U.S. Senate Committee on Energy and Natural Resources
May 4, 2017 Hearing: The Threat Posed by Electromagnetic Pulse and Policy Options to Protect Energy Infrastructure and to Improve Capabilities for Adequate System Restoration
Questions for the Record Submitted to Ambassador Henry F. Cooper, Ph.D.

Questions from Chairman Lisa Murkowski

Question 1: Ambassador Cooper, in your written testimony, you note that a man-made EMP is significantly different from natural EMP events, or Geomagnetic Disturbances. Could you please explain your reasoning on this matter?

- ***A Geomagnetic Disturbance (GMD) involves multiple low frequency pulses lasting minutes over a period of hours to days. Warning is provided by an increase in solar activity 18-72 hours in advance—with a significant update 20-45 minutes before charged particles hit the earth. It couples energy to the long lines of the grid, which is then focused on substations and, in particular, threatens the large generators and transformers. It also will affect long haul communications and the internet. These effects can be regional or worldwide, depending on the duration of the solar storm. Current magnitude estimates being provided by NERC to the electric energy producers are judged by the EMP Commission to be considerably low. These effects are of larger intensity at higher latitudes and near large bodies of water.***
- ***High Altitude EMP (HEMP) pulses include a similar low frequency pulse (called the E3 component of the HEMP pulse) of substantially larger amplitude—by a factor of several greater than current NERC estimates), plus:***
    - ***An extremely high frequency pulse (with a pulse width of 100s of nanoseconds) called the E1 component, effectively an electric "shock" that poses a major threat to all solid state electronics, especially the SCADA systems that control key components of the grid—e.g., generation stations and their natural gas and petroleum pipeline fuel sources. It also poses a significant threat to telecommunications, computers and data centers. Note: This faster E1 component arrives before the E2 and E3 components and will interfere with control systems needed for safe grid shutdown, potentially leading to severe damage of the power generation plants, unless there is adequate protection against E1 effects.***
    - ***A midrange frequency pulse, called the E2 component, is similar to lightning and can be protected against via typical lightning arrestors. But care must be taken to avoid degradation from the effects of the earlier arriving E1 pulse.***
- ***HEMP effects are regional to continental, depending on the height-of-burst of the attacking weapon(s). Geographic coverage increases with weapon yield and E3 intensity increases at lower latitudes (unlike GMD's that decreases at lower latitudes).***
- ***Bottom line: Hardening against GMD leaves the grid vulnerable to HEMP; hardening against HEMP will also protect against GMD.***
- ***Thus, the current government and industry focus on grid GMD protection while ignoring HEMP is shortsighted to say the least.***

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Question 2: Can you tell us more about your work in South Carolina and with Duke Energy and the important lessons learned? Should the federal government put more resources into that type of approach? Should we be looking at similar pilot projects to the one you have ongoing with Duke Energy? What recommendations do you have for the government and private sector to collaborate in order to emulate the success your efforts in South Carolina have enjoyed?

- ***First, please permit me to recap my motivation for and the progress of our Lake Wylie Pilot Study, which I hope will become a model that others can and will follow.***
- ***As indicated in my written testimony, I began this South Carolina effort understanding that neither Federal nor State efforts were dealing effectively with the existential EMP threat—nor were they likely to do so in my lifetime. In my written testimony I quoted liberally from an April 20, 2017 letter from the EMP Commission Chairman to Energy Secretary Rick Perry specifying several important criticisms of ongoing pertinent activities hindering progress in dealing effectively with the EMP/GMD threat.***
- ***For such reasons, I concluded years ago that we had to address the problem "from the bottom up," working with local (e.g., city and county level) authorities and citizens themselves to gain an understanding of the threat and how they need to engage those who provide their electricity to assure the viability of their critical civil infrastructure, in case of a major electric grid shutdown. Without considerable emergency management cooperation at the local level, there will be little hope for most citizens who today depend on electricity for life-line services in our "just-in-time" economy.***
- ***Moreover, I began with several biases, based on a lifetime of pertinent experiences associated with EMP issues, which guide my assessments and recommendations.***
  - ***I have no confidence that we will ever harden the entire grid, so I believe we have to establish priorities—I give top priority to assuring the safety and viability of our ~100 nuclear power plants that produce about 20-percent of the nation's electricity, and half the electricity of my home state, South Carolina. Thus, I believe our top priority is to build protected "islands" within the grid around our nuclear power plants, the vast majority of which are in the Eastern Interconnect of the grid.***
  - ***To assure the viability of the nuclear power plants in an indefinite grid shutdown, we must first assure their cooling water systems are viable to avoid Fukushima-like disasters. Then, we must assure that sufficient generating power and loading conditions are provided by the surrounding "island" in the grid—and linked with other critically important elements of the grid to ensure they are available to restart the nuclear power plants—and other power plants, which will shut down to protect themselves if the grid goes down.***
  - ***I don't believe anything that isn't regularly tested and subjected to independent critical review—effective design and deployment is not enough; truly effective testing and maintenance are major challenges.***
- ***Over the past two years, I have developed excellent relationships with key electrical engineering professors at my alma mater Clemson University and several Duke engineers (including Clemson graduates) who also are concerned about this threat—***

and through them access to other university graduate programs and other energy companies. We agreed on how we could proceed with a meaningful "bottoms-up" program to assure the viability of three Duke Energy power plants on Lake Wylie, on the Catawba River that runs between North and South Carolina—and of course key transmission infrastructure that interconnects those nuclear, hydroelectric and coal power plants and others to their customers. Duke Energy's senior management has agreed to share broadly the lessons learned from this important "Lake Wylie Pilot Study," described in greater detail in my written testimony. I want to make clear I was not and am not selling anything to or for Duke Energy and would not take money from them if they offered it. I just want to cut through the morass described above, and provide hope that my grandkids can survive if we experience an EMP attack or GMD event. I know that all our citizens want this objective met.

- ***A critically important lesson that we have learned is that Duke Energy needs the active participation/cooperation of other Energy Utility Companies and Electric Cooperatives (CoOps) that actually maintain critical infrastructure that delivers Duke's electricity to key customers, e.g., the water/wastewater infrastructure that supports local hospitals and other critically important service activities, including many citizens themselves. Happily, we are now working with these key individuals in the local area around Lake Wylie—including the Deputy Mayor (a Clemson electrical engineering graduate) of Rock Hill, a major suburban city neighboring Charlotte, the home of Duke Energy's corporate headquarters. Moreover we are achieving cooperation of the county sheriff and key local citizens. The SC Adjutant General (a Georgia Tech electrical engineer) is supportive of our effort, and we are working with his emergency management staff to support their participation in November's GRIDEX-IV national exercise focused on the physical and cyberattack threats to the grid. Associated contacts will be helpful in SC and beyond. We expect a regional follow-on exercise involving the EMP/GMD threat, and also including at least the NC emergency management community.***
  - ***I cannot overstate the importance of engaging these local people in any effort to improve the viability of the electric grid—not just locally but in networking throughout the nation. Several thousand electric utility companies and CoOps deliver electricity via their infrastructure to key customers and private citizens around the nation. We hope to demonstrate how to meet this complex challenge.***
  - ***I also can't overstate the important role that informed and concerned local citizens can play. For example, a retired Physician, who has come to understand the threat and the urgent need for local authorities to be actively involved, has provided a great deal of support with the local citizens as well as city and county officials—and through his growing involvement in SC statewide activities, such as the GRIDEX-IV exercise. These connections also involve the National Guard, thereby enabling lessons learned to be propagated through multistate and NORTHCOM connections, potentially to be included in a national network.***

- ***My short answer to your direct question is that I believe we will indeed produce a "bottom's up" pattern worth considering by other states. I personally believe that this approach has more promise of success than anything that can be produced by the currently discordant activities of the Federal Government. Congress could be helpful in addressing that important shortfall—in particular by extending to permanent status the EMP Commission and placing it in the White House with a charter to provide critical assessments of efforts of the several departments with related responsibilities and to recommend to the President and Congress measures to rectify shortcomings.***

Question 3: One of the keys to a successful public-private partnership is trust and the willingness to share information. I am concerned, however, that there is a lack of trust by industry with the government – and for good reason. The December 2016 episode with Burlington Electric in Vermont is a perfect example. As I understand it, Burlington noticed an alert about a suspicious IP address that had connected to one of their computers and responded to that alert by dutifully reporting that fact to the government. The same day that they reported the alert, however, the Washington Post somehow learned about it and reported that Russian hackers had infiltrated the United States' electric grid. Later follow-up would show that the IP address was not necessarily linked to Russia and there was not malicious activity, but the damage to trust had been done. How do we restore and build trust between the private sector and government so that this type of information can be freely shared without concern about it becoming a media spectacle?

- ***I agree there is a major problem in assuring public trust in the government to address this, in my judgment, existential threat. Moreover, their skepticism is well founded. Washington (in both Executive and Legislative branches) is failing to address the issue as I discussed in my testimony—and few state governments acknowledge the existential threat, much less deal with it. This general dysfunctional leadership is why I believe we must actually work the problem "from the bottom up," as I testified and discussed in my answer to Question 2. It would help if the key departments, DoD, DHS and DOE, would get their collective act together. But I believe this will only happen with strong leadership from the White House. Extending the EMP Commission and placing its secretariat in the White House with access to the President would help tremendously.***

Question 4: EMP models are only as good as the data inputs provided. The United States has not tested any nuclear weapons since 1992, and no atmospheric tests since the Test Ban Treaty of 1963. My understanding is that many of our weapon designs have required post-deployment tests to resolve problems – and those problems were discovered only because of ongoing nuclear tests at the time. In each case, the weapons were thought to be reliable and thoroughly tested. How confident are you that the data being inputted into the models with regard to the EMP effects of a nuclear weapon detonation is accurate – particularly since we have not conducted an atmospheric test since 1962?

- ***The usable HEMP data from our most pertinent 1962 South Pacific high-altitude nuclear tests were sparse. However, with theoretical calculations we have always been able to match that limited data. With improvements in measurement uncertainty evaluations (affecting the quality of the data), the theoretical calculations and data (peak values and entire waveforms) have agreed within 20-percent. We subsequently obtained relevant data from low-altitude, low-yield testing at the Nevada Test Site, against which we could evaluate our theoretical models for at least "source-region" EMP. And that experience helped to build additional confidence in our HEMP calculations. My own personal experience was, like all who sought to conduct meaningful nuclear tests—including underground nuclear tests, to try to avoid the EMP disruption of instrumentation intended to measure other effects, e.g., to understand X-ray and Blast and Shock effects.***
- ***I understand the Soviets/Russians executed better planned and instrumented HEMP experiments. They had an advantage since they broke-out of the 1958 atmospheric test moratorium with a well-planned 1961 test series, and then our "knee-jerk" high-altitude test response produced limited results. Because our tests exposed mostly ocean areas rather than large land areas with extensive long-line power and communications infrastructure, we did not experience the system network effects that did the Soviets in their high altitude test series. President Kennedy signed the Limited Test Ban Treaty on October 5, 1963, terminating indefinitely our ability to do better HEMP testing.***
- ***In the early wake of the end of the Cold War in the 1990s, we obtained at least some of that more extensive information from Russian scientists. And the EMP Commission is now looking into how best to use that information to provide more confident estimates of EMP environments and system response information that should be helpful to the electric power companies seeking to protect their infrastructure from EMP effects.***
- ***Moreover, Russian generals informed EMP Commissioners in 2004 that they had passed design information on "super EMP weapons" to North Korea and anticipated that they would have such a weapon in a few years—that was 13 years ago. Now, the electric power industry should be taking these capabilities into account in assuring their infrastructure can operate through—or be restored after—a HEMP attack.***

a. Since most of the data is controlled by the Department of Defense and the National Labs, does the private sector have access to the data needed to accurately model the potential EMP impact and effect of a nuclear explosion?

- ***Much is already public—was made public in the 2008 EMP Commission Report. Additional important data and EMP hardening information are, in my opinion, overclassified and should be made available to the private sector ASAP. For example, the "For Official Use Only" DoD EMP Engineering Handbook, MIL-HDBK-423 should certainly be completely unclassified. Our enemies surely have***

long ago had it. Moreover, the E3 portion of the DoD EMP Environment Standard, MIL-STD-2169C, should be declassified and provided to the energy companies seeking to harden their critical infrastructure.

b. My understanding is that most HEMP models are based on a one dimensional, spherically symmetric model, neglect scattering effects, and are unable to model 2- and 3-D effects. There is also no high-fidelity model that predicts EMP from detonations from 5 kilometers to 20 kilometers above the Earth's surface. Given these shortfalls, how confident are you in the accuracy of current EMP models?

- ***EMP experts tell me that the DoD EMP environment standard established decades ago is reliable for predicting the E1 component of the EMP pulse, and that it is well represented by 1D full-physics models. In fact, I understand that it is a validated (by experiment and 2&3-D calculations) high frequency approximation for the 3-D model, referred to as the Longmire-Karzas-Latter model for E1 generation.***
- ***In the mid-1960s a combination of 1-D and 2-D codes were developed at the Air Force Weapons Laboratory (AFWL), RAND, and Mission Research Corporation (MRC) that accurately predicted the EMP fields produced by air and ground vertical asymmetry effects for nuclear tests, over the altitude range from zero to exo-atmospheric altitudes. Within the atmosphere, the geomagnetic effect is smaller than the vertical asymmetry effects, but has been accurately predicted by the same 1-D approximation used to predict the fields produced by exo-atmospheric nuclear explosions. For explosions where the gamma rays interact with the ground, another 1-D approximation, called the Graham-Schaefer effect, has accurately predicted the close-in near-surface fields, and has been verified in underground nuclear testing. Together, these constitute high-fidelity models of the EMP fields produced by atmospheric and exo-atmospheric nuclear explosions.***
- ***Two independent families of EMP codes were developed and supported by the Defense Nuclear Agency and the USAF/AFWL to enable comparative error analysis that yielded results within 10-30% of each other. The Congressional EMP Commission funded SAIC physicists to recheck the physics of these analyses and found them to be correct. Thus, I conclude that current theoretical analyses are sufficiently accurate to confidently design, develop, deploy and operate critical grid infrastructure to counter E1 pulse. That said, I would insist on prudent defense-conservative designs.***
- ***I understand that the EMP Commission is completing reports on the E2 and E3 components of the HEMP pulse, with an expectation that current calculations will provide accurate results that are expected to be validated within a factor of 2. Again, I would insist on conservative designs to counter E2 and E3.***

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Question 5: Are there military applications to address HEMP or other EMP-related events that are not being made available to civilians? If so, how do we lift that barrier?

- ***As noted in my answer to question 4a, we should declassify as much of the DoD information on EMP effects and hardening technology as possible. I urge that Congress demand that the EMP Commission make specific recommendations on this matter as part of their June 2017 report, if not sooner.***

Question 6: Do you believe any additional research is needed on EMP threats?

- ***I don't want to overstate the issue, but I believe most of the current "research" by the DOE labs and EPRI is at best reinventing what has already been accomplished by DTRA and the military service laboratories (AFRL, ARL, NSWC) over the last 50 years. This DOE redundancy is actually unhelpful and could be eliminated my making that DoD information available to the energy companies that need it to do their job. As noted above, the EMP Commission can make an enormously important contribution by providing specific recommendation in its June 2017 report, if not sooner.***

Question from Senator Debbie Stabenow

Question: During today's testimony, we heard that EMPs are a threat to our national security. However, the range of impacts appear vast, from naturally occurring events causing grid disruptions, up to - and including - the aftermath of a high altitude nuclear detonation.

This Committee has held several hearings in this and previous congresses on the threats facing our electric grid and critical energy infrastructure. From your perspective, how does the threat posed from EMPs compare to other vulnerabilities such as cyber-attacks?

- ***EMP is the "800 pound gorilla" on the list of threats (a view expressed by AT&T officials, with which I agree). It affects the long line systems similarly to solar storm GMD events (but of higher amplitude), and in addition EMP has a high frequency punch (the E1 Component) that will take out office equipment, data centers, and machine control electronics. Today, virtually none of our critical civil infrastructure is protected. As noted above, the low-frequency E3 component is substantially larger than the GMD threat, which is today being underestimated by NERC—so GMD protection may not, probably will not, suffice even for E3 protection.***
- ***From a technical standpoint, EMP can induce over-voltages on everything from computers to heavy machinery controllers to data networks comprising the internet, to telephone networks, electric power plants and substations. And while not all electronic systems will upset or burnout, a large enough fraction will fail such that, without protection, cascading effects can bring the U.S. economy, or any economy, to a***

grinding halt. Among critical infrastructure systems, the power grid is probably the most certain to fail. Without electric power, most other infrastructures will be debilitated. Without protection, the power grid will be out of service for significant portions of time—as explained in the 2008 EMP Commission report.

- ***DHS has identified 16 infrastructures, and of these the electrical power system and communication systems are arguably the most important to the national enterprise, but, ironically, they are also the most vulnerable. The reason is that they depend upon long lines, and since EMP levels are measured in Volts per meter, so the longer the lines in meters the higher the voltage induced on the lines. Intuitively, any system that has long lines (e.g., electric power or communications) will be the most vulnerable.***
- ***We know how to protect systems against EMP. The DoD has been doing it since the 1960s, and has developed EMP environment and protection engineering standards. Simply put a shield around critical equipment; protect all the wire penetrations; include backup power systems and use fiber optics as much as possible. We know how to protect against solar storms (GMD) because Sweden and Canada have protected their grids against solar storms for years. Since we know how to protect against GMD with capacitive blockers and reactive power compensators, we know how to protect against the EMP E3, though we must take care not to underestimate its magnitude. And we must test regularly to assure even the best standards of operations are maintained after sound hardening capabilities are deployed.***
- ***This is not to argue against protecting the grid against cyber and physical attack. Indeed, if there is an EMP attack our adversaries, who are well informed and competent, undoubtedly will include cyber and physical attack precursors to confuse us and disrupt our response not only to those attacks but to the pending EMP attack itself. The best approach is a multi-hazzard approach since the same high impact system failure locations are vulnerable to EMP, cyber and physical attacks.***

Question from Senator Steve Daines

Question: You stated that although EMP attacks are known to be included in North Korea's military doctrine and planning, bureaucracy and inaction have precluded DoD, DoE, and DHS from developing an effective EMP defensive posture. I serve on committees with jurisdiction over all three of those departments. From your perspective, what red tape needs to be cut to get the right leaders in a room and address this issue?

- ***I believe that the Executive Branch must address its dysfunctional activities that inhibit efforts toward this end. The White House must lead. My recommendation is to place the re-instated EMP Commission permanently under a White House Secretariat with direct access to the President, with a mandate to resolve the interagency conflicts of interest and programmatic activities—especially among DoD, DHS and DOE. Initially,***

I would urge that Congress seek an early assessment of the viability of the nation's critical national infrastructure and associated regulatory operations, with specific recommendations to the President and Congress for appropriate improvements.

- ***Congressional initiatives could provide important incentives to encourage significant improvement in the various programs that must be conducted by the Executive Branch. Among them, I would encourage ways to incentivize local and state initiatives to work closely with the nation's several thousand electric utility companies and CoOps to assure electricity flows from the major electric power companies to key local, city and county key infrastructure, e.g, water-wastewater infrastructure that is key to hospitals, businesses, citizens, etc.***
- ***Finally, local leadership and active involvement of all our citizens is key to success. I can think of no more effective means to reach that goal than to work through the National Guard as the vehicle by which our State Adjutant Generals can achieve an effective national arrangement. At the end of the day, success will require a more effective alliance between the Departments of Defense and Homeland Security. And the National Guard should be challenged to help achieve that alliance. Congressional encouragement toward that end could be most helpful in resolving current "roles and missions" gaps. Hopefully, our Lake Wylie Pilot Study will provide a template that other states and the federal government can exploit in working toward that end.***