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STRATEGIC PRIMER: ELECTROMAGNETIC THREATS

CURRENT CAPABILITIES AND EMERGING THREATS

EMP THREAT & NATIONAL SECURITY

The American Foreign Policy Council (AFPC) is dedicated to advancing the prosperity and security of the United States. AFPC's Defense Technology Program launched the Strategic Primer initiative to educate Congressional staffers (and the general public) on technologies that affect U.S. national security. The Primers depict balanced representations of the potential benefits and limitations of a particular technology, its history and uses, and potential threats posed by adversarial use of the technology.

This work seeks to provide insights into the electromagnetic threats to U.S. security, particularly from a nuclear generated Electromagnetic Pulse attack, and public policy responses to them. The Primer provides a succinct and informative background of electromagnetic threats, U.S. protections and offensive capabilities of both the U.S. and our adversaries, it also discusses threats posed by EMP, and offers policy recommendations.

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> "The EMP threat is as real as the Sun and as inevitable as a solar flare."[1]
>
> **- R. James Woolsey**
> Former Director of the CIA

WHAT IS AN ELECTROMAGNETIC PULSE (EMP)?

In 2008, the Congressional Research Service, a public policy research arm of the United States Congress, defined Electromagnetic Pulse (EMP) as "an instantaneous, intense energy field that can overload or disrupt at a distance numerous electrical systems and high technology microcircuits, which are especially sensitive to power surges."[2] An electromagnetic event can develop as a result of natural causes, such as a coronal mass ejection or solar flare from the sun, or as a result of a nuclear weapon detonated at high altitudes. In either scenario, the interaction between the Earth's magnetic field and the high-energy particles from space weather or a nuclear EMP can result in serious damage to unhardened electrical infrastructure across large swathes of territory. An EMP can also be generated by portable high-power electromagnetic devices known as radiofrequency weapons (RFWs) or by high-power microwave (HPM) weapons that can damage electronic systems over ranges from meters to kilometers. This work primarily focuses on the dangers of nuclear EMP, which poses the greatest risks to the United States.

WHY IS THE U.S. AT RISK?

The U.S. has become an increasingly networked society. The American economy has benefited immensely from the internet, the use of GPS and associated communications systems, and a far reaching electric grid that spans the country. However, increased dependency on microelectronics and connected devices that are not effectively shielded across infrastructure sectors (including telecommunication, banking, electric, transportation, and other critical industries) has left the U.S. vulnerable to electromagnetic events, particularly nuclear EMPs.

ADDRESSING THE THREAT

Notwithstanding the convening of a commission in 2002 to assess the EMP threat and suggest mitigating actions, there has as yet been a dearth of legislation and concrete action on the part of Congress. While it can be argued that the threat from a hostile nation state detonating a nuclear device may be low, the proliferation of high power electromagnetic weapons that can cause localized EMPs is growing. A devastating solar flare event, meanwhile, is inevitable. It is therefore imperative that the U.S. put in place protective measures to increase its resilience against electromagnetic threats, whatever their origin.

EMP OVERVIEW

Electromagnetic events resulting from a nuclear EMP or a geomagnetic disturbance (GMD) caused by space weather are a threat because the U.S. is now a deeply technological society. While no nuclear EMP attacks have occurred to date, over the past 50 years a number of intermediate-level space weather events and radiorequency weapon events have provided significant insights into the severe consequences that would result from a major EMP event. From the disabling of statewide electrical grids to a disruption of banking networks, the physical and monetary damage caused by limited EMP effects to date have been significant, yet they are nothing in comparison to the inevitable far-reaching damage that could occur from a major solar storm or high-altitude nuclear burst. Vulnerability to EMP events will only increase as the U.S. economy continues to integrate and modernize. Yet, the threat from an EMP has become an unnecessarily partisan issue in recent years, despite credible warnings by the U.S. military and independent government agencies.

> **"Given the interdependency among infrastructure sectors, an EMP or major GMD event that disrupts the electric grid could also result in potential cascading impacts on fuel distribution, transportation systems, food and water supplies, and communications and equipment for emergency services, as well as other communication systems that utilize the civilian electrical infrastructure."**[3]
>
> - **Government Accountability Office**, an independent, bipartisan agency known as the "congressional watchdog"

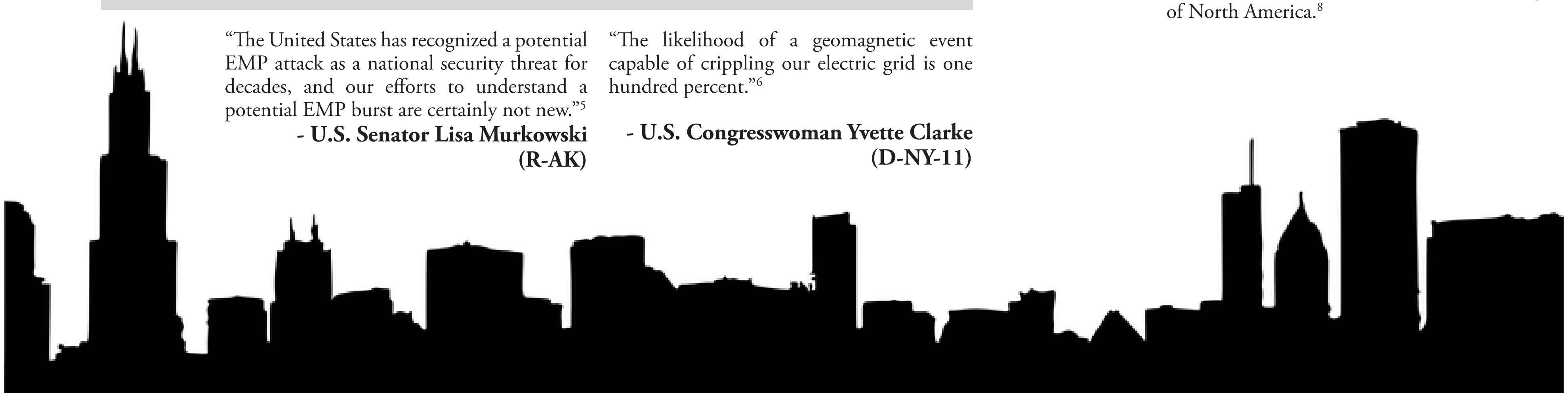
> **"[Solar storms or a large EMP event] impact could be big – on the order of $2 trillion during the first year in the United States alone, with a recovery period of 4 to 10 years."**[4]
>
> - **Dr. John Holdren,** Assistant to President Obama for Science and Technology, Director of the White House Office of Science and Technology Policy (03/19/09 - 01/20/17)

"The United States has recognized a potential EMP attack as a national security threat for decades, and our efforts to understand a potential EMP burst are certainly not new."[5]

- U.S. Senator Lisa Murkowski (R-AK)

"The likelihood of a geomagnetic event capable of crippling our electric grid is one hundred percent."[6]

- U.S. Congresswoman Yvette Clarke (D-NY-11)



WHAT ARE THE CONSEQUENCES OF AN EMP?

An EMP event occurring above the United States could cause severe damage to critical communication, food, electricity, transportation, and space systems infrastructure. Brandon Wales, the Director of the Homeland Infrastructure Threat and Risk Analysis Center for the Department of Homeland Security, has stated: "Overall, EMP in its various forms can cause widespread disruption and serious damage to electronic devices and networks, including those upon which many critical infrastructures rely, such as communication systems, information technology equipment, and supervisory control and data acquisition, commonly known as SCADA modules. Secondary effects of EMP may harm people through induced fires, electric shocks, and disruption of the transportation and critical support systems, such as those at hospitals or sites like nuclear power plants and chemical facilities. EMP places all critical infrastructure sectors at risk. The interdependent nature of all 18 critical infrastructure sectors complicates the impact of the event and recovery from it."[7] An EMP burst just 30 miles above the Earth's surface would have an effect radius of 480 miles, while one 300 miles high would have an effect radius of 1,470 miles, covering most of North America.[8]

WHO ARE THE THREAT ACTORS?

In the context of nuclear EMP, the relevant threat actors are those countries that have both shown hostility toward the United States in the past and also have access to ballistic missiles and nuclear weapons. Countries with the capability to exploit EMP effects for military gain via high-altitude nuclear detonations or high-power microwave (HPM) weapons include Russia and China. They may also include North Korea, which has declared the creation of a "super-powerful EMP attack" capability to be a "strategic goal," and which in September 2017 publicly discussed a potential atmospheric nuclear test.[9] Other rogue states, such as Iran, as well as extremist organizations like the Islamic State (ISIS), now have access to portable EMP devices (a.k.a. radiofrequency weapon (RFW) or HPM weapons) with effective ranges from meters to kilometers that could debilitate electronic-controlled infrastructures of building or entire cities.

In addition to EMP attacks, it is necessary for the United States to guard against GMDs from the sun. Dr. John Holdren, who served as Science Advisor to President Obama, stated that "From sporadic solar flares to ethereal shimmering aurora, manifestations of severe space weather have the power to adversely affect the integrity of the world's power grids, the accuracy and availability of GPS, the reliability of satellite-delivered telecommunications and the utility of radio and over-the-horizon radar. Space weather can affect human safety and economies anywhere on our vast wired planet, and blasts of electrically-charged gas traveling from the sun at up to five million miles an hour can strike with little warning." Such a natural electromagnetic event could cause extreme damage to unhardened U.S. infrastructure. [10]

U.S. MILITARY CONCERNS

U.S. MILITARY EMP VULNERABILITIES

The threat of an EMP event does not exist in a vacuum. Although EMP could potentially have crippling effects on U.S. civilian electrical infrastructure, the American citizenry is not the only sector of society that must consider the effects of an EMP. The U.S. Department of Defense (DoD), the single largest energy consumer in the world, relies on civilian infrastructure for 99% of its electricity needs.[11] Though the DoD is taking active measures to increase its energy resilience—such as investing in microgrid technology, renewable power, and increased energy efficiency—these initiatives are still in their infancy. Backup power for DoD critical infrastructure remains woefully inadequate, with sparsely located diesel generators offering the bulk of back-up generation.[12] Degradation of the civilian electric infrastructure would, therefore, leave the military seriously hampered in its ability to defend our homeland.[13] Energy security, reliability, resilience and redundancy must, by necessity, be a top priority for the U.S. defense community. In addition to this indirect threat to the military, localized, smaller EMP weapons can wreak havoc on military equipment on the battlefield, debilitating critical electronics in many current mission-critical devices, including radar installations, drones, guided missiles, manned aircraft, and communications/data networks.

UNDERSTANDING DOD EMP RESILIENCY

The U.S. military has been aware of the EMP threat for years. In 1990, the Department of Defense released the first edition of its guidance for protection against EMP events, titled *High-Altitude Electromagnetic Pulse (HEMP) Protection For Ground-Based C3I Facilities Performing Critical, Time-Urgent Missions*.[14] This document served as a comprehensive guide for all DoD units on technical protection measures for critical ground-based facilities that provide control, command, computer, and intelligence missions.

The Department of Defense (DoD) is responsible for setting policy on Chemical, Biological, Radiological, and Nuclear (CBRN) Survivability, requiring that:

- "The force will be equipped to survive and operate in CBR or nuclear environments as a deterrent to adversary use of weapons of mass destruction against the United States, its allies, and its interests consistent with the DoD Strategy for Countering Weapons of Mass Destruction."[15]
- "Mission-critical nuclear command and control (NC2) communications system equipment, other mission-critical National Leadership Command Capability (NLCC) systems as required, and nuclear and EMP-survivable MCS must be nuclear hardened, have a hardness assurance (HA) program, and have a continuing hardness maintenance and hardness surveillance (HM/HS) program."[16]

The DoD has recognized the existential threat posed by nuclear EMP weapons, and is beginning to acknowledge the very real threat of smaller, portable weapons of similar design. To this end, the Office of the Secretary of Defense released a memo in 2011 on the subject of DoD survivability against Nuclear Weapons Effects (NWE) and electromagnetic pulse. In it, the Department emphasized that progress has been made since 2009 on the evolution of military readiness and defense in this domain.[17] "[The] Army possesses an improved process for independent review of survivability, the Air Force committed resources for testing major platforms for High Altitude EMP (HEMP) protection, and the Navy implemented a requirements review process."[18] Additionally, U.S.

Strategic Command (STRATCOM) has attempted to identify critical assets in need of protection, and has also begun assessing their survivability in the face of such a threat.[19] Support agencies such as the National Nuclear Security Administration have received directives and funds to supplement the newfound processes outlined in the report in each main branch of the armed services.[20] The Department of Homeland Security has undertaken an analogous effort to launch science and technology programs relevant to understanding the optimal methods to facilitate domestic response and recovery from such an attack.[21]

In 2015, the North American Aerospace Command (NORAD) and U.S. Northern Command decided to take precautionary measures against EMP and general nuclear weapon effects and announced plans to shift resources and communications equipment back to the Cheyenne Mountain Complex. That bunker was built in the 1950s by the military to withstand attacks by long-range Soviet Union bombers. Admiral William Gortney, Commander of NORAD, stated, "because of the very nature of the way that Cheyenne Mountain is built, it's EMP-hardened."[22] NORAD and U.S. Northern Command entered into a 10-year contract with the Raytheon Company for $700 million to help in the transition and assessment of air, missile, and space threats to the complex.[23] Clearly, the potential EMP threat has had an impact on military practices and the importance of shielding vital equipment.

MISSILE DEFENSE

EMP threats posed by the use of intercontinental ballistic missiles (ICBMs) by nations such as Iran and North Korea represent an enormous security risk to the safety, sovereignty, and overall well-being of the United States and American allies around the world. Additionally, many states and groups already possess short to medium range offensive missile systems capable of delivering nuclear EMP attacks. Current U.S. ballistic missile defense systems (BMDs) employ a multi-layered approach designed to address threats through the use of sea, land, and UAV platforms. However, in the scenario of a missile or satellite carrying a nuclear weapon, there is no guarantee that current surface-based missile defense systems will be able to engage the threat prior to a high altitude nuclear detonation. Moreover, existing missile defenses do nothing to counter electromagnetic events resulting from space weather.


METRIC
MIL-STD-188-125
26 JUNE 1990

MILITARY STANDARD

HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) PROTECTION FOR GROUND-BASED C4I FACILITIES PERFORMING CRITICAL, TIME-URGENT MISSIONS

for Common Long-Haul/Tactical Communication Systems

AMSC N/A FSC SLHC

FUTURE RISKS AND CONCERNS

The U.S. military had been proactive in understanding the threat posed by EMP, and in taking steps to address it. However, the problem has not been addressed comprehensively, and coordination and communication challenges persist within the defense and policy communities. Specifically, the Secretary's memorandum discusses operational concerns such as Air Force non-concurrence with new aircraft EMP standards, the confusing and burdensome fragmentation of responsibilities, the lack of prioritization of mitigation efforts—including assessing the end-to-end survivability of critical communications networks and command and control systems—the lack of holistic engagement within the military, and conflicting Missile Defense Agency criteria.[24] These, among other concerns, represent room to grow in the DoD's effort to protect against the EMP threat. Of all possible policy positions to consider, creating a unified set of criteria, vocabulary, and procedures across the military remains of highest priority.

THREAT SCENARIOS

An electromagnetic event impacting the United States is inevitable. There are three types of threats that the country could face, and should consequently prepare for:

LARGE SCALE NATURAL ELECTROMAGNETIC THREAT

A significant natural electromagnetic event, referred to as a geomagnetic disturbance (GMD), could be initiated by space weather. This includes solar flares and coronal mass ejections (CME). CMEs generate vast clouds of plasma from the sun which then impact the Earth's magnetic field. Solar Flares occur when the "plasma gets disconnected from the magnetic fields when the fields come together," according to one description. "Then particles in the hot plasma can speed up greatly and send powerful radiation into space in the form of solar flares."[25]

Solar flares and CMEs represent the largest, most powerful "explosions" that can occur in our solar system, and release "the power of around one billion hydrogen bombs."[26] Ejections of charged gas from the sun can happen at any time, but their frequency ebbs and flows in roughly 11-year cycles. The last peak happened around 2011. Strong solar storms can occur at any time during this 11 year cycle. However, as America becomes ever more reliant on technology, the risks associated with such a disruption become greater with every passing year.[27] Furthermore, massive GMD events are believed to occur roughly every 100 to 200 years, and it has been approximately 98 years since the last high amplitude solar storm (the so-called "Railroad Storm" of 1921).

LARGE SCALE NUCLEAR EMP THREAT

Large-scale EMP threats can be categorized by their method of delivery. High-altitude EMP (HEMP) results from a nuclear detonation, delivered by ballistic missile or fractional-orbital satellite, occurring above an altitude 40 km. The range and amplitude of the resulting electromagnetic field is a function of the weapon's payload and the height of the burst. For example, a powerful nuclear detonation 400 km over Kansas would likely adversely affect the entire continental U.S. However, if a nuclear device were detonated near the ground, the effective footprint of the EMP would be less than five miles in diameter, due to the limited range of gamma rays in the dense surrounding air. Nevertheless, currents resulting from a surface burst could affect systems out to as many as 80 km from the burst.

Iran, Russia, North Korea, and China have all discussed employing EMP weaponry in their military doctrines. Moreover, these countries have information on how to construct low-yield "super" EMP weapons, and have openly discussed using them against the United States.[29 30 31]

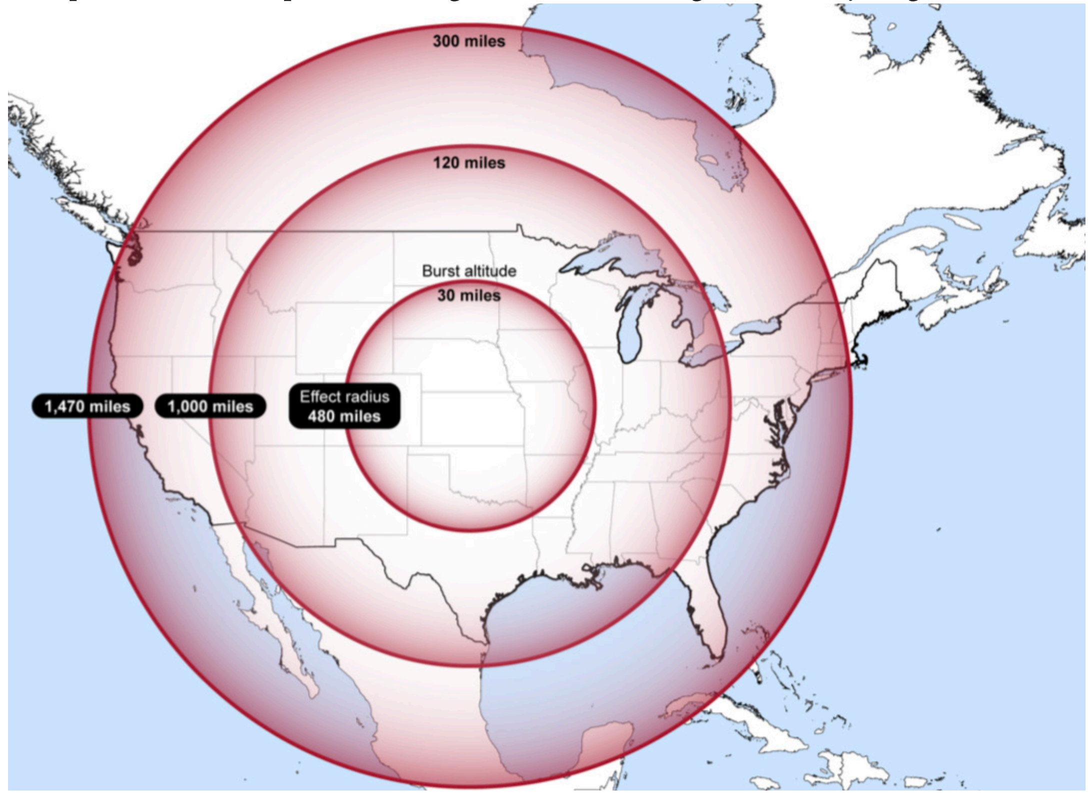
HEMP events result in three pulse components affecting the infrastructure below:[32 33]

ELECTROMAGNETIC THREAT EFFECTS[34]

THREAT	SUSCEPTIBLE SYSTEM
HEMP E1 (fast pulse)	Long-line and short-line electrical and electronic systems
HEMP E2 (similar to lightning)	Electrical and electronic systems not protected from lighting
HEMP E3 (slow pulse)	Long-line and network systems including electric power grid, terrestrial and undersea comm. lines and pipelines
Geomagnetic Disturbance (similar to E3)	Long-line and network systems including electric power grid, terrestrial and undersea comm. lines and pipelines

(See Appendix for full EMP attack vs GMD event comparison)

Example of Estimated Impact Area of High-Altitude Electromagnetic Pulse, by Height of Burst

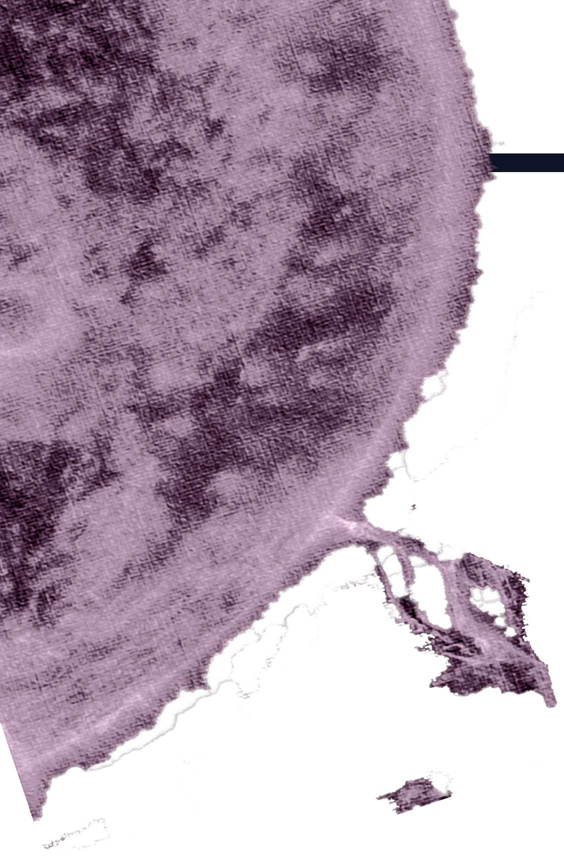


Source: Gary Smith, "Electromagnetic Pulse Threats," Testimony before the House Committee on National Security (July 16, 1997) MapInfo (map). | GAO-16-243

SMALL SCALE ELECTROMAGNETIC THREAT

Existing non-nuclear electromagnetic weapons have effective ranges spanning from meters to kilometers, depending on their size and effective output power. Damage and disruption to electronic systems and networks inside this radius could be significant. Boeing and the U.S. Air Force Research Laboratory (AFRL) Directed Energy Directorate have developed an EMP missile known as the Counter-electronics High-powered Microwave Advanced Missile Project (CHAMP). The CHAMP missile is capable of emitting "bursts of high-powered energy, effectively knocking out the target's data and electronic subsystems." It "allows for selective high-frequency radio wave strikes against numerous targets during a single mission."[35]

With smaller radio frequency weapons, an ambitious terrorist with sufficient knowledge of the inner workings of the electrical grid could conceivably black out a major city.[36] In addition, recent small-scale electromagnetic technologies have further decreased in their size and the amount of power required for their use. An extremely small EMP device powered by AA batteries is now capable of "de-programming" circuitry in a computer from 15 meters away. Such technology utilizes a "flux compression generator," consisting of a chemical bomb or battery wrapped in a copper coil contained within a tube. When energized by capacitors, the resulting chemical explosion can produce a targeted EMP effect, leading experts to describe such technology as an EMP "gun."[37]



TIMELINE

Since the first recorded instance of electromagnetic disruption in 1859, the destructive effects of GMD and HEMP have been demonstrated on several occasions:

1859
AUGUST 1859 SOLAR STORM STRIKES US & EUROPE

One of the earliest natural GMD events on record took place in late August of 1859. The sun emitted massive colorful auroras of light and the northern lights moved and were seen at the equator. This solar flare had the power of 10 billion atomic bombs, and projected electrified gas and subatomic particles at the Earth, resulting in a geomagnetic storm. Powerful electromagnetic currents rendered telegraphs, one of the very few long-line network systems of that time, inoperable. Telegraph systems worldwide went haywire. Spark discharges shocked telegraph operators and set the telegraph paper on fire. Even when telegraphers disconnected the batteries powering the lines, aurora-induced electric currents in the wires still allowed messages to be transmitted. Ice core samples show this to be the most powerful solar flare event in 500 years.[38]

1921
MAY 13TH 1921 GEOMAGNETIC STORM STRIKES NORTHEASTERN US

On May 13th of 1921, a 94,000 mile long sunspot unleashed a massive solar flare. This flare knocked out the entire switching and signal station of the New York City Central Railroad below 125th Street, destroyed the Central New England Railroad station, and burned out a telephone station as far away as Sweden. The Northern Lights were visible as far south as Pasadena, California.[39] The event became known as the "Railroad Storm."

1961
1961-1962 SOVIET UNION K PROJECT NUCLEAR TEST SERIES

The Soviet Union carried out multiple lower atmosphere nuclear detonations above Kazakhstan in 1961 and 1962. In 1994, at the EUROEM conference, Vladimir Loborev delivered a paper discussing the EMP effects that occurred in Kazakhstan as a result of this testing. Loborev detailed the damage done to civilian electronic infrastructure, including how the blasts knocked out a major 600-mile power line running from Astana to Almaty.[40]

1962
JULY 9TH, 1962 OPERATION FISHBOWL: STARFISH PRIME NUCLEAR TEST

America launched a 1.45-megaton hydrogen bomb from Johnson Island as part of an exercise dubbed Operation Starfish. The Starfish Prime test was designed to determine if it was possible to disrupt the Van Allen belt – a zone of charged particles held in place around the Earth by the planet's magnetic field—and, if so, the resulting effects on satellites and radio transmissions. When the detonation took place, the effects were immediate. The explosion led to electrical disturbances as far as 900 miles away on the Hawaiian island of Oahu, ranging from telephone outages to radio blackouts to unusual behavior from electrical devices.[41] The damage to electrical and electronic systems was unexpected, as was the magnitude of the electromagnetic pulse. The U.S. military had deployed instruments to measure the size of the electromagnetic pulse. However, the pulse overwhelmed the instrumentation.[42]

1963
AUGUST 5TH, 1963 JFK SIGNS LIMITED NUCLEAR TEST BAN TREATY

In July 1963, President John F. Kennedy and Premier Nikita Khrushchev signed the Limited Nuclear Test Ban Treaty, banning atmospheric and exo-atmospheric nuclear testing. This signaled the end of large-scale nuclear EMP testing.[43]

1989
MARCH 13TH, 1989 GEOMAGNETIC STORM STRIKES QUEBEC

In 1989, an unexpected geomagnetic storm caused the electric grid of the Canadian province of Quebec to collapse within 120 seconds. This left six million people without power for 12 hours, and caused roughly 200 power grid problems across the United States.[44]

2003
OCTOBER 28TH-29TH HALLOWEEN SOLAR STORMS

In 2003, two intense storms traveled from the Sun to Earth in just 19 hours, causing a blackout in Sweden and affecting satellites, broadcast communications, airlines and navigation.[45]

RUSSIA

BACKGROUND/EMP DOCTRINE

Russia and the former Soviet Union have understood the physics and system-debilitating effects of a nuclear generated EMP for decades. In 1949, the Soviet Union detonated its first atomic bomb. As early as 1957, the USSR successfully tested its first intercontinental ballistic missile, and only a few years later its arsenal included both short range and intercontinental ballistic missiles. In the 1960s, the USSR began experimenting with EMPs after they were discovered as a serious collateral effect of nuclear detonations in Kazakhstan.[46] By 1970, the USSR had land-based intercontinental ballistic missiles capable of traveling 7,000 nautical miles while carrying a 25 megaton nuclear warhead. Since then, Russia's arsenal of nuclear and ballistic missile weaponry has expanded—and consequently, so has the EMP threat it poses. [47] During the late 1990s, U.S. involvement in the Yugoslav war, which ran counter to Russian interests, precipitated Russian officials to threaten potentially catastrophic response, with one leader warning that "we have the ultimate ability to bring you down"—a thinly-veiled reference to an EMP attack.[48] This discussion helped the U.S. realize that EMP attack represents a critical part of Russia's military doctrine, and prompted Congress to create the *Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*.[49] The potential threat was further highlighted in February 2004 when Colonel-General Yuri Baluyevsky, then-chief of the Russian General Staff and Deputy Defense Minister, stressed that if "one reads between the lines" of the first published military doctrine of the government of Russian President Vladimir Putin, "the principal enemy is America and the entire NATO."[50]

Institutions that work for or in the Russian government have discussed ways to counter growing American presence and put up obstacles to them. In 1995, a military think-tank called INOBIS, which serves the Russian General Staff, wrote a paper titled *Conceptual Provisions of a Strategy for Countering the Main External Threats to Russian Federation National Security* in which it recommended that Russia deliberately proliferate missile and nuclear technology to nations hostile to the United States as a way of balancing American power and thwarting Washington's perceived efforts to establish a "new world order."[51]

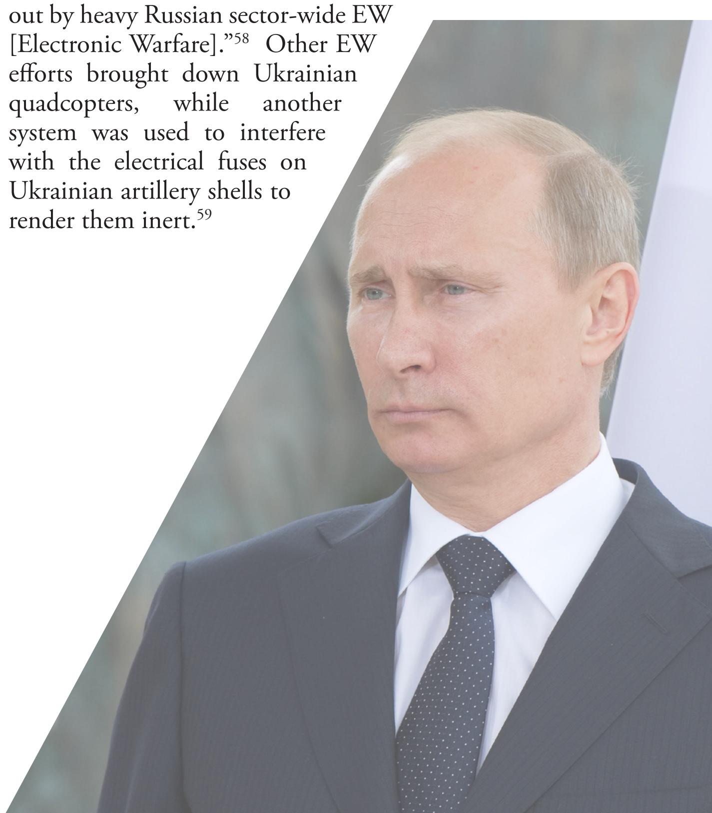
More broadly, EMP attacks and more traditional nuclear threats differ in the context of mutually assured destruction, a concept at the center of U.S.-Russia deterrence policy. While both countries recognize that a nuclear strike on one will lead to an equally destructive retaliation on the part of the other, this is not the case in an EMP attack scenario. As EMP attacks do not result in direct loss of life, only vital infrastructure, it is difficult to predict what a proportional response would be to such an event, creating further uncertainty regarding the wide-reaching foreign policy implications of EMP research, development, and implementation. In addition, the ability to damage or destroy military infrastructure devoted to the use or implementation of conventional defense measures could further shift the balance of power; mutually assured destruction would then be threatened, as one side may have the capability to act without a conventional proportional response from the other.[52]

Additionally, prominent Russian military scholar Vladimir Slipchenko, in his 2005 book "Future War," discussed the development and nature of modern "sixth-generation warfare," wherein high-precision, reconnaissance strike systems will become the dominant military tool in stand-off warfare. He argued that, as war continues to evolve, and defense technology becomes increasingly efficient, the economy of a country will become increasingly important. This is because funding the research, development, and implementation of modern, high-precision systems and the information channels by which to operate them requires a robust, cooperative military industrial complex.[53] In turn, Slipchenko predicted, this economy must by necessity be underpinned by a healthy, wide-reaching infrastructure.[54] With the advent of the digital age, such foundational infrastructure is grounded in the civilian electrical grid. In the context of an emerging Russian EMP threat, this suggests that economic and infrastructure-oriented targets will become a higher priority for destruction—and that exploitation of high-altitude burst EMP represents one of the most effective strategies in this regard.

METHODS OF EMP ATTACK

Based on the recommendations of military analysts, Russia has built its military force around an "Anti Access/Area Denial" (A2AD) strategy, which involves denying an enemy access to a particular region, or preventing freedom of movement within a designated area.[55] While A2AD includes defensive measures for air and sea, it also involves the use of offensive strike weapons, such as different types of missiles (short and medium range ballistic, and cruise) and guided munitions that could be employed in an EMP attack against American allies and the U.S. homeland.[56]

One reporter has posited that Russian forces used an EMP weapon to disable communication among Chechen rebels in the early 2000s, when "Russian military forces fired an EMP mortar round that deployed a small metal-coated parachute. As it floated to earth, the EMP energy burst was reflected downward by the underside of the parachute and also spread by the cords attached to the shell. The result was a cone of anti-electronic energy that disrupted all electronics within its area."[57] The tactical use of EMP weapons is a significant technological advantage and a potential game changer in conventional warfare. More recently, Russia has used electronic warfare in its ongoing conflict with Ukraine. "In the northern section," Lt. Gen. H.R. McMaster, then the Director of the U.S. Army's Capabilities Integration Center, outlined in 2016, "every single tactical radio [the Ukrainian forces] had was taken out by heavy Russian sector-wide EW [Electronic Warfare]."[58] Other EW efforts brought down Ukrainian quadcopters, while another system was used to interfere with the electrical fuses on Ukrainian artillery shells to render them inert.[59]



CHINA 

BACKGROUND/EMP DOCTRINE

China's interest in EMP weaponry is known to date back to at least 1993, when the Chinese State Council Information Office published a white paper on military strategy that specified the importance of the EMP weapon.[60] Subsequently, in 2004, that guideline "was further substantiated, and the basic point for PMS [preparation for military struggle] was modified to winning local wars under conditions of informationization... and aim at building an informationized military and winning informationized wars."[61] China clearly understands the role that electronics play in military technology and is educating its troops on how to engage in environments where technology is degraded—essentially, preparing them to fight when an EMP has been used against them.[62] Chinese publications also refer to asymmetric, or "assassin's mace," weapons that will be used if they need to take Taiwan by force and if America comes to their defense.

A 2012 article by Chinese journalist Lou Xiaoqing notes that such an "assassin's mace" could be an EMP weapon or low-yield nuclear weapon detonated above Taiwan, thereby rendering all defensive military technology useless.[63] Since the People's Liberation Army (PLA) and Chinese government heavily censor sensitive military information, the willingness to allow this article be published may be an indication of the government's desire to insert this line of thinking into the public domain.[64]

Larry Wortzel, one of America's top experts on China and its military strategy, has noted that "[t]here is a serious competition underway between China and the United States to develop and refine EMP weapons, and the PLA is actively working on this area of technology."[65] Since 1999, China has devoted significant resources to the pursuit of EMP weaponry. Beijing's interest in the topic was spurred by the U.S. use of an EMP generator to attack command and control centers in Kosovo in the late 1990s. The official PLA Daily, in describing the event, called the capability a "'knowledge killer' because it destroys command and control and data exchange systems."[66]

In 2001, the U.S. Army National Ground Intelligence Center noted that the Chinese defense establishment had studied how to use electronic pulses to destroy electronics in satellites and weapon systems for sustained periods.[67] This reporting shows that China understands the value of making enemy electronics inoperable, and is diligently working to create the technology by which to do so. China appears to be thinking about EMPs along the lines of radio frequency weapons, high-power microwave and particle beam systems. Furthermore, China is and has been studying the effects of EMP weapons on human personnel.[68]

> **"There is a serious competition underway between China and the United States to develop and refine EMP weapons, and the PLA is actively working on this area of technology."[69]**
>
> **- Dr. Larry M. Wortzel**
> Commissioner, U.S.-China Economic and Security Review Commission

Following the U.S. response to Chinese missile test flights over Taiwan in 1996, Chinese military and political leaders began employing the term "trump card" or "assassin's mace" weapons. As aforementioned, "assassin's mace" weapons describe weapons based on old technology that is used in new or unconventional ways, while "trump card" refers to weapons using new technology developed secretly.[70] In a declassified document, the United States suggests that HEMP or some sort of EMP has been discussed as a possible example of such weaponry. Specifically, there is speculation that a lower altitude detonation (30-40km) could be used against Taiwan, should war occur.[71] This type of attack would be a more intense EMP in a localized area.

China has publicized another military doctrine called "local high-tech warfare under informationalized conditions" that analysts believe represents a key part of its strategy if regional conflicts escalate militarily.[72] For example, if there is an escalation in the dispute over ownership of the Senkaku Islands between Japan and China and the U.S. intervenes, China could be pushed to initiate a High Altitude Electromagnetic Pulse (HEMP) attack over U.S. Pacific military bases.[73]

METHODS OF EMP ATTACK

The idea of an "assassin's mace" written about by Lou Xiaoqing envisions a low-yield nuclear weapon explosion in the atmosphere above Taiwan. From this it is not a significant leap to infer that China has developed low-yield weapons similar to those Russia now claims to have. Additionally, early in 2015 China made a technological breakthrough that could be key to creating an arsenal of EMP weapons, when "the Xian Institute of Optics and Precision Mechanics of the Chinese Academy of Sciences… successfully developed a third-generation X-ray pulsar simulation source."[74] This is seen as a potential power source for a non-nuclear EMP weapon.

Based on publicly available information, it is unlikely that China currently has advanced EMP weaponry aside from ballistic missiles carrying low-yield and normal yield nuclear warheads. However, China has made it a priority to innovate and develop such asymmetric weaponry.

NORTH KOREA

BACKGROUND/EMP DOCTRINE

North Korea has been in the process of developing the ballistic missile systems necessary for an EMP attack for decades. However, the DPRK's nuclear weapons technology is less developed; the first successful nuclear test only occurred in 2006.[75] Over the past two years, however, North Korea has worked tirelessly to miniaturize its nuclear devices in order to fabricate a nuclear warhead that can be paired with its missiles. While it has not spoken often about the use of an EMP, the North Korean regime's military doctrine places emphasis on national security and the military over all else.[76] Its provocative decision to develop and test nuclear weapons at great cost to both its people and its international standing demonstrates the importance that the DPRK attaches to nuclear capability—and, by extension, to EMP weapons.

In his 2017 testimony before the Senate Energy and Natural Resources Committee, Ambassador Henry F. Cooper noted that, over a decade ago, a group of Russian generals was known to be conducting more extensive EMP research than the United States has undertaken to this point. These Russian generals, moreover, confirmed that they had passed information on Russian super-EMP weapon designs to North Korean officials. It is, therefore, conceivable that North Korea's low yield nuclear tests could involve the demonstration of EMP weapon design.[77]

Further evidence of the DPRK understanding of EMP weapons was evidenced after the nuclear test in late November 2017. It was followed by a commonly cited technical report originating from Pyongyang, detailing the, "EMP Might of Nuclear Weapons." The report demonstrates the North Korean understanding of an EMP weapon's potential as evidenced here:

> **"In general, the strong electromagnetic pulse generated from nuclear bomb explosions between 30 kilometers and 100 kilometers above the ground can severely impair electronic devices, electric machines, and electromagnetic grids or destroy electric cables and safety devices…This electromagnetic pulse forms a strong electric field of 100,000 volts per meter when it approaches the ground, and that is how it destroys communications facilities and electricity grids…the discovery of the electromagnetic pulse … in the high-altitude nuclear explosion test process has given it recognition as an important strike method."**[78]

METHODS OF EMP ATTACK

Despite international pressure, North Korea is now actively developing both its ballistic missile program and its nuclear weapon capabilities. North Korea has possessed intermediate range ballistic missile capabilities for years, most conspicuously via the Taeopodong-2, which has an estimated range of 3,400 miles.[79] On July 4, 2017, North Korea successfully tested its first ICBM, the Hwasong-14, which is estimated to have the potential to reach Alaska.[80] On July 28, North Korea conducted its second ICBM test, employing a missile that flew even higher and farther than in its first ICBM trial.[81] Initial indications suggest the missile has a range of up to 10,000 km, making it capable of striking the West Coast of the United States and potentially traveling as far as Chicago or even New York, if launched on a flat trajectory.[82] [83] [84] North Korean state media has declared that this was a repeat test of the Hwasong-14.[85] While the missile still appears to have difficulty with re-entry, reports from the U.S. intelligence community indicate that the DPRK is conducting tests to correct this deficiency.[86] Significantly, a high-altitude burst EMP attack does not require a missile to carry out re-entry.

North Korea appears to have the capability to test small devices, and each nuclear-capable missile is equipped with a payload section about 65cm in diameter, appropriate for a first-generation nuclear missile warhead.[87] The Defense Intelligence Agency (DIA) believes that North Korea will be able to produce a "reliable, nuclear-capable ICBM" program sometime in 2018.[88]

North Korea possesses another delivery system for EMP as well. The DPRK launched two small satellites, the Kwangmyongsong-3 and the Kwangmyongsong-4, into low-earth polar orbits in 2012 and 2016, respectively.[89] These satellites pass over the United States at an altitude of 400 to 500 kilometers. Fractional de-orbiting would be required to reach optimum EMP burst altitudes. However, reports indicate that the Kwangmyongsong-4 is around 200 kg, sufficient to carry a small nuclear device and no re-entry vehicle.

The North Korean EMP threat is no longer simply conjecture or speculation. With the success of its most recent missile launch, North Korea demonstrated that it has the capability to strike anywhere in the continental United States, as well as Alaska and Hawaii.[90] Conventional wisdom holds that the threat of a North Korean nuclear attack is remote, because such action would precipitate a regime-ending response from the U.S. Rather, the North utilizes its nuclear capability as a deterrent, to establish a "balance of terror" with the United States. However, such logic does not apply to the threat of a North Korean EMP attack, since American society and the U.S. military relies on electricity and modern technology to function, while North Korea is far less dependent on electricity.[91] For this reason, an EMP attack would have much more severe consequences for the U.S. mainland than a similar attack would have on North Korea. Indeed, U.S. ally South Korea is responding to this discrepancy, and to the consequent attractiveness of EMP to the DPRK, by hardening its own banking and energy systems against EMP effects.[92]

IRAN

BACKGROUND/EMP DOCTRINE

Electronic warfare is considered one of the pillars of Iranian asymmetric defense.[93] As early as 1998, an Iranian government-linked journal noted highlighting the importance of electronics to the "fate of future wars." "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," it noted. "American soldiers would not be able to find food to eat nor would they be able to fire a single shot."[94] That same year, Iran carried out a ground-to-air test of a ballistic missile from a warship in the Caspian—an event that some interpreted to be a simulated high-altitude EMP detonation.[95]

Iran's defensive strategy against EMP has evolved over the last decade. It underscores the importance of protecting military infrastructure, and the Iranian regime has prudently hardened critical assets. For example, Iran has a key military and research facility, Natanz, that is buried deep beneath the mountains and protected from EMP. Planning for offensive EMP usage, meanwhile, has continued; a 2010 military textbook titled "Passive Defense" openly discusses the destructive capabilities of an EMP attack, while also noting it to be "sharia-compliant."[96] "Iranian military doctrine makes no distinction between nuclear EMP weapons, non-nuclear radio-frequency weapons and cyber-operations," experts have noted. "[I]t regards nuclear EMP attack as the ultimate cyber-weapon."[97]

METHODS OF EMP ATTACK

While Iran is not believed to possess nuclear weapon capabilities, it boasts the largest ballistic missile arsenal in the Middle East.[98] Iran's most common ballistic missiles include the Shahab 1, Fateh-110, Fateh 313, Shabab 2, Shabab 3/Emad/Ghadr, and Sjjil.[99] These have an estimated range between 300 to 2,500 km.[100] Iran also has a cruise missile dubbed the Soumar that has an estimated range of 3,000 km.[101] While none of these weapons can reach the U.S. mainland, they can nonetheless target American allies and U.S. military bases in the Greater Middle East.[102] Additionally, there is evidence that Iran is in the process of developing two intercontinental ballistic missiles (ICBM) with possible ranges greater than 4,000 km or 6,000 km.[103] If Iran is able to weaponize and miniaturize a nuclear device, it will have several missiles in its arsenal capable of delivering the warhead, and thereby the capability to attempt an EMP attack.

Like North Korea, Iran could also conceivably use satellites as an EMP delivery system. Iran placed satellites in orbit in 2009, 2011, 2012, and 2015.[104] These satellites are on south polar trajectories that would, if they contained a nuclear warhead, place an EMP field over the 48 contiguous United States, causing a protracted blackout that could kill millions.[105]

The International Atomic Energy Agency's 2011 report, *Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the Islamic Republic of Iran*, notes that it is likely that Iran already possesses many, if not all, of the necessary components to build an EMP-capable atomic bomb. Additionally, the Iranian regime is deemed to have carried out extensive testing, modeling, and analysis to increase its knowledge of atomic weapons and how to build them.[106] The study notes signs that Iran has specifically considered such a weapon for EMP purposes, detailing that:

> **"...as part of the studies carried out by the engineering groups under Project 111 to integrate the new payload into the re-entry vehicle of the Shahab 3 missile, additional work was conducted on the development of a prototype firing system that would enable the payload to explode both in the air above a target, or upon impact of the re-entry vehicle with the ground....The Agency, in conjunction with experts from Member States other than those which had provided the information in question, carried out an assessment of the possible nature of the new payload. As a result of that assessment, it was concluded that any payload option other than nuclear which could also be expected to have an airburst option (such as chemical weapons) could be ruled out."**[107]

More recent developments indicate that Iran has continued to work on perfecting a ship-based missile capability, which could potentially employ EMP technology. In 2012, Iran reportedly began building a submarine launch missile capable of reaching U.S. bases in the region, which could similarly be armed with EMP technology.[108]

Iran has substantially increased ballistic missile testing in the months since the Joint Comprehensive Plan of Action (JCPOA) was signed in 2015, and has been studying the possibility of using a nuclear warhead with EMP effects as part of its advanced missile technology.[109] Iran is now in the process of developing ships with missile launching capabilities to be deployed with the Iranian fleet in the Caspian Sea.[110] Reports from the Iranian Navy indicate that these ships could be deployed within the next year. However, the Iranian Navy has been known to exaggerate its capabilities.[111] Nevertheless, improvement of its naval capabilities has been an undeniable focus for the Iranian regime. Recent sanctions relief associated with the 2015 nuclear deal may have allowed Tehran to accelerate these plans.

UNITED STATES VULNERABILITIES

As Caitlin Durkovich, former assistant secretary of homeland security for infrastructure protection, has noted to Congress, an electromagnetic pulse attack is "sector agnostic."[112] Because electronics are used in nearly every private and public domain, the EMP threat and the national response simply "cannot be siloed."[113] All technical aspects of an EMP attack, in addition to all infrastructure implications resulting from an EMP attack, cannot be considered in a one-size-fits-all, all-else-being-equal approach. Rather, Durkovich stressed, coordination and inter-agency efforts are imperative in effectively combating the EMP threat.[114] There are many important infrastructure sectors that are vulnerable to an EMP event in the United States, particularly those reliant on digital electronic control systems as well as infrastructure that is dependent on connectivity to long conducting lines. Seven key infrastructures detailed here include the electrical grid, communication, transportation, health and safety infrastructure, food, water and waste, and space systems.

ELECTRICAL GRID

A high altitude nuclear EMP attack, or to a lesser extent a GMD, could have catastrophic effects on the electrical grid, and depending on the altitude could lead to failure across a large geographic section of the country. The electrical grid is the keystone for almost all other critical infrastructure sectors because those sectors are largely dependent on electricity for functioning. As outlined in the EMP Commission's 2004 report, the immediate pulse causes damage to the control and computer systems that carry electricity to customers.[115] That report also warns of serious risk to the transformers and critical electrical power system parts: "A single EMP attack may well encompass and degrade at least 70% of the Nation's electrical service, all in one instant… 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."[116]

COMMUNICATION

Telecommunications is a sector critical to daily use for nearly all people and businesses. Telecom infrastructure, including wireline, wireless, satellite, and radio, is trusted to facilitate all coordination efforts and allow a proper response in the event of an emergency.[118] The wireline (landline) system is arguably the most fragile component in this infrastructure, because long lines are the most efficient collectors of EMP energy. According to the EMP Commission report:

"Each of these four primary systems is unique in their capability to suffer insult from EMP. The wireline system is robust but will be degraded within the area exposed to the EMP electromagnetic fields. The wireless system is technologically fragile in relation to EMP, certainly in comparison to the wireline one. In general, it may be so seriously degraded in the EMP region as to be unavailable.

Protecting Transformers

"Of special concern is the vulnerability to EMP of Extra High-Voltage (EHV) transformers, that are indispensable to the operation of the electric grid. EHV transformers drive electric current over long distances, from the point of generation to consumers (from the Niagara Falls hydroelectric facility to New York City, for example). The electric grid cannot operate without EHV transformers—which could be destroyed by a severe EMP event. The United States no longer manufactures EHV transformers. They must be manufactured and imported from overseas, from Germany or South Korea, the only two nations in the world that manufacture such transformers for export. Each EHV transformer must be custom made for its unique role in the grid. A single EHV transformer typically requires 18 months to manufacture. The loss of large numbers of EHV transformers to an EMP event would plunge the United States into a protracted blackout lasting years, with perhaps no hope of eventual recovery, as the society and population probably could not survive for even one year without electricity."[117]

Low Earth Orbit (LEO) communications satellites may also suffer radiation damage as a result of one or more high-altitude nuclear bursts that produce EMP. The radio communication sub-system of the national telecommunications infrastructure is not widespread, but where it is connected to antennas, power lines, telephone lines, or other extended conductors, it is also subject to substantial EMP damage. However, radio communication devices not so connected or not connected to such conductors at the time of the EMP attack are likely to be operable in the post-attack interval."[119]

TRANSPORTATION

The transportation sector in America is a multidimensional space that includes automobiles, railroad infrastructure, aviation and related ground facilities, and maritime infrastructure.[120] The industry is tied to several others that would be negatively affected as a result of an EMP attack, notably the electric, communications, and fuel sectors.[121] Powering vehicles may prove difficult due to issues with microelectronic components compromised as an effect of EMP. Additionally, "municipal road traffic will likely be severely congested, possibly to the point of wide-area gridlock, as a result of traffic light malfunctions and the fraction of operating cars and trucks that will experience both temporary and in some cases unrecoverable engine shutdown."[122] Without communications, air, port, and rail traffic will likely become impossible, and the respective infrastructure necessary to support them may not function without a power source.

HEALTH AND SAFETY INFRASTRUCTURE

Former House Speaker Newt Gingrich outlined in his Congressional testimony that many of the adverse effects of an EMP attack would fall outside of the scope of what is traditionally considered when discussing the threat. Many of the industries upon which the United States relies require electricity to provide life-essential services. The pharmaceutical and medical industries rely heavily on the implementation and distribution of drugs, some of which require constant refrigeration in order to remain viable.[123] Additionally, hospitals, emergency medical responders, and other groups on the front lines of other humanitarian crises exhibit a similar requirement for constant access to electricity. If an EMP attack were to affect these unprepared areas, the flow of life-saving services, water, and other necessities would stop with the flow of electricity.[124] The interdisciplinary and wide-reaching nature of the EMP problem, therefore requires a coordinated, collaborative solution across multiple government agencies, NGOs, and private industries in order to ensure that a holistic solution can be effectively executed.[125]

FOOD

An EMP attack poses serious problems to America's food supply as the associated infrastructure and distribution networks all rely on the continuous flow of electricity. Since 1900, the U.S. agriculture sector has significantly increased its reliance on technology, and dramatically improved the efficiency of farming.[126] At this time, "less than 2 percent of the population is able to feed the other 98 percent and supply export markets."[127] Without electricity, the ability to harvest and properly distribute food breaks down. The food industry is heavily reliant upon transportation because local stores and warehouses only keep enough food to feed the local population for a few days.[128]

WATER AND WASTE[129]

Traditionally, water infrastructure—including tunnels, pipes, and other water delivery systems—was gravity fed by design. More recently, however, a large portion of this infrastructure has become electricity dependent. The pervasiveness of the electric pump has allowed cities to exist in areas previously uninhabitable due to a lack of gravity fed water. However, disruption of electricity as a result of an EMP attack would cause the failure of any systems reliant on such machinery, including those associated with water purification and delivery. Water sanitization processes, which are vital for human survival, would also be impacted.

SPACE SYSTEMS

In satellites traveling in Low Earth Orbit (LEO), any unhardened electronic components are at major risk of damage from an EMP or space weather. Space systems that both the military and civilian sectors rely upon daily for weather, reconnaissance, communication, and GPS navigation could be compromised during a HEMP attack.[130] Equally important is the risk faced by ground stations that operate and relay information to and from these satellites, if they are located in the area affected by a high altitude nuclear detonation.[131]

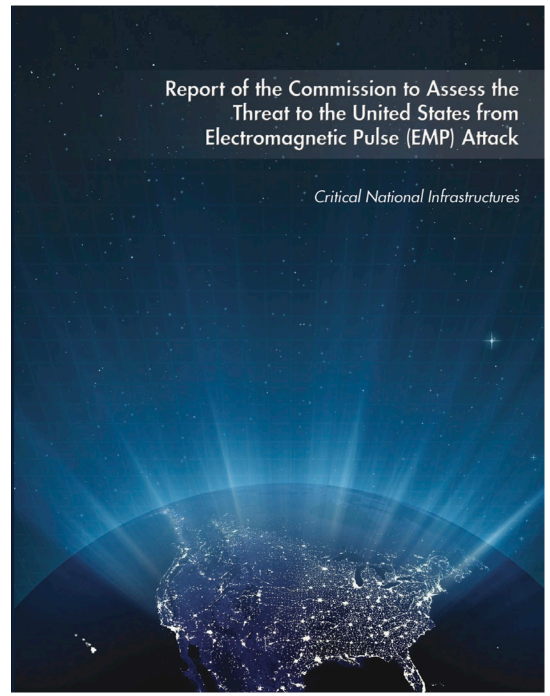
UNITED STATES EMP STRATEGY MITIGATION EFFORTS

CONGRESSIONALLY MANDATED EMP COMMISSION

The Congressionally mandated Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack was established in 2001 for the purpose of evaluating:

1. the nature and magnitude of potential high-altitude EMP threats to the United States from all potentially hostile states or non-state actors that have or could acquire nuclear weapons and ballistic missiles, enabling them to perform a high-altitude EMP attack against the United States within the next 15 years;
2. the vulnerability of United States military and especially civilian systems to an EMP attack, giving special attention to vulnerability of the civilian infrastructure as a matter of emergency preparedness;
3. the capability of the United States to repair and recover from damage inflicted on United States military and civilian systems by an EMP attack; and
4. the feasibility and cost of hardening select military and civilian systems against EMP attack.[132]

Since its inception, the commission has published one Executive Report, in 2004, and two Critical National Infrastructures Reports, in 2004 and 2008, expounding in great detail on the threats posed to high-risk sectors of our society. The EMP commission highly recommends that the government conduct additional research, remedy the vulnerabilities of the power system, craft response plans, secure further funding, implement monitoring agents, safeguard the electrical grid, and encourage cooperation between public and private industries for cost efficiency. Unfortunately, over the last decade, little has been accomplished across the federal government to protect critical infrastructure from an EMP event and the commission has been defunded.



U.S. EMP MIT. EFFORTS (CONT.)

FEDERAL AGENCY MITIGATION EFFORTS

Despite lack of comprehensive and coherent direction from the federal government, there are some limited cooperative efforts between the public and private sectors to combat EMP risks to ensure safety from accidental and intentional electromagnetic events. The government addresses these risks by creating rules, regulations, and informational reports for private companies to employ in managing the electrical grid. Among the leading entities behind EMP mitigation are the Department of Homeland Security (DHS), and the Federal Energy Regulatory Commission (FERC). Each of these organizations has drafted limited protection guidance addressing electromagnetic threats. GMD guidance has received the most attention. For instance, FERC does not include guidance on nuclear EMP in its electric power grid benchmarks.

DHS has issued an EMP protection guidelines document. DHS publications address the risks of an attack on the current electrical system, the impacts of a potential event, the current state of the electrical grid and its vulnerabilities, response plans, protection guidelines, new counter-EMP technological innovations, and exercises to secure the electrical grid. In addition to these informational and instructional publications, DHS has hosted briefings to address electromagnetic risks and has included EMP effects in the National Exercise Program conducted through the Federal Emergency Management Agency (FEMA).

The Department of Energy (DOE) has also issued recent reports on the nature and risks of geomagnetic storms, EMPs, the risks of naturally occurring events on electric power, large power transformers, and national transformer strategy. It also holds space weather workshops in conjunction with the White House Office of Science and Technology Policy (OSTP) to further address the impacts of space weather.

FERC offers a two-phase approach to counteracting GMD, issuing GMD reliability standards and outlining the impacts of a potential event. However, no guidance has as yet been given to addressing HEMP. **The North American Electric Reliability Corporation (NERC) has developed a reliability standard (TPL-007-1) for FERC in coping with GMD. Unfortunately, however, the field levels included in the FERC standards are significantly lower than those that are expected to occur during a major solar storm—and much lower than are necessary to protect the grid against HEMP events.** Experts have outlined to Congress the concrete values needed to protect civilian and military equipment in the event of HEMP (via hardening, redundancy, etc.), and those standards, if implemented, will also protect systems from GMD events.[133]

Government Coordination Background

Various U.S. government agencies in recent years have produced reports in an effort to coordinate policy on GMD and EMP across the federal bureaucracy. In October 2015, an interagency group headed by President Obama's Chief Science Advisor and made up of 20 different agencies and departments published a *National Space Weather Strategy and Action Plan*.[134] The GAO issued its much-discussed Critical Infrastructure report in March 2016, and DOE has subsequently crafted an EMP resilience action plan (released in January 2017) to help address the threat. Subsequently, in May of 2017, the Senate Energy and Natural Resources Committee held a hearing on EMP policy and outlined several methods by which the U.S. could increase its preparedness, including building increased "resistance, resilience, and redundancy" in the electrical grid, with critical assets having backup power sources.[135] There have also been several legislatives attempts to provide funding and guidance to protect against the EMP threat. To date, however, these efforts have not passed.

Most recently, in February 2018, the U.S. Government Accountability Office produced a report titled *Critical Infrastructure Protection - Electricity Suppliers Have Taken Actions to Address Electromagnetic Risks, and Additional Research Is Ongoing*, which highlighted the nature of the EMP threat, detailed the progress of each relevant government entity to date on hardening and protection, and highlighted areas of ongoing concern.

FEBRURARY 2018 GAO REPORT FINDINGS | AREAS FOR IMPROVEMENT

"There is general agreement that more research is needed on both GMD and HEMP. Government and industry have publicly reported on the potential impacts of GMD on the grid. For example, one study identified two main risks: (1) potential voltage instability, causing power system collapse and blackouts; and (2) possible damage to key system components. However, these studies do not address the unique aspects of individual suppliers' networks...

...Department of Energy (DOE) and industry officials told GAO that information on HEMP effects is limited in that suppliers lack key information to fully understand HEMP effects on their networks. Historically, study of HEMP effects focused on impacts to military equipment rather than the commercial electric grid...

...According to DOE, more research is needed to fully investigate and evaluate how an electric utility could protect itself from, or mitigate the effects of, HEMP on its systems. DOE also noted that government and industry have ongoing research efforts to better understand these potential effects and develop possible mitigation measures. For example, DOE has three ongoing research efforts related to HEMP. First, DOE is collaborating with DHS to advance the understanding of HEMP effects on the grid through research at the Los Alamos National Laboratory. Second, DOE has funded efforts underway at the Idaho National Laboratory focused on developing potential HEMP strategies, protections, and mitigations for the electric grid—including hardening of infrastructure, blocking of currents, developing a strategy for stocking and prepositioning of spare parts, as well as developing operational and emergency planning tools. Finally, DOE has enlisted the Oak Ridge National Laboratory in analyzing the vulnerability of the grid to a HEMP event, along with the potential damage from such an event, and how it would impact on the reliability and delivery of electric power."[136]

THE COST OF EMP PROTECTION

The non-profit Foundation for Resilient Societies has put forth cost estimates for protecting the most vital electric and telecommunication infrastructure, together with concurrent systems required for those sectors to continue operating. According to its assessment, this would include electric generation plants, electricity transmission and distribution, electric grid control centers, telecommunications, natural gas system, railroads, and Blackstart plant resiliency. One of the highest estimates given for the total cost for this grid protection is roughly $30 billion, or just 5% of the FY 2017 defense budget.[137] A network of investor-owned electric companies represented by the Edison Electric Institute, meanwhile, puts the projected cost at a more modest figure, closer to $20 billion.[138]

The Congressional EMP Commission "estimates that equipment available today could protect high voltage transformers in the U.S., the elements of the grid most vulnerable to GIC, for an estimated investment of only seventy-five to one hundred and fifty million dollars. That commission also estimated that **very robust protection of the grid, including transformers but also generators, … control equipment, grid islanding and simulation and training could be accomplished for $800 million to $1.5 billion.**[139] According to a CRS report, "hardening most military systems, and mass-produced commercial equipment including PCs and communications equipment, against HEMP or HPM reportedly would add from 3% to 10% to the total cost, if the hardening is engineered into the original design. To retro-fit existing military electrical equipment with hardening would add an additional 10% to the total cost."[140]

CHALLENGES

LEGITIMIZING THE THREAT
Since its initial funding of the EMP Commission, the U.S. Congress has failed to take resolute action against the EMP threat. Nevertheless, a bipartisan group of lawmakers, unified under the Congressional Electromagnetic Pulse Caucus, understands the need to resolutely address the challenge. Unfortunately, public perception of the threat still lags far behind. When then-presidential candidate Newt Gingrich spoke of EMP in 2011, journalists discredited the issue by suggesting the low probability of an attack from North Korea and Iran.[141] This unhelpful and uninformed criticism has created difficulties for efforts to pass legislation that will protect U.S. infrastructure. Today, U.S. adversaries speak openly about a potenial EMP weapon and there is an everpresent dagner of a naturally occuring electromagnetic event. Electromagnetic threats and their implications must therefore be communicated not only to relevant decision makers and policy stakeholders, but to the general public as well.[142]

FAILED/PENDING LEGISLATION
In June 2013, the House of Representatives introduced the *Secure High-Voltage Infrastructure for Electricity from Lethal Damage (SHIELD) Act.*[143] The bill sought to amend the Federal Powers Act to authorize the Federal Energy Regulatory Commission (FERC) to protect the reliability of the U.S. electric infrastructure if it faces an imminent security threat or if there is a presidential directive to that effect. Importantly, this act would give FERC the legal basis to require any owner, user, or operator of bulk-power systems to implement protective measures against vulnerabilities. Additionally, this law would help to establish the best way to protect the bulk-power systems, and it would require the Electric Reliability Organization (ERO) to submit reliability standards on how to protect the domestic bulk-power system from geomagnetic storm events or EMP events, the two biggest threats to our power grid. The bill was never made into law, however.

In December 2013, the *Critical Infrastructure Protection Act (CIPA) of 2014*[144] was introduced. This bill requires the Department of Homeland Security to adopt new National Planning in the event of an EMP event, requires emergency responders to plan and train on how to recover from an EMP event, and to draw on the full expertise of the government to prepare. Additionally, the Senate version of the bill provides that the DHS Under Secretary for Science and Technology conduct research and development on systems to mitigate EMP consequences.[145] This act was finally passed as part of the 2017 *National Defense Authorization Act.*

In March 2014, the *Grid Reliability and Infrastructure Defense (GRID) Act* was introduced.[146] A more broad and inclusive version of the SHIELD Act, it includes a directive for the President to identify facilities that are critical to national defense and vulnerable to electric energy supply disruption. However, this bill was never made into law.

These laws are extraordinarily important for ensuring the safety of key infrastructure in the event that the U.S. comes under attack from a HEMP or is impacted by a natural electromagnetic event.

EMP EMBOLDENS ENEMIES

"EMP attack directed against the United States involving no violent destruction, nor instant death for large numbers of U.S. citizens, may not necessarily evoke massive nuclear retaliation by the U.S. military, where, for example, large numbers of innocent civilians of a nation with a rogue leader might be killed. Such a perceived lower risk of assured destruction by the United States, and widespread knowledge about the vulnerability of U.S. civilian and military computers to the effects of an EMP attack, could actually create a new incentive for other countries or terrorist groups to develop, or perhaps purchase, a nuclear capability."[147]

RECOMMENDATIONS

Pass Legislation
Pass the GRID Act. The GRID Act is the only pending legislation that goes far enough in instituting safety measures for our critical infrastructure. This legislation will amend the *Federal Power Act* and allow the Federal Energy Regulatory Commission (FERC) to issue orders without notice for emergency measures to "protect the reliability of either the bulk-power system or the defense critical electric infrastructure."[148] Power is critical to daily life and to the continued functioning of institutions. Maintaining our ability to provide it is paramount to avoiding a catastrophe.

Establish Authority
Establish a single authority at the NSC level with responsibility and accountability for national EMP preparedness. To a large extent, the lack of progress in protecting our most critical infrastructure to EMP and GMD can be attributed to the distributed nature of responsibility. Simply put, there is no single point of responsibility within the Federal bureaucracy for developing and implementing a national protection plan, and without centralized leadership, efforts to mitigate the threat have been disjointed at best. At worst, they have been nonexistent.

Educate Key Recovery Actors
This requires work toward the implementation of the National Space Weather Action Plan, through which the U.S. can firmly establish metrics regarding the level of protection our infrastructure needs to meet in order to survive a recurrence of the 1859 Carrington Event, and to disseminate these findings to the proper parties.

Harden Key Infrastructure
Such nodes include both electrical grids and infrastructures directly supporting grid operation (including communication, fuel production and transportation, and water infrastructure). An action plan for hardening power generation infrastructure is provided in the GRID Act. This should be taken one step further with the hardening of key telecommunication hardware in order to maintain the free flow of communication in the event of a disaster.

Empower Local Infrastructure
Should progress continue to be slow on a national level, individual states should be encouraged to support hardening their local infrastructure. Some are already interested in doing so, though their efforts have been somewhat hampered by federal inaction and apathy.[149] Virginia has successfully passed legislation for risk assessment, while Maine is currently struggling with resistance from its electric utilities and is hampered by the slow response of its Utility Commission.[150] Most interesting perhaps is the case of Texas, which operates largely on its own electric grid. Home to a large population, a massive economy, and some 11% of the country's military population, the state is an attractive target.[151] Strengthening its defensive capabilities should consequently be a high priority. However, since it operates its own electrical grid, Texas could also provide an opportunity to "test drive" the effectiveness of EMP defense capabilities and how to quickly and cost-efficiently deploy such technologies.[152]

Commit Resources for Research on High Voltage Systems
Effective EMP policy is informed EMP policy. The U.S. knows how to harden and protect individual communication and data systems and facilities—something that DoD has done successfully for decades (and is now sharing its expertise with industry). However, further research is needed to better understand and mitigate EMP effects on large networks.[153] In order to determine where to invest scarce protection resources, improved modeling capability is needed to identify the most critical failure points within interdependent networks.

APPENDIX

EMP versus GMD Characteristics

Attribute	EMP	GMD
Cause	Adversarial threat	Natural hazard
Warning	Strategic: unkonwn 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: lightening: power lines and tower structures-"flashover", telecommunications, electronics, control 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 hight latitudes although events have been seen in southern latitudes

Source: U.S. Department of Energy Electromagnetic Pulse Resilience Action Plan, U.S. Department of Energy, January 2017, https://www.energy.gov/sites/prod/files/2017/01/f34/DOE%20EMP%20Resilience%20Action%20Plan%20January%202017.pdf

EMP / GMD PROTECTION | UNDERSTANDING HARDENING

Advocates of policy to protect against the threat from GMD or EMP have suggested multiple methods by which the United States can increase preparedness for such an event. Namely, they advocate for increased "resistance, resilience, and redundancy" in the electrical grid, with critical assets having backup power sources. **During Congressional testimony, the EMP Commission chairman listed concrete values to protect civilian and military equipment (to guard against the E3 pulse component, harden infrastructure to withstand 85 volts/kilometer; this will also protect systems from GMD events).**[155] Further system redundancy can be achieved through the promotion of distributed energy sources, such as self-powered individual homes using rooftop solar panels connected to the electrical grid. Generally, increasing electrical grid resiliency and educating the public regarding the potential issues involving, and solutions to, an EMP event could limit the severity and efficacy of such an attack on the daily lives of Americans.

The most practical method by which an EMP threat can be mitigated is through hardening. Hardening is the process of designing electrical and electronic systems to be able to handle abnormally high power surges. One way to do this is through a process called layered mitigation. An important first step is to surround vulnerable equipment in a Faraday Cage, creating a metallic shielding around the device which reroutes harmful electromagnetic fields away from the sensitive components. Objects (such as cables) penetrating into the Faraday Cage must also be treated (using surge arrestors and metal door/window/conduit field attenuation designs) to achieve effective protection. Geo-magnetically Induced Current (GIC) blocking devices can help further decrease EMP stress on electric power infrastructure. Yet another important and easy hardening technique is to replace metal cables with optical fiber.

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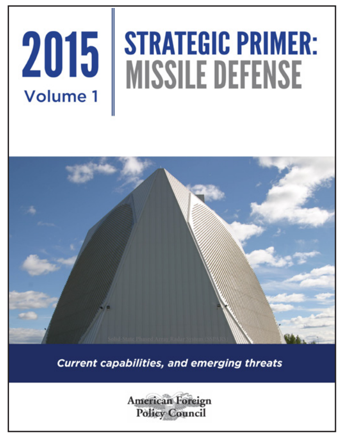

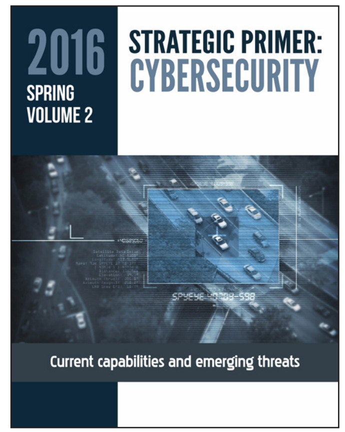

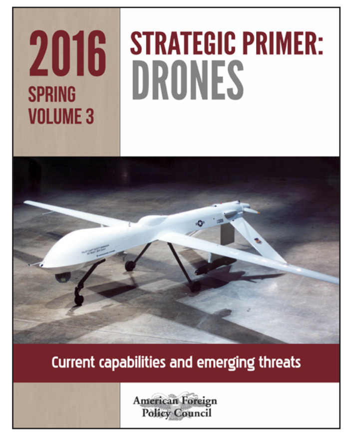

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