically address electromagnetic threats. We will continue to assess the extent to which DHS's efforts align with the EMP Commission recommendations as well as the extent to which DHS's current and planned actions align with its own risk management framework, as identified in the NIPP, as we complete our work. We will report our final results later this year.

Preliminary Analysis Indicates DHS Has Not Fully Coordinated with Stakeholders to Address some Risks to the Electric Grid

Our preliminary analysis indicates that since the EMP Commission issued its recommendations in 2008, DHS has coordinated with federal and industry stakeholders to address some, but not all risks to the electric grid. Specifically, DHS has not fully coordinated with stakeholders in certain areas such as identifying critical assets or collecting information necessary to assess electromagnetic risks. Our preliminary work has identified eight projects in which DHS coordinated with other federal agencies or industry to help protect the electric grid. These projects encompass a range of different protective efforts, including the development of plans to address long term power outages, participation in exercises, and research and development activities which address the

resiliency of electrical infrastructure (See Appendix II for a list of projects we identified.)

Four of the eight projects we identified were initiated within the past 2 years and three specifically address the risks associated with an EMP or GMD event.[17] The three EMP or GMD-related projects include 1) participation in a White House Task Force to support development of an interagency space weather action plan; 2) collaboration with NASA to develop precise, localized forecasts that can help utilities better respond to solar weather events; and 3) development of EMP protection guidelines for critical equipment, facilities, and communications/data centers.

In addition to the specific projects identified above, DHS also coordinates with sector stakeholders through the Energy Sector Government Coordinating Council (EGCC)—which it co-chairs with DOE—and the Electricity Subsector Coordinating Council (ESCC) through the Critical Infrastructure Partnership Advisory Council. While federal officials generally identified that EMP and GMD issues have been discussed via these groups in recent years, they noted that the EMP threat has not been an area of particular focus.

Although DHS participation in the identified projects is a positive step to help mitigate some potential impacts of electromagnetic threats, our preliminary work suggests that DHS has not fully coordinated with stakeholders in other areas to help facilitate EMP and GMD protective efforts. Specifically, our preliminary analysis indicates that DHS has not fully coordinated with stakeholders to address electromagnetic threats to the electric grid in the following areas:

Providing threat information. DHS has not identified any efforts to specifically provide EMP-related threat information to industry stakeholders. Industry officials we spoke with generally stated that they do not have sufficient threat information to determine the extent to which specific actions should be taken to mitigate the effects of an EMP event. Whereas industry officials reported having a greater understanding of the potential likelihood of a major GMD caused by solar weather, they noted

[17]Although each of the eight projects identified may facilitate some level of risk reduction to electrical infrastructure, we identified three projects that were specifically initiated to address the unique causes or vulnerabilities associated with electromagnetic events.

that applicable EMP threat briefings by DOD or DHS could help them to better justify to their management or stockholders the level of investment required to take protective actions. According to the Quadrennial Energy Review, incomplete or ambiguous threat information may lead to inconsistency in physical security among grid owners, inefficient spending on security measures, or deployment of security measures against the wrong threat.[18]

This concern generally aligns with previous work related to cyber threats in which we reported that federal partners' efforts to share information did not consistently meet industry's expectations, in part, due to restrictions on the threat information that can be shared with industry partners.[19] DHS generally concurred with our prior recommendations directed at strengthening its partnership and information-sharing efforts, and has since taken steps to enhance its information sharing activities, including granting security clearances, and establishing a secure mechanism to share cyber threat information. We will continue to assess DHS's actions regarding providing threat information on EMP as part of our ongoing work.

Identifying key infrastructure assets. Our preliminary analysis indicates that DHS and DOE have not taken action to identify the most critical substations and transformers on the electric grid. According to the NIPP risk management framework, such information is important to better understand system dependencies and cascading impacts, as well as help determine priorities for collecting additional information on specific asset vulnerabilities or potential mitigation actions.

According to the 2008 EMP Commission report, government entities, such as DHS and DOE, must identify the specific electrical assets that are critical to remain in service or that can be restored within hours following an EMP attack. Protection of these assets may be necessary to ensure the continuation of emergency response and recovery functions. As part of our ongoing work, we will continue to assess actions by DHS

[18]See Presidential Memorandum—*Establishing a Quadrennial Energy Review* (Jan. 9, 2014). The initial Quadrennial Energy Review was released on April 21, 2015.

[19]GAO, *Critical Infrastructure Protection, Observations on Key Factors in DHS's Implementation of its Partnership Approach*, GAO-14-464T (Washington, D.C.: March 6, 2014).

and other federal agencies regarding the identification of key infrastructure assets.

Collecting risk information. DHS has not fully leveraged existing programs or utilized collaboration opportunities with federal partners to collect additional vulnerability and consequence information related to potential impacts to the electric grid. For example, DHS-IP has not fully leveraged the Infrastructure Survey Tool and Regional Resiliency Assessment Program (RRAP) to help collect additional information related to infrastructure vulnerabilities and impacts related to electromagnetic threats.[20] As we have concluded previously, coordination with other federal partners may also help ensure an integrated approach to vulnerability assessment activities.[21] For example, DHS has also not fully leveraged other agency efforts such as DOD's Defense Critical Infrastructure Protection program which could provide useful information about potential consequences of electric grid failure. According to the NIPP, to assess risk effectively, critical infrastructure partners—including owners and operators, sector councils, and government agencies—need timely, reliable, and actionable information regarding threats, vulnerabilities, and consequences. As part of our ongoing work, we will continue to assess actions by DHS and other federal agencies regarding the collection of applicable risk information.

Engaging with industry to identify research priorities and funding mechanisms. Enhanced collaboration among federal and industry partners is critical to help identify and address key research gaps and

[20]The Infrastructure Survey Tool is a voluntary, web-based vulnerability survey conducted by DHS protective security advisors to identify and document the overall security and resilience of a facility. The RRAP is an analysis of infrastructure clusters and systems in specific geographic areas or regions. Using the RRAP, DHS examines vulnerabilities, threats, and potential consequences to identify (1) dependencies and interdependencies among the assets that participate in the RRAP, (2) cascading effects resulting from an all-hazards disruption of these assets or the region, (3) characteristics that make the assets and the region resilient, and (4) any resilience gaps that may hinder rapid recovery from disruptions.

[21]GAO, Critical Infrastructure Protection: *DHS Action Needed to Enhance Integration and Coordination of Vulnerability Assessment Efforts*, GAO-14-507 (Washington, D.C., Sept. 14, 2014). DHS concurred with our recommendation that DHS identify and analyze key critical infrastructure (CI) security-related assessment tools and methods used or offered by SSAs and provide guidance for what areas should be included in vulnerability assessments of CI that can be used by DHS and other CI partners in an integrated and coordinated manner.

priorities, and leverage available funding mechanisms. Our preliminary analysis identified two areas—assessing transformer impacts and development of mitigation tools—where DHS has not fully pursued opportunities to collaborate with federal and industry stakeholders on research, testing and identifying funding sources that could help facilitate efforts to address electromagnetic threats to the electric grid. With respect to transformer impacts, industry and government officials identified the need for additional modeling and assessment as the most critical research gap. For example, the 2012 NERC GMD Task Force found that modeling the effects of GIC flows on transformers during a GMD event is not sufficiently developed. Stakeholders also noted that additional action is needed for evaluating and testing equipment that could help mitigate electromagnetic impacts to key infrastructure assets. Specifically, stakeholders identified that there are limited sites available for large-scale testing, and opportunities may exist to further leverage DOE research laboratories and other federal resources, including potential funding mechanisms.

In our ongoing review, we will continue to evaluate federal and industry actions to determine where specific coordination efforts could be improved and we will report the final results later this year.

Chairman Johnson, Ranking Member Carper and Members of the Committee, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

Appendix I: Summary of 2008 EMP Commission Recommendations Addressing Electrical Infrastructure

Table 1: Summary of 2008 Electromagnetic Pulse (EMP) Commission Recommendations Addressing Electrical Infrastructure

EMP Commission Recommendations [a]
1. The Commission recommends research be conducted to better understand infrastructure system interdependencies and interactions, along with the effects of various EMP attack scenarios. In particular, the Commission recommended that such research include a strong component of interdependency modeling. Funding could be directed through a number of avenues, including the Department of Homeland Security (DHS) and National Science Foundation.
2. Expand activities to address the vulnerability of Supervisory Control and Data Acquisition (SCADA) systems to other forms of electronic assault, such as EMP.
3. It is vital that DHS, as early as practicable, make clear its authority and responsibility to respond to an EMP attack and delineate the responsibilities and functioning interfaces with all other governmental institutions with individual jurisdictions over the broad and diverse electric power system. This is necessary for private industry and individuals to act to carry out the necessary protections assigned to them and to sort out liability and funding responsibility.
4. DHS particularly needs to interact with the Federal Energy Regulatory Commission (FERC), North American Electric Reliability Corporation (NERC), state regulatory bodies, other governmental institutions at all levels, and industry in defining liability and funding relative to private and government facilities, such as independent power plants, to contribute their capability in a time of national need, yet not interfere with market creation and operation to the maximum extent practical.
5. DHS must establish the methods and systems that allow it to know, on a continuous basis, the state of the infrastructure, its topology, and key elements. Testing standards and measurable improvement metrics should be defined as early as possible and kept up to date.
6. Working closely with industry and private institutions, DHS should provide for the necessary capability to control the system in order to minimize self-destruction in the event of an EMP attack and to recover as rapidly and effectively as possible.

EMP Commission Recommendations [a]
7. DHS and DOE must utilize industry and other governmental institutions to assure the most cost effective outcome occurs and that it does so more rapidly than otherwise possible. In many instances, these initiatives are extensions or expansions of existing procedures and systems such as those of NERC. Separate recommended initiatives are listed below.
a. Understand system and network level vulnerabilities, including cascading effects
b. Evaluate and implement quick fixes
c. Develop national and regional restoration plans
d. Assure availability of replacement equipment
e. Assure availability of critical communications channels
f. Expand and extend emergency power supplies
g. Extend black start capability
h. Prioritize and protect critical nodes
i. Expand and assure intelligent islanding capability
j. Assure protection of high-value generation assets
k. Assure protection of high-value transmission assets
l. Assure sufficient numbers of adequately trained recovery personnel
m. Simulate, train, exercise, and test the recovery plan
n. Develop and deploy system test standards and equipment
o. Establish installation standards

Source: 2008 EMP Commission recommendations. | GAO-15-692T

Notes:

[a]The EMP Commission recommendations cited above capture two key areas: infrastructure commonalities and the electric power sector which both have a nexus to electrical infrastructure. The Commission also made recommendations addressing potential EMP impacts affecting other infrastructure sectors, such as telecommunications, banking, and emergency services, among others.

Appendix II: DHS Coordination on Activities to Address Electromagnetic Impacts to the Electric Grid

Table 1: Department of Homeland Security (DHS) Coordination on Activities to Address Electromagnetic Impacts to the Electric Grid

Activity	Status	DHS Role	Focus Area (Electromagnetic or All Hazards)
Grid Security Exercise (GridEx II)[a]	Completed–2013	Participant	All-Hazards
Recovery Transformer (RecX)[b]	Completed–2014	Lead	All-Hazards
Resilient Electric Grid (REG)[c]	Ongoing	Lead	All-Hazards
Power Outage Incident Annex[d]	Ongoing	Lead	All-Hazards
National Emergency Communications Plan (2014 Update)[e]	Ongoing	Lead	All-Hazards
Space Weather Operations, Research and Mitigation Task Force[f]	Ongoing	Participant	Electromagnetic
Solar Storm Mitigation[g]	Ongoing	Co-Lead	Electromagnetic
EMP Protection Guidelines (Version 6.0)[h]	Ongoing	Lead	Electromagnetic

Source: GAO analysis of DHS activities addressing threats to the electric grid. | GAO-15-692T

Notes:

[a]The North American Electric Reliability Corporation (NERC) conducted the second industry-wide Grid Security Exercise in 2013. The exercise simulated a coordinated cyber and physical attack on the electric grid and tested the response capability of government and industry stakeholders.

[b]The Recovery Transformer program was a partnership between DHS Science &Technology (S&T) and the electric industry to develop a prototype transformer that could be transported, installed, and energized in a shorter timeframe to aid recovery from power outages associated with transformer failures from several months to less than one week.

[c]The Resilient Grid program is being coordinated through S&T. Specifically, S&T is developing a superconducting cable that would allow substations to interconnect and share power while eliminating the risk of cascading fault currents. The cable enhances the flexibility and resiliency of the electric grid.

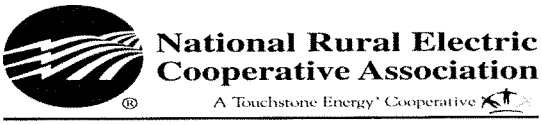
[d]FEMA is coordinating the development of a Power Outage Incident Annex (POIA). The POIA will describe the process and organizational constructs that the federal government will utilize to respond to and recover from loss of power resulting from deliberate acts of terrorism or natural disasters, including electromagnetic pulse (EMP) and space weather events.

[e]DHS developed the National Emergency Communications Plan to coordinate emergency communication across all levels of government, the private sector, and the nongovernmental sector.

[f]The Space Weather Operations, Research and Mitigation Task Force operates under the direction of the White House National Science and Technology Council and is working to finalize two key products: the National Space Weather Strategy, and the Space Weather Action Plan

[g]The Solar Storm Mitigation project is being coordinated through S&T. For additional information, see dhs.gov/science-and-technology/solar-storm-mitigation.

[h]Development of EMP Protection guidelines is led by the Federal Executive Branch Continuity Communications Managers Group (CCMG). The guidelines include four levels of protection and are based on using specific devices such as EMP-capable surge arresters on power cords to mitigate EMP vulnerabilities.



Testimony of Mrs. Bridgette Bourge

Senior Principal

National Rural Electric Cooperative Association

to the Committee on Homeland Security and Governmental Affairs

U.S. Senate

July 22, 2015

Bridgette Bourge, Senior Principal, Legislative Affairs
National Rural Electric Association
July 22, 2015 Testimony

Introduction

Chairman Johnson, Ranking Member Carper, and members of the Committee, thank you for inviting me to testify today on "Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse."

I serve as the lead legislative representative of the National Rural Electric Cooperative Association (NRECA) on homeland security issues. NRECA isthe service organization for over 900 not-for-profit electric utilities serving over 42 million people in 47 states. NRECA's members include 67 generation and transmission ("G&T") cooperatives that generate and transmit power to 668 of the 838 distribution cooperatives across the nation. Electric cooperative service territory makes up 75 percent of the nation's land mass. Kilowatt-hour sales by rural electric cooperatives account for approximately 11 percent of all electric energy sold in the United States. NRECA members generate approximately 50 percent of the electric energy they sell and purchase the remaining 50 percent.

As member owned not-for-profit utilities, distribution cooperatives and G&Ts reflect the values of their membership and they are uniquely focused on providing reliable electricity at the lowest reasonable cost. Cooperatives have to answer to their member/owners and justify every expense as they are the ones who will have to bear the cost. There is never any debate over whether a proposed project will benefit a cooperative's shareholders or customers because they are one and the same.

Today I am offering testimony on behalf of the electric industry to discuss two distinct issues: Geomagnetic Disturbances, or GMDs, and Electromagnetic Pulses, or EMPs.

Clarifying the Terms

Manmade EMPs

An EMP is a blast of electromagnetic energy that can disrupt or destroy electronic devices. There is a broad range of EMPs with significant variations in terms of impacts and responses. Just as the consequences and likelihood of each of these threats vary, so too does the approach to protecting the electric grid against them.

The only type of EMP that poses a potential widespread threat to the electrical grid are those generated by man through a high-altitude nuclear explosion. In the case of directed energy weapons or "suitcase EMPs" the threat is more localized, likely only impacting an individual facility similar to any other physical assault on grid infrastructure Due to the redundancy and resiliency of the grid, localized events like this have significantly less likelihood of causing a cascading electric system event.

The impact of an EMP from a high-altitude nuclear explosion over the United States would affect more than just electric infrastructure, however. Other critical infrastructures that utilize microprocessors are also vulnerable, including those with which the electric sector has interdependencies. Any activity that relies upon devices containing integrated circuitry- such as industrial process control systems, hospital equipment, as well as transportation and telecommunications systems - could be affected by an EMP attack on our country. As such, the

primary responsibility for protecting the United States from such an attack should fall on the country's defense intelligence and military services, not on individual critical infrastructure owners/operators.

Natural GMDs

Geomagnetic disturbances caused by solar storms are initiated by natural events on the surface of the sun in which ejected masses of electrically charged particles are hurled toward the Earth. These create the potential for Earth-based disturbances due to their interaction with the Earth's magnetic field.

When the particles interact with the Earth's magnetic field, especially in certain geographic regions (e.g., northern latitudes), they can cause ground-induced currents (GIC) and other potentially disruptive phenomena. The direct impact of GMDs is primarily limited to reliability of the bulk power system and communication systems. GMDs are common and in fact happen pretty regularly. These are natural events and, as such, industry incorporates them into planning and mitigation efforts. Early alert systems using NOAA satellites allow owners and operators to take action to protect their systems, if necessary. With currently deployed satellites nearing the end of their reliable life cycle, these systems will need to be maintained and enhanced with new satellites in the near future to ensure that early alerts remain available and their timeliness is enhanced.

GMDs are ranked by storm levels, ranging from G1 (minor) to G5 (extreme). GMDs at higher levels have the potential to damage bulk power system assets (e.g., higher-voltage transformers) and to cause a loss of reactive power support, which could lead to voltage instability and power system collapse. The most significant issue for the bulk power system stemming from a strong GMD is the ability for operators to maintain voltage stability[1]. We see lower level GMDs pretty regularly. In fact, a few weeks ago we had a number of days in a row of G3 (strong) storms but no impact was felt on the bulk power system from these occurrences because proper measures were taken and procedures followed.

Based on these risks, in May 2013, under a statutory framework and authority established by Congress in the 2005 Energy Policy Act (Section 215 of the Federal Power Act), Federal Energy Regulatory Commission (FERC) Order No. 779 directed the North American Electric Reliability Corporation (NERC), to develop reliability standards to address the potential impact of GMDs on the reliable operation of the bulk electric system. NERC is an independent, government standards setting body that, under FERC oversight, develops and enforces mandatory reliability and critical infrastructure protection standards for the bulk power system owners, operators and users. NERC, FERC, and the electric power sector have since implemented a mandatory and enforceable GMD standard requiring owners and operators of the North American electric grid to prepare specific tailored operating procedures for use during severe GMD events. NERC has developed a second GMD standard, currently pending FERC approval, which will require tailored assessments and mitigation of the potential impacts of a 100-year GMD event on the

[1] Based upon the NERC 2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System. http://www.nerc.com/files/2012GMD.pdf

bulk-power system, including high voltage power transformers. NRECA and its members support the approval and implementation plans developed in both of these standards

Distinctions between EMPs and GMDs

Unfortunately, sometimes EMPs and GMDs are mistakenly conflated in the policy dialogue. It is important to keep these two separate threats distinct and to not conflate them from a policy, planning, protection or mitigation perspective. As stated earlier, EMPs are manmade and GMDs are caused by naturally occurring events. Furthermore, the magnetic fluctuations that result from GMDs are fundamentally different from EMPs generated by a high-altitude nuclear explosion and, as a result, pose different risks. Nuclear EMPs actually have three components—E1, E2, and E3—each of which arises from a different physical effect following a nuclear detonation. E3 is a slow pulse and resembles GMDs generated by a very severe solar flare. However, GMDs do not have an E1 or E2 component. The similarity between an EMP E3 component and a GMD caused by a sever solar flare may have led some to mistakenly confuse EMP and GMD, but such confusion overlooks critical distinctions and can have unintended consequences, including potentially undermining or conflicting with mitigation measures and protective standards already in place.

When considered as part of the broader spectrum of potential threats to the electric grid, nuclear-induced EMP is considered an extremely low-likelihood, high-consequence event. That doesn't mean the electric industry disregards or ignores its significance; merely that it is considered appropriately as part of a broader risk management strategy. The electric sector's approach to protecting critical assets against all types of threats is known as defense-in-depth, which includes balancing preparation, prevention, response, and recovery for a wide variety of hazards to electric grid operations. The industry recognizes that it cannot protect all assets from all threats. Instead, its priorities are to protect the most critical grid components against the most likely threats; to build in system resiliency; and to develop contingency plans for response and recovery when either man-made or natural phenomena impact grid operations.

Fundamentally, a nuclear-induced EMP would take the form of either a terrorist attack or an act of war occurring on or above U.S. soil. As such, the principal responsibility for preventing or guarding against a nuclear attack lies with the federal government. However, whatever the threat, industry works to ensure that the grid remains safe, and that reliable and affordable electricity is delivered to customers when and where they need it. We can't prevent every attack, remove every vulnerability, or respond in advance to every threat, but our defense-in-depth approach has proven successful in maintaining a highly reliable grid.

Industry works closely with government on matters of critical infrastructure protection through the Electric Sector Coordinating Council (ESCC). The ESCC brings together industry executives and senior-level government officials for high level policy discussions on important security issues affecting the electric industry. Both the public and private sector have unique roles, responsibilities, and capabilities. Leveraging each of these in a coordinated way is imperative. An EMP is the type of emerging issue that the ESCC can address at the policy level with DOE, DHS, the Department of Defense, and other federal agencies that have unique national resources beyond the capabilities of the private sector.

Bridgette Bourge, Senior Principal, Legislative Affairs
National Rural Electric Association
July 22, 2015 Testimony

Moving Forward

How do we minimize the potential consequences of an EMP or GMD? Some propose that industry install their particular "protective device" or fully "gold plate" the entire grid so that it could, theoretically, at least partially survive a high altitude nuclear blast. However, there is no consensus on precisely what measures should be taken, the unintended effects they might have on the system, how much such an effort would cost, or how successful such efforts would be in limiting impacts to the bulk power system. For example, due to non-uniform designs and complexity, substation solutions (e.g., Faraday-cages) would have to be individually customized, which would not come at a standardized rate. Additionally, there are concerns that installing "protective devices" in some areas of the bulk power system could unintentionally cause problems in other areas. Further research and testing of these devices is needed, and is underway.

Even assuming that every conceivable blocking device were installed to protect every inch of the electric grid and caused no problems, power supplies still would likely be disrupted for a significant length of time in an impacted area. That is because other critical infrastructures that utilities rely upon to function—such as transportation systems for our fuel, water systems for cooling, and telecommunications for operations—would also not be available.

The North American power grid is a huge, complex machine that spans the entirety of the United States, Canada and even parts of Mexico. Its function can be impacted by many different types of events or threats, from natural events like GMDs and severe storms to man-made malicious threats like EMP, cyber or physical attacks. Due to the expanse of not only these threats as well as the system itself, the electric sector addresses risk management through our defense-in-depth approach. This includes preparing for and preventing what we can, while at the same time planning for response and recovery in case of worst case scenarios.

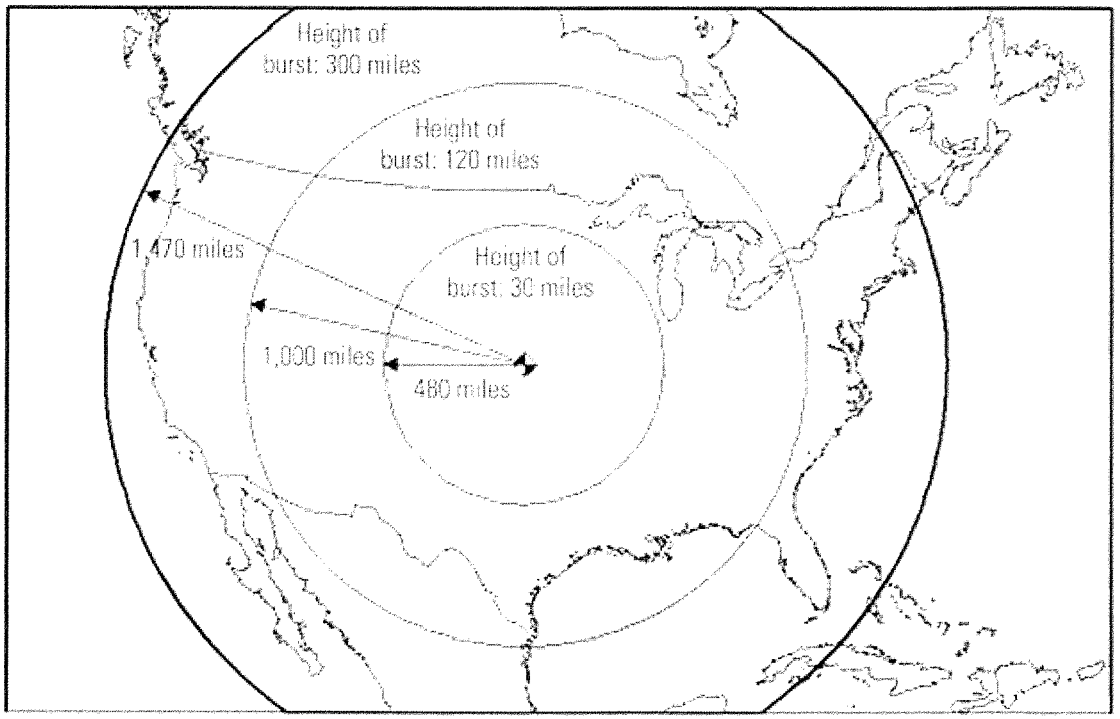
Unfortunately, planning for recovery at a national level for widespread destructive events is necessary in today's world. Efforts aimed at bolstering reserves of strategic transformers, for example, are a step in the right direction, as could be tasking DHS with further examination of EMP threats as a national security issue.

Conclusion

Owners and operators of critical electric infrastructure have every incentive to prevent their systems from going down for even a moment if they can avoid it. Electric utility professionals know their systems best, including the operational and reliability impacts of potential external threats, so they should be included in any efforts commissioned to look into these matters. Utilizing existing public-private critical infrastructure partnership frameworks, like the Electricity Subsector Coordinating Council (ESCC), to ensure input and engagement on national security issues like recovery from a nuclear blast is, for a large part, why they exist.

Thank you for holding this hearing and inviting the electric industry to provide perspective on these very important issues and how they impact the complex machine that is the electric grid. I would be happy to address any questions you may have.

Radius of EMP Effects From Nuclear Explosion at Various Altitudes



Regions Susceptible to Collapse Due to Severe GMD

(Covers about 130 Million People)

Source: National Academy of Science Workshop, 2008

American Public Power Association

Statement of the

AMERICAN PUBLIC POWER ASSOCIATION

Submitted to the

SENATE HOMELAND SECURITY AND GOVERNMENT AFFAIRS COMMITTEE

For the July 22, 2015 Hearing on

"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"

(Submitted July 22, 2015)

The American Public Power Association (APPA) appreciates the opportunity to submit this statement for the record for the Senate Homeland Security & Government Affairs Committee (HSGAC) hearing on "Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse." APPA supports the testimony of Ms. Bridgette Bourge, Senior Principal, National Rural Electric Cooperative Association (NRECA).

APPA is the national service organization for the more than 2,000 not-for-profit, community-owned electric utilities in the U.S. Collectively, these utilities serve more than 48 million Americans in 49 states (all but Hawaii).

Protecting the nation's electric power grid and ensuring a reliable and affordable supply of energy are of upmost importance to APPA and the electric power industry. The power grid is a complex, interconnected network of generation, transmission, distribution, control, and communication technologies that can be impacted by natural events, such as geomagnetic disturbances (GMDs) caused by solar flares, and man-made events, such as electromagnetic pulses (EMPs) caused by the high-altitude denotation of nuclear weapons. As detailed in Ms. Bourge's testimony, GMDs and EMPs, though commonly referred to interchangeably, are separate issues with different causes, impacts and potential solutions.

The electric and nuclear sectors are the only critical infrastructure providers with mandatory and enforceable standards. As applied to the electric sector, these standards help protect the reliability and security of the bulk power grid assets they own and operate. Under the statutory and regulatory framework established in the 2005 Energy Policy Act (Section 215 of the Federal Power Act), the Federal Energy Regulatory Commission (FERC) in May 2013 directed the North American Electric Reliability Corporation (NERC) to develop reliability standards to address the potential impact of GMDs on the reliable operation of the bulk electric system. NERC, FERC and the electric power sector have since implemented a mandatory and enforceable GMD standard requiring owners and operators of the electric grid to prepare specific operating procedures for use during severe GMD events. A second NERC GMD standard, currently pending approval by FERC, will require tailored assessments and mitigation of the potential impacts of a 100-year GMD event on the bulk power system, including high voltage power transformers. APPA supports both GMD standards.

However, standards are not the only way for electric utilities to address GMDs. Since the electric grid in the U.S. is, in fact, a North American grid, with significant interconnections to Canada and a few to Mexico, communication and coordination with our fellow electric utilities in Canada, especially, has been beneficial to the broader understanding of the impact of GMDs on utilities – impacts that are not uniform.

Public power utilities and others in the electric sector undertake this ongoing coordination formally through NERC committees and studies and informally through long-term relationships. The Electricity Subsector Coordinating Council (ESCC) which, like other critical infrastructure sector coordinating councils, interfaces with key federal government officials on matters of disaster preparation and response (whether natural or manmade) is also a forum for these discussions as the Canadian Electricity Association is a member of the group.

In contrast to naturally-occurring GMDs, the high-altitude denotation of a nuclear weapon causing an EMP would be a terrorist attack or act of war. As such, the principal responsibility for preventing such an attack lies with the federal government in its role as the provider of a national defense. That said, however, government-industry coordination on national security issues such as EMPs is critical and is a regular topic of discussion by the ESCC in its three meetings annually with the Department of Energy, the Department of Homeland Security, and the White House. Coordinating efforts and bringing together government and industry expertise helps to improve the security posture of the industry and the nation. Both the federal government and the critical infrastructure sectors have unique roles, responsibilities, and capabilities; leveraging each of these in a coordinated way is imperative. EMP is the type of emerging issue that the ESCC was established to address engaging with DOE, DHS, the Department of Defense, and other federal agencies that have unique national resources beyond the capabilities of the electric sector.

Texas is Working to Protect the Electrical Grid Against Natural or Man-Made Electromagnetic Pulse

Statement for the Record

Lieutenant Colonel Allen B. West (U.S. Army, Ret)

President and Chief Executive Officer
National Center for Policy Analysis

"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"

U.S. Senate Committee on Homeland Security and Governmental Affairs

July 22, 2015

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Washington Office: • 202-830-0177 • governmentrelations@ncpa.org • www.ncpa.org

Chairman Johnson, Senator Carper and members of the committee, thank you for the opportunity to submit written comments about securing the electrical grid against solar storms and electromagnetic pulse. I am Allen B. West, president and CEO of the National Center for Policy Analysis (NCPA). We are a nonprofit, nonpartisan public policy research organization dedicated to developing and promoting private alternatives to government regulation and control, solving problems by relying on the strength of the competitive, entrepreneurial private sector. The NCPA is headquartered in Dallas, Texas.

Having recently moved to Texas, I am proud to report that the state of Texas is showing leadership on this issue by taking action to protect the Texas electrical grid from the damaging effects of a natural or man-made electromagnetic pulse (EMP) that could blackout the entire state for months, with catastrophic consequences. The Texas legislature is moving potential legislative solutions, and members of the Executive Branch have met with experts to determine the best course of action to protect the electrical grid in Texas.

EMP sounds like science fiction, but it is a real and present danger. EMPs have occurred numerous times with damaging consequences. As far back as 1859, an EMP from a solar storm disrupted telegraph systems throughout America and Europe. In 1921, a solar EMP knocked out railroad signals and switching systems. More recently, in 1989, a solar EMP shut down power transmission in Canada and jammed radio signals throughout North America.

The events of 1859, 1921 and 1989 ought to inform our decisions today. An EMP is like a super-energetic radio wave, so powerful that it can damage and destroy electronic systems within the EMP field. As the world has become more reliant on technology, if a solar EMP of similar magnitude were to occur today, it would potentially cause a protracted nationwide or even global blackout of the electrical grid and other life-sustaining critical infrastructures—including communications, transportation, business and finance, food and water—potentially for months or years.

NASA estimates the likelihood that the Earth will encounter a catastrophic solar storm is 12 percent per decade. This virtually guarantees that we will see a natural EMP catastrophe within our lifetimes or our children's lifetimes. It underscores the vital importance of protecting the electrical grid against solar EMPs.

But solar storms aren't the only sources of catastrophic EMPs. In 2006, Congress created the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack. The EMP Commission warned that a nuclear weapon detonated at high-altitude, 300 kilometers above the United States (so high that there would be no blast, fallout, or other effects on the ground from the explosion in the atmosphere) would generate an EMP field over the entire nation. The EMP Commission estimated that a nationwide blackout lasting one year could kill up to 90 percent of Americans by starvation and societal collapse.

North Korea and Iran may have already practiced nuclear EMP attacks by orbiting satellites over the United States, simulating the delivery of an EMP. On a south polar trajectory, the satellites approach the United States from the south, passing over Texas and other states bordering on the Gulf of Mexico. Currently, the United States does not have ballistic missile early warning radars or missile interceptors facing south.

Even if the United States could intercept a warhead disguised as a satellite approaching from the south, the nuclear weapon could "salvage-fuse" by automatically triggering the EMP attack before being intercepted. The Gulf States, including Texas, would be closest to the EMP field, and most at risk.

Furthermore, North Korea and Iran may have also practiced nuclear EMP attacks delivered by short-range missiles. In July 2013, a North Korean freighter transited the Gulf of Mexico with two unarmed, but nuclear capable, SA-2 missiles mounted on their launchers, hidden in the hold. Additionally, Iranian freighters regularly visit their allies in Cuba and Venezuela and have the same potential to carry short-range missiles capable of causing a catastrophic EMP. Again, the Gulf States, including Texas, are most at risk from a ship-launched EMP attack.

Indeed, because Texas has its own electrical grid, and is not part of the Eastern or Western electrical grids that include all the other contiguous states, Texas might be most at risk – and at the same time, the only state in control of its own grid security. An adversary who wants to warn or terrorize the United States might well choose to focus an attack on the Texas grid to demonstrate their power to Washington and the world.

Non-nuclear EMP weapons, called radiofrequency weapons, can also damage or destroy the electrical grid. Terrorists have already employed such weapons in Europe and Asia. Boeing demonstrated such a weapon, called the Counter-electronics High-powered Microwave Advanced Missile Project (CHAMP), which is capable of being delivered by a drone. It is not out of the realm of possibility to imagine a terrorist launching something like a CHAMP from a freighter, or even from Mexico, to deliver a devastating EMP attack on the United States. Texas, once again, is forefront in the danger zone.

Terrorists have figured out that electrical grids are a major societal vulnerability. Terror attacks against the electrical grid have blacked-out 420,000 people in Mexico (October 2013), Yemen's 18 cities and 24 million people (June 2014), 80 percent of Pakistan (January 2015), and most of Turkey (April 2015). Prudence should warn us about the potential for a similar terror attack in the United States. The EMP Commission found that hardening the electrical grid to protect against the worst threat—nuclear EMP attack—would mitigate all lesser threats, including natural and non-nuclear EMP, cyber attacks, physical sabotage, and severe weather.

I am proud of the efforts of Texas state leaders like Representative Tan Parker, Representative Byron Cook, Senator Troy Fraser and Senator Bob Hall, himself an EMP expert, who are working to educate policy makers in Austin about the threat, a service to all Texans who do not want to be in the bull's-eye of an EMP Alamo. Texas Governor Greg Abbott and his administration have an amazing opportunity to take leadership on this important issue. Likewise, there is an important role for your committee and for Congress to take to harden the nation's electrical grid against the dangers of natural and man-made EMPs. The time to act is now.

Thank you for the opportunity to submit these comments. If there is anything the NCPA or I can do to assist you, we are at your service.

Post-Hearing Questions for the Record
Submitted to the Honorable R. James Woolsey
From Senator Ron Johnson

"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"

July 22, 2015

1. Based on your past experience as Director of Central Intelligence, how do you weigh the urgency and importance of needing to address electromagnetic threats, including high-altitude EMP, as compared to all other threats and hazards facing our homeland? Please prioritize the urgency and importance of this need utilizing a cost-benefit analysis.

Response:

According to the EMP Commission somewhere in the range between 2/3 and 90% of the US population would perish in the first year after an EMP attack, caused by an attacker detonating a nuclear weapon (even a small and simple one) above the earth in low-earth orbit, or by some type of solar coronal mass ejection. It is easy to see how the losses could be so high, since the US has some eighteen critical infrastructures—food, water, telecommunications, finance, medical, transportation etc. All seventeen of the others depend on one: electricity. Without it we are vulnerable to starvation, thirst, disease and social chaos. So if the electric grid is out, not just for hours or days, but for weeks to months, we are faced with the need to obtain the basics of life as was done before the creation of the electric grid. We would be thrust back, not just to the 1980's pre-web, but rather to the 1880's pre-grid. And few of us are prepared to function without being able to obtain life's basic needs in the ways we obtain them today.

What would it cost to build resilience into the grid to a sufficient degree to avoid having America, essentially die (and fulfill the exhortations of Ayatollah Khamenini)?

The EMP Commission says the cost would be around $2 billion. It would be reasonable to assume that, whereas spending such a sum could protect some key nodes with well-known types of protection, such as surge arresters and faraday cages, a more thorough protection of the grid could require more, say $5 billion, and protection of individuals electronic components, such as home computers, could add further to the cost. So assume for purposes of discussion that a cost of $10 billion would not solve all the grid's problems, but that it could quite well protect us from a complete failure of the grid could turn a potential civilization-ending total catastrophe into a very major but manageable, disaster.

So let us say that an expenditure of $10 billion would save a very large share (245-250 million) of the American population of some 321 million from death caused by grid, and resulting infrastructure, and social collapse.

How much is it worth to save 245-250 million American lives?

By way of comparison, we lost 750,000 in combat in the Civil War (both Union and Confederate) and just over 400,000 in WWII. Grid collapse and the resulting collapse of our infrastructure would kill 245-250 million Americans. What is it worth to avoid an event that would kill more than 300 times the number of Americans killed in the Civil War and some 600 times the number killed in WWII?

If economic loss is used for a measurement tool, it is noteworthy that our GDP today is about $16.8 trillion. WWII cost us about $3.6 trillion in today's dollars. A grid collapse would not only cost us about 5 WWII's, but there would, very soon, be no GDP, because essentially nothing could be produced.

Most fundamentally, however, in spite of our failings America is, as Lincoln said, "the last, best, hope of earth." So with us into oblivion would go a great deal of what much of the world sees as it hopes and dreams for liberty, prosperity, the rule of law, and much else.

Ending those hopes with an EMP detonation would not only end them in North America. The costs and benefits of action and inaction are clear.

We should fix the grid.

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D. C. 20426

September 9, 2015

The Honorable Ron Johnson
Chairman
Committee on Homeland Security and Government Affairs
United States Senate
Washington, D.C. 20510

Dear Chairman Johnson:

Thank you for the opportunity to testify before the Committee on Homeland Security and Government Affairs on July 22, 2015 on "Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse." Enclosed are my responses to the post-hearing questions that you submitted to me.

Should you need additional information, please contact John Peschke at 202-502-6714 or John.Peschke@ferc.gov.

Sincerely,

Joseph McClelland
Director
Office of Energy Infrastructure Security

Responses to Senator Johnson's Post Hearing Questions

1. In your written testimony, you noted that several countries have already protected or are starting to protect their electric grids from electromagnetic threats. (A.) From your experience in working with other nations, what has prompted these countries to start their work? (B.) How would you compare the U.S. grid's readiness to the grids in these other nations?

   A. In my experience, I have found that countries that have taken action did so because they have experienced a near-miss or a significant outage from solar Geomagnetic Disturbance (GMD) event or have acted out of concern for current or emerging threats from electromagnetic pulse (EMP). The following are some examples of nations that are protecting against these threats:

      a. **Quebec, Canada** in 1989 experienced a provincial-wide outage from a solar related GMD event. Since then system modifications, which included the installation of series capacitors, have not only provided operating efficiencies but also provide the additional benefit of blocking geomagnetic current (GIC) flow where installed.
      b. The **United Kingdom** has had a long standing program in place to prepare for solar GMD events. Prompted by the failure of two transformers during the March 1989 solar storm, National Grid (the UK system operator) implemented mitigation actions which include specifying more GIC resistant transformers, performing studies to determine at-risk transformers and requiring a stockpile of spare transformers. National Grid also recognized the potential threat from Intentional Electromagnetic Interference (IEMI) devices and has implemented shielding and other security measures at select locations. A 2012 report from the UK House of Commons Defence Committee has raise public awareness of EMP but no regulatory or publically known application of system protections are available.
      c. **Sweden** which experienced a 2003 solar GMD related outage in the city of Malmo, has a state owned public utility that has implemented mitigation policies for GMD that include the installation of more geomagnetically induced current (GIC) resistant transformers when replacing older units, specifying GIC withstand for transformers and is planning to expand its monitoring capability. Sweden's power grid also employs series compensated lines that provide a benefit of limiting GIC flow.
      d. **Norway's** deregulated stated owned and operated transmission system has regulatory requirements that require mitigation of the risk associated with GMD and EMP (including IEMI). In 2000 a GMD system study was performed and now planned expansions will be done using technology more resistant to GMD and EMP.

e. **Finland** has designed its power grid to reduce GIC flow which includes using specific types of transformers that provide additional GIC protection, employing neutral point grounding reactors and utilizes series capacitors that can effectively block GIC.
f. **South Africa** has a state owned and operated electrical system, however there are no legislative or regulatory requirements for GMD protection. Traditionally, and as still is the case in the US, low latitude locations are generally considered as an unlikely area of impact for GMD. However, in 2003 South Africa, geographically a low latitude area, experienced destruction and severe damage to more than a dozen transformers due to a three day low-level geomagnetic storm. This event severely impacted grid operations for the months and years that repairs were being made. In the aftermath, GIC monitoring was added and resiliency projects to withstand GMD events are in the beginning stages.
g. **New Zealand** is another example of a low-latitude area considered to have a low vulnerability to solar related GMD. However, in 2001 and 2002 during minor GMD events, two transformers on Transpower's (a state owned company) grid were damaged. As a result New Zealand implemented a GMD mitigation program that employs both operational and automatic hardware solutions to protect 32 of its key transformers. As part of the GMD mitigation program, situational awareness was also improved by employing robust system of monitoring and system modeling.
h. While **Australia** has had no significant impact from GMD, system modeling has shown some potential vulnerability. An extensive monitoring system along with operational procedures have allowed for manual positioning of the system during a GMD event.
i. **Israel** has an ongoing project entitled "E-Threat Protection for Infrastructure Continuity (EPIC). The project purpose is to provide a detailed plan for preparing the Israeli grid to stand and recover from nationwide EMP/GMD events.

B. The Commission has approved mandatory reliability standards that require certain US Bulk Power System (BPS) operators to mitigate the effects of selected GMD thresholds by implementing operating plans, processes, and procedures. Also, the North American Electric Reliability Corporation (NERC) recently submitted to the Commission a Reliability Standard that establishes requirements for transmission system planned performance during GMD events.

   Although a few electric utilities in this country have implemented some form of EMP mitigation at a few locations, in general the United States is well-behind those nations that have taken steps to address the GMD and EMP threats.

According to a November 2003 IEEE Spectrum article, more than 20 countries had programs to develop some type of RF weapon. While some work to establish a US BPS GMD baseline performance for solar events has begun under NERC standards, those standards are not designed to protect against EMP and IEMI. NERC has stated for the record that "... the threat of EMP and HEMP attacks is beyond the scope of the civilian power industry to address."

2. During the hearing, you said that the commission did perform comprehensive network modeling and identified the most critical substations.

a. To the extent able, please submit a detailed discussion of the commission's findings from this network analysis.

i. Commission Staff conducted the study that I referenced at the hearing in order to identify critical substations and nodes. The methodology for this study involved applying industry standard system analysis techniques using commercial products and incorporating known system responses derived from publically available blackout and event reports. This study included the three interconnections in the contiguous United States. This study did not include either distribution systems or facilities in Alaska and Hawaii.

b. What were the results of sharing the findings with industry and offering assistance? In your view, are any of the critical substations identified by the commission protected from severe solar weather or high-altitude EMP?

ii. FERC provided assistance related to the study that I referenced at the hearing only to utilities that specifically requested such assistance. That assistance consisted primarily of discussions on study methods. FERC does not have further information on the extent to which industry has used this study. This study neither evaluated the impacts of GMD or EMP, nor identified any recommendations for protecting the grid against those impacts.

3. Do you believe the commission and/or other federal agencies have the tools they need to assess the vulnerability of the nation's grid to electromagnetic and other threats?

More work would be valuable to assess the vulnerability of the nation's grid to electromagnetic and other threats. For example, better modeling techniques are being developed to more accurately predict system performance under severe loss scenarios (including interdependency issues), which could be employed by the government in conjunction with industry. In addition, access to effective

EMP mitigation techniques should be made available to industry members at a non-classified level.

GAO U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

September 4, 2015

The Honorable Ron Johnson
Chairman
Committee on Homeland Security and Governmental Affairs
United States Senate

"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"—Response to Question for the Record

Dear Mr. Chairman:

We appreciated the opportunity to testify before the Committee on July 22, 2015, about efforts the Department of Homeland Security's (DHS) efforts to protect the grid from the potential threats of solar storms and electromagnetic pulse events. On August 6, 2015, we received the Committee's question for the record; the enclosure provides our response. If you or members of your staff have any questions about our response, please contact me at (404) 679-1875 or CurrieC@gao.gov.

Sincerely yours,

Chris P. Currie

Christopher P. Currie
Director, Homeland Security and Justice

Enclosure

cc: Chris Currie, Tim Minelli, Dawn Hoff, Ryan Lambert, Josh Diosomito, John Rastler

441300

Enclosure

Chairman Ron Johnson
Written Question for the Record to
Mr. Christopher P. Currie
"Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse"
July 22, 2015

Question 1: Based on GAO's ongoing and previous work, please discuss what process the Department of Homeland Security has utilized, if any, to compare and prioritize the potential threats of electromagnetic pulse (EMP) and severe solar weather to other threats to the homeland.

In 2011, the Department of Homeland Security (DHS) initiated an effort to identify the types of threats that pose the greatest risk to the security of the nation. This effort, called the Strategic National Risk Assessment (SNRA), was also supported by representatives from the offices of the Director of National Intelligence and the Attorney General, among others. In 2011, the SNRA process identified 23 individual risk events across 3 different categories: 1) natural hazards; 2) technological/accidental hazards; and 3) adversarial, human-caused threats/hazards.[1] Space weather was included as one of the 9 natural hazards identified during this process; however, the threat posed by an EMP event was not included.

In 2012-2013, DHS conducted a subsequent effort to identify risk events with specific DHS equities, called the Homeland Security National Risk Characterization (HSNRC). According to DHS, the HSNRC process leveraged and updated information from the SNRA process and included a combination of contingent (sudden onset and gradual onset events) as well as frequent, small scale events that are part of day-to-day operations (illegal drug seizures, small oil spills, illegal migration, etc.).[2] Space weather and electric grid failure (not specifically EMP) were among the 40 individual risk events that the DHS Risk Executive Steering Committee identified as part of this process (and both are included on the updated HSNRC risk register for 2014-2015). According to DHS Policy officials, an EMP attack remains as a proposed risk event for future iterations of the HSNRC process; however, to date it has not been identified as a "standout risk" based on 24 consequence categories. Officials also noted the existence of a classified appendix that contains the individual consequence scores for the various risk scenarios that were evaluated. While GAO did not independently review these consequence scores, DHS officials reported there were natural breakpoints in the data that helped them to identify "standout risks" that generally ranked high across all consequence categories and an EMP event ranked below this breakpoint. According to DHS officials, EMP and other events not

[1] According to DHS, the department identified thresholds of consequence necessary to create a national-level event. These thresholds were informed by subject matter expertise and available data. For some events, economic consequences were used as thresholds, while for others, fatalities or injuries/illnesses were deemed more appropriate as the threshold to determine a national-level incident. DHS reported that the SNRA drew data and information from a variety of sources, including existing government models and assessments, historical records, structured analysis, and judgments of experts from different disciplines.

[2] The purpose of the HSNRC is to inform the Quadrennial Homeland Security Review (QHSR) and Department internal deliberations related to strategic posture to effectively and efficiently manage risks in DHS mission space.

considered "standout risks" still serve as risk drivers for strategic decision-making (and can identify where additional risk information may be needed), but the HSNRC methodology assessed these particular hazards to be less frequent or less consequential than other events.

As part of our ongoing work for your committee, we are evaluating the extent to which DHS has effectively leveraged information from stakeholders, such as threat-related information from the Department of Defense and existing DHS critical infrastructure assessment programs, to collect necessary risk information regarding EMP events. Such information is important to help guide risk management decisions, including protection priorities, and could be used to further inform subsequent iterations of the SNRA and HSNRC processes.

National Rural Electric Cooperative Association
A Touchstone Energy® Cooperative

September 4, 2015

Chairman Ron Johnson
U.S. Senate Committee on Homeland Security and Governmental Affairs
Washington, DC 20510

Ranking Member Thomas Carper
U.S. Senate Committee on Homeland Security and Governmental Affairs
Washington, DC 20510

Dear Chairman Johnson and Ranking Member Carper:

Thank you for providing me the opportunity to testify at the July 22nd Senate Homeland Security and Governmental Affairs Committee hearing on "Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse." Please find attached my responses to the Questions for the Record from Chairman Johnson and Senator Ayotte.

If there are any further questions or you would like to discuss any of my responses in further detail please let me know. Again, thank you for the opportunity to testify in front of the committee on these very important issues.

Sincerely,

Bridgette Bourge
Senior Principal, Legislative Affairs
National Rural Electric Cooperative Association

U.S. Senate Committee on Homeland Security and Governmental Affairs
July 22, 2015 Hearing: "Protecting the Electric Grid from the Potential Threats of Solar Storms and Electromagnetic Pulse."
Questions for the Record Submitted to & Answered by Mrs. Bridgette Bourge

Question 1 (Chairman Johnson): A Lloyd's of London-commissioned study that was published in 2013 estimated that in the wake of a severe solar weather event 20-40 million people could be left without power for an extended period, due to the damage or destruction of key grid assets.

a. Do you agree that a severe solar weather event could significantly damage or destroy large power transformers and other assets on the U.S. electric grid?

Depending on the strength of the "severe solar event," the potential for damage to a large power transformer is possible. Upon final approval by the Federal Energy Regulatory Commission (FERC), the North American Electric Reliability Corporation (NERC) geomagnetic disturbance (GMD) reliability standards will establish mandatory requirements for large power transformers from the impacts of a 100-year GMD event[1].

b. What is your assessment of the grid's current vulnerability to a severe solar weather event? To a high-altitude electromagnetic pulse?

The NERC 2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System[2] addresses vulnerability concerns for the electric grid in relation to GMDs or solar storms. NRECA supports the findings in this report as well as the Phase 1 NERC GMD standards that have been approved by FERC to address these concerns. NERC's Phase 2 GMD standards are currently awaiting final FERC action.

As to high-altitude EMPs, the prevention of the planning and launching of a nuclear weapon on U.S. critical infrastructure, while a concern and focus in industry, is a national security responsibility of the federal government. The most effective mitigation strategy for high-consequence, low-likelihood threats, like a nuclear attack, is deterrence, prevention, or preemption by the nation's law enforcement, military, and intelligence agencies. If an EMP ever happened, our industry would do what we do best - recover as quickly as possible.

Question 2 (Senator Ayotte): While scientists have gotten better at predicting IF a coronal mass eruption will hit Earth, we still don't have a good idea of how severe the event might be. However, as our ability to measure and detect solar activity improves, it seems we learn more about how many near misses we've had. Indeed, only years after new observational satellites came online, in 2012 scientists measured another once-in-a-century event that would have struck Earth had it occurred only one week earlier. I'm proud that the University of New Hampshire is a leader in the field of heliophysics and researching space weather. UNH is one of only a few US universities that is actually building spacecraft instruments to predict and detect solar eruptions and other space weather events, with many of the early warning tools operational today being built in UNH labs. Ms. Bourge, you note that with adequate warning utilities can take some steps to mitigate damages or manage solar storm events. What lead time is needed to best protect infrastructure currently?

Improved lead time, especially in the warnings and predictions of event severity, would help improve the effectiveness of a response.

Question 3 (Senator Ayotte): What is the process and source of the warning you receive now?

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[1] NERC GMD standards at http://www.nerc.com/pa/Stand/pages/project-2013-03-geomagnetic-disturbance-mitigation.aspx

[2] NERC 2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2012GMD.pdf

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Most electric utilities register to receive National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC) alerts directly via email and/or monitor the Electric Power Community Dashboard on the NOAA SWPC website[3]. The severity of the events are described using K and G factors. Presently for a K7 or greater events (G3 or greater on the NOAA Geomagnetic Strom Scale) the SWPC directly notifies the Midwest Independent System Operator (MISO) who then notifies all other North American Reliability Coordinators (RCs) using the RC Hotline and RC Information System. The RCs will notify the NERC functional entities within their footprint as required/necessary.

When a solar event is predicted or begins, a geomagnetic storm Watch is sent out from the SWPC using the process described above providing 1-3 day lead time that the impacts from a storm might be heading toward the earth along with a prediction of the strength of the storm. As early as 15-60 minutes before a storm that will hit the earth, a Geomagnetic storm Warning is issued by the SWPC. Once the storm has reached earth, Geomagnetic storm Alerts are utilized and updated as the k-index (strength of the impact) thresholds are crossed. This process - similar to earth weather where you have a watch area for a hurricane and as it gets closer, and while it is impacting an area, warnings and alerts are issued – allows for possible actions to be taken to further prepare or protect a system utilizing already established plans as required by associated NERC Reliability standards.

Question 4 (Senator Ayotte): What can be improved, either in terms of communicating warnings or the actual content of warnings?

Effectiveness of operating procedures, which are required to provide reliable operations of the bulk power system, could be improved with earlier warnings, earlier prediction of severity, and regionalized predictions of where an event is likely to have the most impact.

[3] http://www.swpc.noaa.gov/communities/electric-power-community-dashboard

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