Joosten, Sandy

From:	Thomas S Popik <thomasp@resilientsocieties.org>
Sent:	Saturday, June 29, 2013 9:51 AM
To:	CHAIRMAN Resource
Subject:	Government Emergency Actions on Electromagnetic Pulse Threats
Attachments:	EMP Threats Letter to President_6_28_2013_Final.pdf

Chairman Macfarlane:

Attached please find your courtesy copy (cc:) of our letter sent to President Obama with the subject line "Government Emergency Actions on Electromagnetic Pulse Threats," dated June 28, 2013.

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June 28, 2013

President Barack Obama
The White House
1600 Pennsylvania Avenue NW
Washington, DC 20500

Subject: Government Emergency Actions on Electromagnetic Pulse Threats

Dear Mr. President:

We are writing to urge protection of the United States against both man-made and naturally-occurring electromagnetic pulse (EMP). The recent actions of Iran and North Korea—including ongoing nuclear weapons development and missile tests—increase the chance that these nations will threaten and perhaps even execute a high altitude nuclear EMP attack against the continental United States. However, if Presidential initiatives were to protect even a modest proportion of the U.S. electric power grid against EMP, nuclear deterrence could be strengthened and benefits to nuclear proliferators diminished.

The Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack was authorized by the U.S. Congress and worked from 2001 to 2008 to conduct the most comprehensive study to date on EMP protection for civilian infrastructure. We ask the current Administration to revisit and implement selected findings of the EMP Commission. A summary of the EMP Commission findings on protection of electric power infrastructure is included as Appendix 1 to this letter. (Dr. William Graham, chairman of the EMP Commission, is both a director of our Foundation and a signatory to this letter.) Other government bodies also recommending EMP protection include the National Academy of Sciences and the National Intelligence Council.

We commend the Administration for supporting bipartisan efforts to protect against naturally-occurring EMP—also called "solar storms" or "geomagnetic disturbance"—and appreciate the recent White House report, "Space Weather Observing Systems: Current Capabilities and Requirements For The Next Decade." We also appreciate the positive ruling of the Nuclear Regulatory Commission (NRC) on Petition for Rulemaking PRM-50-96, a petition submitted by our Foundation which would require unattended backup power systems at nuclear power plants vulnerable to solar storm EMP. (See 77 Fed. Reg. 74788-74798; Dec 18, 2012 and Appendix 7 of this letter.) As the events at Fukushima amply showed, nuclear power plants without grid power—and without reliable and protected control and backup systems—can pose a catastrophic danger to surrounding populations. Without power to control and cool reactor cores and spent fuel pools, thousands of square miles surrounding scores of nuclear power plants in this country could be uninhabitable for centuries in the wake of a national-level EMP event. Additional reports of the EMP Commission are available to authorized persons through the Congress and the Department of Defense.

A high altitude nuclear EMP attack from North Korea is an imminent threat to the United States, and an EMP attack from Iran could shortly become an imminent threat. We propose three protective actions against rogue nations with nuclear EMP capability. In the short term, we propose emergency deployment of cost-effective missile defense systems, including Aegis systems that can defend against southern approaches to the continental United States; this proposal is more fully explained in Appendix 2. In the medium term, we propose E1 (fast pulse) protection of electric grid control rooms at regional balancing authorities, as well as E1 and E3 (magnetohydrodynamic pulse) protection of critical Extra High Voltage (EHV) transformers. This protection, while incomplete, would increase the uncertainty of a successful nuclear EMP attack and could have substantial deterrent effect upon rogue state adversaries. In the long-term, we propose that all high-priority critical infrastructures when upgraded or replaced should be subject to nuclear EMP protection standards; for example, all of the Bulk Power System under jurisdiction of FERC should eventually have both E1 and E3 protection.

Engineering practices for EMP protection are well developed and have been successfully implemented by the Department of Defense (DoD) for its strategic systems. The American public deserves protection for critical civilian infrastructure as well. It is particularly important for DoD to make its expertise available to the Department of Homeland Security, the Department of Energy, NRC, FERC, and the electric power industry. A summary of DoD expertise that could be used to provide EMP protection for the U.S. electric power grid is provided in Appendix 3.

While FERC has a standard for solar storm EMP protection in development, the timeline for installation of protective hardware will be in year 2015 at the earliest. In the meantime, and during the peak and active backside of the 11-year solar cycle, the United States will be unprotected, absent a government emergency plan to de-energize the electric grid upon warning of a severe solar storm. De-energizing transformers with long replacement times could reduce grid recovery time and save millions of lives.

Our legal analysis indicates that the President has existing authority to de-energize substantial portions of the three U.S. regional grid interconnections, including all nuclear, gas-fired, and oil-fired generation facilities. We understand from the NOAA Space Weather Prediction Center that a final 10 to 20-minute warning from the ACE satellite, as well as preliminary two-day warnings from space satellites closer to the sun, could be part of a feasible plan to de-energize vulnerable equipment within the electric grid. While the final warning time would be short, de-energizing the most vulnerable portions of the U.S. electric grid could still be accomplished if an emergency plan had previously been developed and all necessary processes and procedures were in place. Significantly, Presidential authority to de-energize critical generation facilities is non-delegable, except for nuclear power plants where the NRC has direct authority. More background on an emergency plan to de-energize generation facilities is explained in Appendix 4 of this letter; a review of Presidential legal authority is presented in Appendix 5.

In the fall of 2012 our Foundation conducted a pilot qualitative survey of national security and foreign policy experts regarding awareness of EMP threats. To our surprise, we found that EMP threats are poorly understood and often discounted among these experts, despite nuclear EMP protection being required for U.S. strategic defense systems and continuity of government for more than 40 years. Some in Washington view EMP as a problem without a ready solution and therefore politically infeasible to address. In actuality, Idaho National Laboratory has already tested a neutral blocking device to protect transformers against both nuclear E3 and severe solar storms. This blocking device is commercially available for a cost of $250,000 per substation. Furthermore, at least one electric utility (Centerpoint Energy in Houston, Texas) has installed on its own initiative a nuclear E1 hardened control room at a cost of $8.75 million dollars. Nations such as Israel are already implementing cost-effective EMP protection for their electric grids.

Focused EMP protection of the most critical infrastructure would be both practical and cost-effective. But lack of timely EMP protection could result in the death of over one hundred million Americans and threaten the existence of the United States as a functioning country.

There is increasing public awareness and concern over EMP threats. This legitimate public concern, if not addressed, could have a destabilizing effect on our society. Already there is a "prepper" movement, where individual citizens store food and water and sometimes take more extreme measures. But no amount of personal preparation can supplant the constitutional duty of the federal government to provide for a common defense. We urge the Administration to take concrete steps for EMP protection before the next major solar storm and before the Islamic Republic of Iran conducts a successful nuclear test. Actions for EMP protection must be made public—secret plans will not reassure the populace, nor will secret EMP defenses deter rogue nations.

Given the importance and immediacy of EMP threats to the United States and its population, we ask for the courtesy of a reply from the Administration. Thank you for consideration of our concerns.

Sincerely,

William R. Graham

Dr. William R. Graham, Chair of Congressional EMP Commission and former Assistant to the President for Science and Technology

Ambassador Henry F. Cooper, former Director of the Strategic Defense Initiative Organization

Dr. George H. Baker, Professor Emeritus, James Madison University

William R. Harris, International Lawyer & Secretary, Foundation for Resilient Societies

Stephen L. Mott, Nuclear Engineer; 30 years' experience in the nuclear power industry

Thomas S. Popik, Chairman, Foundation for Resilient Societies

Attachments:
Appendix 1: Extracts from Executive Report of Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack
Appendix 2: An Immediate Plan to Defend U.S. against Nuclear EMP Attack
Appendix 3: EMP/GMD Protection of the U.S. Electric Power Grid
Appendix 4: Presidential Plan to Protect from Long-Term Electric Grid Outage Due to GMD
Appendix 5: Legal Authority for the President of the United States to Order Interruption of U.S. Electric Generation and Related Electric Grid Protections during a Severe Solar Geomagnetic Storm
Appendix 6: Recognizing Electromagnetic Pulse Attack
Appendix 7: Vulnerability of Nuclear Power Plants to Electromagnetic Pulse

cc:

The White House
Sylvia Mathews Burwell, Director, Office of Management and Budget
John P. Holdren, Director, Office of Science and Technology Policy
Lisa O. Monaco, Assistant to the President for Homeland Security and Counterterrorism
Susan E. Rice, Assistant to the President for National Security Affairs

Departments
Charles T. Hagel, Secretary of Defense
John F. Kerry, Secretary of State
Ernest J. Moniz, Secretary of Energy
Janet Napolitano, Secretary of Homeland Security

Agencies
James R. Clapper, Director of National Intelligence
Allison M. Macfarlane, Chairman, Nuclear Regulatory Commission
Kathryn Sullivan, Acting NOAA Administrator
Jon Wellinghoff, Chairman, Federal Energy Regulatory Commission

Appendix 1

Extracts from Executive Report of Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack

Full report available at http://www.empcommission.org/docs/empc_exec_rpt.pdf.

ABSTRACT

Several potential adversaries have or can acquire the capability to attack the United States with a high-altitude nuclear weapon-generated electromagnetic pulse (EMP). A determined adversary can achieve an EMP attack capability without having a high level of sophistication.

EMP is one of a small number of threats that can hold our society at risk of catastrophic consequences. EMP will cover the wide geographic region within line of sight to the nuclear weapon. It has the capability to produce significant damage to critical infrastructures and thus to the very fabric of US society, as well as to the ability of the US and Western nations to project influence and military power.

The common element that can produce such an impact from EMP is primarily electronics, so pervasive in all aspects of our society and military, coupled through critical infrastructures. Our vulnerability is increasing daily as our use of and dependence on electronics continues to grow. The impact of EMP is asymmetric in relation to potential protagonists who are not as dependent on modern electronics.

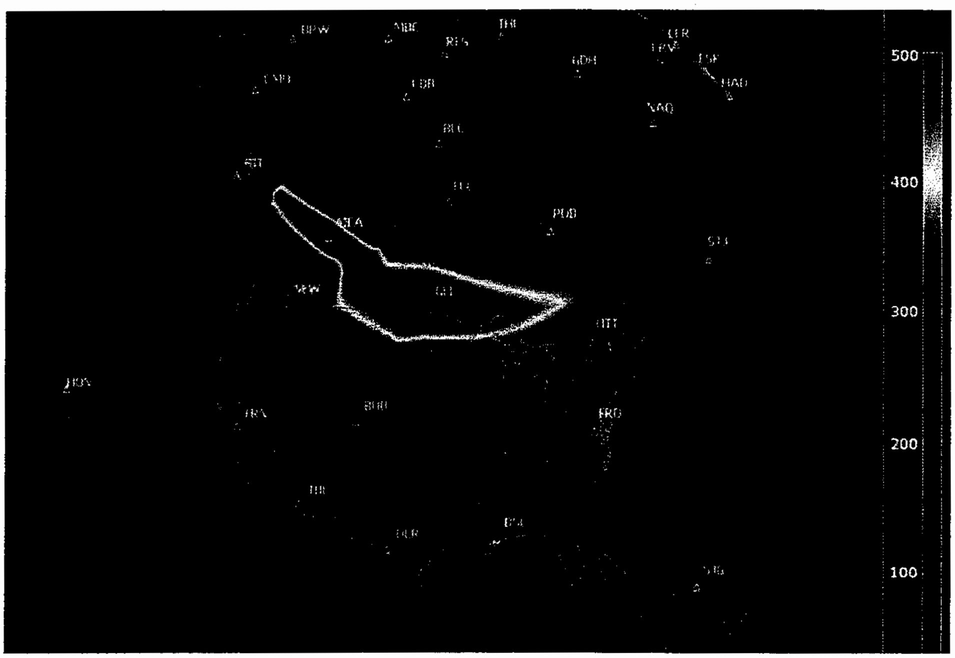
The current vulnerability of our critical infrastructures can both invite and reward attack if not corrected. Correction is feasible and well within the Nation's means and resources to accomplish.

ELECTRIC POWER INFRASTRUCTURE

NATURE OF THE PROBLEM

Electric power is integral to the functioning of electronic components. For highly reliable systems such as commercial and military telecommunications, electric power usually comes from batteries (in the short term), local emergency power supplies (generally over time-intervals of less than 72 hours), and electricity delivered through the local electrical utility ("power" lines in the home, office and factory). Local emergency power supplies are limited by supplies of stored fuel. Increasingly, locally-stored fuel in buildings and cities is being reduced for fire safety and environmental pollution reasons, so that the emergency generation availability without refueling is limited.

Geomagnetic storms, a natural phenomenon driven by the solar wind, may, by a different physical mechanism, produce ground-induced currents (GIC) that can affect the electrical system in a manner similar to the E3 component of EMP. Disruptions caused by geomagnetic storms, such as the collapse of Quebec Hydro grid during the geomagnetic storm of 1989, have occurred many times in the past (Figure 5).



Geomagnetic field disturbance conditions, dB/dt (nT/min) over North America at time 7:45 UT on March 13, 1989

Source: Metatech Corporation, Applied Power Solutions

Figure 5. Extent of 1989 Geomagnetic Storm

Depending on the explosive yield of the nuclear weapon used, EMP-induced GIC may be several times larger than that produced by the average geomagnetic storm, and may even be comparable to those expected to arise in the largest geomagnetic storm ever observed. It may also occur over an area not normally affected by historic geomagnetic storms.

The North American economy and the functioning of the society as a whole are critically dependent on the availability of electricity, as needed, where and when needed. The electric power system in the US and interconnected areas of Canada and Mexico is outstanding in terms of its ability to meet load demands with high quality and reliable electricity at reasonable cost. However, over the last decade or two, there has been relatively little large-capacity electric transmission constructed and the generation additions that have been made, while barely adequate, have been increasingly located considerable distances from load for environmental, political, and economic reasons. As a result, the existing National electrical system not infrequently operates at or very near local limits on its physical capacity to move power from generation to load. Therefore, the slightest insult or upset to the system can cause functional collapse affecting significant numbers of people, businesses, and manufacturing. It is not surprising that a single EMP attack may well encompass and degrade at least 70% of the Nation's electrical service, all in one instant.

The impact of such EMP is different and far more catastrophic than that affected by historic blackouts, in three primary respects:

1. The EMP impact is virtually instantaneous and occurs simultaneously over a much larger geographic area. Generally, there are no precursors nor warning, and no opportunity for human-initiated protective action. The early-time EMP component is the "electromagnetic shock" that disrupts or damages electronics-based control systems and sensors, communication systems, protective systems, and control computers; all of which are used to control and bring electricity from generation sites to customer loads in the quantity and quality needed. The E1 pulse also causes some insulator flashovers in the lower-voltage electricity distribution systems (those found in suburban neighborhoods, in rural areas and inside cities), resulting in immediate broad-scale loss-of-load. Functional collapse of the power system is almost definite over the entire affected region, and may cascade into adjacent geographic areas.
2. The middle-time EMP component is similar to lightning in its time-dependence, but is far more widespread in its character although of lower amplitude—essentially a great many lightning-type insults over a large geographic area which might obviate protection. The late-time EMP component couples very efficiently to long electrical transmission lines and forces large direct electrical currents to flow in them, although they're designed to carry only alternating currents. The energy levels thereby concentrated at the ends of these long lines can become large enough to damage major

electrical power system components. The most significant risk is synergistic, because the middle and late time pulses follow after the early time, which can impair or destroy protective and control features of the power grid. Then the energies associated with the middle and late time EMP thus may pass into major system components and damage them. It may also pass electrical surges or fault currents into the loads connected to the system, creating damage in national assets that are not normally considered part of the infrastructure *per se*. Net result is recovery times of months to years, instead of days to weeks.

3. Proper functioning of the electrical power system requires communication systems, financial systems, transportation systems and, for much of the generation, continuous or nearly continuous supply of various fuels. However, the fuel-supply, communications, transportation, and financial infrastructures would be simultaneously disabled or degraded in an EMP attack and are dependent upon electricity for proper functioning. For electrical system recovery and restoration of service, the availability of these other infrastructures is essential. The longer the outage, the more problematic, and uncertainty-fraught the recovery will be.

The recent cascading outage of August 14, 2003, is an example of a single failure compounded by system weaknesses and human mistakes. It also provided an example of the effectiveness of protective equipment. However, with EMP there are multiple insults coupled with the disabling of protective devices simultaneously over an extremely broad region—damage to the system is likely and recovery slow.

RECOMMENDED MITIGATION AND RESPONSIBILITY

The electrical system is designed to break into "islands" of roughly matching generation and load when a portion of the system receives a severe electrical insult. This serves both to protect electricity supply in the non-impacted regions and to allow for the stable island-systems to be used to "restart" the island(s) that have lost functionality. With EMP, the magnitude, speed, and multi-faceted nature of the insult, its broad geographic reach, along with the number of simultaneous insults, and the adverse synergies all are likely to result in a situation where the islanding scheme will fail to perform as effectively as intended, if at all. Since the impacted geographic area is large, restoring the system from the still-functioning perimeter regions would take a great deal of time, possibly weeks to months at best. Indeed, the only practical way to restart much of the impacted electrical system may be with generation that can be started without an external power source. This is called "black start" generation and primarily includes hydroelectric (including pumped storage), geothermal, and independent diesel generators of modest capacity.

The recommended actions will substantially improve service and recovery during 'normal' large-scale blackouts, as well as critically enabling recovery under EMP circumstances.

PROTECTION

It is impractical to protect the entire electrical power system from damage by an EMP attack. There are too many components of too many different types, manufacturers, designs and vulnerabilities within too many jurisdictional entities, and the cost to retrofit is too great. Widespread functional collapse of the electrical power system in the area affected by EMP is likely in the face of a geographically broad EMP attack, with even a relatively few unprotected components in place. However, it is practical to reduce to low levels the probability of widespread damage to major power system components that require long times to replace. This will enable significantly improved recovery times, since it avoids the loss of long lead-time and critical components. It is important to protect the ability of the system to fragment gracefully into islands, to the extent practical in the particular EMP circumstance. This approach is cost-efficient, and can leverage efforts to improve reliability of bulk electricity supply and enhance its security against the broader range of threats.

> ***Widespread functional collapse of the electric power system in the area affected by EMP is likely.***

RESTORATION

The key to minimizing adverse effects from loss of electrical power is the speed of restoration. Restoration involves matching generation capacity to a load of equivalent size over a transmission network that is initially isolated from the broader system. The larger system is then functionally rebuilt by bringing that mini system or 'island' to the standard operating frequency and thereupon by adding on more blocks of generation and load to this core- in amounts that allow the growing subsystem to absorb. This is a demanding and time-consuming process in the best of circumstances. In the singular circumstance of an EMP attack with multiple damaged components, related infrastructure failures, and particularly severe challenges in communications and transportation, the time required to restore electrical power is expected to be considerably longer than we have experienced in recent history.

However, by protecting key system components needed for restoration, by structuring the network to fail gracefully, and by creating a comprehensive prioritized recovery plan for the most critical power needs, the risk of an EMP attack having a catastrophic effect on the Nation can be greatly reduced. DHS must ensure that the mitigation plan is jointly developed by the Federal government and the electric power industry, implemented fully, instilled into systems operations and tested and practiced regularly to maintain a capability to respond effectively in emergencies. The North American Reliability Council and the Electric Power Research Institute are aptly positioned to provide much of what's needed to support DHS in carrying out its responsibilities. The US Energy Association is well-suited to coordinating activities between and among the various energy sectors that together affect the electric power system and its vitality.

1. Assure protection of high-value long-lead-time transmission assets.
2. Assure protection of high-value generation assets. System-level protection assurance is more complex due to the need for multiple systems to function in proper sequence.
3. Assure Key Generation Capability. Not all plants can or should be protected. However, regional evaluation of key generating resources necessary for recovery should be selected and protected.
    a. Coal-fired generation plants make up nearly half the Nation's generation and are generally the most robust overall to EMP, with many electromechanical controls still in operation. Such coal plants also normally have at least a few days to a month of on-site fuel storage.
    b. Natural gas-fired combustion turbines and associated steam secondary systems represent the newest and a significant contributor to meeting loads. These have modern electronics-based control and thus are more vulnerable. Natural gas is not stored on-site and likely will be interrupted in an EMP attack. However, provision can be made to have gas-fired plants also operate on fuel oil; many do already.
    c. Nuclear plants produce roughly 20% of the Nation's generation and have many redundant fail-safe systems that tend to remove them from service whenever any system upset is sensed. Their safe shut down should be assured, but they will be unavailable until near the end of restoration.
    d. Hydroelectric power is generally quite robust to EMP, and constitutes a substantial fraction of total national generation capacity, albeit unevenly distributed geographically.
    e. In general, the various distributed and renewable fueled generators are not significant enough at this time to warrant special protection.
    f. "Black start" generation of all types is critical will need to be protected from EMP upset or damage.
4. Assure functional integrity of critical communications channels. The most critical communications channels in the power grid are the ones that enable recovery from collapse, such as ones that enable manual operation and coordination-supporting contacts between distant system operators and those that support system diagnostics. Generation, switching, and load dispatch communications support is next in importance.
5. Assure availability of emergency power at critical facilities needed for restoration. Transmission substations need uninterruptible power to support rapid restoration of grid connectivity and operability, and thereby to more quickly restore service. Most have short-life battery backup systems, but relatively few have longer-duration emergency generators; much more emphasis on the latter is needed.

6. Assure protection of fuel production and its delivery for generation. Fuel supply adequate to maintain critical electrical service and to restore expanded service is critical. See Fuel/Energy Infrastructure, page 34) for details.
7. Expand and assure intelligent islanding capability. The ability of the larger electrical power system to break into relatively small subsystem 'islands' is important to mitigate overall EMP impacts and provide faster restoration.
8. Develop and deploy system test standards and equipment. Device-level robustness standards and test equipment exist, but protection at the system level is the overarching goal. System level robustness improvements such as isolators, line protection, and grounding improvements will be the most practical and least expensive in most cases relative to replacement with more robust individual component devices. Periodic testing of system response is necessary.

System Restoration

1. Develop and enable a restoration plan. This plan must prioritize the rapid restoration of power to government-identified critical service. Sufficient "black start" generation capacity must be provided where it's needed in the associated subsystem islands, along with transmission system paths that can be isolated and connected to matching loads. The plan must address outages with wide geographic coverage, multiple major component failures, poor communication capabilities, and widespread failure of islanding schemes within the EMP-affected area. Government and industry responsibilities must be unequivocally and completely assigned. All necessary legal and financial arrangements, e.g., for indemnification, must be put into place to allow industry to implement specified government priorities with respect to service restoration, as well as to deal with potential environmental and technical hazards in order to assure rapid recovery.
2. Simulate, train, exercise, and test the plan. Simulators must be developed for use in training and developing procedures similar to those in the airline industry; a handful should suffice for the entire country. Along with simulation and field exercises, Red Team discipline should be employed to surface weaknesses and prioritize their rectification.
3. Assure sufficient numbers of adequately trained recovery personnel.
4. Assure availability of replacement equipment. R&D is under way—and should be vigorously pursued—into the production of emergency "universal" replacements. The emergency nature of such devices would trade efficiency and service-life for modularity, transportability, and affordability.
5. Implement redundant backup diagnostics and communication. Assure that system operators can reliably identify and locate damaged components.

Appendix 2

An Immediate Plan to Defend the U.S. against Nuclear EMP Attack

Considered below are: the nature of the electromagnetic pulse (EMP) threat posed by several ballistic missile attack scenarios; near term ways to defend against such scenarios; and a possible diplomatic adjunct to assure the effectiveness of some of these defenses.

Nature of the New Nuclear EMP Threat

During the Cold War, U.S. strategic planners assumed that any attack by the Soviet Union on the United States would begin with high-altitude nuclear detonations to generate EMP and disrupt or destroy strategic mission critical communications and other electronic systems. Former Soviet planners have confirmed this attack scenario since the fall of the Berlin Wall and subsequent dissolution of the Soviet Union. In accordance with U.S. defense doctrine, Department of Defense policy required EMP-hardening of our strategic forces and supporting command, control and communication systems to assure that these systems could survive a massive Soviet attack and permit the National Command Authority to authorize a devastating retaliatory strike.

While our current strategic force planning still includes "nuclear deterrence" plans, the range of international adversaries and threat scenarios has expanded since the end of the Cold War. In addition to states with large nuclear arsenals such as Russia and China, the United States is now threatened by rogue states such as North Korea and Iran, as well as terrorist organizations that may obtain nuclear weapons on the black market or from proliferators. U.S. strategic force planning needs to adjust to these new nuclear threat scenarios.

During the Cold War, EMP was a highly classified topic. A reduced threat environment at end of the Cold War brought extensive disclosure on Soviet atmospheric tests of EMP phenomena, as well as additional disclosure of United States EMP tests. Rogue nations, nuclear proliferators, and terrorist organizations are now well aware of the devastating nature of the EMP attack vector.

Increasing societal reliance on electric power and sophisticated electronic devices has also increased vulnerability to EMP attack. Because of the fragility of the electric power grid and ubiquitous use of integrated circuits, an EMP attack by a single nuclear device could pose an existential threat to the United States and its population. But we as a nation have not yet developed the conceptual framework or practical means to cope with today's EMP threat, even as rogue nations such as Iran threaten EMP attack in their rhetoric and military literature.

Some national security experts now recognize the EMP threat and consider it a subset of threats that target highly industrialized "information societies." For example, on May 23, 2013, former CIA Director R. James Woolsey testified to the House Energy and Commerce Committee that our cyber and information warfare doctrines are dangerously blind to an all-out information warfare campaign designed to cripple U.S. critical infrastructures. Because EMP would destroy both the electric power grid and integrated circuits essential to computers, EMP could be a key component of an information warfare attack.

Mr. Woolsey noted that his assessment reflected the 2001-2008 work of the Congressional EMP Commission, the subsequent Congressional Strategic Posture Commission, and several other major U.S. Government studies—collectively representing a non-partisan scientific and strategic consensus that such an attack upon the United States is an existential threat. The foundation for identifying the existential nature of the information warfare and EMP threats was laid by the unanimous conclusions (based on all-source intelligence) of the 1998 Commission to Assess the Ballistic Missile Threat to the United States. In the intervening 15 years since this Commission, subsequent Commissions have met, but little has been done to adjust U.S. strategic planning.

Mr. Woolsey, who was a member of the above mentioned Commissions, testified that Russia, China, North Korea, and Iran all include in their strategic doctrine and plans a wide spectrum of information warfare threats, including cyber-attack, sabotage and kinetic attacks on key system nodes, and wide-area EMP attack. The EMP component of an information warfare attack could be executed by a long-range ballistic missile launched from the homeland of these states. However, a more simple—and perhaps less defensible—EMP attack could be executed by a short-range ballistic missile launched from a ship near the U.S. coast. Even unsophisticated and under-resourced terrorists could threaten EMP attack by mating a small nuclear device to a SCUD missile—or other missile of simple design—and mounting the missile and payload to a small freighter.

Perhaps the most troubling of these potential threats comes from North Korea and Iran, both of which have benefited from nuclear and ballistic missile technology obtained from Russia and China. Furthermore, Russia and China have an excellent understanding of EMP effects, and their scientists, whether officially authorized or not, have proliferated this information to North Korea and Iran.

Both North Korea and Iran have launched ballistic missiles in large numbers as part of military exercises; both have demonstrated intercontinental ballistic missile (ICBM) range capability; and both have placed satellites in orbit. Notably, North Korea and Iran have launched satellites over the South Polar region to approach the United States from the south in their maiden orbit at a few hundred miles altitude—just right for casting EMP effects over the entire continental United States. Unfortunately, our primary missile defenses are arrayed against ICBMs that approach the United States from trajectories near to the North Pole, a fact that is surely known to North Korean and Iranian war planners.

North Korea has conducted three underground nuclear tests, including the most recent test in February 2013. Open source reports indicate that Iranian scientists have been present at North Korean nuclear tests—and it is not implausible to suggest that when North Korea is satisfied with a given nuclear design, Iran may be also.

Some reports have characterized North Korean tests as "failures" because of their low explosive yield. However, North Korea may be testing light-weight, low-yield advanced nuclear weapon designs obtained from Russia or China. These specialized devices may be designed to produce a low explosive yield, but a significantly higher output of gamma rays. In operational use, the gamma rays produced by such weapon designs would interact with the earth's magnetic field to produce enhanced EMP effects. Low-yield entry-level weapons—even those without EMP enhancements—if detonated at an altitude of 60-70 kilometers will produce EMP fields sufficient to cause permanent damage to integrated circuits.

Because of technical interchanges between North Korea and Iran, there should be great concern that Iran will be following North Korea's lead in short order—perhaps even concurrently—to mate EMP-enhanced weapons to ballistic missiles or to include light-weight EMP weapons as satellite payloads.

Iran clearly understands how to leverage EMP effects created by nuclear weapons in its strategic and tactical planning. Mr. Woolsey testified that Iranian doctrinal writings include assertions such as:

- "Nuclear weapons . . . can be used to determine the outcome of a war, without inflicting serious human damage [by neutralizing] strategic and information networks;"
- "Terrorist information warfare [includes] the technology of directed energy (DEW) or electromagnetic pulse (EMP);" and
- ". . . [W]hen you disable a country's military's 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."

Finally, Iran first launched a ballistic missile from a vessel in the Caspian Sea over a decade ago and, as Mr. Woolsey testified, has several times demonstrated the capability to detonate a warhead at the high-altitudes necessary for an EMP attack on the entire United States. Thus, these tests are signatures of Iranian planning for an EMP attack that could be launched from a vessel off the U.S. coast.

In summary, there are multiple indicators that rogue nations and terrorist organizations are aware of the destructive potential of EMP attack, have included EMP attack in their war plans, and could soon have an ability to execute such an attack. Time is short for the United States to develop EMP defenses.

Gaps in Our Defenses against EMP Attacks

Our strategic defenses should be designed to deter and defeat the war-fighting doctrines of nations with substantial nuclear arsenals, rogue states with just a few nuclear weapons, and terrorist organizations that obtain nuclear weapons on the black market or from proliferators. But, regrettably, our current defenses are focused on intercontinental missile attack via northern trajectories, and therefore leave the United States vulnerable to an EMP attack in at least three major ways:

- Nuclear-armed ballistic missiles launched from ships off our coasts and detonated a hundred miles or so over the United States;
- Nuclear-armed ballistic missiles launched from an aircraft and detonated over the United States; and
- Detonation of a nuclear weapon carried on a low earth orbit satellite as it passes over the United States.

None of these attack modes offer significant technological challenges to nation states with a modicum of nuclear weapon and ballistic missile technology. Indeed, in the 1960s, the United States launched Minutemen intercontinental ballistic missiles (ICBMs) both from a ship and a cargo aircraft. The Soviet Union deployed a Fractional Orbital Bombardment System (FOBS) designed to carry a nuclear weapon over the South Pole and to be de-orbited to attack anyplace on earth. Their dedicated FOBS site, operational between November 1968 and January 1983, was dismantled following June 1982 diplomatic commitments relating to the unratified SALT II Treaty.[1] There is now no international agreement that prohibits a ready-to-launch FOBS to detonate a nuclear weapon in outer space.[2]

The Outer Space Treaty of 1967 prohibits placing nuclear weapons in space orbit. This agreement can be circumvented simply by preparing a ready-to-launch vehicle with a nuclear weapon and placing the launch vehicle in reserve. Upon launch during international crisis, the satellite and nuclear weapon payload could be placed in a longitudinally progressive polar orbit that would eventually be above any point on earth. When above the location of choice, and upon command, the nuclear weapon could then be detonated to produce an EMP attack. Not only Russia and China, but also North Korea and Iran have demonstrated an inherent capability to execute such an attack.

While satellite tracking systems could pinpoint the responsible nation for a satellite-based EMP attack, there is no similar assurance for an attack from a ship or aircraft. And without the National Command Authority knowing the origin of an EMP attack, the doctrine of deterrence based on massive nuclear retaliation fails. Retaliatory doctrines also fail in the case of terrorists prepared to commit suicide to kill several hundred million Americans. While terrorists might find it difficult to carry out an aircraft or satellite-based EMP attack, short range ballistic missiles and their mobile launchers can be easily purchased and carried covertly on any of the numerous vessels daily traversing near U.S. national waters. Thus, deploying defenses to counter the ship-based EMP attack scenario deserves top priority in rectifying the nation's current vulnerability to an EMP attack. Fortunately, there are operational capabilities that can be quickly adapted to provide such an EMP defense.

Near-Term Defenses against EMP Threats from Ships Off our Coasts

The nearest term defense against ship-based EMP attack can be provided by the U.S. Navy's Aegis Ballistic Missile Defense (BMD) system. In its impressive test record—26 successful intercepts out of 32 attempts, all executed by operational crews—the Aegis BMD system has already demonstrated it can shoot down short, medium and intermediate range ballistic missiles, in both their ascent (post-burnout) and midcourse phases of flight. Today, there are 27 Aegis BMD Cruisers and Destroyers at sea around the world—currently funded plans will grow this number to 35 by 2017 and more of the approximately 80 Aegis ships could be given BMD capability for less than $50 million per ship. The marginal cost of the current SM-3 interceptor is less than $10 million per interceptor.

For Aegis BMD ships to protect the United States from an EMP attack, there are two prerequisites. First, Aegis crews must be operationally trained to intercept missiles in their ascent and midcourse phases of flight—as they are. Second, Aegis ships must be in the vicinity of the ship from which a potential attack

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[1] See "The Soviet Fractional Orbital Bombardment System Program," Technical Report APA-TR-2010-0101 by Miroslav Gyűrösi, January 2010 (updated April 2012), available at http://www.ausairpower.net/APA-Sov-FOBS-Program.html, last accessed June 23, 2013.

[2] However, the *employment* of a space-based nuclear EMP weapon, whether launched by a FOBS system or otherwise, would constitute a "material breach" of the U.N. Convention on Environmental Modification, the ENMOD Treaty of 1977. This Convention entered into force on October 5, 1978; for the U.S. on January 17, 1980. It prohibits environmental modifications with "widespread, long-lasting or severe effects" as the means of "destruction, damage, or injury to any other State Party." North Korea ratified the ENMOD Convention on November 8, 1984. Iran became a treaty signatory on May 18, 1977, but did not ratify. Iran has a continuing duty not to act so as to defeat the "object and purpose" of the Convention.

is launched. Normally, a few Aegis BMD ships are near our east and west coasts or in a coastal port—where they can maintain a BMD operational status if desired and so ordered. Furthermore, if these coastal ships were to be periodically tested against short and medium range ballistic missiles near our east and west coasts, such tests could contribute to deterring a terrorist EMP attack.

However, defending against an EMP attack from the Gulf of Mexico is not so easily and quickly addressed, because our Aegis BMD ships do not normally traverse the Gulf—and these ships are needed overseas by our global combatant commanders. Thus, except for an urgent requirement, perhaps on the basis of confirmed strategic warning, the United States will remain vulnerable to an EMP attack from the Gulf (or from the south, e.g., Venezuela) until a dedicated defense against this contingency is provided.

A near-term dedicated defense against short and medium range missiles launched from the south would be to deploy Aegis Ashore sites on several military bases proximate to the Gulf of Mexico. Development of the Aegis Ashore concept is approved and funds are being appropriated for deployment in Romania (2015) and Poland (2018). No additional development costs would be required to deploy the same system concept at key locations proximate to the Gulf of Mexico. Associated site selection and environmental impact studies would be required, of course. Given the approved plans for an initial Aegis Ashore site in Romania by 2015, it should be possible to deploy the first Gulf of Mexico site by that same date, or possibly sooner.

The Defense Authorization Act for FY2014, reported favorably by the Senate Armed Services Committee (SASC) in June 2013[3] could provide an expedited process to evaluate missile defense options against EMP threats to the homeland. If enacted, this legislation would direct the Secretary of Defense to submit to Congress within 180 days after enactment, a report on several potential future options for enhancing United States homeland ballistic missile defense. Among them, the SASC proposal explicitly calls for consideration of missile defense options to "defend the United States homeland against ballistic missiles that could be launched from vessels on the seas around the United States, including the Gulf of Mexico, or other ballistic missile threats that could approach the United States from the south, should such a threat arise in the future." An example of this latter important future threat is discussed below.

Near-Term Defenses Against EMP Attacks from Over the South Pole

Concepts for Aegis-based ballistic missile defense (i.e., both the currently deployed ships and future Aegis Ashore sites) should be integrated into the global missile defense architecture. Furthermore, the Aegis SPY-1 radar provides important tracking and warning information to this global system—and provides an important complement to the nation's BMD warning, attack assessment and tracking capability which historically has focused on detecting and countering ballistic missile attack over via trajectories close to the North Pole.

In addition to the U.S. space sensors and other limited surface sensor capabilities, all the Aegis ships deployed worldwide, whether BMD capable or not, can help provide warning and tracking information

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[3] See S. Rpt. 113-044, accompanying S.1197, the Defense Authorization Act for FY2014 as reported to the Senate on June 20, 2013. Text of. Sec. 231 is available at http://www.gpo.gov/fdsys/pkg/BILLS-113s1197pcs/pdf/BILLS-113s1197pcs.pdf.

to the BMD global command and control system. And this global system can provide critical information on attacks that come from either north or south.

In particular, a global tracking capability would help counter ballistic missile attacks that might come over the South Pole from North Korea or Iran—both nations have already launched satellites in such South Polar orbits that pass over the U.S. With such warning and track information on attacks over the South Pole, our ground-based interceptors, particularly those based in California, may be capable of intercepting an attacking satellite before it orbits over the United States.

If such a potential satellite-based attack is detected in time and tracked by our forward-based Aegis ships and other integrated sensors, other "downstream" Aegis BMD ships would also have a chance to shoot down the satellite before it overflies U.S. territory — even earlier than the longer range ground-based interceptors in California. (In 2008, the currently deployed Aegis BMD system shot down a dying satellite over the Pacific Ocean to protect cities from the toxic fuel it carried.)

In summary, a "South Pole" EMP attack via an orbiting satellite is within the near-term capabilities of rogue nations such as North Korea and Iran. Deploying a single-layer defense using ship-based or land-based AEGIS systems should be immediately feasible and could provide substantial deterrent effect. Deploying a multi-layered defense against such "Attacks from the South" should be feasible within three years and could provide both deterrent effect and high-certainty defense.

An Associated Arms Control Challenge for Prevention of Satellite-Based EMP Attack

A key problem in defending against a FOBS is determining within a very few minutes after a satellite is launched to the south from North Korea or Iran (indeed from anywhere) that it carries a threatening nuclear weapon. Therein is a challenge for arms control and/or other diplomatic constraints.

Effective verification of arms control agreements banning potential satellite-based EMP attack would be very difficult but not impossible. More effective would be a multilateral agreement to inspect by appropriate means all space launch payloads to be launched to the south once on the launch pad but shortly before launch, with the agreed understanding that all noncomplying launched payloads will be shot down. As previously explained, the Outer Space Treaty of 1967 already prohibits placing weapons of mass destruction in space orbit, but cooperative verification measures are lacking.[4]

[4] Article IV of the Outer Space Treaty provides that "State Parties... undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction." Both Iran and North Korea are signatory states, but without treaty ratification are not "state parties." With at least 102 State Parties, this treaty may constitute a peremptory norm of international law binding not only "state parties" but also "non-state parties."

Complicating verification requirements for the Outer Space Treaty is the need to distinguish pre-launch nuclear power sources for space missions from pre-launch nuclear weapons payloads. United National General Assembly Resolution 47/68 of December 24, 1992 sets forth "Principles Relevant to the Use of Nuclear Power Sources in Outer Space." Highly enriched uranium 235 is a mandatory fuel source. When nuclear power sources are to be used for space missions, prior public reporting and prior notification to the United Nations are established U.N. procedures. See "Safety Framework for Nuclear Power Source Applications in Outer Space." UN A/AC.105/934. /

Developing acceptably-intrusive and mission effective sensors to assure compliance should be a high priority program to accompany negotiations to achieve such an international agreement. Given the practical difficulty of effectively shielding radiation emitted from a low-weight nuclear device to be placed on a satellite, cooperative verification of payload signatures may be useful. Nonetheless, it will be a significant challenge to assure detection of a nuclear weapon while at the same time not betraying compromising other national security secrets. Any verification procedure must apply to all parties and in particular must not compromise U.S. national security interests.

Concluding Comments

EMP attack is an imminent threat and potential adversaries—including North Korea, Iran, and terrorists—well understand how to execute this kind of attack. Especially Iran, once it achieves a nuclear weapon that can be mated to essentially any of its many ballistic missile systems, poses an imminent existential threat to the United States. Iran might deliver such an attack directly (e.g., by launching a nuclear weapon on a satellite over the South Pole and detonating it in its first orbit over the United States) or it might engage surrogate terrorists to launch a high-altitude EMP attack from a vessel near our coasts.

Our current homeland missile defense systems are deployed primarily to defend against ICBMs that approach the United States from the north—over the North Pole. Urgently needed are defenses against EMP attacks that might be launched from vessels off our coasts—particularly off the coast of the Gulf of Mexico. Near term and relatively inexpensive defenses are feasible using existing Aegis ballistic missile defense systems, both ship-based and land-based.

We also need defenses and a companion diplomatic strategy to counter the possible threat posed by a nuclear weapon carried by a satellite in a south polar orbit, which might be detonated in its maiden orbit before currently deployed defenses can counter it. Confident warning and attack assessment information is needed to defend against this EMP attack scenario—which may be aided by an appropriate diplomatic strategy employing pre-launch payload inspections and related confidence building measures.

Appendix 3

EMP/GMD Protection of the U.S. Electric Power Grid

The Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack has provided a compelling case for protecting civilian infrastructure against the effects of nuclear EMP and geomagnetic disturbances (GMDs) caused by severe solar storms. According to the findings of the EMP Commission, the electric power grid is the infrastructure that is most vulnerable to nuclear EMP and solar GMD. Our most vulnerable infrastructure is arguably also the most critical since it is necessary for the operation of all other infrastructure sectors. In addition, experience from Hurricanes Sandy and Katrina clearly demonstrates that the electric power grid is essential to prompt disaster recovery.

The nuclear EMP and solar GMD phenomena are more challenging than conventional weather-related catastrophes in that the affected geography can be continental in scale. These wide-area electromagnetic effects represent a class of high-consequence disasters that is unique in coverage and ubiquitous system debilitation. Such disasters deserve particular attention with regard to preparedness and recovery since assistance from non-affected regions of the nation could be scarce or nonexistent. The combination of large area coverage of nuclear EMP and solar GMD effects combined with the high vulnerability and operational criticality of the grid heighten the societal risks of grid failure. Grid failure is an existential threat to the survival of the United States as a nation and to the American population.

The Congressional EMP Commission concluded in its April 2008 Report that grid protection is technically feasible and affordable for both nuclear EMP and solar GMD. EMP effects from nuclear bursts are not new threats to our nation. DoD experience in implementing EMP protection began in the 1960s with the Minuteman system acquisition. Over the last fifty years, the military has hardened a large number of systems and developed protection, testing, and life-cycle maintenance guidelines and standards that provide a sound and proven basis for affordable protection of the electric power grid. Protecting the grid against nuclear EMP also provides protection against solar GMDs. It will be most important that DoD share its experience in hardening and maintaining systems with the electric power industry.[5]

Wide-Area Electromagnetic Environments

The nuclear electromagnetic pulse (EMP) results from the detonation of a nuclear weapon high above the tropopause. Solar storm geomagnetic disturbances (GMDs) occur naturally when an intense wave of charged particles from the sun perturbs the earth's magnetic field.

In the case of high altitude nuclear bursts, two principal wide-area electromagnetic phenomena affect the electric power system, each with distinct waveform characteristics and system effects:

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[5] There is a mutual benefit to DoD since 99% of defense installation power is supplied by the commercial electric power grid.

1. The first, a "prompt" EMP field, also referred to as E1, is created by gamma ray interaction with stratospheric air molecules. It peaks at tens of kilovolts per meter in a few nanoseconds, and lasts a few hundred nanoseconds. E1's broad-band power spectrum (frequency content from DC to 1 GHz) enables it to couple to electrical and electronic systems in general, regardless of the length of their penetrating cables and antenna lines. Induced currents range into the thousands of amperes. Exposed systems may be upset or permanently damaged.

2. The second phenomenon, "late-time" EMP, is also referred to as magnetohydrodynamic (MHD) EMP or E3, and is caused by the distortion of the earth's magnetic field lines due to the expanding nuclear fireball and the rising of heated, ionized layers of the ionosphere. The change of the magnetic field at the earth's surface induces low frequency currents of hundreds to thousands of amperes in long conducting lines (a few kilometers or longer) that damage components of the electric power grid itself as well as connected systems. Long-line communication and data networks, including those using copper as well as fiber-optic signal lines with repeaters, are also vulnerable.

In the case of solar storms, electric power grid effects originate from large excursions in the flux levels of charged particles from the Sun and the interaction of these particles with the Earth's magnetic field. Similar to MHD EMP generation, these particles introduce changes of the magnetic field at the surface of the earth (GMDs) that induce low frequency currents of hundreds to thousands of amperes in long-line systems affecting electric power and communication networks over large regions of the earth's surface.

<u>Consequent Wide-Area Electromagnetic System Effects</u>

EMP and GMD effects are most pronounced for long line networks such as electric power, telecommunications and data networks. While E3 and GMD couple significant energy only to long lines (greater than several kilometers), E1, because of its wide-band nature, couples efficiently to both long lines and local system conductors including antennas, local-area networks, telephone equipment, computer workstations, and SCADA systems.

Empirical evidence of EMP system effects has accrued from both U.S. and Russian atmospheric tests in the 1950s and early 1960s. A U.S. test named "Starfish Prime" in July 1962 involved a 1.4 megaton device detonated at 400 km. The event caused street light failures in Hawaii some 1300 kilometers away. The Russians collected more extensive data than the U.S. since their high altitude nuclear EMP tests occurred over expansive continental land areas. Soviet scientists observed EMP effects due to high altitude nuclear detonation at distances of hundreds of kilometers. Effects on exposed power grid elements included shut-down of power transmission lines, overvoltage-induced punctures of transmission line insulation, lines knocked to the ground due to the failure of mounting insulators on transmission line towers, and transformer fires.

Tests of U.S. equipment in simulated nuclear EMP environments by the EMP Commission indicate that later vintage electronics are more susceptible to EMP transients due to semiconductor device miniaturization and high speed digital processing. An example of effects includes burnout of a GPS system, which exhibited failures at levels as low as 5 KV/m, an effect achievable with low yield, entry-level nuclear weapons. Tests also reveal EMP vulnerabilities in telecommunications switches/routers, cell phone stations, and local multiplexers.

Moderate solar storms have provided empirical evidence that bulk power EHV transformers will fail during solar geomagnetic disturbances. Laboratory tests and analyses of the electric power transmission systems indicate the likelihood of power outages due to transformer and control system debilitation and network reactive power instabilities. Because of the long lead time for manufacturing, difficulty of moving, and expense, replacement of failed large bulk power transformers dominates the grid restoration timeline. Including manufacture time, transformer replacement times range from months to years. In March2012 a 345 kV transformer stockpiled by the Department of Homeland Security was replaced in only five days. However, at present, the U.S. electric utility industry lacks large-scale stockpiling of extra high voltage transformers with custom configurations to replace hundreds of concurrently damaged or destroyed transformers.

Research performed for the Congressional EMP Commission indicates that nuclear EMP and large solar storm GMDs can cause debilitating system effects including:

1) EMP/E1- caused malfunctions and damage to solid-state relays in electric substations.
2) EMP/E1-caused malfunctions and damage to computer controls in power generation facilities, substations, and control centers.
3) EMP/E1-caused malfunctions and damage to power system communications.
4) EMP/E1-caused flashover and damage to distribution class insulators, sometimes resulting in downed lines.
5) EMP/E1-caused flashover and damage to transformers.
6) EMP/E3 and GMD-caused voltage collapse of the power grid due to transformer saturation.
7) EMP/E3 and GMD-caused damage to extra-high-voltage (EHV) transformers due to internal heating and vibration.

Table 1 provides a summary comparison of nuclear EMP and GMD environment and effects characteristics.

Table 1. Wide-Area Electromagnetic Electric Power Grid Effects

Threat	Environment	Characteristics	Maximum Coupling Levels	Susceptible Systems
High Altitude Nuclear Burst	Prompt EMP – E1 Amplitude: 10s of Kilovolts/meter	Broad frequency Bandwidth of 1GHz – couples to short and long conductors	Millions of volts 1000s of amperes	Power Generation and Delivery Networks Including Transformers Communication/Control Electronics
	MHD EMP – E3 Amplitude: 10s of Volts/kilometer	Low frequency (sub-Hz) Couples efficiently only to long lines	1000s of volts 1000s of amperes	Power Generation and Delivery Networks Including Transformers
Solar Storms	GMD (similar to EMP-E3) Amplitude: 10s of Volts/kilometer	Low frequency (sub-Hz) Couples efficiently only to long lines	1000s of volts 1000s of amperes	Power Generation and Delivery Networks Including Transformers

EMP and GMD Protection.

Importantly, hardening the electric power grid against nuclear EMP also protects the system from solar storm GMD effects. The converse is not true – protecting only against GMD effects does not address EMP/E1 effects.

We know how to protect systems against EMP and GMD. EMP (including E1 and E3 effects) protection has been implemented since the 1960s and standardized since the 1990s by the U.S. Department of

Defense. The low risk approach used to protect our nuclear command and control facilities is embodied in MIL-STD-188-125 and MIL-HDBK-423. The approach used in these guides may be applied to grid communication and control centers and systems. In addition, GMD-specific protection experience accrues from programs in Great Britain, Canada, and Sweden. Because of their northerly latitudes, these countries have experienced severe solar storm effects on their power grids that have led them to develop effective countermeasures.

An initial expedient countermeasure would be to expand the provision of back-up power systems supporting life-line infrastructure systems. This is a lesson learned from past weather disasters, most notably from Hurricanes Katrina and Sandy. Many critical national defense, medical, communication, and financial facilities now have emergency generators. Additional provision of emergency power systems is needed, especially for water supply systems, gas stations, food stores, and pharmacies. Backup power may be provided by generators or new micro-grid technology.

Protection of the grid itself should begin by protecting EHV transformers with ground-induced current (GIC) blocking devices in their neutral to ground connections (see Figure 1). This practice would significantly reduce the probability of grid collapse and transformer damage due to GMD and E3. In addition, E1 overvoltage protection of transformers is achievable by installing common overvoltage protection devices (metal oxide varistors or spark gaps) on transformer terminals. Estimates for protecting the most vulnerable and difficult to replace transformers (extra high-voltage bulk power transformers) in the U.S. range $1B - $5B; on an annualized basis, protection of transformers against E3 would cost the equivalent of one postage stamp per person per year.

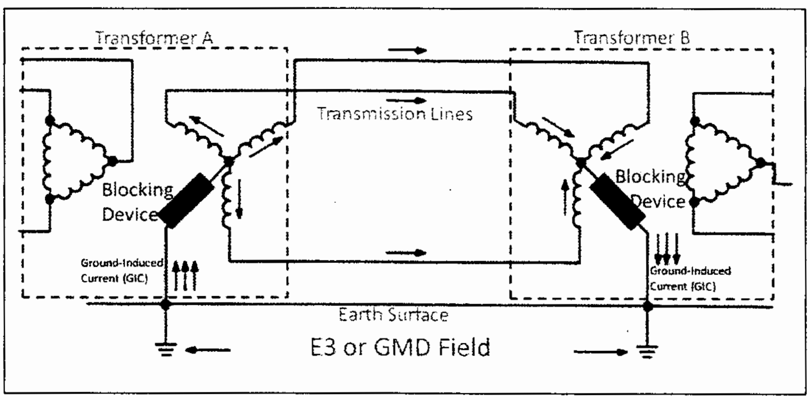

Figure 1. Transformer Protection Using Neutral Blocking Devices

EMP protection methods (including both E1 and E3) applicable to power grid communication and control systems and facilities have been developed and implemented by DoD and are well-documented. The basic concept is to keep EMP energy away from mission-critical electrical and electronic systems by enclosing them within an electromagnetic barrier. Engineering approaches usually include metal enclosures and protecting each wire penetration with filters and/or voltage limiting devices. Protection also involves assurance of back-up power and provision for hardness surveillance and maintenance.

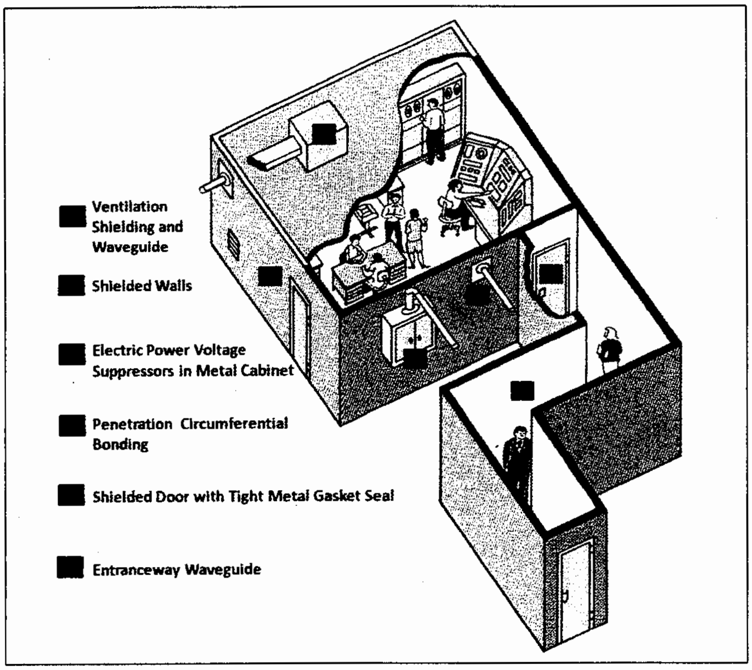

Figure 2. Low-Risk EMP Protection Approach for Control and Communication Facility

Figure 2 illustrates the low-risk protection approach described in MIL-STD-188-125. The standard specifies the following hardening program elements:

- Facility shield. The facility HEMP shield is a continuous conductive enclosure that meets or exceeds specified shielding effectiveness requirements. The shield is normally constructed of a metal, such as steel or copper. Other materials may be used if they can provide the required shielding effectiveness and are fully compatible with the penetration protection and grounding requirements.
- Shield penetrations or points of entry (POEs) including wire penetrations, conduit/pipe penetrations, doors, and apertures. The number of shield POEs is limited to the minimum required for operational, life-safety, and habitability purposes. Each POE is protected with an energy limiting device that satisfies standard performance requirements.
- HEMP testing. The standard requires protection performance certification by test. The protection program includes quality assurance testing during facility construction and equipment installation, acceptance testing for the electromagnetic barriers, and verification testing of the completed and operational facility.
- Hardness Maintenance and Surveillance (HM/HS). HM/HS is included in the facility planning, design, and construction phases to assure that hardness features stay intact over the life cycle of the protected facility and systems.

In summary, the electric power grid is the keystone infrastructure upon which all other critical infrastructures depend—protection of the grid against both nuclear and solar EMP should be a top priority. Engineering practices and technologies to protect against E1 caused by nuclear EMP—as well as E3 caused by both nuclear EMP and solar GMD—are well developed and currently in use by the Department of Defense and/or available from commercial vendors. It will be important for DoD to make its expertise available to DHS, DOE, NRC, FERC and the electric power industry.

Appendix 4

Presidential Plan to Protect American Public from Long-Term Electric Grid Outage Due to Geomagnetic Disturbance

On May 16, 2013 the Federal Energy Regulatory Commission (FERC) issued Order 779 requiring development of reliability standards to protect the Bulk Power System against geomagnetic disturbances (GMD). The vote of the FERC Commissioners was 5-0. This FERC action confirmed that solar storms and resulting GMD are serious threats to the health and safety of the American public. FERC now requires the North American Electric Reliability Corporation (NERC), the FERC-approved Electric Reliability Organization, to develop and submit new GMD standards in a two-stage process.

In the first stage, NERC will have six months to file reliability standards requiring owners and operators of the Bulk-Power System to develop and implement operational procedures to forestall cascading grid collapse during GMD events. This short-term fix, operational procedures, will prop up power reserves during solar storms, but is unlikely to prevent permanent equipment damage and resulting long-term grid outage.

In the second stage, NERC will have 18 months to file standards identifying "benchmark GMD events," which define the severity of GMD events. Owners and operators will then conduct their own assessments of grid stability during solar storms, and also assess vulnerability of their critical equipment to permanent damage. Only after these assessments will any protective measures for critical equipment—such as extra high voltage transformers—begin to be implemented.

The FERC process and timeline exposes a fundamental shortfall in the protection of the American public; while the solar storm threat has been unambiguously confirmed by a federal body, the public could still be unprotected from long-term grid outage for many years. We propose that existing Presidential authority to de-energize the electric grid fill this shortfall and that a solar storm emergency plan be developed.

A solar storm emergency plan could be legally and operationally supported by a Presidential Executive Order, a DHS National Planning Scenario, a FERC Electric Reliability Order, a NRC Emergency Preparedness Rule, and a DOD Defense Planning Scenario. The President currently has authority to order such an emergency plan; see the attached legal brief, " Legal Authority For The President Of The United States To Order Interruption Of U.S. Electric Generation And Related Electric Grid Protections During A Severe Solar Geomagnetic Storm," authored by William R. Harris.

Advance emergency planning would avoid hasty and potentially ill-considered decisions when a major Coronal Mass Ejection (CME) by the sun has been detected by satellites near the sun, but the impact on the earth has not been confirmed by the Advanced Composition Explorer satellite near the earth. Without an advance plan, the two day transit time for a major CME is likely insufficient to allow for coordination with electric utilities to de-energize the grid.

References:

1. "Docket No. RM12-22-000; Order No. 779; Reliability Standards for Geomagnetic Disturbances," FERC, Issued May 16, 2013
2. "Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack; Volume 1: Executive Report," Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, 2004
3. "Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack; Critical National Infrastructures," Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, April 2008
4. "Geomagnetic Storms and Their Impacts on the U.S. Power Grid," Oak Ridge National Laboratory, January 2010
5. "Solar Storm Risk to the North American Electric Grid," Lloyd's and Atmospheric and Environmental Research (AER), Inc., 2013

Appendix 5

Legal Authority for the President of the United States to Order Interruption of U.S. Electric Generation and Related Electric Grid Protections during a Severe Solar Geomagnetic Storm

William R. Harris

The President of the United States holds powers both enumerated and implied by Article II of the U.S. Constitution, and by the President's role as commander-in-chief. Moreover, the Presidential oath of office to "faithfully execute" the laws provides a duty to fulfill a wide array of presidential functions, including the continuity and functionality of the executive branch, aid to the legislative and judicial branches, fulfillment of treaties and other international agreements, and support to state and local governments. Beyond these powers and responsibilities, the President has duties and powers, many of them delegable to Cabinet secretaries, or others.[6] While the police powers are generally reserved to the states (per the 10th Amendment to the federal constitution), the President retains powers granted under the U.S. Constitution and under statutory laws.

Severe solar geomagnetic storms fall under the more general category of high impact, low frequency events that could result in the death of millions of Americans and threaten the existence of the United States as a country. Real-world experience during small solar geomagnetic storms shows that current induced by these storms can overheat and otherwise permanently damage extra high voltage (EHV) transformers used for electric grid transmission. Under normal conditions, the lead time for ordering replacement transformers is months to years; additionally, most EHV transformers are manufactured outside of the United States. As a result, any solar geomagnetic disturbance that results in widespread damage of critical grid infrastructure—including but not limited to EHV transformers—could result in a blackout lasting months or even years. Because the electric grid is the keystone infrastructure upon which all other critical infrastructures depend, long-term grid outage is an existential threat.

Unlike other most other natural disasters that affect only a single state, or several adjoining states, a severe solar geomagnetic storm is more likely to affect a region of the United States, the entire continental U.S., or even multiple countries. During a severe solar storm, it is unlikely that states acting alone will be capable of effectively exercising their police power functions for

[6] Title 3, section 301 of the U.S. Code provides a general authorization for presidential delegation of functions, excepting specifically non-delegable functions, so long as these acts of delegation are published in the Federal Register. For example, the duty to maintain a domestic industrial base, including national defense resources preparedness, is a delegation by President Obama in March 2012. See 77 FR 16651 (2012).

disaster management, whether through a state public utility commission, or a governor's office of emergency management, or other executive authority. Might instead the federal government retain the power and duty for emergency preparedness? With warnings of a severe solar geomagnetic storm, might the President have the authority and duty to interrupt electric power generation to protect critical electric infrastructures? Without prompt action supported by the express and implied powers of the President, substantial portions of the North American electric grid might not endure, or might not be expeditiously reconstituted after the emergency has passed. Indeed, the United States as a nation might not endure, absent appropriate exercise of Presidential authority.

What are some of the presidential powers or powers delegated by the President or Congress to subordinate executive officers of the federal government? Title 42 U.S.C. sec. 5195 (P.L. 93-288, Title VI, sec. 601) explains as a purpose the provision of "a system of emergency preparedness for the protection of life and property in the United States." The Federal Government "*shall* provide necessary direction, coordination, and guidance, and *shall* provide necessary assistance as authorized by the subchapter so that a comprehensive emergency preparedness system exists for all hazards." (Italics added.) A federal preparedness plan and system to cope with *all hazards* is mandatory, not optional.

The Federal government would likely have multiple sources of confirmation of an impending severe geomagnetic storm, beyond the Advance Composition Explorer (ACE) satellite or its prospective replacement satellite: for example, a variety of National Aeronautical and Space Administration (NASA), or National Reconnaissance Office (NRO) space assets or other Department of Defense space assets might independently confirm an impending solar geomagnetic storm. Notably, these are assets of the federal government, not the several states.

How might the President utilize specified emergency powers that complement Article II presidential powers under the U.S. Constitution? Two statutes are of special interest in anticipating and preparing to protect critical electric grid infrastructure before, during, and after a severe solar geomagnetic disturbance.

The first statute is the Carter era International Emergency Economic Powers Act [P.L. 95-223] and its year 2007 enhancements [P.L. 110-96], the International Emergency Economic Powers Act found at 50 U.S.C. § 1701 et seq. Section 1701, enables a President "to deal with an unusual and extraordinary threat, which has its source in whole or substantial part outside the United States" with impacts upon the national security, foreign policy, or the economy.

A coronal mass ejection from the sun, causing severe geomagnetic disturbance and threat to critical national infrastructure, including the bulk power system, would trigger presidential emergency powers. Importantly, with proper exercise of federal authority, the President and his staff could reasonably anticipate scenarios involving the potential loss of electric grid facilities, and plan for temporary protection of key assets. Many of these assets, such as EHV transformers, or static (or dynamic) VAR capacitors, might be protected from irreversible damage by a presidential order to de-energize key equipment, while allowing an "operate through" regime for other equipment assessed as having a "withstand" capability or shielded by neutral blocking devices.

Emergency plans and related exercises would require a national inventory of critical assets, including identification of those assets most likely to sustain permanent damage if left unprotected. In contrast, generating facilities without long transmission lines, or operating at lower voltages, or operating where soil conditions might provide some protection against *geomagnetically induced currents* could be candidates to "operate through" all but the most severe solar geomagnetic disturbances. Generation facilities and transmission lines protected by "neutral ground blocking equipment" might also "operate through" solar storms. It would be important that the White House Situation Room, national monitoring facilities, and regional electric balancing authorities keep track of which electric grid assets could be designated as "operate through" assets versus those critical assets that are candidates for prompt *de-energizing*. Mere "de-rating" of equipment, so that generators operate at reduced electric loads, may be insufficient to prevent damage, because an energized transformer at near-zero load can still be vulnerable to both overheating hazards and to vibrational stress.

A second federal statute provides the President specific authority to order the de-energizing of energy facilities that utilize natural gas or petroleum "as a primary energy source" for the duration of "a severe energy supply disruption." This statute, known as the Powerplant and Industrial Fuel Act of 1978 [P.L. 95-620, found at Title 42 U.S.C. § 8374], anticipated the need for the President to halt uses of natural gas or petroleum products during an international oil embargo or more generally "an energy supply disruption."

The larger purpose of P.L. 95-620 was to preserve a functional U.S. economy and the public health, safety, and welfare despite a threat to sustainable electricity production and availability of fuel supplies for transportation. The specific scenario linked to this legislation, a disruption of imported oil, may no longer be likely, but the specific, literal authorities of the President remain; and these authorities remain useful to cope with a solar geomagnetic disturbance that requires de-energizing critical electric grid equipment.

Under the Powerplant and Industrial Fuel Use Act, if the President declares a severe energy supply interruption, or anticipates this outcome from future confirmed warnings of severe solar geomagnetic storms, per Title 42 U.S.C. section 8374(a), the President may make findings: that a national or regional fuel shortage exists or may exist; that the effect is likely to be of significant scope and duration, and "of an emergency nature." Thence, the President may by order –

> "prohibit any electric powerplant or major fuel-burning installation from using natural gas or petroleum, or both, as a primary energy source for the duration of such [energy supply] disruption."

The duration of the emergency Presidential order is limited to the lesser of the "duration" of the emergency or 90 days – which should suffice for the several-day duration of previously observed severe solar geomagnetic storms. Under this statute, the President may not delegate authority to issue relevant orders to other federal officials. [42 U.S.C. § 8374(e).]

What might be the operational use of these two statutes? Assuming development of appropriate equipment databases and communication systems that can operate during severe solar storms, the President might – with prior practice exercises and a validation system to confirm presidential orders – cause the immediate shutdown of all unprotected gas-fired and petroleum-fired electric generation facilities within the bulk power system of the United States.

U.S. Energy Information Administration projections for year 2013 U.S. electric generation, by fuel type, estimate natural-gas electric generation as 27.6% of the annual total, and petroleum at just 0.6% of the annual total, or a combined share of about 28.2% of total electric generation.[7]

Concurrently, the Nuclear Regulatory Commission (NRC) has existing authority to de-energize all 102-licensed nuclear power plants operating under its supervision.[8] Temporary plant shutdown is done routinely during earthquakes and hurricanes under NRC safety authority. At the April 30, 2012 FERC Technical Conference on geomagnetic disturbances and reliability of the bulk power system[9], an NRC nuclear engineer testified that the prudent course of action before a severe solar geomagnetic storm might be to shut down all NRC licensed power reactors. But since these facilities produce about 18-19% percent of national electric supply, their uncoordinated shutdown would by itself produce a risk of electric grid instability.

With combination of the President's non-delegable authority to de-energize natural gas and petroleum fired generating facilities, and the NRC's authority to de-energize 18-19% percent of projected U.S electric generation, generating facilities that will produce about 46-47% of total U.S. electric generation can be protected – either by de-energizing orders or by "operate through" instructions.

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[7] See U.S. Energy Information Administration, "Short-Term Energy Outlook," June 2013.
[8] The two San Onofre (SONGS) power plants in Southern California are now inoperable and scheduled for decommissioning.
[9] See FERC Docket AD12-13-000 (2012).

In a severe solar storm, might the United States be able to protect a higher share of its critical electric infrastructure than merely 46-47% of annual generating capacity? The largest single source of U.S. electric generation, by fuel type, remains coal. The U.S. Energy Information Administration estimates that coal-fired electric generation will remain just above 40% of total U.S. electric generation in years 2013 and 2014.[10]

The President cannot rely upon the Powerplant and Industrial Fuel Use Act of 1978 to de-energize coal-fired power plants because that Act specifically authorizes restrictions on natural gas and petroleum fuels but not coal. It was assumed, in 1978, that coal-fired electric generation would be increased during an energy supply disruption.

Might the President order de-energizing of coal-fired plants before or during an impending solar storm by declaring a national emergency under the International Emergency Economic Powers Act [50 U.S.C. §1701 et seq.], or under the Defense Production Act of 1950 as amended, or under the doctrine of "necessity"?[11] Under our interpretation, the President has these emergency powers, and exercise of these powers in anticipation of a severe solar geomagnetic storm could preserve critical electric grid equipment. Moreover, if actionable intelligence were sufficiently precise, the President could order the de-energizing of all critical but unprotected electric grid equipment in anticipation of a man-made electromagnetic pulse (EMP) attack.

In substance and in law, the President does have emergency powers to order the de-energizing of coal-fired electric generation during a solar geomagnetic storm emergency. However, without express legislative authority—specifically legislation that reverses the implied prohibition of Presidential authorization to de-energize coal-fired electric generation facilities—the federal government might be liable under the U.S. Constitution for the uncompensated "taking" of private property.[12] The Constitutional obligations of the federal government are not waived merely because of the necessity of action.[13] If the President acts to de-energize a

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[10] See U.S. Energy Information Administration, "Short-Term Energy Outlook, June 2013."

[11] Thomas Jefferson wrote of "the unwritten laws of necessity, of self-preservation, and of the public safety, control the written laws...." Letter, Thomas Jefferson to John Colvin, Sept. 20, 1810, in 11 The works of Thomas Jefferson at 146 (Paul Leicester Ford, ed. 1905). Before adoption of the U.S. Constitution, Alexander Hamilton wrote in The Federalist No. 23, "[T]he circumstances which may affect the public safety are [not] reducible within certain determinate limits... there can be no limitation of that authority which is to provide for the defense and protection of the community, in any matter essential to its efficacy...." (December 18, 1787).

[12] "Private property" under the takings clause could include damage to capital equipment, loss of income for electric utilities, and business interruption losses for utility customers. The issuance of a Presidential Order to de-energize generating facilities may have advantages for utility owners compared to their voluntary decision(s) to de-energize their power plants during a severe solar storm. Under many insurance policies the intentional shutdown of a power plant by an insured owner may void insurance coverage against customer claims and for property damage of insureds.

[13] "The American Constitution contains no general provision authorizing suspension of the normal government processes when an emergency is declared by appropriate government authority." Quoted from Henry P. Monaghan, "The Protective Power of the President," 93 Colum. L. Rev. 1 at 33 (1993). For a review of presidential

regional electric grid or the national electric grid, or if the President declines to act, and the nation suffers greater losses of human life and harm to the national economy, most likely the President's actions or inactions would be precluded from federal liability under the "discretionary function exception" to the Federal Tort Claims Act.[14]

The primary reason to seek unambiguous legislative authority for the President to order the de-energizing of the U.S. or a regional electric grid is to avert needless pre-decisional delay. Legal authority should be crystal clear, and known to federal and state officials, and by utility operators and regional electric balancing authorities that might be subject to presidential orders, especially if the window of necessary action involves minutes, not hours. Hence, the more prudent course, in anticipation of a severe solar geomagnetic storm or man-made EMP hazard, might be for the President and his legal advisors to seek a clean legislative authorization from the U.S. Congress: to protect critical electric facilities essential to the bulk power system, the national defense, or other critical national infrastructure; and including the authority to order the de-energizing or re-energizing of the bulk power system of the United States or regional entities served by the bulk power system. Anticipating the risk of widespread electric blackouts during a severe geomagnetic storm, any federal legislation to broaden presidential authority to authorize temporary de-energizing of critical electric power generation might also: provide incentives for "grid islanding" to ensure critical electricity supply to hospitals and nursing homes; to provide for continual electricity supply to critical telecommunications systems; and prioritize off-site power to military facilities and nuclear power plants.[15] A temporary but controlled shutdown of the North American electric grid would lead to loss of life and extraordinary economic damage. But the costs of inaction—including the risk of catastrophic grid collapse--appear to be even higher.

Might a Bill introduced in June 2012 in the U.S. House of Representatives, H.R. 2417, be a legislative vehicle to clarify presidential authority to act in anticipation of a severe solar geomagnetic storm?[16] The so-called SHIELD Act, a variant of legislation introduced in prior

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emergency powers when supporting legislation does not exist, and when contradictory legislation is in effect see the concurring opinion of Justice Robert Jackson in Youngstown Sheet & Tube Co. v. Sawyer, 343 U.S. 579 (1952).

[14] See 28 U.S.C. §2680(a).

[15] Without the design and exercise of reliable emergency communication systems capable of operating through a severe solar geomagnetic storm, the President might be incapable of reliably ordering and authenticating orders to de-energize or re-energize as appropriate electric grid facilities essential to critical national or critical defense infrastructure. President Obama's Executive Order 13618 of July 6, 2012, "Assignment of National Security and Emergency Preparedness Communications Functions," 22 Federal Register 40779, does provide in Sec. 2.2: "The Director of the Office of Science and Technology Policy (OSTP) shall: (a) issue an annual memorandum ... highlighting national priorities for Executive Committee analyses, studies, research and development regarding [National Security and Emergency Preparedness] communications;" and to "advise the President" on radio spectrum prioritization.

[16] On June 18, 2013, twenty Members of Congress filed H.R. 2417, the "Secure High-voltage Infrastructure for Electricity from Lethal Damage (SHIELD) Act." Text is available from the Government Printing Office at http://www.gpo.gov/fdsys/pkg/BILLS-113hr2417ih/pdf/BILLS-113hr2417ih.pdf.

sessions of the U.S. Congress, would expand the authority of the Federal Energy Regulatory Commission (FERC) to set reliability standards and to provide for cost-recovery for grid-protective equipment. This legislation is designed to accelerate protection against both a severe solar geomagnetic storm and man-made electromagnetic pulse (EMP) hazards.[17]

In its as-filed text, H.R. 2417 (113th Congress) would create a new Section 215A of the Federal Power Act. Under proposed emergency authorities, if the President issues to the Commission "a written directive or determination identifying an immediate grid security threat," FERC, a five member commission -

> "may, with or without notice, hearing, or report, issue such orders for emergency measures as are necessary in its judgment to protect the reliability of the bulk power system or of defense critical electric infrastructure against such threat."[18]

The proposed emergency measures would require the assembly of a quorum of FERC Commissioners. Even if the Commissioners acted without notice or public hearing, as would be allowed by the proposed legislation, the FERC Commissioners could not, within the 10 to 20 minute confirmatory warning time of the ACE satellite (or its successor satellite) reliably order the de-energizing of critical electric grid equipment in time to preclude permanent damage. It would appear that authorization by the President, and not a Commission of five presidential appointees, would be necessary.

If the President and his team of legal advisers seek clarifying authority for reliable federal action under inherently short warning time, they might consider either supplementing the proposed authorities in H.R. 2417, or proposing some other legislative vehicle to provide the President the authority to issue emergency orders, including the power to de-energize or re-energize critical electric grid equipment and/or "defense critical electric infrastructure."

In conclusion: the President, in coordination with the Nuclear Regulatory Commission, has existing authority to de-energize critical U.S. electric grid equipment producing about 46% to 47% of annual U.S. net electric generation. These are the gas-fired, petroleum-fired, and nuclear-fueled electric generating facilities.

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[17] The Foundation for Resilient Societies is organized in the State of New Hampshire as a non-profit corporation with the mission of conducting research and public education on high-impact, low-frequency risks to societal resilience. The Foundation does not endorse H.R. 2417 or any other specific legislation. In this specific instance, the Foundation contrasts the limits of proposed Presidential authority under H.R. 2417 with the practical necessity of action within a 10-to-20 minute warning time for solar storms, and points out that public safety may require alternative or complementary Presidential authority.

[18] H.R. 2417 (June 18, 2013) at page 8, lines 15-20.

The President also has emergency powers to mandate the de-energizing of coal-fired electric generating plants, but with the risk of claims of uncompensated "takings" of property and possible federal liability for tort claims.

The President has an opportunity to obtain clarifying Congressional authority for the President to enable an emergency action system that could, under Presidential order, cause the selective de-energizing and possibly the re-energizing of critical electric grid infrastructure before or during a severe solar geomagnetic storm or, if reliable warning were available, in anticipation of a man-made electromagnetic pulse hazard.

Appendix 6

Recognizing Electromagnetic Pulse Attack

Electronic upsets and failures occur under normal operating circumstances, even in high-reliability equipment such as that supporting critical infrastructure. EMP-induced upsets and failures, however, are different from those encountered in the normal operation of infrastructure systems, and in fact have unique aspects not encountered under any other circumstances.

EMP produces nearly simultaneous upset and damage of electronic and of other electrical equipment over wide geographic areas, determined by the altitude, character, and explosive yield of the EMP-producing nuclear explosion. Since such upset and damage is not encountered in other circumstances and particularly not remotely to the same scale, the normal experience of otherwise skilled system operators and others in positions of responsibility and authority will not prepare them to identify what has happened to the system, what actions to take to minimize further adverse consequences, and what actions must be carried out to restore the impacted systems as swiftly and effectively as possible.

Special system capabilities and operator awareness, planning, training, and testing will be required to deal with EMP-induced system impacts. The first requirement is for the operators of critical infrastructure systems to be able to determine that a high-altitude nuclear explosion has occurred and has produced a unique set of adverse effects on their systems.

It will be necessary to distinguish high altitude nuclear EMP (HEMP) effects from regional EMP effects that could be generated by a cruise missile or ground based vehicle employing non-nuclear intentional electronic interference devices. These have fast rise times measured in nanoseconds but limited geographic impacts.[19]

That information can be provided by local electromagnetic sensors, by information from Earth satellite systems, or by other means. Whatever the means, the operators and others in positions of authority and responsibility must receive the information immediately. Therefore, the EMP event notification system must itself be highly reliable during and after an EMP attack.

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[19] Employment of a high altitude nuclear EMP weapon would violate the U.N. Environmental Modification Convention of 1980 (ENMOD), and the Outer Space Treaty of 1967 (OST). A non-nuclear EMP device might not violate either of these international treaties, and might have only limited impact on electric and electronic devices. For purposes of damage assessment and policy response, it is essential to be able to distinguish these classes of events.

Operators and others in positions of authority and responsibility must be trained to recognize that an EMP attack in fact has taken place, to understand the wide range of effects it can produce, to analyze the status of their infrastructure systems, to avoid further system degradation, to dispatch resources to begin effective system restoration, and to sustain the most critical functions while the system is being repaired and restored. Failures similar to those induced by EMP do not occur in normal system operation, and therefore the training for, and experience developed in the course of, normal system operation will not provide operators with the skills and knowledge-base necessary to perform effectively after EMP-induced system disruption and failure. Training, procedures, simulations, and exercises must be developed and carried out that are specifically designed to contend with EMP-induced effects.

Appendix 7

Vulnerability of Nuclear Power Plants to Electromagnetic Pulse

Events at the Fukushima—Daiichi nuclear complex in Japan in March 2011 clearly established that nuclear plants deprived of outside power and without adequate backup systems can pose a catastrophic danger to surrounding populations. While the initiating event for loss of commercial grid power at Fukushima was an earthquake followed by a tsunami, any initiating event causing long-term loss of outside power could result in reactor core damage and boil-off of spent fuel pools, with associated risk of zirconium fuel rod ignition. The resulting fire and spread of dangerous radionuclides could cause the surrounding area to be uninhabitable for centuries. Initiating events could include solar electromagnetic pulse (EMP), nuclear EMP, cyber attack, and coordinated physical attack of critical grid substations.

In October 2010, Oak Ridge National Laboratory released "Electromagnetic Pulse: Effects on the U.S. Power Grid," a series of comprehensive technical reports for the Federal Energy Regulatory Commission (FERC) in joint sponsorship with the Department of Energy and the Department of Homeland Security. These reports disclose that the commercial power grids in two large areas of the continental United States are vulnerable to solar EMP. The reports conclude that solar activity and resulting large earthbound Coronal Mass Ejection (CME), occurring on average once every one hundred years, would induce a geomagnetic disturbance and cause collapse of the commercial grids in these vulnerable areas. Excess heat from induced currents in transmission lines could permanently damage approximately 350 extra high voltage transformers. The replacement lead time for extra high voltage transformers is approximately 1-2 years. As a result, about two-thirds of nuclear power plants and their associated spent fuel pools would likely be without commercial grid power for a period of 1-2 years.

When extreme value theory is applied to the one-in-one-hundred-year frequency supplied by the Oak Ridge National Laboratory, the resulting probability of long-term loss of outside power is 33% over the standard 40-year licensure term for nuclear power plants and associated spent fuel pools. Loss of outside power with probability of 1% per year and duration of 1-2 years far exceeds the current design basis for nuclear power plants and associated spent fuel pools.

The Foundation for Resilient Societies submitted a proposal to adjust nuclear plant design basis to the NRC as Petition for Rulemaking PRM-50-96 in draft on February 8, 2011 (a full month before the Fukushima disaster) and in final form on March 14, 2011. On December 3, 2012, the NRC determined that "its rulemaking process can appropriately consider a petition on maintaining the safety of used nuclear fuel at U.S. reactors if an extreme solar flare disables the electrical grid." Moreover, in a Federal Register Notice on December 18, 2012, the NRC stated that:

"... the NRC has concluded that the expected frequency of such storms is not remote compared to other hazards that the NRC requires NPPs licensees to consider."

"The NRC believes that it is possible that a geomagnetic storm-induced outage could be long-lasting and could last long enough that the onsite supply of fuel for the emergency generators would be exhausted. "

"It is also possible that a widespread, prolonged grid outage could cause some disruption to society and to the Nation's infrastructure such that normal commercial deliveries of diesel fuel could be disrupted. In such a situation, it would be prudent for licensees to have procedures in place to address long-term grid collapse scenarios."

"Solar storms are not specifically identified as natural hazards in GDC 2 [General Design Criteria 2], but the information currently available to the NRC indicates that the frequency of these storms may be consistent with other natural hazards within the intended scope of the GDC."

"Accordingly, it is appropriate for the NRC to consider regulatory actions that could be needed to ensure adequate protection of public health and safety during and after a severe geomagnetic storm."

"Thus, the NRC concludes that the petitioner's scenario is sufficiently credible to require consideration of emergency planning and response capabilities under such circumstances. Accordingly, the NRC intends to further evaluate the petitioner's concerns in the NRC rulemaking process."

Petition for Rulemaking PRM-50-96 addressed the consequences of long-term loss of outside power only on spent fuel pools. However, in its ruling on PRM-50-96, the NRC decided on its own initiative to also evaluate the effect of long-term loss of outside power on safe shutdown and core cooling:

"Although outside the scope of this PRM, it should be noted that the NRC, as a part of its core mission to protect public health and safety, is updating its previous evaluation of the effects of geomagnetic storms on systems and components needed to ensure safe shutdown and core cooling at nuclear power reactors."

In addition to the ongoing evaluation of the NRC, the congressionally-authorized Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack performed a risk assessment of the vulnerability of the U.S. national electric power infrastructure to EMP. This risk assessment is addressed in the Commission's Report on Critical National Infrastructures. Additional Reports are available to authorized persons through the Congress and the Department of Defense.