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State Electromagnetic Pulse (EMP) and Geomagnetic Disturbance (GMD) Mitigation Efforts [SJ61, 2014]

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State EMP & GMD Mitigation Efforts

Prepared by the Staff of the Joint Commission on Technology & Science

Introduction

Electromagnetic pulses (EMPs) are extreme electromagnetic incidents caused by an intentional electromagnetic pulse. EMPs are generally associated with intentional attacks using high-altitude nuclear detonations, specialized conventional munitions, or non-nuclear directed energy devices. Effects vary in scale from highly local to regional to continental, depending upon the specific characteristics of the weapon and the attack profile. High-altitude electromagnetic pulse attacks using nuclear weapons are of most concern because they may permanently damage or disable large sections of the national electric grid and other critical infrastructure control systems. Depending on the nature of the attack, cascading failures of major infrastructure and related industry could result. Damage could spread through the electric power infrastructure and into telecommunications, energy, and other infrastructures. This cascading damage would seriously impact other important aspects of life such as means of getting food, water, and emergency care to the general public.

A nuclear EMP is often described in three components. The E1 stage consists of a broadband energy pulse occurring in less than a microsecond emitting the initial waveform that disrupts electrical systems in general.[1] The E2 component is lower in amplitude and similar to lightning in its effect by enhancing currents on long electrical lines within milliseconds.[2] The final E3 stage consists of a lower-amplitude, longer-duration pulse that induces currents in long power and communication lines.[3] The impacts to critical infrastructure resulting from EMP incidents differ significantly from other large-scale, naturally occurring hazards, such as hurricanes. Many of the most harmful effects caused by electromagnetic incidents occur within milliseconds or seconds with little to no warning.

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[1] Infrastructure Security and Energy Restoration Division, U.S. Dep't of Energy EMP Resilience Action Plan, at 1 (Jan. 10, 2017), https://www.energy.gov/sites/prod/files/2017/01/f34/DOE%20EMP%20Resilience%20Action%20Plan%20January%202017.pdf.
[2] *Id*.
[3] *Id*.

While often discussed simultaneously, geomagnetic disturbances (GMDs) and EMPs are distinct disaster events.[4] Extreme GMDs are associated with solar coronal mass ejections and can cause widespread and long-lasting damage to electric power systems, satellites, electronic navigation systems, and undersea cables. A coronal mass ejection (CME) – sometimes called a "solar EMP" – is a large ejection of plasma and magnetic field from the sun. These ejections can then be carried into space on "solar winds", the continuous flow of charged particles from the sun. CMEs are a daily occurrence and, in most cases, have no effect on the Earth. But if a sufficiently large CME hit the Earth's magnetosphere, it could cause similar disruptions to electricity as a weaponized EMP. Space weather phenomena are relatively well understood within the scientific community, but the historical rarity of extreme GMD events limits the availability of data useful for predictive analysis. When a geomagnetic storm induces transmission lines with additional, unregulated current, but the output of voltage stays the same, mechanical failures can occur, causing large power outages and damage in seconds.[5] Geomagnetic storms can result in widespread electrical failures, though most electric power companies have procedures in place to mitigate the impacts of these storms.[6] However, the precise nature of these procedures and the technology in place are closely guarded company information for obvious security reasons.

Any comprehensive regulatory or legislative approach to mitigating or preventing damage from an EMP or GMD incident is largely a task for the federal government. The most recent federal action related to EMPs was an executive order issued by President Trump on March 26, 2019 directing several agencies to immediately undertake numerous studies and reviews related to improving the nation's resilience to the effects of EMPs.[7] While the Department of Homeland Security, the Federal Energy Regulatory Commission, and the Department of Energy have primary responsibility to protect against a potential EMP or GMD incident there are still numerous potential actions that states could take in order to harden

[4] Refer to Appendix A for a chart detailing specific similarities and differences of EMPs and GMDs.
[5] "Geomagnetic Disturbances," ISO New England, https://www.iso-ne.com/about/what-we-do/in-depth/geomagnetic-disturbances.
[6] Va. Dep't of Emergency Management, Commonwealth of Va. Hazard Mitigation Plan, Ch. 3 Section 3.16 page 1 (Mar. 2018), https://www.vaemergency.gov/wp-content/uploads/2018/03/COV-SHMP-3-2018-Public.pdf.
[7] *See* Executive Order on Coordinating National Resilience to EMPs, (Mar. 26, 2019), https://www.whitehouse.gov/presidential-actions/executive-order-coordinating-national-resilience-electromagnetic-pulses/.

themselves against the potential effects of an incident. In the following sections, this report will detail several approaches Virginia could take to prepare for and mitigate the effects of an EMP or GMD incident.

Current Virginia Approaches & Resources

Despite the scientific and general uncertainty surrounding the exact potential impact of any large-scale EMP or GMD incident, Virginia has already taken steps to improve its resiliency and emergency response measures. Since 2015 the Virginia Department of Emergency Management (VDEM) has been required to specifically plan for disasters caused by EMPs and GMDs in all of its comprehensive emergency management plans.[8] Previously, VDEM was required to submit to the Governor for adoption every four years the Commonwealth of Virginia Emergency Operations Plan. The most recent version of this plan was adopted in 2015 and had no mention of an EMP or GMD incident response plan.[9] However, legislation from the 2019 session amended VDEM's reporting requirements.[10] That bill eliminated the annual requirement that VDEM submit an annual Commonwealth Threat and Hazard Identification and Risk Assessment (C-THIRA) to the Governor and General Assembly.[11] It further consolidated the other annual reporting requirements into one tabulated report called the Virginia Comprehensive Emergency Management Report. This report can, and should, include EMP and GMD disaster planning and response measures. The last C-THIRA issued in January 2019 listed a GMD incident as a "low-probability, high-impact" potential threat but did not include response plans or ways to prepare for a GMD incident.[12] The governor is also statutorily required to conduct an annual statewide drill on response to a large-scale disaster, specifically including "electrical power outages."[13] While this drill usually focuses on state-wide responses to a hurricane, in the future it could be used to simulate a state-wide EMP or GMD incident.

In terms of federal reporting requirements, Federal Emergency Management Agency (FEMA) regulations require states maintain an approved state mitigation plan as a condition of

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[8] Va. S.B. 1238 (2015) amended Va. Code Ann. §44-146.18(B) to include EMPs and GMDs.
[9] *See* Va. Dep't of Emergency Management, *Commonwealth of Va. Emergency Operations Plan*, (Mar. 2015), https://www.vaemergency.gov/wp-content/uploads/drupal/2012COVEOPPlan2015March.pdf.
[10] H.B. 2133, 2019 Va. Gen. Assem., Reg. Sess., Ch. 615 Acts of Assem.
[11] *Id*.
[12] Va. Dep't of Emergency Management, 2018 Commonwealth Threat and Hazard Identification and Risk Assessment, at 7 (Jan. 2019), https://rga.lis.virginia.gov/Published/2019/RD181/PDF.
[13] *See* Va. Code Ann. § 44-146.17:2.

receiving non-emergency Stafford Act assistance and FEMA mitigation grants.[14] Section 3.16 of Virginia's Mitigation Plan is devoted entirely to solar storms, with geomagnetic storms being one subcategory of solar storms. When analyzing solar storms generally, the plan describes their incidence probability as low and designated a total of 2,420 state facilities at risk from solar storms.[15] The plan offers little in terms of strategic guidance or response methods in the event of a GMD incident. The plan does note that no local plans address solar storms however it anticipates that future plans will likely include a discussion.[16]

Beyond plans specific to EMP and GMD emergency response, Virginia has a number of other tools at its disposal to confront such a multifaceted threat. The Office of the Secretary of Public Safety and Homeland Security could direct its Critical Infrastructure Focus Group or the Secure and Resilient Commonwealth Panel to examine the potential effect of an EMP or GMD incident on Virginia. Currently the panel is tasked with exploring actions related to homeland security, risk management, resilience, and situational awareness of Virginia's critical assets during emergencies.[17] While most emergency planning in Virginia to date related to EMP and GMD incidents has focused on preparatory measures, that does not mean that nothing can be done at the state level in the aftermath of an incident. For example, the Governor has the statutory authority to take possession of public utilities if "an imminent threat of substantial curtailment, interruption or suspension of the utility exists" and it will constitute "a serious menace or threat to public health, safety, or welfare."[18] Thus, this provision could be invoked in the event an EMP/GMD incident severely impacts a public utility such that it would require a direct infusion of government resources to restore service.

General Mitigation Techniques

As previously stated, while mitigation and response efforts for a large-scale EMP/GMD incident would mostly fall to the federal government, Virginia could supplement this federal response as well as engage in traditional forms of natural disaster relief and preparation. There

[14] *See* 44 C.F.R. § 201.4.
[15] Va. Hazard Mitigation Plan, *supra* note 5, at Sec. 3.16 pg. 5; *See* Appendix B for a breakdown of facilities by category.
[16] Va. Hazard Mitigation Plan, *supra* note 5, at Sec. 3.16 pg. 6.
[17] Sec. of Public Safety and Homeland Security, Secure and Resilient Commonwealth Panel, https://www.pshs.virginia.gov/initiatives/secure-and-resilient-commonwealth-panel/.
[18] Va. Code Ann. § 56-510.

are likely a number of steps private individuals are already taking to prepare for traditional natural disasters that could double as preparation for an EMP/GMD incident. Measures include stockpiling emergency supplies and food/water rations as well as being aware of any local emergency management plans. VDEM officials should also track the status of the EMP preparedness program being drafted by the Arizona Department for Emergency & Military Affairs due out later this year.[19] Arizona is set to release a plan recommending the type and quantity of supplies that each person should possess in the event of an EMP and such a plan could serve as a strong template for a similar plan in Virginia. The biggest factor in preparing Virginia for an EMP/GMD incident involves educating and communicating the threat posed to the general public. Robust community outreach explaining what EMP and GMD incidents consist of, the effects of each, and best practices in the event of an incident. Community outreach can not only educate the public on the potential threat but also increase the groundswell of support for definitive action at the federal level to secure the electrical grid and develop a comprehensive emergency management approach to EMPs and GMDs.

In addition to the outreach work being done at the federal level, the Commonwealth should strive to ensure private entities are aware of the impact an EMP/GMD incident could have on their day-to-day operations and best practices to mitigate any potential threat. In February 2019 the National Cybersecurity and Communications Center released a four-level guide for protecting infrastructure and equipment against an EMP incident.[20] Level One consists of low-cost methods and best practices to help protect critical infrastructure from severe damage. This level of protection ensures that personnel have backup power, food/water, and other supplies needed to maintain mission-critical systems given that supply chains are likely to be interrupted for a week or more.[21] Level Two guidelines are based on using EMP-capable filters and blockers to protect critical equipment where EMP facility shielding is not feasible or cost-effective for certain facilities.[22] Levels One and Two are for organizations where days of

[19] *See* Ariz. Rev. Stat. Ann. § 26-305.03.
[20] *See* Appendix C for the detailed chart.
[21] National Coordinating Center for Communications, *Electromagnetic Pulse Protection and Resilience Guidelines for Critical Infrastructure & Equipment*, Version 2.2 (Feb. 5, 2019), National Cybersecurity and Communications Integration Center, https://www.dhs.gov/sites/default/files/publications/19_0307_CISA_EMP-Protection-Resilience-Guidelines.pdf
[22] *Id*.

interruption can be tolerated and cost to harden is the critical factor.[23] Level Three guidelines are appropriate for organizations that cannot tolerate more than a few minutes of power outage, in order to protect life, health, or security.[24] Finally, Level Four guidelines are for organizations that cannot tolerate more than a few seconds of outage and where immediate safety is at stake, such as military infrastructure.[25]

Beyond educating the general public, the most effective method in planning for an EMP/GMD incident is collaborating closely with the relevant federal authorities such as FEMA. VDEM should discuss its operational plans with FEMA and coordinate with the Virginia National Guard to plan for a mitigation and emergency response plan. Additionally, Virginia should also begin a discussion regarding specific EMP/GMD incident response as part of the Emergency Management Assistance Compact.[26] Furthermore, VDEM should participate in the North American Electric Reliability Corporation's GridEx V if it does not already plan to partake. Virginia participated in GridEx IV and should continue to work with other stakeholders in this space as well as encourage neighboring states to also participate. Scheduled for November 13-14, 2019 GridEx V seeks to bring together public and private stakeholders allowing utilities to demonstrate how they would respond to and recover from cyber and physical security threats.[27] One of the biggest challenges in working with utilities is the sensitivity of private company information regarding critical infrastructure.[28] Virginia is one of four states that has recently been proactive on this front, exempting certain detailed information about the grid, utilities and state energy infrastructure from disclosure under the Freedom of Information Act.[29] VDEM could also deploy the use of its Crisis Track Software in the event of an EMP/GMD incident such that state and local officials can efficiently prioritize where resources are needed

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[23] *Id*.
[24] *Id*.
[25] *Id*.
[26] EMAC is an all hazards mutual aid compact that serves as the bedrock of the nation's mutual aid system. With each state enacting legislation to become EMAC members, the compact offers assistance during governor-declared states of emergency or disaster. *See* https://www.emacweb.org/index.php/learn-about-emac/what-is-emac.
[27] *GridEx*, North American Electric Reliability Corporation, https://www.nerc.com/pa/ci/cipoutreach/pages/gridex.aspx.
[28] For example in August 2017 Dominion Energy unveiled its 113,000 square-foot Systems Operation Center hardened with military-grade EMP protections for critical operations. *See Perspectives on Protecting the Electric Grid from an EMP or GMD Before the S. Comm. on Homeland Security*, 116th Cong. at 7 (2019) (statement of David W. Roop, Director, Electric Transmission Operations & Reliability, Dominion Energy).
[29] Daniel Shea, State Efforts to Protect the Electric Grid, National Conference of State Legislatures, at 11 (Apr. 2016), http://www.ncsl.org/Portals/1/Documents/energy/ENERGY_SECURITY_REPORT_FINAL_April2016.pdf.

most in the aftermath of an event. The use of this software and other technology-based emergency response tools however naturally assumes at least some limited internet functionality.

Hardening the Grid

It is widely understood that in the event of an EMP incident there would likely not be enough lead time to communicate a credible threat to affected parties or position the grid to withstand such an incident.[30] While a GMD as the result of a solar storm can be predicted and tracked with more scientific certainty, there is no way to prevent the naturally-occurring incident itself. Thus for both a potential EMP or GMD incident the focus has largely been on mitigating the effects of an incident rather than trying to prevent the unpredictable/unavoidable.

The practice of "hardening" can refer to a multitude of different measures meant to improve the resiliency of the electric grid. According to the Idaho National Laboratory hardening techniques can include faraday cage shielding, grounding, filters, fast acting current shunt devices, and responsive control systems to manage the effects of possible cascading outages.[31] A 2019 study by the Electric Power Research Institute (EPRI) echoed the recommendations from the National Lab concluding that some of the most effective mitigation measures include shielded cables with proper grounding, low-voltage surge protectors, and enhanced electromagnetic shielding of electric substation control houses.[32]

Despite federal regulatory control over the interstate electric grid, some state legislators have insisted they have a responsibility to do more to protect the grid. Proponents of state action argue that since they have regulatory authority over the electric grid's transmission and distribution systems they can, and should, require power companies to install current blocking

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[30] PJM Systems Operation Division, *PJM Manual 13: Emergency Operations*, Section 4 (May 30, 2019), https://www.pjm.com/~/media/documents/manuals/m13.ashx.
[31] Idaho National Laboratory, *Strategies, Protections, and Mitigations for the Electric Grid from EMP Effects*, at 15 (Jan. 2016) https://inldigitallibrary.inl.gov/sites/STI/STI/INL-EXT-15-35582.pdf; Va. S.B. 1473 declares it is in the public interest that certain existing overhead electrical lines with an elevated history of unplanned outage events should be grounded to increase system reliability. *See* S.B. 1473, Va. Gen Assem. 2017, Ch. 583 Acts of Assem.
[32] Electronic Power Research Institute, *High-Altitude Electromagnetic Pulse and the Bulk Power System - Potential Impacts and Mitigation Strategies*, at x (Apr. 2019), https://www.epri.com/#/pages/product/3002014979/?lang=en-US.

devices or other technologies to protect large transformers and generators against EMPs or GMDs.[33] Critics of this approach have argued that piecemeal state legislation is the wrong way to go about working on such a technologically sophisticated issue. Critics have further noted that even if current blocking devices were required, there is no substantive evidence that they would adequately work in the event of an EMP/GMD incident in order to justify their cost.[34] Industry representatives have mostly come out against state legislation requiring current blockers arguing engineering experts need to study the problem more to ensure that installing these devices does not lead to any unintended consequences.[35] More recently, EPRI concluded that the blocking/reduction in the flow of geomagnetic induced currents (GICs) in system transformers is an effective means of reducing the potential impact of an E3 pulse, since the flow of GICs in large power transformers is the root cause of transformer failure.[36] This blockage/reduction in the flow of GICs can be achieved through neutral blocking devices, GIC reduction devices, and series capacitors.[37]

As the federal impetus to pass meaningful EMP/GMD legislation has stalled, more and more states have taken up the mantle to study and respond to this looming threat. From 2013-2015 EMP or solar-related legislation was filed in 11 states and passed in five.[38] These measures ranged from establishing commissions to study potential threats to requiring electricity providers to install certain technologies to protect grid infrastructure.[39] Maine was the first state to make the push to prepare against an EMP/GMD incident, directing its public utility commission (PUC) to examine the vulnerabilities of the state's transmission infrastructure and report back to the legislature.[40] The original version of the legislation mandating the Maine PUC study would have required anyone submitting a petition to the PUC for the purposes of building a transmission line to include a description of design measures to ensure protection against an EMP or GMD

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[33] Jenni Bergal, *States Work to Protect Electric Grid*, Pew Charitable Trusts, (Feb. 27, 2015), https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2015/2/27/states-work-to-protect-electric-grid.
[34] Despite the general pushback from the industry, the American Transmission Company installed a geomagnetic blocker on a substation in northeastern Wisconsin in February 2015 to protect against the effects of a GMD at a total cost of $500,000. *Id*.
[35] *Id*.
[36] *High-Altitude Electromagnetic Pulse and the Bulk Power System, supra* note 30, at 5-12.
[37] *Id*.
[38] *Bergal*, supra note 31.
[39] During this time Kentucky, Arizona, and Louisiana each passed legislation directing the relevant state agency to study, analyze, and recommend measures for EMP/GMD preparedness. *Id*.
[40] H.P. 106, 126th Maine Legislature, First Reg. Session 2013, Ch. 45.

incident.[41] While ultimately watered down to remove this requirement and only calling for a study, this goes to show the more aggressive side of state action in this space. The Maine PUC delivered its report in January 2014 concluding that while there may be low-cost mitigation options that state regulatory commissions could employ, due to the highly integrated nature of the bulk power system a state by state approach is ill-suited to protect the grid.[42] The report also stressed the need for strong coordination among federal and state agencies as well as the electric industry in establishing GMD and EMP mitigation plans.[43] The report cited an estimate by the Foundation of Resilient Societies that it would cost approximately $25 million to protect Maine's electric utility control rooms against E1 level EMP events.[44] Additionally, estimates for installing geomagnetically induced current monitoring equipment were listed at $10,000 per unit and neutral current blocking devices were estimated at $350,000 per substation.[45] These high costs create concerns that customers could end up paying far more on their utility bill, but the report largely dodged this issue. Additional mitigation measures highlighted included the need to have spare transformers on site, but the report found that the number of transformers and breakers in reserve pales in comparison to the number needed to properly stabilize a region following an EMP or GMD incident.[46] The high-cost of these components and custom manufacturing process required especially hinders the feasibility maintaining a meaningful stockpile of spare transformers.

In 2017 at least seven states considered nearly 20 measures relating to protecting critical energy infrastructure from an EMP.[47] While ultimately vetoed by the governor, Maine continued to lead the pack with legislation that would have required electric companies to report to the Maine PUC annually on actions taken regarding protections from EMPs and GMDs.[48] More recently, there has been a push in Texas to adopt meaningful legislation related to EMP and

[41] *See* H.P. 106, Maine House of Representatives, First Reg. Session 2013, Leg. Doc. No. 131, http://www.mainelegislature.org/legis/bills/getPDF.asp?paper=HP0106&item=1&snum=126.
[42] Maine Public Utilities Commission, Report to the Legislature Regarding GMD and EMP, at 31 (Jan. 20, 2014) https://www.maine.gov/mpuc/legislative/archive/2013-2014ReportstoLegislature.shtml.
[43] *Id*.
[44] *Id*. at 25.
[45] *Id*. at 19.
[46] *Id*. at 25.
[47] Daniel Shea, *Hardening the Grid: How States Are Working to Establish a Resilient and Reliable Electric System*, National Conference of State Legislatures, at 10 (Apr. 2018), http://www.ncsl.org/Portals/1/Documents/energy/HardeningGrid_1_32298.pdf.
[48] H.P. 373, 128th Maine Legislature, First Reg. Session 2017, Leg. Doc. No. 529.

GMD protection. While examples from Texas are instructive to show what lengths a state may go to in order to harden its transmission and distribution systems, the Texas grid is also unique in that it is almost entirely an intrastate grid under the jurisdiction of ERCOT. Conversely, Virginia is part of the PJM regional transmission organization that serves parts of 13 states. Practically speaking it would be more difficult to implement "hardening" legislation related to EMP/GMD protection beyond Texas and any legislation would be less effective if only one state in an ISO or RTO adopted specific EMP/GMD hardening requirements. However, for some businesses that view reliability and resiliency as key concerns, a focus on hardening Virginia's grid from the distribution and transmission side could attract/retain business. Introduced in March 2019, Texas legislation would have created the Texas Grid Security Commission tasked with identifying critical components of the grid vulnerable to EMP, GMD, cyber, or physical attack.[49] The bill would have required any entity that owns/operates a critical component to upgrade its infrastructure to meet specified standards.[50] Furthermore it would have required the Security Commission to prepare a plan for continuity of services in the event of a power emergency including provisions for installing transformers and control systems that can withstand E1 and E3 pulses by at least 2024.[51]

<u>Microgrids</u>

The most obvious difficulty in attempting to mitigate the effect of an EMP or GMD incident is the heavily interconnected nature of the nation's electrical grid. An incident in one localized area could quickly cascade into a regional or even nationwide emergency within a matter of minutes. This key concern has led proponents of grid reform to study ways to decentralize the electrical grid and improve overall resiliency. The most promising method of decentralization has taken the form of microgrid technology which has the ability to disconnect from the traditional electric grid enabling microgrid users to "island."[52] Microgrids can operate independently from the main grid making them particularly useful for military installations,

[49] S.B. 1003, 86h Tx. Leg., (2019).
[50] *Id*.
[51] *Id*.
[52] A microgrid is defined by DOE as "A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode." *See* Dan Ton & Merill Smith, *The U.S. Dep't of Energy's Microgrid Initiative*, THE ELECTRICITY JOURNAL, Vol. 25, Issue 8 at 84 (Oct. 2012).

emergency services, and critical infrastructure to deploy in the event of an EMP/GMD incident. Currently, microgrid technology has yet to reach the scale where the technology could take on a significant share of the electrical load shouldered by the grid in the event of an incident. Microgrids can help boost the integration of renewables as a power source, self-sufficiently generate power in the event of the need for a black start, and lessen the demand on the grid during periods of peak consumption.[53] Advances in battery storage technology are promising and could expand the capabilities of microgrids but presently microgrids are likely be best suited for keeping critical systems running in the event of a blackout and using them as a source of power to get the grid back online.

Virginia is no stranger to the deployment of microgrids with at least three large-scale microgrids coming online since 2015. The numerous military installations across the Commonwealth makes the use of microgrids in Virginia an appealing concept. The first large microgrid in Virginia was installed at a dairy plant in Winchester. With 15 megawatts of natural gas-fired generators, HP Hood's dairy plant is able to "island" in the event of a power outage and continue to ensure its product remains uncontaminated.[54] The technology has spread to Fort Belvoir in Fairfax County where the Department of Defense in 2018 began operating a four megawatt microgrid complete with energy storage capabilities.[55] Beyond its obvious military application, microgrid technology could also be a lifesaver for the critical research being carried out by universities across the Commonwealth. In 2018 Eastern Mennonite University (EMU) began utilizing three 500-kilowatt natural-gas fired generators along with a 104-kilowatt solar system to independently power its 97-acre campus.[56] While some entities have taken the initiative in developing microgrids, for others, high costs and the complexity of the technology have left them to rely on the bulk power grid. In 2018, Delegate David Toscano introduced a joint resolution that would have directed the Department of Mines, Minerals, and Energy to study and determine what regulatory reforms and market incentives are necessary to increase the

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[53] For an exhaustive list of the benefits of microgrids *See* Is a Microgrid Right for You?, S&C Electric Co., (Jun. 11, 2018), https://www.sandc.com/globalassets/sac-electric/documents/sharepoint/documents---all-documents/education-material-180-4504.pdf.
[54] Jim Pierbon, *Microgrids Expand in Virginia with Two New Projects*, Energy News Network, (Jan. 5, 2017), https://energynews.us/2017/01/05/southeast/microgrids-expand-in-virginia-with-two-new-projects/.
[55] *Id*.
[56] *Id*.

use of energy storage devices (including microgrids) in the Commonwealth.[57] While the joint resolution failed to pass the House, this legislation shows that the issue is on the minds of Virginia's legislators and could be revisited in the near future.

Several states across the country have introduced legislation related to encouraging and studying microgrids. In 2017 there were at least 24 bills introduced in seven states related to microgrids, with only Connecticut enacting legislation.[58] Faced with the devastating impact of Superstorm Sandy in 2012, Connecticut has come out on the forefront of microgrid technology with four sets of policies in order to preserve and rapidly restore power to critical services in the event of a large-scale power outage. In 2013, Connecticut established a first-in-the-nation pilot program distributing up to $48 million across several projects throughout the state.[59] The town of Fairfield brought its microgrid online in October 2015 to power its police headquarters, the emergency communications center, a cell phone tower service, fire station, and Operation Hope Homeless Shelter.[60] Connecticut also included microgrid projects under its definition of "energy improvements" authorizing the state's green bank to assist with microgrid financing.[61] On top of that, legislation amended the definition of "energy improvement districts," to include microgrids as one of the projects that cities can develop and fund under this bond program.[62] Lastly, in 2017 Connecticut included microgrids in the state's Property Assessed Clean Energy financing program.[63] A bill to implement a similar grant program failed in New York in 2017 which would have awarded funding for microgrid projects through the New York State Energy Research and Development Authority.[64] In New Hampshire, the legislature recently established a committee to study the applications of microgrids in the state and issue a report with findings and recommendations by November 1, 2019.[65]

Naturally any push for increased deployment of microgrids has been met with significant pushback from electric utilities. Microgrids present utilities with the problem that as more

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[57] H.J. 101, 2018 Va. Gen. Assem., Reg. Sess., 18105778D.
[58] Shea, *supra* note 46, at 4.
[59] Dep't of Energy and Environmental Protection, Microgrid Protection, (Aug. 2017), https://www.ct.gov/deep/cwp/view.asp?a=4405&Q=508780.
[60] *Id*.
[61] Shea, *supra* note 46, at 4.
[62] *See* H.B. 6360, Ct. Gen. Assem. (2013); Conn. Gen. Stat. § 32-80a-c.
[63] Shea, *supra* note 46, at 4.
[64] A.B. 8212, N.Y. State Assem., Reg. Sess. (2017).
[65] H.B 183, N.H. Gen. Ct. (2019).

customers exit the bulk-power system to buy power from microgrids, utilities are still required to provide reliable electricity to the entire grid but without the revenue from those sales to pay for it. While utilities might be hesitant to see large customers go off and build their own electrical generation capabilities, microgrid technology is still only at the point where the most feasible projects involve critical infrastructure and emergency services. Utilities could actually benefit from this decreased stress on the grid during peak hours if certain heavy consumers of energy are now self-sufficient or even returning excess power back into the grid. This relationship can improve overall energy reliability and ensure utilities meet the needs of their most vulnerable customers in an efficient manner especially in times of peak energy demand and extreme weather. In building its microgrid at Fort Belvior, the Department of Defense faced some initial resistance from Dominion Virginia Power but the two eventually worked together in the name of reliability and resiliency.[66] Despite the potential for a love-hate relationship between microgrids and utilities balancing a loss of customers with increased grid reliability, utilities seem to have begrudgingly come around to the implementation of microgrids in certain situations. Electric companies are involved in forty-two percent of the microgrid projects in the US according to the research firm Navigant.[67] The trade association representing electric utilities, the Edison Electric Institute (EEI), seems to be softening its position on the growth of microgrids, preferring a role in their operation rather than remaining totally opposed to the technology.[68] In its November 2018 issue brief, EEI recognized the resiliency and critical infrastructure benefits of microgrids while stressing the need for electric utilities to participate in the development and operation of microgrids.[69] EEI's stance can be best summed up as while microgrids may have a valuable role in helping protecting critical entities, electric utilities must continue to have a lead role in operating the energy grid.

In response to the concerns of the utility industry California recently took a new approach to encouraging microgrid growth. The California bill would open the door for the creation of a

[66] Pierbon, *supra* note 53.
[67] Edison Electric Institute, Microgrids Trends & Key Issues, at 1 (Nov. 2018), https://www.eei.org/issuesandpolicy/Energy%20Storage/Microgrids_Trends_Key_Issues.pdf.
[68] *Id*.
[69] *Id*. at 2.

microgrid tariff and predictable interconnection rules and time frames.[70] David Chiesa, senior director of global business development at S&C Electric and Mike Neylan, CEO of CellCube Energy Storage, see this bill as a potential model for other states microgrid programs.[71] Supporters of the legislation argue that the tariff solves the "death spiral" problem of consumers leaving utilities to buy power from microgrids while utilities remain on the hook to ensure a reliable supply of electricity.[72] With a microgrid tariff in place, utilities will have an assured revenue stream to cover the costs of required back-up power. While the specifics of the tariff and interconnection rules will be established by the California Public Utilities Commission by December 2020, the bill prevents costs shifting between ratepayers and the costs/benefits of microgrids will likely be borne by the owner or operator.[73] All three of California's investor-owned utilities opposed the bill despite the tariff, arguing the legislation was duplicative and would result in low-income customers unfairly subsidizing the costs of customers benefitting from microgrids.[74] While it remains to be seen how effective the California model will be at encouraging the growth of microgrids, it could go a long way in bridging the divide between customers seeking decentralized, resilient methods of power generation and utilities hesitant to lose customers and loosen their grip on the electrical grid.

Effects on Related Industries

Society's intense reliance on sophisticated technology and electricity makes the threat of an EMP/GMD incident particularly dangerous. The interconnected nature of different industries means that an incident seriously damaging the electrical grid would quickly cause a ripple effect across nearly all aspects of daily life. The potential for a cascading effect across different industries, which even in the event of a localized incident, could quickly spread across state lines necessitates a coordinated, uniform federal response plan. When it comes to dealing with the

[70] S.B. 1339, Ca. State Leg., Ch. 566 (2018); S. Comm. on Energy, Utilities, and Communications, SB 1339 Analysis, (Apr. 16, 2018), http://leginfo.legislature.ca.gov/faces/billAnalysisClient.xhtml?bill_id=201720180SB1339.

[71] Lisa Cohn, *What California's Microgrid Bill Means to the State - and Everybody Else,* Microgrid Knowledge (Sept. 7, 2018), https://microgridknowledge.com/microgrid-legislation-california/.

[72] *Id*.

[73] Cal. Pub. Utilities Code, Div. 4.1 Ch. 4.5 § 8371; Cohn, *supra* note 69.

[74] Cohn, *supra* note 69; And yet, the Public Utilities Code has clear language addressing the concerns of the utilities, "*Without shifting costs between ratepayers*, develop separate large electrical corporation rates and tariffs, as necessary, to support microgrids, while ensuring that system, public, and worker safety are given the highest priority." *See* Cal. Pub. Utilities Code, Div. 4.1 Ch. 4.5 § 8371(d) (emphasis added).

effects of an EMP/GMD incident on telecommunications, emergency response services, transportation, and food/water supply chains, state/local officials would serve to assist federal officials. With that said, there are still steps that Virginia could take unilaterally and in coordination with federal authorities in order to better prepare for an EMP/GMD incident.

As noted above, the single greatest measure a state/local government can take in terms of preparation is educate its citizens on the nature of the threat posed and best practices in the event of an EMP/GMD incident. An orderly and calm response to a potential incident could go a long way towards lessening the harm caused and decreasing the time it takes to restore critical services. One of the biggest practical differences between an EMP and a GMD incident is the ability to predict and provide sufficient warning time in the case of an incident. In the event of a GMD, PJM would likely be well informed of its impending occurrence through the National Oceanic and Atmospheric Administration's geomagnetic storm warning system.[75] Upon receiving a credible warning, PJM would immediately disseminate this threat via its ALL-CALL system and Emergency Procedure application.[76] Conversely, PJM does not expect there to be sufficient time before an EMP to communicate a credible threat or position the system to defend against the effects of an incident.[77] For either an EMP or GMD incident one of the biggest issues is the potential loss of communications, especially if totally unexpected in the case of an EMP. PJM's Emergency Operations Manual encourages its members to store back-up satellite phones in shielded bags in the event normal methods of communication become unavailable.[78] The key to utilizing the telecommunications network following an EMP/GMD incident is the extent to which your device (and the infrastructure operated by telecommunications providers) is protected during the initial E1 pulse. While cellular towers and related infrastructure currently have built in protections against lightning, these measures were not designed to protect against the rapid multi-stage effects of an EMP or GMD and would likely be an insufficient level of protection.[79] The functionality of devices dependent on a cellular network for service would ultimately depend on the operational status of the network itself even assuming a particular

[75] *PJM Manual*, *supra* note 28, at 68.
[76] *Id*.
[77] *Id*. at 83
[78] *Id*.
[79] U.S. EMP Commission, *Report of the Commission to Assess the Threat to the US from EMP Attack: Critical National Infrastructures*, at 67 (Apr. 2008), http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf.

device was properly shielded from an EMP/GMD incident. Individuals might turn to short and long wave CB radios, HAM radios, satellite phones, or handheld two-way radios in the aftermath of an EMP/GMD incident to communicate with others.

Preservation of telecommunications or rapid restoration of communications is most important for emergency services and between government personnel to coordinate recovery efforts. The federal Emergency Alert System (EAS) is likely the best way to communicate with the general public immediately after and during an EMP/GMD incident similar to its use following weather-related natural disasters.[80] The U.S. EMP Commission, in assessing the functionality of the EAS following an EMP incident, concluded it would continue functioning at near-normal conditions but may experience delays due to dependency on the commercial telecommunications system and the potential loss of some radio and television stations from power loss or damage to transmission components.[81] To meet the immediate demands of local law enforcement and emergency response officials, DHS's Emergency Communications Division offers a wide range of national security/emergency preparedness services that support state and local government, industry, and nonprofit personnel responding to emergencies.[82] Services include the Government Emergency Telecommunications Service (GETS) and Wireless Priority Service (WPS) which enable certain landline and wireless users priority use during periods of network congestion.[83] In Virginia, the VA 9-1-1 Service Board could work with DHS and other relevant federal officials to plan for the development of an emergency services IP network resilient against an EMP/GMD incident.[84]

In addition to telecommunications, a sufficiently intense EMP/GMD incident could trigger intense traffic congestion in urban areas, disrupt the transportation industry, and paralyze mass transit. The effects of an EMP/GMD incident could knock out traffic control systems and depending on the severity of the incident could require either a manual reset for all traffic signals or replacement parts for damaged traffic systems.[85] This could require local law enforcement to

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[80] *Id*. at 149.
[81] *Id*. at 155.
[82] Cybersecurity and Infrastructure Security Agency, *Emergency Communications Division Priority Telecommunications Services*, Department of Homeland Security, https://www.dhs.gov/cisa/emergency-communications-division-priority-telecommunications-services.
[83] *Id*.
[84] The 9-1-1 Service Board supports the operation of local 9-1-1 services with a focus on future public safety technologies. *See* Va. Code Ann. § 56-484.13(B)(2) for the Board's statutory authority.
[85] Report of the Commission, *supra* note 77, at 114.

be deployed to critical traffic areas to prevent extreme congestion and even fatal crashes. The rise of increasingly sophisticated electronics in automobiles enhances the potential impact of an EMP/GMD incident and while a car could serve as a natural faraday cage, in some cases vehicles in operation could experience a failure or crash.[86] As electronic vehicles become more prominent, they are especially vulnerable to an EMP/GMD incident. Methods of mass transportation such as subways and trains that utilize long metal tracks would be severely affected by an E3 pulse essentially disabling these forms of mass transit.[87] Current blockers could help mitigate the effect of an E3 pulse on mass transit but would likely be costly to install and require temporary shutdown of services to completely harden the transit system. State officials should engage in outreach programs with federal and local officials, including traffic engineers, to analyze the effects of an EMP/GMD on traffic signals, vehicle damage, and traffic congestion. Additionally, states should work in tandem with cities and counties to formulate recovery plans, including emergency clearing of traffic congestion and ensuring spare traffic control parts are locally available.[88]

VDEM and other emergency response officials should first look to historical instances of large-scale disaster responses such as Hurricanes Katrina and Andrew to properly plan for the impact of a potential EMP/GMD incident on food supplies. In localized disasters such as Hurricane Andrew, as local food supplies become quickly depleted, neighboring areas unaffected by the disaster would ideally quickly step in to provide emergency food, water, and medical supplies.[89] In the event of a localized EMP/GMD incident, emergency response officials would likely look to beyond the blast radius and seek emergency supplies from groups on the fringes of the incident. The modern food supply infrastructure is heavily dependent on electronics including refrigeration meant to preserve food being shipped from around the country. The distribution system is a vulnerable chokepoint in the food supply chain because modern supermarkets typically carry only enough food to support the local population for one to three days.[90] Regional food warehouses support local supermarkets and typically have a food supply to

[86] Report of the Commission, *supra* note 77, at 115; George Lane, *Effects of and Responses to EMP*, Center for Homeland Defense & Security, (Mar. 23, 2017), https://www.chds.us/ed/resources/uploads/2010/05/2017_HS_Summit_Lane_Electromagnetic_Pulses.pdf.
[87] Lane, *Effects of and Responses to EMP*.
[88] Report of the Commission, *supra* note 77, at 127.
[89] *Id*. at 130.
[90] *Id*. at 133.

support a multicounty area for about a month.[91] The EMP Commission found these warehouses to be the best near-term defense against a food shortage in the immediate aftermath of an EMP/GMD incident.[92] Regional food warehouses could be a prime candidate for microgrid technology but should at least have sources of robust backup power. While DHS and the USDA manage federal food stockpiles, Virginia might consider developing supplemental food stockpiles of nonperishable goods as well as water across the Commonwealth.

Conclusion

Ultimately, preparation and response for an EMP/GMD incident largely falls upon the federal government. Some of the easiest and most cost-effective steps towards mitigating the potential effects of an EMP/GMD incident can be taken unilaterally by the private sector without any need for government intervention or support (i.e. faraday cages, shielded cables, and reserve supplies.). The biggest and most immediate impact Virginia can have is working with local officials to engage in a dialogue with communities regarding the nature of an EMP/GMD threat and best course of action following an incident. Potentially the most drastic course of action a state could take is using its authority to regulate the power grid's local transmission and distribution system to require utilities harden their grid infrastructure with current blockers and similar protective shielding equipment. However, legislation requiring enhanced grid hardening has largely stalled in the states where bills have been introduced. The best course of action for states seeking to mitigate the potential effects of an EMP/GMD incident may be encouraging and incentivizing the development of microgrids for critical infrastructure. Microgrids not only improve grid resiliency through their self-sufficiency but can also reduce costs and help certain states meet their emissions reduction goals by incorporating more renewables into the grid. Strong opposition from utilities may prevent the widespread deployment of microgrids but there is space for all stakeholders to work together to enhance the resiliency of critical infrastructure and government facilities.

[91] *Id*.
[92] *Id*.

APPENDIX A [93]

Table 1. EMP versus GMD Characteristics

Attribute	EMP	GMD
Cause	Adversarial threat	Natural hazard
Warning	Strategic: unknown Tactical: none to several minutes	Strategic: 18 to 72 hours Tactical: 20 to 45 minutes
Effects	*E1:* High peak field – quick rise time *E2:* Medium peak field *E3:* low peak field, but quicker rise time and higher field than for GMD (possibly 3 times higher)	No comparable E1 wave forms No comparable E2 wave forms *E3:* low peak field – fluctuating magnitude and direction
Duration	*E1:* less than a 1 microsecond *E2:* less than 10 millisecond *E3 Blast:* ~10 seconds *E3 Heave:* ~1 – 2 minutes	No comparable E1 wave forms No comparable E2 wave forms *E3:* hours
Equipment at Risk	*E1:* telecommunications, electronics and control systems, relays, lightning arrestors *E2:* lightning: power lines and tower structures – "flashover", telecommunications, electronics, controls systems, transformers. *E3:* transformers and protective relays – long run transmission and communication - generator step-up transformers	*E3:* transformers and protective relays – long-haul transmission and communications – generator step-up transformers
Footprint	Regional to continental depending on height of burst	Regional to worldwide, depending upon magnitude
Geographic Variability	Can maximize coverage for E1 or E3 *E3*: intensity increases at the lower latitudes and as distance from ground zero is decreased or as yield is increased	*E3:* intensity increases near large bodies of water and generally at higher latitudes although events have been seen in southern latitudes

[93] EMP Resilience Action Plan, *supra* note 1, at 4.

APPENDIX B [94]

Table 3.16-2: Critical Facilities at Risk from Solar Storms

Critical Facility Use	Number at Risk from Solar Storms
Airfield	12
Animal Health	27
Armory	39
Childcare	10
Communications	76
Emergency Operations Center	1
Fire Service/Support/Suppression	35
Food Service/Storage	88
Fuel Storage/Delivery	516
Hazardous Materials Storage	433
Medical Services/Support/EMS	128
Public Safety/Security	200
Research	178
Special Populations Housing / Shelter	27
Utilities	650
Total:	**2,420**

[94] Va. Hazard Mitigation Plan, *supra* note 5, at Sec. 3.16 pg. 5.

APPENDIX C [95]

Table 1. Four EMP Protection Levels for Infrastructure and Equipment

Level 1: Lowest cost; longer mission outages permitted	**Level 2: Only hours of mission outages are permitted**	**Level 3: Only minutes of mission outages are permitted**	**Level 4: Only seconds of mission outages permitted**
• Unplug power, data, and antenna lines from spare equipment where feasible. • Turn off equipment that cannot be unplugged and is not actively being used. • Use at least a lightning rated surge protection device (SPD) on power cords, antenna lines, and data cables; maintain spare SPDs. • Have either EMP protected backup power or a generation source that is not connected to the grid with one (1) week of on-site fuel or equivalent (e.g., renewable source). • Wrap spare electronics with aluminum foil or put in Faraday containers. • Use priority phone services like GETS, WPS (for cell phones), and TSP; join SHARES if applicable (see Appendix C). • Consider land mobile radios with standalone capabilities, HF radios, and FirstNet. • Store one week of food, water, and other supplies for personnel. • Use battery operated AM/FM/NOAA radios to receive Emergency Alerts.	In addition to Level 1 ... • Use EMP-rated SPDs on power cords, antenna lines, and data cables to protect critical equipment. • Use on-line/double-conversion uninterruptible power supplies (UPS) or a high quality line interactive UPS. • Use fiber optic cables (with no metal); otherwise use shielded cables, ferrites, and SPDs. Note: shielded racks, rooms or facilities may be more cost-effective than hardening numerous cables. • Use EMP protected backup power that is not vulnerable to EMP coupled through the power grid. • Implement EMP protected, high frequency (HF) voice and email for long-distance communications. • Consider geosynchronous (GEO) orbit satellite services, like BGAN. Avoid low-earth orbit (LEO) satellite services. Use terminals that are EMP resilient. • Consider shortwave radio for situational awareness.	In addition to Level 2 ... • Use International Electrotechnical Commission (IEC) EMP and IEMI protection standards (IEC SC 77C series, see Appendix F). • Shielding should be 30+ dB of protection through 10 GHz. • Use EMP shielded racks, rooms, or facilities to protect critical computers, data centers, phone switches, industrial and substation controls and other electronics. • Use "Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures" from EMP Commission for grid and undersea cable protection planning. Use 85 V/km for CONUS E3 threat. • Use EMP tested SPDs and equipment. • Institute IEC level hardness maintenance & surveillance (HM/HS). • Have 30 days of EMP protected power/fuel. • Store 30 days of food, water, and critical supplies and spares. • Use time-urgent EMP resilient comms, like X, Ku and Ka satellite, and either HF groundwave or Automatic Link Establishment (ALE) HF.	In addition to Level 3 ... • Use Military EMP Standards (like MIL-STD-188-125-1 and MIL-HDBK-423), and 80+ dB hardening through 10 GHz. • Use EMP shielding in rooms, racks, and buildings as needed to protect critical equipment. • Use EMP protected double-door entryways. • Validate per Military guidelines, like Test Operations Procedure (TOP) 01-2-620 HEMP. • Have 30+ days of Military Standard protected power and fuel, plus alternate generation source (renewables preferred). • Consider double surge protection on critical external lines entering EMP protected areas. • Consider using communications systems/networks that are designed to meet Military EMP standards, like: Advanced EHF (AEHF) satellite, EMP protected fiber optic networks, and EMP protected radios. • Institute ongoing Military Standard HM/HS programs.

Note: These guidelines do not endorse any referenced product, company, service, or information external to DHS.

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Guidelines are subject to change and only represent the views of the NCC.

[95] *EMP Protection and Resilience Guidelines*, *supra* note 19.