

# **BLACKOUT WARFARE**

## **High-altitude Electromagnetic Pulse (HEMP) Attack On The U.S. Electric Power Grid**



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## KEY JUDGMENTS

Nuclear HEMP attack is part of the military doctrines, plans and exercises of Russia, China, North Korea, and Iran for a revolutionary new way of warfare against military forces and civilian critical infrastructures by cyber, sabotage, and HEMP.

Significantly, because HEMP attack entails detonating a nuclear weapon at such high altitude that no blast or other prompt effects injurious to humans are delivered, only the HEMP that immediately damages only electronics, potential adversaries do not appear to regard nuclear HEMP attack as an act of nuclear warfare.

Ignorance of the military doctrines of potential adversaries and a failure of U.S. strategic imagination, as noted in military writings of potentially hostile powers, is setting America up for an HEMP Pearl Harbor.

Russia, China, North Korea and Iran appear to regard nuclear HEMP attack as the ultimate weapon in an all-out “Cyber War” aimed at defeating U.S. and allied military forces on the battlefield, in a theater of operations, and as a means of defeating entire nations by blacking-out their electric grids and other critical infrastructures.

Russia, China, and North Korea presently have the capability to make a HEMP attack that would blackout the U.S. electric power grid and other life-sustaining critical infrastructures. Iran may have clandestinely developed capabilities to make a HEMP attack against the U.S. or may soon be able to do so.

Russia, China, and North Korea have developed “Super-EMP” nuclear weapons that can generate extraordinarily powerful HEMP, exceeding hardening standards for the best protected U.S. military forces.

Contrary to biased “junk science” studies by the electric power industry lobby, a nuclear HEMP attack on the U.S. would not affect only a few states, be quickly recoverable, comparable to localized blackouts caused by hurricanes. HEMP attack would cause protracted blackout of electric grids and life-sustaining critical infrastructures, imperiling national existence.

HEMP attack by a single nuclear weapon can collapse the U.S. national electric power grid.

A more likely scenario for HEMP attack by Russia, China, or North Korea might focus HEMP peak fields on U.S. nuclear forces and C3I to paralyze U.S. nuclear retaliatory capabilities, with blacking-out the U.S. national electric grid and other critical infrastructures an important additional objective, which would inevitably result from such an attack.

The HEMP threat is not merely theoretical, but well-established empirically, including by real world blackouts: ***“With few exceptions, the U.S. national electric grid is unhardened and untested against nuclear EMP attack. In the event of a nuclear EMP attack on the United States, a widespread protracted blackout is inevitable.”*** (EMP Commission Chairman, Dr. William R. Graham)

# HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) ATTACK

by Dr. William A. Radasky and Dr. Peter Vincent Pry

## A Revolution In Military Affairs

Nuclear HEMP attack is part of the military doctrines, plans and exercises of Russia, China, North Korea, and Iran for a revolutionary new way of warfare against military forces and civilian critical infrastructures by cyber, sabotage, and HEMP. This new way of warfare is called many things by many nations. In Russia, China, and Iran it is called Sixth Generation Warfare, Non-Contact Warfare, Electronic Warfare, Total Information Warfare, and Cyber Warfare. Some U.S. analysts, the very small number paying attention, call it Cybergeddon, Blackout War, or Combined-Arms Cyber Warfare.<sup>1</sup>

Significantly, because HEMP attack entails detonating a nuclear weapon at such high altitude that no blast or other prompt effects injurious to humans are delivered, only the HEMP that immediately damages only electronics, potential adversaries do not appear to regard nuclear HEMP attack as an act of nuclear warfare.

Potential adversaries understand that millions could die from the long-term collateral effects of HEMP and cyber-attacks that cause protracted black-out of national electric grids and other life-sustaining critical infrastructures. At least some regard this relatively easy, potentially anonymous, method of inflicting mass destruction as an attractive feature of what they describe as a “Revolution in Military Affairs”.

Ignorance of the military doctrines of potential adversaries and a failure of U.S. strategic imagination, as noted in military writings of potentially hostile powers, is setting America up for an HEMP Pearl Harbor.<sup>2</sup> Russia, China, North Korea and Iran appear to regard nuclear HEMP attack as the ultimate weapon in an all-out “Cyber War” aimed at defeating U.S. and allied military forces on the battlefield and in a theater of operations. They also see HEMP and Combined-Arms Cyber Warfare as a means of defeating entire nations by blacking-out their electric grids and other critical infrastructures for longer periods of time than technologically developed societies, including the U.S., can tolerate without major disruption and loss of life.<sup>3</sup>

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<sup>1</sup> While many analysts are paying attention to cyber warfare, narrowly defined as the use of computer viruses and hacking and other such techniques, relatively few conceive of “cyber warfare” as potential adversaries do— as Combined-Arms Cyber Warfare entailing coordinated use of computer viruses etc., sabotage and kinetic attack, non-nuclear and nuclear EMP weapons. EMP Commission, *Nuclear EMP Attack Scenarios and Combined-Arms Cyber Warfare* (July 2017). Dr. Peter Vincent Pry, *Blackout Wars* (Task Force on National and Homeland Security, 2015).

<sup>2</sup> For Example: Zhang Shouqi and Sun Xuegui, “Be Vigilant Against ‘Pearl Harbor’ Incident In The Information Age” *Jiefangjun Bao* (Official newspaper of the PRC People’s Liberation Army, May 14, 1996) translated in FBIS FTS19960514000049

<sup>3</sup> Ambassador R. James Woolsey, “Heading Toward An EMP Catastrophe” Statement for the Record before the Senate Homeland Security and Governmental Affairs Committee, July 22, 2015.

## Russia

For example, Russian General Vladimir Slipchenko in his military textbook *Non-Contact Wars* describes the combined use of cyber viruses and hacking, physical attacks, non-nuclear EMP weapons, and ultimately nuclear HEMP attack against electric grids and critical infrastructures as a new way of warfare that is the greatest Revolution in Military Affairs (RMA) in history. Slipchenko sees HEMP as such a departure from traditional ways and means of warfare that he describes HEMP weapons and warfare as “based on new physical principles”—a phrase that has become ubiquitous in Russian literature to describe the RMA that is HEMP:

*“In practically all preceding generations of wars...weapons were employed that acted against targets primarily by kinetic, chemical and thermal energy. In addition to these arms...new ones will also appear in...wars of the future....Weapons based on new physical principles having an electromagnetic effect will see considerable development. They will represent a form of casualty and damage producing effect on targets through the energy of electromagnetic emissions of various wavelengths and levels of power generated by radio frequency and laser weapons and by means of electronic countermeasures using a conventional or high-altitude nuclear burst....Depending on the power of emission, such weapons will be capable of...suppressing practically all classic electronic equipment...causing the melting or evaporation of metal in the printed circuit boards...or causing structural changes of electronic elements...”<sup>4</sup>*

Like Nazi Germany's Blitzkrieg (“Lightning War”) Strategy that coordinated airpower, armor, and mobile infantry to achieve strategic and technological surprise that nearly defeated the Allies in World War II, the New Blitzkrieg is, literally and figuratively, an electronic “Lightning War” so potentially decisive in its effects that an entire civilization could be overthrown in hours.

According to General Slipchenko, HEMP and the new RMA renders obsolete modern armies, navies and air forces. For the first time in history, small nations or even non-state actors can humble the most advanced nations on Earth.

An article in *Military Thought*, the flagship journal of the Russian General Staff, “Weak Points of the U.S. Concept of Network-Centric Warfare” points to nuclear HEMP attack as a means of defeating the United States:

*“American forces may be vulnerable to electronic warfare attacks, in particular, an electromagnetic pulse that is a brief powerful electromagnetic field capable of overloading or destroying numerous electronic systems and high-tech microcircuits that are very sensitive to the electromagnetic field, even if transmitted from a distance. A single low-yield nuclear weapon exploded for this purpose high above the area of combat operations can generate an electromagnetic pulse covering a large area and destroying electronic equipment without loss of life that is caused by the blast or radiation.”<sup>5</sup>*

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<sup>4</sup> General Vladimir Slipchenko, *Non-Contact Wars* (Moscow: January 1, 2000) translated in FBIS CEP20001213000001.

<sup>5</sup> Colonel A.V. Kopylov, “Weak Points of the U.S. Concept of Network-Centric Warfare” *Military Thought*, Volume 3, 2011.

Moreover: “Today, too, a considerable body of administrative information in the U.S. armed forces goes through the civilian Internet. Many commercial communication satellites, particularly satellites in low orbits, can have their functions impaired or they can be disabled by electromagnetic shocks from high altitudes.”<sup>6</sup>

According to another Russian article: “Nuclear war strategy has already planned nuclear explosions at an altitude of 50-100 km to destroy enemy satellites’ electronic instruments with electromagnetic pulse”:

*“There are now 683 space craft in near-earth orbit. Of these about 150 are Russian and about 400 American. In the estimation of specialists, for every 100 of our 'purely' military espionage artificial earth satellites there are 300 civilian satellites. Clearly, this discrepancy will increase both quantitatively and qualitatively (considering the state of the Russian military-industrial complex)....Nuclear war strategy has already planned nuclear explosions at an altitude of 50-100 km to destroy enemy satellites' electronic instruments with an electromagnetic pulse.”<sup>7</sup>*

A 2015 article from Russia’s A.A. Maksimov Scientific Research Institute for Space Systems, alludes to “cyber weapons in the nuclear variant” as the most effective cyber weapon: “Even more effective are remote-controlled cyber weapons in the nuclear variant, but in this case a warhead is required with a capacity many times smaller by comparison with the charges of the typical strategic missiles.”<sup>8</sup> The low-yield nuclear weapon described sounds like what Russians call a “Super-EMP” warhead maximally designed, not to make a big explosion, but to emit enhanced-gamma rays to generate HEMP.

Russia made a thinly veiled HEMP threat against the United States on May 2, 1999, in an apparent effort to blackmail the U.S. to stop the Balkans War. During the spring of 1999, tensions between the United States and Russia rose sharply over Operation ALLIED FORCE, the NATO bombing campaign against Yugoslavia. A bipartisan delegation from the House Armed Services Committee of the U.S. Congress met at Vienna with their Russian counterparts on the Duma International Affairs Committee, headed by Chairman Vladimir Lukin. The object of the meeting was to reduce U.S.-Russia tensions and seek Russian help in resolving the Balkans War.

On May 2, during the Vienna meeting, Chairman Lukin and Deputy Chairman Alexander Shabanov chastised the United States for military aggression in the Balkans, and warned that Russia was not helpless to oppose Operation ALLIED FORCE. LUKIN—“Hypothetically, if Russia really wanted to hurt the United States in retaliation for NATO's bombing of Yugoslavia, Russia could fire a submarine launched ballistic missile and detonate a single nuclear warhead at high-altitude over the United States. The resulting electromagnetic pulse would massively disrupt

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<sup>6</sup> Ibid.

<sup>7</sup> Aleksandr Khokhlov, “If There Are Star Wars Tomorrow,” *Novyye Izvestiye*, November 5, 1997, p. 2t translated in FBIS FTS19971106000897.

<sup>8</sup> Department Chief Dr. Grigoriy Vokin, “Remote Custodian. Warheads with Artificial Intelligence for Reconnaissance, Guaranteed Destruction of Targets, and Human Rescue” A.A. Maksimov Scientific Research Institute (2015).

U.S. communications and computer systems, shutting down everything. No internet. Nothing." SHABANOV—"And if that didn't work, we'd just launch another missile."<sup>9</sup>

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### **"Super-EMP Is A...First-Strike Weapon"**

"The further direction of the work on the development of Super-EMP was associated with the increase of its kill effect by focusing Y-radiation, which should have resulted in an increase of the pulse's amplitude. These properties of Super-EMP make it a first strike weapon, which is designed to disable the state and military command and control system, the economy, ICBMs, especially mobile based ICBMs, missiles on the flight trajectory, radar sites, spacecraft, energy supply systems, and so forth. So, Super-EMP is obviously offensive in nature and is a destabilizing first-strike weapon."

"The Russian nuclear component relies on the Super-EMP factor, which is the Russian response to U.S. nuclear blackmail."

From Aleksey Vaschenko, "A Nuclear Response To America Is Possible" Zavtra (November 1, 2006) translated in CEP20061108358006.

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### **China**

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

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

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<sup>9</sup> HASC Transcript On Vienna Conference (May 2, 1999). Interview with Vienna Conference participants Rep. Curt Weldon and Rep. Roscoe Bartlett.

An article from the People's Republic of China's Air Force Engineering University describes nuclear HEMP weapons as the most powerful and effective variant of electronic warfare weapons for waging Information Warfare. Nuclear and non-nuclear EMP weapons in the context of Information Warfare are the crucial instruments for implementing this Revolution in Military Affairs:

*"In future high-tech warfare under informatized conditions, information warfare will span multiple dimensions, including ground, sea, air, and the EM spectrum. Information superiority has already become central and crucial to achieving victory in warfare...If the communications equipment used for the transmission of battlefield information were attacked and damaged by an opponent's EMP weapons, then the one attacked would face the danger of disruption in battlefield information transmission. EMP severely restricts the tactical performance and battlefield survivability of informatized equipment."*<sup>10</sup>

Moreover, the article clearly makes a distinction between nuclear weapons and nuclear HEMP weapons, describing the latter as "a new type of weapon" like non-nuclear EMP weapons, all for waging Information Warfare:

*"As opposed to conventional and nuclear weapons, EMP weapons are a new type of weapon capable of causing mass destruction by instantly releasing high-intensity EMP...They can interfere, damage, and overheat electronics, resulting in logic circuit dysfunctions, control malfunctions, or total failure. The unique destructive effect that EMP have on electronic equipment was unintentionally discovered by the United States in the 1960s during a nuclear test. In July 1962, the United States conducted a high-altitude nuclear explosion in the Pacific Ocean. This...unexpectedly overloaded the Honolulu power grid in Hawaii, 1,400 km away, even overheating lightning protection devices on powerlines. On a battlefield, this new-type weapon will cause devastating damage to electronic systems, including computers, communications and control systems, and radars, resulting in immeasurable losses."*<sup>11</sup>

Furthermore, according to the article: "There are 3 types of military EMP based on pulse sources: the first is the HEMP produced by the detonation of a low yield nuclear bomb in the atmosphere at high-altitude; the second is...produced by high explosives and related devices; the third is the HPM...produced by HPM devices such as magnetrons and vircators." Nuclear EMP weapons are, or include, Enhanced-HEMP or so-called Super-EMP weapons designed to produce gamma rays and high-frequency E1 HEMP: "HEMP weapons are a type of weak nuclear explosive EMP bomb that produces EMP through the detonation of low-yield nuclear bombs at high-altitudes (70 to 100 km above ground)." The E1 HEMP field "produced by nuclear EMP is about 10 to 100 kV/m and can penetrate and melt any electronic components."

Another article "Special Means of Warfare in the Information Age" notes that Information Warfare includes computer viruses and nuclear HEMP attack, and can be used to collapse an enemy's electric grid and other national critical infrastructures:

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<sup>10</sup> Zhao Meng, Da Xinyu, and Zhang Yapu, "Overview of Electromagnetic Pulse Weapons and Protection Techniques Against Them" Winged Missiles (PRC Air Force Engineering University: May 1, 2014).

<sup>11</sup> Ibid.



*“The methods used to achieve destruction or manipulation of the 'byte' can be 'atomic'—such as electromagnetic pulse bombs and so on—or can be 'byte' type—such as computer viruses....The so-called strategic information warfare is the use of destruction or manipulation of the flow of information on a computer network to destroy the enemy's telephone network, fuel pipelines, electric grid, transportation control system, national funds transfer system, various bank clearance systems, and health and sanitation systems, in order to achieve a strategic goal.”*<sup>12</sup>

A January 2016 article “General Trend of the Worldwide Revolution in Military Affairs” by China’s National Security Policy Committee sees “electromagnetic pulse bombs” among the new “disruptive technologies” that “can change the ‘rules of the game’” by disrupting U.S. military “precision warfare capabilities centered on information technology” thereby sounding “the horn of a new round of revolution in military affairs.”<sup>13</sup>

An article in the newspaper of the People’s Liberation Army notes that “The United States is more vulnerable than any other country in the world” to attacks by HEMP and Combined-Arms Cyber Warfare:

*“Some people might think that things similar to the 'Pearl Harbor Incident' are unlikely to take place during the information age. Yet it could be regarded as the 'Pearl Harbor Incident' of the 21st century if a surprise attack is conducted against the enemy's crucial information systems of command, control, and communications by such means as the electronic warfare, electromagnetic pulse weapons, telecommunications interference and suppression, computer viruses, and if the enemy is deprived of the information it needs as a result. Even a super military power like the United States, which possesses nuclear missiles and powerful armed forces, cannot guarantee its immunity...In their own words, a highly computerized open society like the United States is extremely vulnerable to electronic attacks from all sides. This is because the U.S. economy, from banks to telephone systems and from power plants to iron and steel works, relies entirely on computer networks....When a country grows increasingly powerful economically and technologically...it will become increasingly dependent on modern information systems....The United States is more vulnerable to attacks than any other country in the world...”*<sup>14</sup>

## **North Korea**

North Korea appears to have practiced the military doctrines described above against the United States--including by simulating a nuclear HEMP attack against the U.S. mainland.<sup>15</sup>

Following North Korea's third illegal nuclear test in February 2013, North Korean dictator Kim Jong-Un repeatedly threatened to make nuclear missile strikes against the U.S. and its allies. In what was then the worst ever nuclear crisis with North Korea, that lasted months, the U.S.

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<sup>12</sup> Wang Xiaodong, “Special Means of Warfare in the Information Age,” Jianchuan Zhishi, June 30, 1999 translated in FBIS FTS19990727000426.

<sup>13</sup> Li Bingyan, “General Trend of the Worldwide Revolution in Military Affairs” PRC National Security Policy Committee (January 2016).

<sup>14</sup> Zhang Shouqi and Sun Xuegui, Jiefangjun Bao, 14 May 1996.

<sup>15</sup> “EMP Threat From North Korea, 2013” Family Security Matters, April 27, 2014.

responded by beefing-up National Missile Defenses and flying B-2 bombers in exercises just outside the Demilitarized Zone to deter North Korea.<sup>16</sup>

North Korea's first satellite, the KMS-3, was launched successfully on December 12, 2013, exactly two months before, and probably in anticipation of, North Korea's illegal nuclear test on February 12, 2013. On April 2, 2013, a study by the U.S. Department of Homeland Security warned that North Korea might be able to deliver on its nuclear threats against the United States by making an HEMP attack by satellite.<sup>17</sup>

However, the study was suppressed as "politically incorrect" because it contradicted public statements by President Obama and his administration that North Korea could not make a nuclear missile strike on the U.S.<sup>18</sup>

On April 9, 2013, North Korea's KMS-3 satellite orbited over the U.S. moving from south to north on a polar trajectory that evades U.S. early warning radars and National Missile Defenses, at the near optimum altitude and location to place an HEMP field over all 48 contiguous United States.<sup>19</sup>

On April 16, 2013, the KMS-3 again orbited over the Washington, D.C.-New York City corridor where, if the satellite contained a nuclear warhead, it could project the peak HEMP field over the U.S. political and economic capitals and collapse the Eastern Grid, which generates 75 percent of U.S. electricity. On the same day, parties unknown used AK-47s to attack the Metcalf transformer substation that services San Francisco, the Silicon Valley, and is an important part of the Western Grid. Blackout of the Western Grid, or of just San Francisco, would impede U.S. power projection capabilities against North Korea.<sup>20</sup>

In July 2013, a North Korean freighter (the Chong Chon Gang) transited the Gulf of Mexico with SA-2 missiles in its hold, mounted on their launchers hidden under bags of sugar, discovered only after the freighter tried to return to North Korea through the Panama Canal.<sup>21</sup> Although the missiles were not nuclear-armed, they are designed to carry a 10 kiloton warhead, and could execute the Congressional EMP Commission's nightmare scenario of an anonymous HEMP attack launched offshore from a freighter. All during this period, the U.S. electric grid and other critical infrastructures experienced various kinds of cyber-attacks, as they do continuously every day.

On January 6, 2016, North Korea provoked another nuclear crisis with its fourth illegal nuclear test of what it claimed was an H-Bomb. On February 7th, again amidst threats to make a nuclear

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<sup>16</sup> "U.S. Warns North Korea With Stealth Bomber Flights" Wall Street Journal, March 29, 2013.

<sup>17</sup> U.S. Department of Homeland Security, "North Korean Nuclear Threats (April 2, 2013 FOUO).

<sup>18</sup> F. Michael Maloof, "DHS Study: North Korea Capable Of EMP Attack On U.S." World Net Daily (April 9, 2014).

<sup>19</sup> KMS-3 is NORAD's acronym for North Korea's satellite Kwangmyongsong-3 (Lodestar-3 or Guiding Star-3), a name richly symbolic for Korean mythology and the deification of Kim Jong-Un who according to official propaganda was born on Mt. Paeku under a newly appeared bright guiding star, signifying the birth of a great general.

<sup>20</sup> Rebecca Smith, "Assault On California Power Station Raises Alarm On Potential For Terrorism" Wall Street Journal, February 5, 2014.

<sup>21</sup> ; "North Korean Ship Yields Worrisome Cargo" Wall Street Journal, July 17, 2013; "North Korea's Cuban Missile Crisis" 38 North, August 1, 2013.

missile strike on the United States, Pyongyang orbited another satellite, the KMS-4, on the same polar trajectory as the KMS-3.<sup>22</sup>

North Korea now has two satellites orbiting over North America on trajectories optimized to evade U.S. Ballistic Missile Early Warning radars and missile defenses and make a surprise HEMP attack, if the satellites are nuclear-armed. The satellites could be nuclear-armed and constitute a constant HEMP threat, the 21st Century equivalent of "battleship diplomacy."

Kim Jong-Un has threatened to reduce the United States to "ashes" with "nuclear thunderbolts" and threatened to retaliate for U.S. diplomatic and military pressure by "ordering officials and scientists to complete preparations for a satellite launch as soon as possible" amid "the enemies' harsh sanctions and moves to stifle" the North.<sup>23</sup> North Korean press (for example in Rodong Sinmun; March 7, 2016) asserts readiness for "any form of war" and includes their satellite with "strengthening of the nuclear deterrent and legitimate artificial satellite launch, which are our fair and square self-defensive choice." Moreover: "The nuclear [weapons] we possess are, precisely, the country's sovereignty, right to live, and dignity. Our satellite that cleaves through space is the proud sign that unfolds the future of the most powerful state in the world." The same article, like many others, warns North Korea makes "constant preparations so that we can fire the nuclear warheads, which have been deployed for actual warfare for the sake of national defense, at any moment!"<sup>24</sup>

On April 30, 2017, South Korean officials told The Korea Times and YTN TV that North Korea's test of a medium-range missile on April 29 was not a failure, as widely reported in the world press, because it was deliberately detonated at 72 kilometers altitude. According to South Korean officials, "It's believed the explosion was a test to develop a nuclear weapon different from existing ones." Japan's Tetsuro Kosaka wrote in Nikkei, "Pyongyang could be saying, 'We could launch an electromagnetic pulse (EMP) attack if things get really ugly.'"<sup>25</sup>

On September 3, 2017, North Korea conducted its sixth underground nuclear test. The test produced a seismic signal of 6.3 on the Richter scale, indicating a yield of over 100 kilotons: an H-bomb. Shortly after that test, North Korea released an article titled "Kim Jong-Un Gives Guidance to Nuclear Weaponization" which contained the following paragraph: "**The H-bomb, the explosive power of which is adjustable from tens of kilotons to hundreds kiloton, is a multifunctional thermonuclear nuke with great destructive power which can be detonated even at high altitudes for super-powerful EMP attack according to strategic goals.**" On September 4, 2017, Pyongyang published a technical report "The EMP Might of Nuclear Weapons" accurately describing what Russia and China call a Super-EMP nuclear weapon.<sup>26</sup>

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<sup>22</sup> "North Korea May Have Tested Components Of A Hydrogen Bomb" CNN, January 29, 2016; "North Korea Launches 'Satellite,' Sparks Fears About Long-Range Missile Program" Washington Post, February 6, 2016.

<sup>23</sup> Alex Lockie, "North Korea Threatens 'Nuclear Thunderbolts' As U.S. And China Finally Work Together" American Military News (April 14, 2017); Fox News, "U.S. General: North Korea 'Will' Develop Nuclear Capabilities To Hit America" (September 20, 2016) [www.foxnews.com/world/2016/09/20/north-korea-says-successfully-ground-tests-new-rocket-engine.html](http://www.foxnews.com/world/2016/09/20/north-korea-says-successfully-ground-tests-new-rocket-engine.html)

<sup>24</sup> Rodong Sinmun (March 7, 2016).

<sup>25</sup> Tetsuro Kosaka, "North Korea's 'Failed' Missile Test May Have Been A Thinly Disguised Threat" Nikkei (May 2, 2017).

<sup>26</sup> Kim Song-won, "The EMP Might of Nuclear Weapons" Rodong Sinmun (Pyongyang: September 4, 2017).

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### ***Are North Korea's Satellites an EMP Threat?***

*“North Korea’s KMS-3 and KMS-4 satellites orbit over the U.S. daily... Their trajectory is similar to that planned for a Soviet-era secret weapon called the Fractional Orbital Bombardment System (FOBS) deployed by the USSR to make a surprise nuclear attack on the United States. In 2004, two retired Russian generals, then teaching at Russia’s Voroshilov General Staff Academy, told the EMP Commission that the design for Russia’s Super-EMP nuclear weapon was accidentally transferred by Russian scientists and engineers working on North Korea’s missile and nuclear weapons program. They said North Korea could test a Super-EMP weapon ‘in a few years.’ The 2006 and subsequent low-yield tests do not appear to have been failures because North Korea proceeded with weaponization. In 1997, Andrey Kokoshin, then Russia’s First Deputy Defense Minister, stated Russia was deploying a new generation of advanced nuclear warheads ‘that have no counterparts in the world’ including EMP weapons and ‘ultra-small warheads weighing less than 90 kilograms.’ Such weapons would be small enough for North Korea’s satellites. General Vladimir Slipchenko and General Vladimir Belous, who warned the EMP Commission about North Korean development of Super-EMP weapons, are among Russia’s most prominent military scientists and experts on EMP and advanced technology warfare. General Slipchenko’s advocacy of EMP and Combined-Arms Cyber Warfare is recognized in Iran’s military textbook *Passive Defense* that advocates development of capabilities for nuclear EMP attack.”*

Source: EMP Commission, *Chairman’s Report* (July 2017) p. 24

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### **Iran**

Iran in more than 20 passages of a military textbook ironically titled *Passive Defense* (2010) endorses the theories of Russian General Slipchenko and the potential defeat the United States decisively by nuclear HEMP attack. Ambassador R. James Woolsey, former Director of Central Intelligence, writes:

*“‘Death to America’ is more than merely an Iranian chant--Tehran’s military is planning to be able to make a nuclear EMP attack....Rep. Trent Franks quoted from an Iranian military textbook recently translated by the Defense Intelligence Agency’s National Intelligence University...The official Iranian military textbook advocates a revolutionary new way of warfare that combines coordinated attacks by nuclear and non-nuclear EMP weapons, physical and cyber-attacks against electric grids to blackout and collapse entire nations. Iranian military doctrine makes no distinction between nuclear EMP weapons, non-nuclear radio-frequency weapons and cyber-operations--it regards nuclear EMP attack as the ultimate cyber weapon.”<sup>27</sup>*

HEMP is most effective at blacking-out critical infrastructures, while it does not directly damage the environment or harm human life, according to Iran’s *Passive Defense*:

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<sup>27</sup> "A Shariah-Approved Nuclear Attack" Washington Times, September 15, 2015.

*“As a result of not having the other destructive effects that nuclear weapons possess, among them the loss of human life, weapons derived from electromagnetic pulses have attracted attention with regard to their use in future wars...The superficiality of secondary damage sustained as well as the avoidance of human casualties, serves as a motivation to transform this technology into an advanced and useful weapon in modern warfare.”*<sup>28</sup>

Former CIA Director Woolsey notes: "Because EMP destroys electronics directly, but people indirectly, it is regarded by some as Shariah-compliant use of a nuclear weapon. *Passive Defense* and other Iranian military writings are well aware that nuclear EMP attack is the most efficient way of killing people, through secondary effects, over the long run. The rationale appears to be that people starve to death, not because of EMP, but because they live in materialistic societies dependent upon modern technology."<sup>29</sup>

An Iranian political-military journal, in an article entitled “Electronics To Determine Fate Of Future Wars,” states that the key to defeating the United States is HEMP attack and that, “If the world’s industrial countries fail to devise effective ways to defend themselves against dangerous electronic assaults, then they will disintegrate within a few years.”:

*“Advanced information technology equipment exists which has a very high degree of efficiency in warfare. Among these we can refer to communication and information gathering satellites, pilotless planes, and the digital system....Once you confuse the enemy communication network you can also disrupt the work of the enemy command and decision-making center. Even worse, today when you disable a country’s military high command through disruption of communications you will, in effect, disrupt all the affairs of that country....If the world’s industrial countries fail to devise effective ways to defend themselves against dangerous electronic assaults, then they will disintegrate within a few years....American soldiers would not be able to find food to eat nor would they be able to fire a single shot.”*<sup>30</sup>

Iran reportedly has attempted to purchase radiofrequency weapons from Russia, displaying interest in the kind of capability that nuclear HEMP would better provide.<sup>31</sup>

Ironically, while electric power lobbyists are fighting against HEMP protection of the U.S. grid in Washington, the Iranian news agency MEHR reported that Iran is violating international sanctions and going full bore to protect itself from nuclear HEMP attack, that the article equates with “cyber attack”:

*“Iranian researchers...have built an Electromagnetic Pulse (EMP) filter that protects country's vital organizations against cyber attack. Director of Kosar Information and Communication Technology Institute Saeid Rahimi told MNA correspondent that the EMP (Electromagnetic Pulse)*

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<sup>28</sup> Ibid. Army of the Islamic Republic of Iran, *Passive Defense: Approach to the Threat Center* (Tehran: Martyr Lt. General Sayad Shirazi Center for Education and Research, Spring 2010).

<sup>29</sup> Ibid

<sup>30</sup> Tehran, *Nashriyeh-e Siasi Nezami*, December 1998 -January 1999.

<sup>31</sup> Roger Fontaine, “Iran Said to be Developing New Class of Weapons,” *Washington Times* (14 July 1997), p. A10. Iran Brief (Middle East Data Project: 3 July 1997).

*filter is one of the country's boycotted products and until now procuring it required considerable costs and various strategies. 'But recently Kosar ICT...has managed to domestically manufacture the EMP filter for the very first time in this country,' said Rahimi. Noting that the domestic EMP filter has been approved by security authorities, Rahimi added 'the EMP filter protects sensitive devices and organizations against electromagnetic pulse and electromagnetic terrorism.' He also said the domestic EMP filter has been implemented in a number of vital centers in Iran.*"<sup>32</sup>

Artwork for this Iranian article depicts a satellite orbiting above the Earth apparently making a nuclear HEMP attack. Ambassador Henry Cooper, former Director of the Strategic Defense Initiative, has warned repeatedly that some Iranian satellite launches appear to be practice for making a nuclear HEMP attack on the United States.<sup>33</sup>

### **HEMP Attack Basic Facts**

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

High-altitude electromagnetic pulse (HEMP) attack is technically and operationally the easiest, least risky, and most effective use of a nuclear weapon available to a nuclear-armed state or non-state actor.

Any nuclear weapon, even a primitive first-generation weapon like the A-bombs that destroyed Hiroshima and Nagasaki, will produce gamma rays that generate the high-frequency (E1 HEMP) and medium-frequency (E2 HEMP), and magnetic bubbles that generate the low-frequency (E3 HEMP) electromagnetic pulses. A HEMP attack delivers a three-fold punch to electronics small and large, ranging from personal computers to national electric grids and everything in-between:

--Nuclear HEMP attack entails detonating the weapon at such high altitude (generally above 30 km altitude) so that no blast, thermal, fallout or effects other than the HEMP are experienced on the ground.

--HEMP is like "super-lightning" in that it delivers a high power shock much more powerful than lightning against, not a point, but against electronics over a vast area.

--A single nuclear weapon can potentially make a HEMP attack against a target the size of North America.

--E1 HEMP fields are much faster (rises in nanoseconds), they have a higher peak power over thousands of kilometers than a single lightning event, the coupled power and data pulses cannot be stopped by devices designed for lightning protection, and they can damage and destroy small electronics and control systems necessary for the operation of everything from automobiles to airplanes, including electric grids, communications, and all other critical infrastructures.

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<sup>32</sup> "Iran Builds EMP Filter For 1st Time" MEHR News Agency, June 13, 2015.

<sup>33</sup> Ambassador Henry F. Cooper, "Another Satellite Launch By Iran" High Frontier, February 23, 2016; "Quick Fixes to Counter the Existential EMP Threat" High Frontier, July 29, 2014.

--E2 HEMP is as fast (lasting milliseconds) as lightning but can be stopped by lightning protection, but many commercial enterprises and homes lack adequate lightning protection. Also a larger area on the ground is exposed to the E2 HEMP than for lightning.

--E3 HEMP is much slower (lasting seconds) and also covers an enormous range on the ground as compared to lightning, and is typically more powerful than the electromagnetic fields that could be generated by a solar super-storm that can melt transformers designed to carry hundreds of thousands of volts.<sup>34</sup>

--Because HEMP propagates in three "waves" their damaging effects will be dynamic and mutually reinforcing, the E1 HEMP damaging and destroying systems (including possibly lightning protection) that opens the door for wider and deeper damage by E2 and E3 HEMP.

Any nuclear weapon detonated at an altitude of 30 kilometers or higher will generate a potentially catastrophic HEMP. A nuclear detonation at 30 kilometers altitude will generate an HEMP field with a radius on the ground of about 600 kilometers. Detonated at 400 kilometers altitude, the radius of the HEMP field will be about 2,200 kilometers.<sup>35</sup> While the altitude of burst affects the area of coverage, higher burst heights typically reduce the maximum peak E1 HEMP fields on the ground, so for each weapon design there is an optimum burst height for producing the maximum fields.

### **HEMP Attack Is Easy**

Accuracy is not necessary for a HEMP attack because the target altitude (30-400 kilometers) is so wide, and the radius and the coverage of the HEMP field is so vast.

HEMP attack does not require a re-entry vehicle, heat shield, shock absorbers and other paraphernalia associated with a nuclear missile warhead designed for blasting a city. These are unnecessary for a HEMP attack, which detonates the warhead above the atmosphere, in outer space.

HEMP attack can be executed by a wide variety of delivery vehicles, anything that can loft a nuclear weapon to 30 kilometers or higher. Possible delivery vehicles against the United States include a satellite, a long-range missile, a medium- or short-range missile launched off a freighter, some kinds of cruise missiles and anti-ship missiles (like Russia's Club-K exported to Iran), a jet fighter or some kinds of jet airliner doing a zoom climb, even a meteorological balloon.

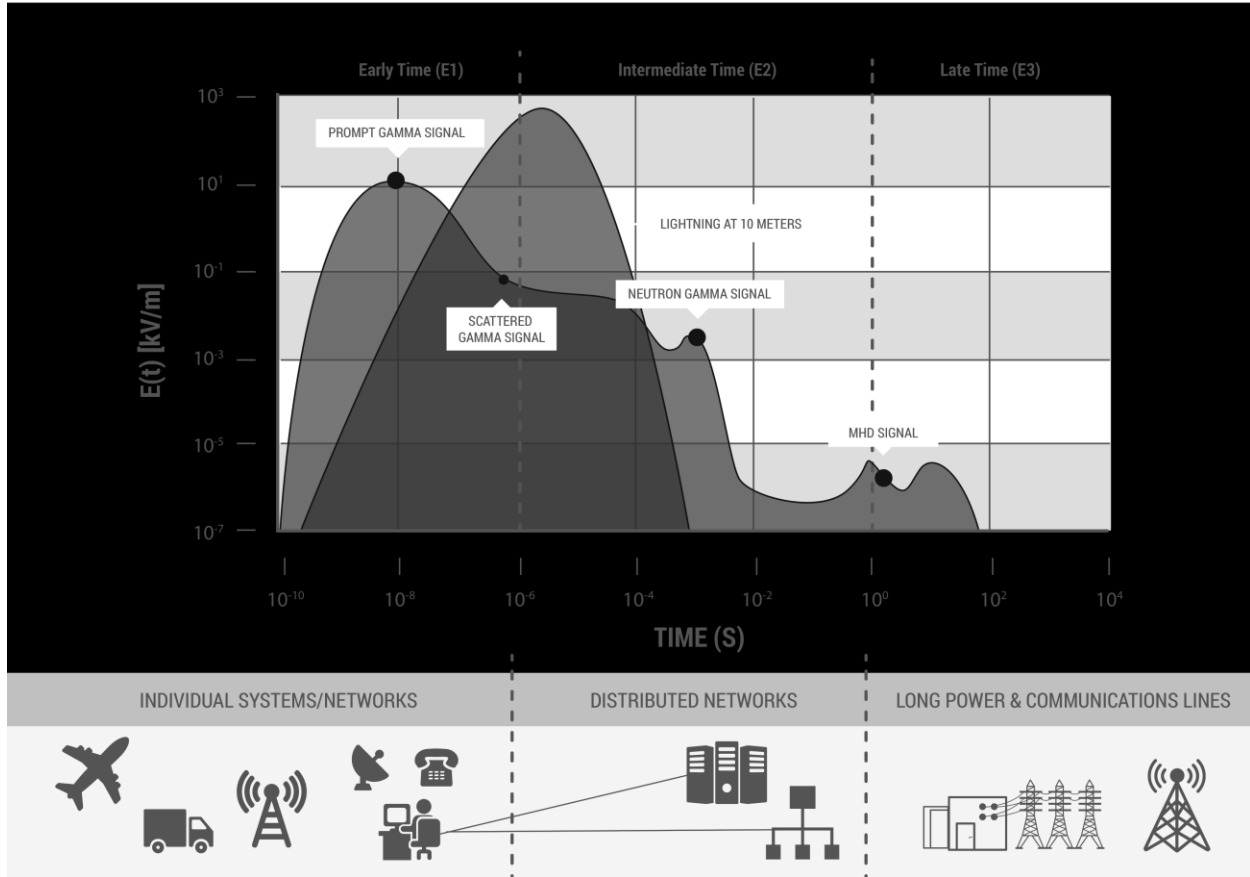
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<sup>34</sup> For example, the 1989 Hydro-Quebec solar storm melted the coils of an EHV transformer at the Salem Nuclear Power Plant in New Jersey, designed to carry 1,000 MVA (Mega-Volt Amperes). The storm generated field strengths equivalent to 2 volts/kilometer E3 HEMP, yet a nuclear weapon can generate field strengths over 40 times higher, 85 volts/kilometer or more. See EMP Commission, *Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures* (July 2017).

<sup>35</sup> For the best background on nuclear HEMP attack and effects see: Congressional EMP Commission, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Executive Report* (2004); *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: National Critical Infrastructures* (2008) and the unclassified 2017 EMP Commission reports at [www.firstempcommission.org](http://www.firstempcommission.org).

# HEMP

E1, E2, & E3 DESCRIBED  
SOURCE: EMP COMMISSION BRIEFING





## HEMP Fields and Effectiveness

The size of the HEMP field on the ground is determined by the altitude of detonation, HEMP propagating from the point of detonation to the horizon of the Earth. Each weapon has an optimum burst height and for higher burst heights the E1 HEMP fields tend to increase, while their area of coverage increases.

In general, HEMP field strengths on the ground are stronger when the weapon is detonated at lower altitudes (especially for weapon yields below 100 kilotons), where the effects are more concentrated within a smaller radius, and weaker when the weapon is detonated at higher altitudes, where the effects occur within a larger radius and cover a bigger area. HEMP fields are dangerous at all altitudes as it does not require the maximum levels of HEMP to create problems for unhardened electronics. Varying the altitude of the HEMP attack can be used to adjust the size of the HEMP field to better fit the target. Since the radius of the HEMP field is not highly sensitive to altitude, relative to any delivery system (even the Houthis or Taliban could use commercial off-the-shelf technology to rig a fusing system that will detonate within less than one kilometer of the desired altitude) again accurate delivery is not an issue.

HEMP fields are strongest to the south of surface zero in the Northern Hemisphere (the point directly below the burst and to the north of surface zero in the Southern Hemisphere), where the maximum peak E1 HEMP field is located, and they reduce in strength toward the tangent radius. The EMP peak field strength at the outer edge of the exposed area will be on the order of about one-half of the maximum peak field strength for a weapon detonated at its optimum burst height (for higher non-optimum burst heights the fields fall off more rapidly toward the Earth's tangent). Even for a primitive first-generation nuclear weapon, the entire field coverage can be dangerous. It is important to understand that the burst height selection is in the control of the attacker, who can choose to optimize the peak field levels and the area coverage.

Damage to electric grids and other critical infrastructures will not be the only impact from the local HEMP field. Cascading failures will propagate far beyond the HEMP field coverage area through an unprotected electric grid, assuming the HEMP field exposure area is smaller than the electric grid being attacked. There have been many cases where a large area power outage has occurred and cascaded to significant distances from the original failure point. The difference with HEMP is that failures will occur not at just one point in the grid, but at potentially thousands of points at the same time (within 1 power cycle).

For example, a 10 kiloton weapon detonated at 30 kilometers over the U.S. Eastern Grid would generate a HEMP field over about 600 kilometers in radius, much smaller than the Eastern Grid. But the national electric grid being aged, over-taxed with demand, and often operating on the verge of failure, is capable of blackouts that put 50 million people into the dark because of cascading failures from a tree branch (like the Great Northeast Blackout of 2003), the entire Eastern Grid would certainly be plunged into a protracted blackout from such an HEMP attack. The U.S. cannot

survive without the Eastern Grid which generates 75 percent of the nation's electricity and supports most of the national population.<sup>36</sup>

### **Any Nuke Will Do**

For nuclear weapons of normal design, a high-yield weapon will generate a more powerful HEMP field than a low-yield weapon, but the difference in field strength is not nearly as great as the difference in yield. For example, a 1,000 kiloton nuclear weapon will not generate a HEMP field 100 times greater than a 10 kiloton nuclear weapon. Indeed, a 10 kiloton weapon can generate an E1 HEMP field nearly as powerful as the 1,000 kiloton weapon, but over a smaller area.<sup>37</sup> This is due to the well-established saturation effect that does not allow the E1 HEMP fields to increase linearly with the yield of the weapon, as the atmosphere will become highly conducting very rapidly and will prevent an unlimited E1 HEMP field. While this might appear to be comforting, the maximum levels reached far exceed the protection levels of electronic equipment.

Even a primitive first-generation nuclear weapon such as terrorists might build, like the first nuclear weapon ever built, the 10 kiloton bomb that destroyed Hiroshima, detonated at 30 kilometers altitude, will generate an E1 HEMP field that at the weakest, on the margins, will be several thousand volts per meter. This is enough to put at risk all unprotected civilian and military systems within the field.<sup>38</sup>

Worldwide, most civilian electronic systems, and most military general purpose forces—including those of the United States—are not hardened against HEMP. According to the Congressional EMP Commission *Executive Report* (2004):

*“The end of the Cold War relaxed the discipline for achieving EMP survivability within the Department of Defense, and gave rise to the perception that an erosion of EMP survivability of military forces was an acceptable risk. EMP simulation and test facilities have been mothballed or dismantled, and research concerning EMP phenomena, hardening design, testing, and maintenance has been substantially decreased. However, the emerging threat environment, characterized by a wide spectrum of actors that include near-peers, established nuclear powers, rogue nations, sub-national groups, and terrorist organizations that either now have access to nuclear weapons and ballistic missiles or may have such access over the next 15 years have combined to place the risk of EMP attack and adverse consequences on the US to a level that is not acceptable.”<sup>39</sup>*

Military planners correctly assume, and civilian emergency managers and engineers should assume, that electronic systems not protected against HEMP are vulnerable.

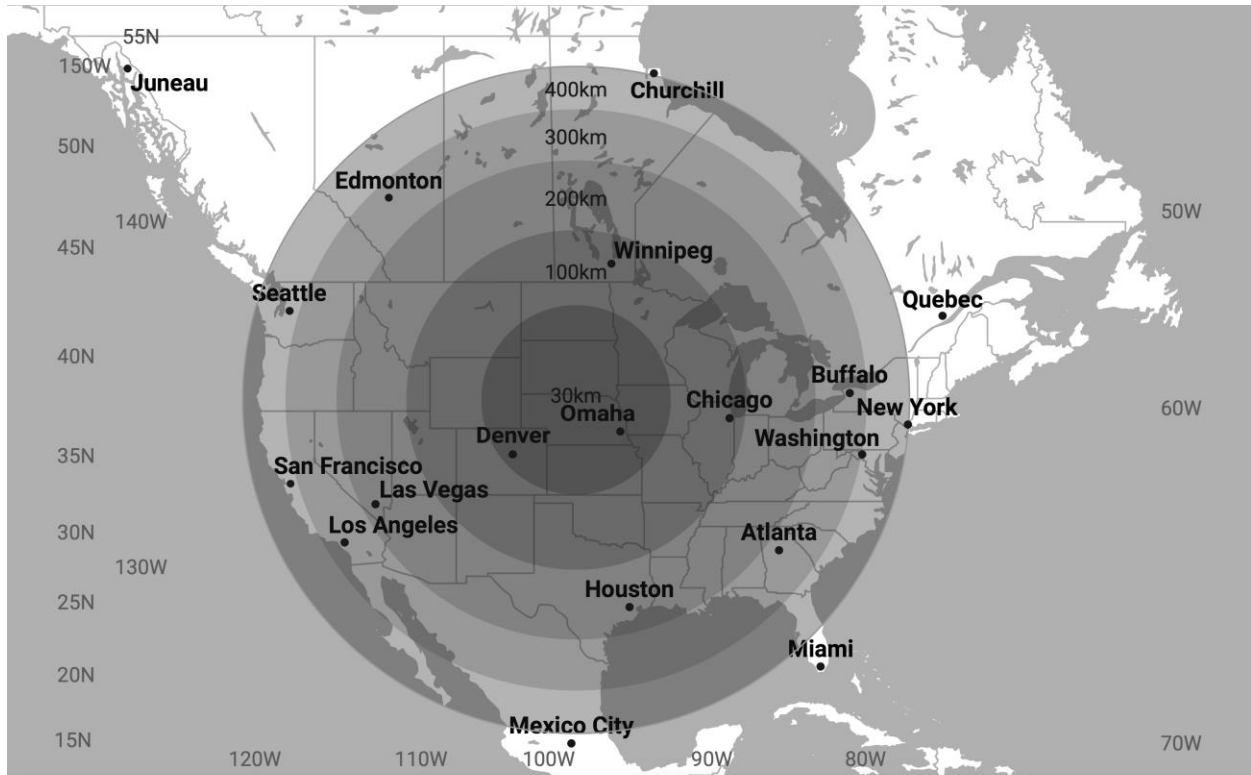
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<sup>36</sup> For a more in depth description of technical characteristics of nuclear HEMP attack, various HEMP attack scenarios and impact on the U.S. power grid see the Metatech studies Meta-R-320 and Meta-R-321 fully referenced later.

<sup>37</sup> Ibid.

<sup>38</sup> Ibid.

<sup>39</sup> EMP Commission, *Executive Report* (2004) p. 47.



**NUCLEAR HEMP AREA COVERAGE**  
 NUCLEAR EMP ATTACK SCENARIOS

EMP field coverage increases with increasing height-of-burst. A balloon or jet aircraft could loft a nuclear warhead to an altitude of 30 kilometers which, targeted over New York City, would also cover Washington, D.C., New York State, New Jersey, Pennsylvania, Virginia, Maryland, Delaware, and most of New England.

**ELECTROMAGNETIC PULSE (EMP) FIELD RADIUS  
ON EARTH'S SURFACE FROM NUCLEAR WEAPON  
DETONATED AT GIVEN HEIGHT OF BURST(HOB)  
(Kilometers)**

HOB	EMP Radius	HOB	EMP Radius	HOB	EMP Radius
30	602*	160	1,391	290	1,873
40	696	170	1,434	300	1,905
50	778	180	1,476	310	1,937
60	852	190	1,516	320	1,968
70	920	200	1,556	330	1,998
80	984	210	1,594	340	2,028
90	1,044	220	1,632	350	2,058
100	1,100	230	1,668	360	2,087
110	1,153	240	1,704	370	2,116
120	1,205	250	1,739	380	2,144
130	1,254	260	1,774	390	2,172
140	1,301	270	1,807	400	2,200**
150	1,347	280	1,841		

Calculated from Radius = 110 ( $\sqrt{HOB}$ ) in kilometers

\* Radius exceeds distance from New York to Washington

\*\* Radius covers all of continental United States

## Super-EMP Weapons

"Super-EMP" weapons, as they are termed by Russia and China, are nuclear weapons specially designed to generate an extraordinarily powerful E1 HEMP field. Super-EMP warheads are designed to produce increased levels of gamma rays, which generate the E1 HEMP effect, not a big explosion, and typically have very low explosive yields, only 1-10 kilotons. According to Russian open sources, a Super-EMP weapon can generate a peak E1 HEMP field of 100,000-200,000 volts per meter, and could be 50-100 kilovolts/meter at the edge of the exposed area. Even HEMP hardened U.S. strategic forces and C4I are potentially vulnerable to such a threat.<sup>40</sup>

The Congressional EMP Commission warns that Russia, China, and probably North Korea have Super-EMP warheads. Moreover, according to the EMP Commission *Executive Report* (2004):

*"Certain types of low-yield nuclear weapons can be employed to generate potentially catastrophic EMP effects over wide geographic areas, and designs for variants of such weapons may have been illicitly trafficked for a quarter-century."*<sup>41</sup>

EMP Commission Chairman, Dr. William Graham, acknowledged the potential vulnerability of the U.S. nuclear deterrent to HEMP attack in 2008 testimony to Congress: **"We designed both the missiles and their bases and the strategic communications systems during the Cold War to be able to survive and operate through EMP fields on the order of 50 kilovolts per meter, which was our concern at the time, before we realized that weapons could be designed that had larger EMP fields."**<sup>42</sup>

The U.S. has no Super-EMP weapons in its nuclear deterrent.

## Questions and Answers to Common Myths and Misconceptions

***Why would a military planner use HEMP attack when its exact effects on any specific target, like a particular EHV transformer or an individual computer, are highly unpredictable?***

Although it is very difficult to predict exactly which electronic systems would be upset, damaged, or destroyed by a HEMP attack, with certainty massive disruption and damage will be inflicted on unprotected electronics within the HEMP field and, because of cascading failures, far beyond. HEMP is analogous to carpet bombing or an artillery barrage that causes massive random damage that is specifically difficult to predict, but reliably catastrophic in its macro-effects.

Cyber-attacks and physical sabotage against electric grids would rely far more heavily than HEMP on highly unpredictable cascading failures resulting from random damage to cause a protracted blackout. Yet cyber threats and sabotage despite their randomness of effect, unlike HEMP, are

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<sup>40</sup> "Russia: Nuclear Response To America Is Possible Using Super-EMP Factor" CEP20061108358006, Aleksey Vaschenko, "A Nuclear Response To America Is Possible," *Zavtra*, November 1, 2006.

<sup>41</sup> EMP Commission, *Executive Report* (2004) p. 2.

<sup>42</sup> "Threat Posed By Electromagnetic Pulse Attack" Hearing before the House Armed Services Committee (Washington, D.C.: July 10, 2008). EMP Commission, *Nuclear EMP Attack Scenarios and Combined-Arms Cyber Warfare* (July 2017) pp. 50-51.

deservedly top priorities for the U.S. Department of Homeland Security and the electric power industry.

HEMP should be a top priority threat for DHS and industry too, but currently is not.

***Are the effects of HEMP attack merely theoretical? No.*** The empirical basis for the threat of a HEMP attack to electric grids and other critical infrastructures is far deeper and broader than the data for cyber-attacks or sabotage. The notion that a cyber-attack or sabotage can plunge the U.S. into a protracted blackout—while very real threats that warrant deep concern—are far more theoretical constructs than HEMP attack.

We know for certain that HEMP will cause widespread damage of electronics and protracted blackout of unprotected electric grids and other critical infrastructures from such hard data as:

--The U.S. STARFISH PRIME high-altitude nuclear test in 1962 over Johnston Island that generated a relatively small HEMP field over the Hawaiian Islands, over 1,800 kilometers away, caused widespread effects to electronic systems.<sup>43</sup>

--Three Russian HEMP tests in 1962 over Kazakhstan, an area larger than Western Europe, that proved a single detonation can cause widespread impacts on communications and the electric grid.<sup>44</sup>

--30 years (1962-1992) of U.S. underground nuclear testing that included collecting data on the accuracy of EMP modeling and the impacts of the fields and induced currents and voltages on selected electronic equipment.

--Over 50 years of testing by HEMP simulators, still ongoing, including by the Congressional EMP Commission (2001-2008) that proved modern electronics are over 1 million times more vulnerable to HEMP than the electronics of 1962.<sup>45</sup>

Moreover, hard data proving the threat from nuclear HEMP is available from natural EMP generated by geomagnetic storms, accidental damage caused by electromagnetic transients (electromagnetic interference), and Non-Nuclear EMP (NNEMP) weapons (more commonly called Radio-Frequency or Electromagnetic Weapons). All of these produce field strengths less powerful than nuclear HEMP, and in the case of accidental electromagnetic transients and Radio-Frequency Weapons, they are much more localized. There are many thousands of such cases, including millions of localized unreported or misunderstood cases, indicating that: transformers, SCADAS, control systems, computers, navigation systems—everything from elevators, to gas stoves, to TVs, to automobile automatic-braking systems—are potentially vulnerable to HEMP.

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<sup>43</sup> Phil Plait, "The 50th Anniversary of Starfish Prime: The Nuke That Shook The World" Discover, July 9, 2012.

<sup>44</sup> Jerry Emanuelson, "Soviet Test 184: The 1962 Soviet Nuclear EMP Tests Over Kazakhstan" Future Science, Undated; Vladimir M. Loborev, "Up to Date State of the NEMP Problems and Topical Research Directions" Electromagnetic Environments and Consequences: Proceedings of the European International Symposium on Electromagnetic Environments, EUROEM Conference, Bordeaux, France, 1994; V. N. Mikhailov, *The Nuclear Tests of the USSR*, Vol. 2, Institute of Strategic Stability, Rosatom.

<sup>45</sup> "Electromagnetic Pulse: Threat to Critical Infrastructures" Hearing before the Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies, House Committee on Homeland Security, Washington, D.C.: May 8, 2014.

***Instead of nuclear HEMP attack, why not rely on cyber-attack and physical sabotage to black-out the electric grid and other critical infrastructures?*** An adversary could black-out the United States for a protracted period of weeks, months, or longer by means of cyber-attack alone, sabotage employing small arms and explosives alone, or Non-Nuclear EMP attack alone.

However, compared to HEMP attack, cyber-attack, sabotage, and NNEMP are less proven and more problematical as means to effect a protracted nationwide blackout, especially against a nation like the United States that has 3,000 different electric utilities using a wide array of different hardware and software. Such technological diversity poses a significant challenge to other attack vectors, but not to HEMP attack. Anything that is not hardened against HEMP is potentially vulnerable. Also in a cyber-attack, it is possible to reboot computers to eliminate a threat, but in the case of HEMP, permanent damage to equipment is not as easy to recover from.

A prudent military planner prosecuting a Blackout War against the United States or its allies would not likely gamble victory or defeat on cyber and sabotage operations alone, if he has the capability to make a HEMP attack. HEMP is the "big stick" and "ace in the hole" and is rightly regarded by Russia, China, North Korea, and Iran as "the ultimate cyber weapon."

Even those cyber warriors and commandos who may insist cyber and sabotage operations are just as great a threat to electric grids as HEMP cannot deny that the historically proven efficacy of combined-arms operations argues for including HEMP attack. Military history and common sense suggest that a threefold attack—using cyber, sabotage, and HEMP—will be better than an attack using just one of these.

Indeed, Lanchester's Square Law, a long-established war-gaming tool familiar to military theorists of all nations, can be used as a heuristic device to demonstrate the above point mathematically. Lanchester's Square Law—proven by calculations, war-gaming, and actual warfare since before World War I—is that the advantages of increasing firepower are not merely additive, but multiplicative. So if the value of cyber-attack = 1 and the value of sabotage = 1, then their net firepower value is not merely 2 but the square of two = 4. Doubling firepower results in a fourfold advantage.

Thus, if the value of cyber-attack = 1 and the value of sabotage = 1 and the value of EMP attack = 1, then their net firepower is 3 squared = 9. Even if one assumes EMP attack is no better than cyber or sabotage, its inclusion more than doubles the effectiveness of a combined-arms attack.

More realistically, since HEMP brings far more firepower to bear than cyber or sabotage, the equation should look more like cyber = 1, sabotage = 1, HEMP = 3, for net firepower of 5 squared = 25. In this case, inclusion of HEMP attack would increase attack effectiveness by more than sixfold.

***Why won't the threat of U.S. nuclear retaliation assuredly deter a nuclear HEMP attack, just as the USSR was deterred from nuclear aggression throughout the Cold War?*** Deterrence depends on knowing who launched the HEMP attack so they can be punished by retaliation. But a HEMP attack can be delivered anonymously. Launched off a freighter, a submarine, by jet, or by satellite

(hundreds of satellites are in low Earth orbit), the perpetrator of HEMP attack might never be identified.

HEMP attack can destroy radars, satellites and their downlinks and other national technical means necessary to identify the attacker. Bomb debris from a weapon detonated at high-altitude for HEMP attack is not collectible, unlike debris from a nuclear weapon detonated in a city, so forensic analysis cannot identify the perpetrator. HEMP attack leaves no fingerprints.

HEMP attack, especially from a Super-EMP weapon, might paralyze strategic forces and C4I (Command, Control, Communications, Computers and Intelligence), making retaliation impossible. In the aftermath of a nuclear HEMP attack that threatens the survival of millions of Americans, it seems likely that any president would order the U.S. military to give highest priority to helping the Department of Homeland Security rescue the nation, instead of prosecuting a war.

*Instead of HEMP attack, why not just blast a city?* A nation or terrorists having only one or a few nuclear weapons would not necessarily calculate that, instead of making a HEMP attack, it is technically and operationally less risky and likely to produce a bigger payoff by blasting a city.

Missile delivery of a nuclear warhead to blast a city requires an accurate guidance system, a reentry vehicle to penetrate the atmosphere and protect the physics package from the shock and heat of re-entry, and a fusing system capable of surviving re-entry and detonating the warhead at low-altitude or on impact. All of these requirements add significant technological and operational risk, compared to HEMP attack.

Moreover, blasting a North American city by missile would require penetrating U.S. National Missile Defenses—no mean feat for one or a few primitive nuclear missiles, the very kind of threat NMD is designed to intercept. For HEMP attack, the warhead can be rigged to "salvage fuse" so it will detonate if intercepted, thereby still successfully delivering HEMP.

Smuggling a nuclear weapon into a city by ship or truck would be riskier than HEMP attack. As soon as the weapon enters U.S. waters or territory, risks escalate dramatically that the operation may be detected by the Coast Guard or police or by sensors now deployed in harbors and metropolitan areas to detect nuclear threats.

What if the bomb smuggling operation is penetrated by the CIA or FBI, and they are waiting to seize the weapon as soon as it crosses into U.S. territory? What if a member of the smuggling team decides to betray the operation and sell the bomb to the CIA or FBI? What if something breaks on the bomb when it is stowed in the hold of a ship, or when off loaded from a freighter at sea, motor boated through choppy surf to shore, hauled up a beach, driven over bumpy roads by truck? Would the smuggling team, necessarily a small group, have the expertise necessary to make repairs, or would they be stuck inside U.S. territory with an inert nuclear bomb?

The worst possible outcome for a rogue state or terrorists would be for the U.S. to capture their nuclear weapon. Trying to smuggle a bomb into a U.S. city maximizes that risk.



And if a hostile nation succeeds in blasting a U.S. city, what have they accomplished but their own doom? A 10-kiloton weapon detonated in a city might kill and injure 300,000 through blast, thermal, and radiation effects, but the United States will not be destroyed, and the demand for revenge will be immediate and overwhelming.<sup>46</sup> Blasting a city is the ideal scenario for forensic analysis of bomb debris, and virtually guarantees that the U.S. can identify the culprit for annihilation.

In contrast, what could be accomplished by HEMP attack?

A HEMP attack could be made by satellite or launched from a ship outside U.S. territory. Shipboard there could be plenty of technicians to ensure nothing goes wrong, and plenty of security to ensure the operation is not betrayed.

HEMP attack detonates in outer space, leaving no collectible bomb debris. No fingerprints. HEMP attack might be executed anonymously, to escape retaliation.

The consequences of HEMP attack would be catastrophic and debilitating upon the United States, crippling U.S. military power projection capabilities and endangering national existence. According to the Congressional EMP Commission *Executive Report* (2004):

*“EMP is one of a small number of threats that can hold our society at risk of catastrophic consequences....It has the capability to produce significant damage to critical infrastructures and thus to the very fabric of U.S. society, as well as to the ability of the United States and Western nations to project influence and military power....The recovery of any one of the key national infrastructures is dependent on the recovery of others. The longer the outage, the more problematic and uncertain the recovery will be. It is possible for the functional outages to become mutually reinforcing until at some point the degradation of infrastructure could have irreversible effects on the country's ability to support its population.”<sup>47</sup>*

The Congressional EMP Commission estimates that a HEMP attack causing a protracted nationwide blackout lasting one year could kill up to 90 percent of the American people through starvation and societal collapse.<sup>48</sup>

During the height of the Cold War, close upon the 1962 Cuban missile crisis when nuclear conflict with the USSR was a very real possibility, then Defense Secretary Robert McNamara estimated the Soviet Union could be deterred if U.S. nuclear retaliation could kill 25 percent of the Soviet population and destroy 75 percent of the USSR's industry. McNamara calculated this "Assured Destruction" of the USSR would require delivering 400 "equivalent megatons"—a force equivalent to hundreds or thousands of nuclear weapons.

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<sup>46</sup> Alex Wellerstein's NUKEMAP model calculates a 10 kiloton weapon ground-burst in New York City, on Manhattan, would kill 103,000 and injure 213,430.

<sup>47</sup> EMP Commission, *Executive Report* (2004) pp. 1-2.

<sup>48</sup> Staff Paper, *Congressional EMP Commission Examples From Testimony And Reports That Fatalities Could Be High Numbering Millions And 90 Percent Of Population*, EMP Task Force On National And Homeland Security.

Yet a nuclear rogue state or terrorists could by HEMP attack threaten or deliver upon the United States catastrophic destruction greater than McNamara's "Assured Destruction"—and do so employing just one or a few nuclear weapons. The Congressional EMP Commission warns (*Executive Report* 2004):

*“Therefore, terrorists or state actors that possess relatively unsophisticated missiles armed with nuclear weapons may well calculate that, instead of destroying a city or military base, they may obtain the greatest political-military utility from one or a few such weapons by using them—or threatening their use—in an EMP attack. The current vulnerability of U.S. critical infrastructures can both invite and reward attack if not corrected...”<sup>49</sup>*

In 2017, the EMP Commission warned again: “The critical national infrastructure in the United States faces a present and continuing existential threat from combined-arms warfare, including cyber and manmade electromagnetic pulse (EMP) attack, as well as from natural EMP from a solar superstorm. During the Cold War, the U.S. was primarily concerned about an EMP attack generated by a high-altitude nuclear weapon as a tactic by which the Soviet Union could suppress the U.S. national command authority and the ability to respond to a nuclear attack—and thus negate the deterrence value of assured nuclear retaliation. Within the last decade, newly-armed adversaries, including North Korea, have been developing the ability and threatening to carry out an EMP attack against the United States. Such an attack would give countries that have only a small number of nuclear weapons the ability to cause widespread, long-lasting damage to critical national infrastructures, to the United States itself as a viable country, and to the survival of a majority of its population.”

HEMP attack is the only realistic scenario where a rogue state or terrorists having one or a few nuclear weapons could prevail by annihilating the U.S., or by credibly threatening Assured Destruction of the United States.

***What about the international taboo against nuclear warfare?*** Russia, China, North Korea, and Iran in their military doctrines and training regard HEMP attack as part of all-out cyber warfare or radio-electronic warfare, not necessarily as nuclear warfare. China in military writings and exercises, despite its nuclear No First Use pledge, employs HEMP attacks, even though there is no evidence of U.S. nuclear first use.<sup>50</sup>

The EMP Commission warns: “Combined-arms cyber warfare, as described in the military doctrines of Russia, China, North Korea, and Iran, may use combinations of cyber-, sabotage-, and ultimately nuclear EMP attack to impair the United States quickly and decisively by blacking-out large portions of its electric grid and other critical infrastructures. Foreign adversaries may aptly consider nuclear EMP attack a weapon that can gravely damage the U.S. by striking at its technological Achilles Heel, without having to confront the U.S. military. The synergism of such combined arms is described in the military doctrines of all these potential adversaries as the

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<sup>49</sup> EMP Commission, *Executive Report* (2004) p. 2.

<sup>50</sup> Dr. Peter Vincent Pry, "Foreign Views of Electromagnetic Pulse (EMP) Attack" Testimony before the U.S. Senate Subcommittee on Terrorism, Technology and Homeland Security, March 9, 2005.

greatest revolution in military affairs in history—one which projects rendering obsolete many, if not all, traditional instruments of military power.”<sup>51</sup>

Even some analysts in Germany and Japan, among the most anti-nuclear nations, because HEMP destroys electronics instead of blasting cities, is regarded by them as acceptable use of a nuclear weapon.<sup>52</sup>

HEMP attack would be perfect for implementing Russia's strategy of "de-escalation"—that also appears to have been adopted by China and North Korea—where a conflict with the U.S. and its allies would be won by limited nuclear use, their version of "shock and awe" to cow the U.S. into submission.<sup>53</sup> An HEMP attack would be the most militarily effective use of one or a few nuclear weapons, while also being the most acceptable nuclear option in world opinion, the option most likely to be construed in the U.S. and internationally as "restrained" and a "warning shot."

In the West, generations of leaders and citizens have been educated that use of nuclear weapons is "unthinkable" and the ultimate horror. Not so in Russia, China, and North Korea where their nuclear capabilities are publicly paraded, missile launches and exercises are televised as a show of strength, an important part of national pride. Whereas the U.S. nuclear deterrent is kept low-profile, almost invisible, and its utility and legitimacy much debated, Russia and China run TV documentaries describing how they would win a nuclear war with the United States.<sup>54</sup>

The "international taboo" on nuclear warfare is one-sided and far more likely to have a psychologically paralyzing effect on the U.S., NATO and their allies than on Russia, China, North Korea, or Iran. A HEMP attack or demonstration made to "de-escalate" a crisis or conflict could raise a chorus of voices in the West against nuclear escalation and send some Western leaders in a panicked search for the first "off ramp."

Some analysts think the world is on the threshold of a "new nuclear age" where Cold War rules and assumptions about deterrence no longer apply and the likelihood of nuclear use is greatly increasing.<sup>55</sup> The first nation to use nuclear weapons today—even a rogue state like North Korea or Iran—will immediately become the most feared and most credible nuclear power in the world, a formidable force to be reckoned with, and perhaps the dominant actor in a new world order.

### **Nationwide Blackout**

One of the biggest and most dangerous myths about HEMP attack is that the consequences would be confined to a relatively small region comprising a few states, similar in extent and severity to the electric blackouts experienced during hurricanes. In fact, HEMP attack by a single nuclear

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<sup>51</sup> EMP Commission, *Assessing the Threat from EMP Attack* (July 2017) p. 5.

<sup>52</sup> See for example Sun Tzu-yun in *Jadi* June 1, 2000 FBIS JPP 20000901000004 and Wolfgang Haas in "Infowarfare and the Military Strategy of the Bundeswehr," *Telepolis* November 3, 1998 FBIS EUP 20000413000200.

<sup>53</sup> Dr. Mark Schneider, *The Nuclear Forces And Doctrine Of The Russian Federation* Nation Institute Press for United States Nuclear Strategy Forum, 2006.

<sup>54</sup> "LIGNET: Why China Televised 'Nuclear War' Against The U.S." *Newsmax*, November 21, 2013.

<sup>55</sup> Paul Bracken, *The Second Nuclear Age*, Macmillan 2013.

weapon, such as those now possessed by North Korea, would almost certainly result in a protracted nationwide blackout.

Gross underestimation of the HEMP threat originates from:

--Non-expert journalists and academics, posturing as experts, who falsely claim the EMP Commission threat assessments are “overblown.”<sup>56</sup>

--“Junk science” studies from so-called “think tanks” for the electric power industry—especially the Electric Power Research Institute (EPRI)—authored by non-experts who never worked on HEMP for the defense or intelligence communities, never had access to classified data, and who flagrantly “cook the books” to make the existential HEMP threat disappear, becoming comparable to a hurricane.<sup>57</sup>

--Obama Administration non-experts in the intelligence community produced a classified “junk science” study grossly underestimating the HEMP threat to justify ignoring the recommendations of the EMP Commission. In 2016 the EMP Commission discovered this bogus classified study, that the Obama Administration tried to hide from scrutiny, provided a classified rebuttal, and recommended the recall of this erroneous report as injurious to U.S. national security.<sup>58</sup> Unaccountably, the Trump Administration failed to recall the erroneous JAEIC EMP classified report, despite issuing the “Executive Order on Coordinating National Resilience to Electromagnetic Pulses” (March 26, 2019) that is still undergoing implementation by the Biden Administration.

Unfortunately, the EMP Commission never had a megaphone as large as the mainstream media or as well-funded as lobbies for the electric power industry, such as NERC, EPRI, and EEI, that can spend hundreds of millions of dollars annually. Consequently, the myth that HEMP is not an existential threat, is not capable of inflicting a protracted nationwide blackout, is comparable to a hurricane, continues to persist even in some documents crucial to advancing national EMP preparedness, such as the Department of Homeland Security’s *Strategy for Protecting and Preparing the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances* (October 9, 2018).<sup>59</sup>

The entire purpose of congressional commissions, like the Congressional EMP Commission, is to provide the best possible threat assessment and recommendations, using the best science and facts available to the U.S. Government, performed by the nation’s foremost experts, to provide, as near as possible, definitive guidance for making public policy. This process of using presidential and congressional commissions to address complex issues of science and technology to make sound

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<sup>56</sup> See for example the deeply erroneous articles by Yousaff Butt, “The EMP Threat: Fact, Fiction, and Response” *Space Review* (Part 1 January 25, 2010; Part 2 February 1, 2010). See also Dr. William Radasky and Dr. Peter Vincent Pry, “Rebuttal to ‘The EMP Threat: Fact, Fiction, and Response’” *Space Review* (July 6, 2010).

<sup>57</sup> See for example the deeply erroneous report by Electric Power Research Institute, *High-Altitude Electromagnetic Pulse and the Bulk Power System* (April 30, 2019) and Randy Horton, “Impact of High-Altitude Electromagnetic Pulse on Transmission Systems” *T&D World* (August 16, 2019).

<sup>58</sup> EMP Commission, *Assessing the Threat from EMP Attack* (July 2017) p. 18 “The Commission recommends the Director of National Intelligence circulate to all recipients of the 2014 JAEIC report the EMP Commission critique and direct a new assessment be prepared that supersedes the 2014 JAEIC EMP report.”

<sup>59</sup> For a critique see Dr. Peter Vincent Pry, *The Power And The Light: The Congressional EMP Commission’s War To Save America 2001-2020* (EMP Task Force on National and Homeland Security, 2020) Chapter 10.

public policy has worked well over the years, for example providing early warning about Cyber Warfare, Biological Warfare, and resulting in the National Missile Defense.

Thus, the Congressional EMP Commission threat assessments and recommendations should serve as the baseline for building national EMP preparedness. A rigorous study by the USAF Electromagnetic Defense Task Force agrees: *“EDTF recommends that the EPRI report, heavily dependent on theoretical analysis and optimistic scenarios, not be used as the basis for grid reliability standards, protection decisions, and other government/industry policies. EDTF instead recommends that the Congressional EMP Commission Reports, supported by real-world data, be used by government and industry as the most accurate assessment of the high-altitude EMP threat. EDTF recommends that the Congressional EMP Commission’s recommendations be implemented.”*

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**U.S. AIR FORCE  
ELECTROMAGNETIC DEFENSE TASK FORCE  
ASSESSMENT OF  
EPRI HEMP REPORT:**

*Abstract*

*“In spring 2019, a group of nearly 200 military, government, academic, and private industry experts in various areas of electromagnetic defense gathered for the second Electromagnetic Defense Task Force (EDTF) summit. During this time a full analytical and technical review was initiated on the recently released report titled “High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies” authored by the Electric Power Research Institute (EPRI)...”*

*Executive Summary*

*“The Electric Power Research Institute (EPRI) authored an April 2019 report titled: “High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies.” If US Government policymakers rely upon the methodology and conclusions of the EPRI report, effective high-altitude EMP protections will not be implemented, jeopardizing security of the US electric grid and other interdependent infrastructures.”*

*“Participants in the Electromagnetic Defense Task Force 2.0 (EDTF 2.0) commend the work of EPRI and its supporting utilities for the testing of digital protective relays (DPRs) against ultrafast E1 high-altitude electromagnetic pulses (HEMP). Readers should understand however, that if EPRI’s report recommendations are to be followed, the ultimate result would be a US power grid with remaining vulnerabilities impacting large power transformers, generating equipment, communication systems, data systems, and microgrid designed for emergency backup power.”*

*“EPRI’s effort draws conclusions about the survivability of the complete electric grid based on a limited assessment of the transmission grid only, omitting attention to the other two main grid*

*sectors: generation and distribution. Furthermore, EPRI's assessment of the transmission grid focuses on transformers and digital protective relays and does not take into consideration the vulnerability of other essential electronic systems necessary for transmission grid communication and control."*

*"To be sure, the protective relays tested by EPRI are an important component of the electric grid since they take transmission lines out of service to prevent equipment damage during grid disturbances. Therefore, EPRI's testing does further the industry's understanding of HEMP effects on DPRs. However, while some test results among EPRI and recent Defense Threat Reduction Agency (DTRA) supported studies are consistent, the EPRI test results are inconsistent with those published by the Congressional Electromagnetic Pulse (EMP) Commission."*

*"When the Congressional EMP Commission tested protective relays, it found upsets and damage at 3-5 kV injected, indicating significantly more relay sensitivity to HEMP than tests conducted by EPRI. Those tests found relay malfunctions at 15 to 80 kV injected. EPRI did not disclose the relay manufacturers and models tested, nor did EPRI analyze relay populations by model used within the US electric grid. Because of the discrepancy between the EMP Commission's test results and EPRI's test results, EPRI may have significantly underestimated the number of malfunctioning or destroyed relays during a HEMP attack.\*"*

*"Notwithstanding these differences in test results, the EPRI-sponsored testing does indicate the need for cost-effective E1 HEMP protections for the electric grid and other infrastructures. Still, more relay testing and more research on relay populations is needed to accurately predict HEMP effects on the electric grid. EPRI did not adequately assess relay responses over the time period from the beginning of the E1 (early) pulse to the end of the E3 (late) pulse. Additionally, EPRI's report does not address interdependencies between E1 and E3 impacts on essential generation, transmission and distribution equipment. EPRI also incompletely assessed the risks of cascading grid collapse due to widespread relay malfunctions..."*

*"EPRI used a wide range of optimistic assumptions that downplay the threat of high-altitude EMP from the detonation of nuclear weapons over the United States. Despite having access to defense-conservative Department of Defense threat scenarios, EPRI used alternative Department of Energy scenarios that assume adversaries would detonate nuclear weapons at non-optimal altitudes, when the optimal altitudes are available in the open literature."*

*"For example, rather than modeling an optimal burst height of 75 km for peak E1 field strengths, EPRI chose a non-optimal burst height of 200 km, lowering the peak E1 field strength by approximately 65 percent. Rather than modeling the optimal burst height of 150 km for peak E3B field strengths, EPRI used an Oak Ridge National Laboratory scenario to assume a burst height of 400 km, significantly lowering the peak E3B field strength. EPRI used a Los Alamos National Laboratory (LANL) scenario to assume a non-optimal burst height of 200 km, again significantly lowering the maximum E3B field strength. EPRI also assumed latitudes and longitudes for its detonation scenarios that are non-optimal for producing maximum HEMP fields in the Northern Hemisphere."*

*“Additionally, the EPRI report implies that megaton class weapons are needed to cause serious HEMP effects, which is technically incorrect. Multiple high-altitude nuclear detonation scenarios will amplify high-altitude EMP effects, but EPRI assumes that adversaries will conduct a HEMP attack with only one nuclear weapon.”*

*“EPRI scientists did not use the data and modeling most accurate for assessing high altitude EMP impacts at northern latitudes, including the Soviet high-altitude nuclear tests over Kazakhstan. EPRI had available but chose not to use the HEMP model and waveforms of the Congressional EMP Commission Report of July 2017 which were derived from this real-world Soviet data. The Soviet data indicates that a peak E3 high-altitude HEMP threat of 85 V/km is possible over continental United States locations. The EPRI report relied instead on a DOE Laboratory (LANL) model that projected the late-time E3 peak field of approximately 35 V/m, which is just 41 percent of the peak field that the EMP Commission recommends for US critical infrastructures.”*

*“By avoiding the use of data from declassified Soviet EMP tests on the realistic E3 threat level EPRI was able to minimize numerical estimates of damaged grid equipment, including hard-to-replace high voltage transformers.”*

*“EPRI’s optimistic assumptions and scenarios obtained from non-DOD sources allowed them to reach conclusions that do not accurately portray risks to the US electric grid.”*

*“For example, EPRI’s report states: ‘Based on the assumptions made in the assessments, it was estimated that approximately 5% of the transmission line terminals in a given interconnection could potentially have a DPR that is damaged or disrupted by the nominal E1 EMP environment, whereas approximately 15% could potentially be affected by the scaled E1 EMP environment.’”*

*“The EDTF disputes EPRI’s conclusion that potential loss of 5 percent of transmission line terminals is only a “moderate” concern. Protective relay damage and associated line terminal loss from realistic HEMP scenarios could be far greater, especially with a multiple-bomb EMP attack. Relay malfunction during a HEMP attack would likely cause other electric grid systems to fail, resulting in large-scale cascading blackouts and widespread equipment damage. Notably, E1 effects on protective relays are likely to interrupt substation self-protection processes needed to interrupt E3 current flow through transformers.”*

*“According to EPRI’s test results, a high-altitude EMP attack would cause relay malfunctions at thousands of points in the grid, simultaneously.”*

*“Notably, large-scale grid blackouts have occurred in the past from single-point failures, such as the Northeast Blackout of 2003 which was caused by overgrown trees contacting electric transmission lines. According to the North American Electric Reliability Corporation (NERC) technical analysis of this blackout, it affected more than 70,000 megawatts (MW) of electrical load and left an estimated 50 million people without power. In contrast, EPRI’s report concludes that a HEMP attack on the same Eastern Interconnection would cause limited regional voltage collapses and affect roughly 40 percent of the electrical load lost in the 2003 blackout. Experience with cascading collapse in the Eastern Interconnection shows EPRI’s finding to be optimistic in the extreme.”*

*“EDTF recommends that the EPRI report, heavily dependent on theoretical analysis and optimistic scenarios, not be used as the basis for grid reliability standards, protection decisions, and other government/industry policies. EDTF instead recommends that the Congressional EMP Commission Reports, supported by real-world data, be used by government and industry as the most accurate assessment of the high-altitude EMP threat. EDTF recommends that the Congressional EMP Commission’s recommendations be implemented.”*

*\*In the early 2000s NERC recommended that the EMP Commission test protective relays and other power electronics. Relay tests performed under contract to the EMP Commission showed the onset of serious upsets and some damage around 3-5 kV injected, a factor of three lower than the 15 kV reported level for failure onset by EPRI in April 2019. As a result, the EPRI tests indicate significantly lower failure rates for the more than one million protective relays in the electric grid. For the EMP Commission-sponsored testing of protective relays and other power system electronics, see E. Savage, W. Radasky, J. Kappenman, J. Gilbert, K. Smith and M. Madrid, HEMP Impulse Injection Testing of Power System Electronics and Electrical Components, Metatech Corporation, Meta-R225, December 2003.*

SOURCE: USAF EDTF, “Electromagnetic Pulse Threats To America’s Electric Grid: Counterpoints To Electric Power Research Institute Positions” OTH Journal (August 27, 2019).

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### **HEMP Attack Impact on the U.S. Electric Power Grid**

Still the best assessments of the HEMP threat to the U.S. power grid are in depth studies done by Metatech originally for the EMP Commission, and then in further depth for the Department of Defense’s Oak Ridge National Laboratory and the U.S. Federal Energy Regulatory Commission:

*--The Early-Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid<sup>60</sup>*

*--The Late-Time (E3) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid<sup>61</sup>*

Metatech assessed the results from multiple attack scenarios including five E3 HEMP Blast Wave attack scenarios, all scenarios postulating a single nuclear weapon detonated at high-altitude over the United States. The five scenarios assess the results of a HEMP attack using a single high-yield (100-1,000 kt) nuclear weapon at 500 kilometers HOB to generate peak HEMP fields centered over five different U.S. locations: New York, Chicago, Dallas/Fort Worth, Portland, and Las Vegas.

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<sup>60</sup> Edward Savage, James Gilbert, William Radasky, *The Early Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid*, Meta-R-320 (Metatech: January 2010).

<sup>61</sup> James Gilbert, John Kappenman, William Radasky, Edward Savage, *The Late-Time (E3) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid*, Meta-R-321 (Metatech: January 2010).



**New York Scenario:** “Every major state from the East Coast to the west coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten collapse of the entire U.S. Power Grid.”<sup>62</sup>

**Chicago Scenario:** “This disturbance is even more severe in total impacts than Case B16a [the New York Scenario]...The same impact concerns described for that event are even more of a concern for this larger disturbance scenario. As in Case B16a, every major state from the East Coast to the west coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten collapse of the entire U.S. Power Grid.”<sup>63</sup>

**Dallas/Fort Worth Scenario:** “This disturbance is, in total, slightly less severe than Case B16a [the New York Scenario]...however the same impact concerns described for that scenario are also of concern for this slightly smaller disturbance scenario. As in Case B16a, every major state from the East Coast to the west coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten the collapse of the entire U.S. Power Grid.”<sup>64</sup>

**Portland Scenario:** “This disturbance is, in total, 35% less severe than Case B16a [the New York Scenario]...As a result, the estimated extent of power system collapse is not as extensive in as in B16a...the highest impact portions of the U.S. are the entire western grid and Texas grid, along with the portions of the Eastern grid from Minnesota to New York through Georgia...Considering the extent of the disturbance, it is conceivable that neighboring system may also collapse through a cascading process [resulting in collapse of the entire U.S. Power Grid].”<sup>65</sup>

**Las Vegas Scenario:** “This disturbance is, in total, 20% less severe than Case B16a [the New York Scenario]...As a result the estimated extent of power system collapse is not as extensive as in B16a...the highest impact portions of the U.S. are the entire Western grid and Texas grid, along with portions of the Eastern grid from Minnesota to New York through Florida. Considering the extent of the disturbance, it is conceivable that neighboring system may also collapse through a cascading process [resulting in collapse of the entire U.S. Power Grid].”<sup>66</sup>

In all five scenarios, HEMP attack threatens the entire U.S. Power Grid with collapse, directly everywhere in 3 of 5 scenarios, and indirectly through cascading collapse in 2 of 5 scenarios. In all five scenarios, HEMP attack from a single nuclear weapon threatens all or most of the U.S. Power Grid in all or most states, spanning the continent to the East and West coasts.

To liken a nuclear HEMP attack to a hurricane is grossly inaccurate and recklessly irresponsible.

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<sup>62</sup> Ibid, p. 3-15.

<sup>63</sup> Ibid, p. 3-16.

<sup>64</sup> Ibid, p. 3-17.

<sup>65</sup> Ibid, p. 3-18.

<sup>66</sup> Ibid, p. 3-19.

## A More Likely HEMP Scenario?

HEMP experts for many years and today typically describe a HEMP attack scenario using a single nuclear weapon to illustrate the existential threat that can be posed to an entire nation even by such a limited HEMP attack—using only one warhead. Non-experts and HEMP “naysayers” like EPRI, through ignorance or intellectual dishonesty or both, base their false claims that the HEMP threat is “overblown” on the “one warhead scenario.”

Nuclear-armed terrorists or nations whose highest priority is blacking-out the U.S. power grid and other life-sustaining critical infrastructures can do so, as proven by the EMP Commission and Metatech, with a single warhead.

However, Russia, China, and North Korea waging “Blackout Warfare” against the United States may well give highest priority to using nuclear HEMP attack for disabling U.S. nuclear retaliatory forces and C4I, along with collapsing the U.S. power grid as a vital secondary objective. Counterforce HEMP attack against the U.S. nuclear deterrent could entail, optimally, multiple HEMP bursts at 30-100 kilometers HOB to maximize peak field strength over U.S. strategic targets.

Even North Korea could probably execute a disarming counterforce HEMP attack against the United States, targeting peak fields on:

- U.S. National Missile Defenses at Fort Greely, Alaska.
- U.S. National Missile Defenses at Vandenberg AFB, California.
- Washington, DC.
- North American Aerospace Defense Command (NORAD) Headquarters at Peterson AFB and Alternate Headquarters inside nearby Cheyenne Mountain, Colorado.
- 91<sup>st</sup> ICBM Missile Wing and B-52 Bomber Wing at Minot AFB, North Dakota.
- 90<sup>th</sup> ICBM Missile Wing at F.E. Warren AFB, Wyoming.
- 341<sup>st</sup> ICBM Missile Wing at Malmstrom AFB, Montana.
- B-2 Bomber Wing at Whiteman AFB, Missouri.
- B-52 Bomber Wing at Barksdale AFB, Louisiana.
- Trident SSBN Base at Bangor, Washington.
- Trident SSBN Base at King’s Bay, Georgia.
- C4I TACAMO Wing of E6B aircraft for emergency communications (to ICBMs, bombers, and patrolling submarines) at Tinker AFB, Oklahoma.

A single Super-EMP warhead detonated at 70 kilometers HOB over each of these 12 targets would generate HEMP peak field strengths of 100 kilovolts/meter or more, greatly exceeding the U.S. military HEMP hardening standard of 50 kilovolts/meter. The EMP Commission warned: “Current policy is to continue to provide EMP protection to strategic forces and their controls; however, the end of the Cold War has relaxed the discipline for achieving and maintaining that capability within these forces.”<sup>67</sup>

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<sup>67</sup> EMP Commission, *Executive Report* (2004) p. 47.

In 2021, according to Colonel Erik Quigley, Director of the Minuteman III Systems Directorate: “Quigley said he couldn’t share photos to show ‘how much corrosion we have...on things like launch and closure doors, and the actual blast doors and the B-plug.’ The corrosion ‘prevents us from being able to close the blast doors and lock [them] appropriately. And you only scrape away the rust and take away layers so many times before you’re putting the crews at risk for potential hardness concerns...[resulting from] an EMP blast and potential radiation.”<sup>68</sup>

The HEMP counterforce attack postulated here, targeting 12 Super-EMP warheads on 12 U.S. strategic forces and C4I targets at 70 kilometers HOB over each target, would also generate 12 HEMP fields, each having a radius of 920 kilometers, covering virtually all the contiguous United States. The collective HEMP effects would surely collapse the national power grid and black-out other life-sustaining critical infrastructures. According to EMP Commission assessments, all the life-sustaining critical infrastructures are seriously at risk, including:

Government  
Military  
Electric Power  
Telecommunications  
Water  
Food  
Transportation  
Petroleum and Natural Gas  
Emergency Services  
Banking and Finance  
Space Assets<sup>69</sup>

A U.S. President, in the aftermath of the postulated HEMP attack to paralyze the U.S. nuclear deterrent and inflict protracted nationwide blackout, would not have much left to work with, the sinews of U.S. military and economic power, and all the critical infrastructures that support modern electronic civilization, having been collapsed or severely disrupted at the speed of light.

Would a U.S. President even attempt to wage World War III, for revenge, or for example to preserve the sovereignty of South Korea, or of Taiwan, or of Ukraine and the Baltic states, under such disadvantageous circumstances? Or would the President’s highest priority be mobilizing all remaining U.S. assets, including the Department of Defense, to recover the national electric power grid and other life-sustaining critical infrastructures, before millions of Americans die from starvation and societal collapse? The Constitution and common sense would vote for the latter.

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<sup>68</sup> John Tirpak, “New GBSD Will Fly in 2023; No Margin Left for Minuteman” Air Force Magazine (June 14, 2021).

<sup>69</sup> EMP Commission, *Critical National Infrastructures* (2008) passim.

### 3.3.2 Blast Wave Case B16a – New York

This case refers to an E3 HEMP Blast Wave event whose peak electric fields are centered over the New York region; this location will spread a large footprint of the disturbance, particular over much of the eastern U.S.

Every major state from the East Coast to the West Coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten collapse of the entire U.S. Power Grid (Figure 3-11). The disturbance also generated very high levels of geomagnetic induced current (GIC) in the Pennsylvania/New York/New Jersey and neighboring regions. These levels could be large enough to exceed the normal AC current loads, and, as a result, could have consequential impacts that may lead to permanent damage to circuit breakers and other apparatus on the high voltage networks in these regions, due to attempts to operate under these unusual conditions. Possible widespread failures of this type could lead to significant delays in power system restoration in these regions.

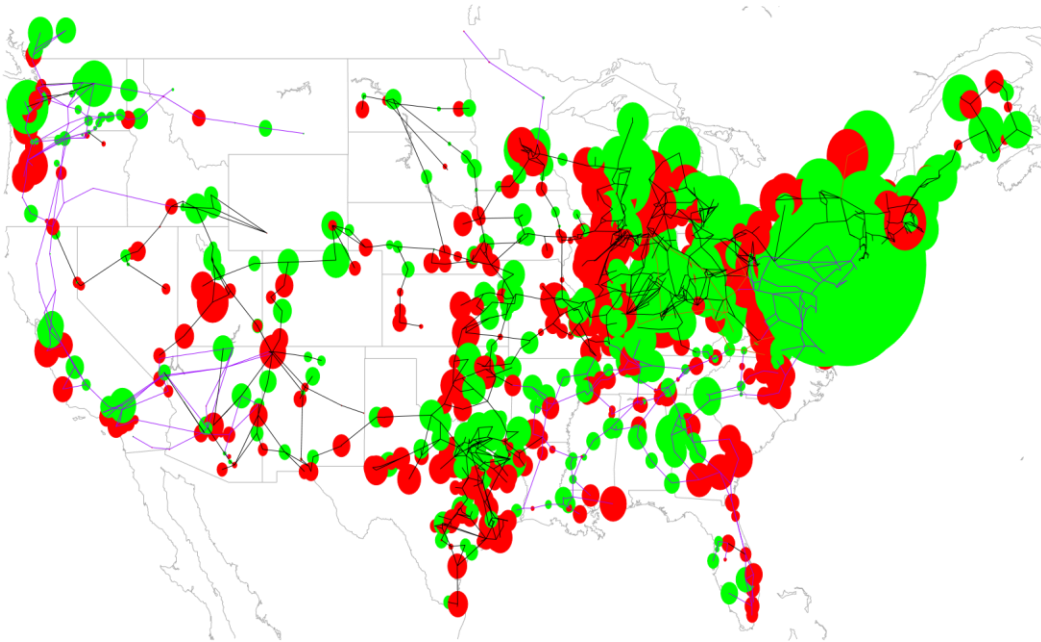


Figure 3-11. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B16a. The entire U.S. Power Grid is expected to collapse.

### 3.3.3 Blast Wave Case B16b - Chicago

This case refers to an E3 HEMP Blast Wave whose peak electric fields are centered over the Chicago region; this location will spread a large footprint of the disturbance over much of the U.S.

This disturbance is even more severe in total impacts than Case B16a, which was previously described. The same impact concerns described for that event are even more of a concern for this larger disturbance scenario. As in Case B16a, every major state from the East Coast to the west coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten collapse of the entire U.S. Power Grid (Figure 3-12). The disturbance also generated very high levels of GIC from Chicago to New Jersey and neighboring regions. These levels could be large enough to exceed the normal AC current loads, and, as a result, could have consequential impacts that may lead to permanent damage to circuit breakers and other apparatus on the high voltage networks in these regions. Possible widespread failures of this type could lead to significant delays in power system restoration in these regions.

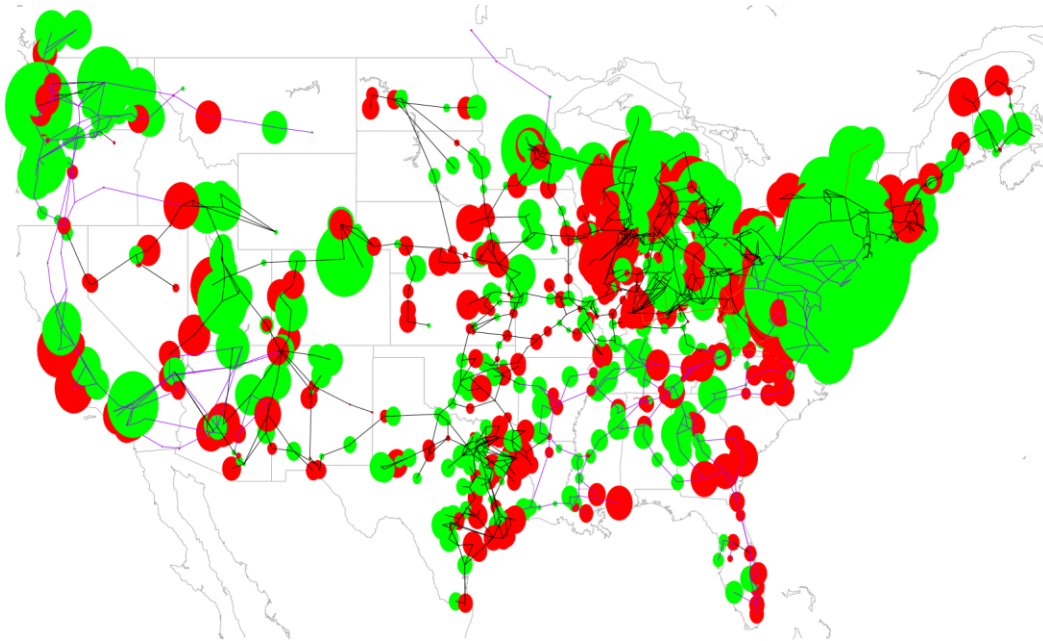


Figure 3-12. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B16b. The entire U.S. Power Grid is expected to collapse.

### 3.3.4 Blast Wave Case B17a – Dallas / Ft. Worth

This case refers to a Blast Wave whose peak electric fields are centered over the Dallas/Ft Worth region; this location will spread a large footprint of the disturbance over much of the U.S.

This disturbance is, in total, slightly less severe than Case B16a, which was previously described, however the same impact concerns described for that event are also of concern for this slightly smaller disturbance scenario. As in Case B16a, every major state from the East Coast to the west coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten collapse of the entire U.S. Power Grid (Figure 3-13). The disturbance also generated very high levels of GIC in much more widely scattered regions than Case B16a. These levels could be large enough to exceed the normal AC current loads, and, as a result, could have consequential impacts that may lead to permanent damage to circuit breakers and other apparatus on the high voltage networks in these regions. Possible widespread failures of this type could lead to significant delays in power system restoration in these regions.

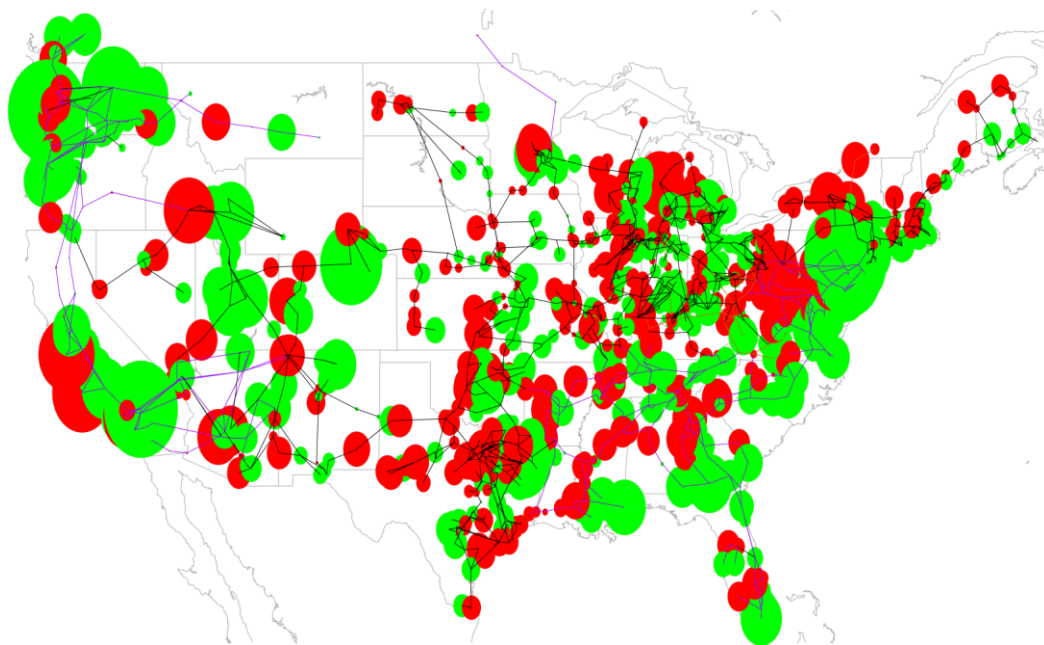


Figure 3-13. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B17a. The entire U.S. Power Grid is expected to collapse.

### 3.3.5 Blast Wave Case B15a – Portland, Oregon

This case refers to a Blast Wave whose peak electric fields are centered over the Portland, Oregon region; this location will spread a large footprint of the disturbance over much of the U.S.

This disturbance is, in total, 35% less severe than Case B16a, which was previously described. As a result, the estimated extent of power system collapse is not as extensive as in B16a. In Case B15a, the highest impact portions of the U.S. are the entire western grid and Texas grid, along with the portions of the Eastern grid from Minnesota to New York through Georgia (Figure 3-14). Considering the extent of the disturbance, it is conceivable that neighboring system may also collapse through a cascading process. The disturbance also generated very high levels of GIC in much of the western U.S. These levels could be large enough to exceed the normal AC current loads, and, as a result, could have consequential impacts that may lead to permanent damage to circuit breakers and other apparatus on the high voltage networks in these regions. Possible widespread failures of this type could lead to significant delays in power system restoration in these regions.

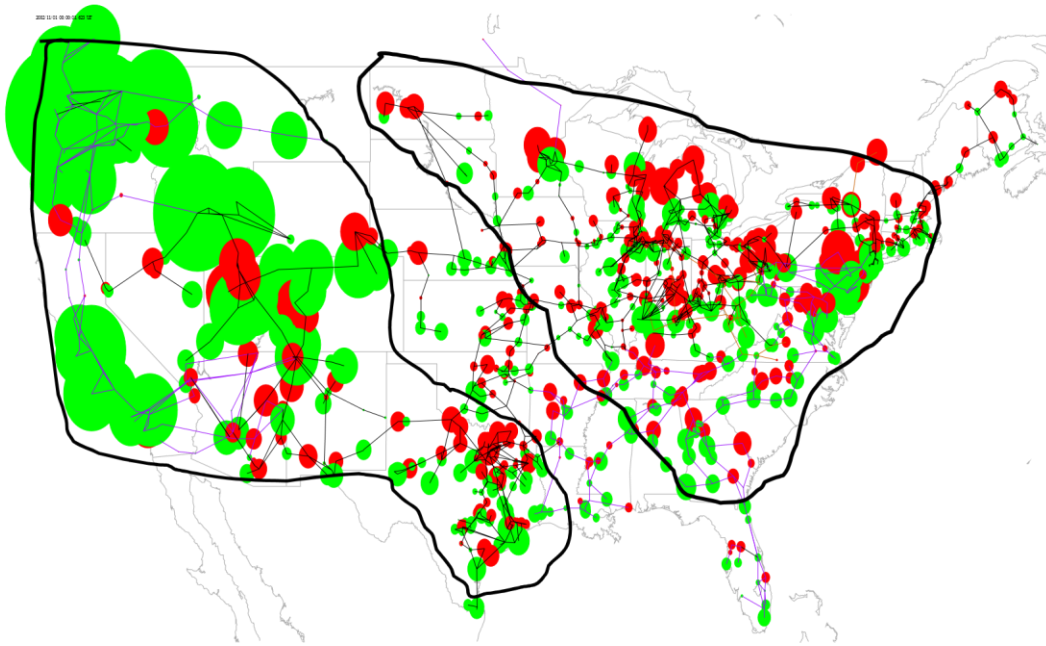


Figure 3-14. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B15a.

### 3.3.6 Blast Wave Case B15b – Las Vegas, Nevada

This case refers to a Blast Wave whose peak electric fields are centered over the Las Vegas, Nevada region; this location will spread a large footprint of the disturbance over much of the U.S.

This disturbance is, in total, 20% less severe than Case B16a, which was previously described. As a result the estimated extent of power system collapse is not as extensive as in B16a. In Case B15b, the highest impact portions of the U.S. are the entire Western grid and Texas grid, along with the portions of the Eastern grid from Minnesota to New York through Florida (Figure 3-15). Considering the extent of the disturbance, it is conceivable that neighboring system may also collapse through a cascading process. The disturbance also generated very high levels of GIC in much of the western U.S. These levels could be large enough to exceed the normal AC current loads, and, as a result, could have consequential impacts that may lead to permanent damage to circuit breakers and other apparatus on the high voltage networks in these regions. Possible widespread failures of this type could lead to significant delays in power system restoration in these regions.

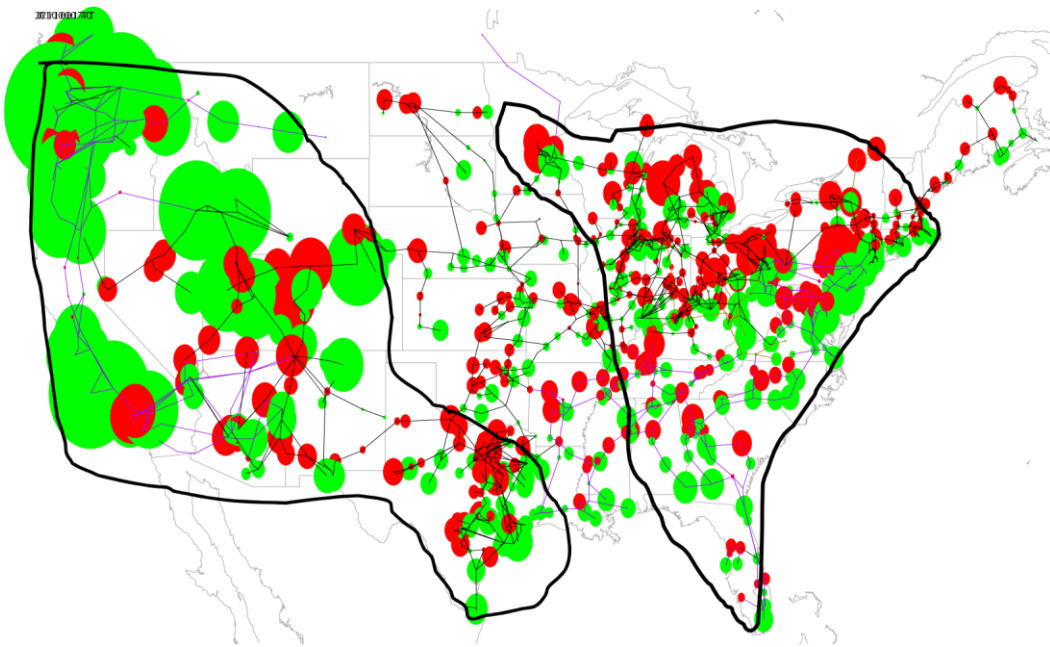


Figure 3-15. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B15b.





NUCLEAR EMP ATTACK SCENARIOS

# HEMP Counterforce Attack

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**VULNERABILITIES TO EMP**  
**Dr. William R. Graham, Chairman**  
**Dr. Peter Vincent Pry, Chief of Staff**  
**Commission to Assess the Threat to the United States from**  
**Electromagnetic Pulse (EMP) Attack**  
**Testimony Before Congress**  
**(October 12, 2017)**

*When assessing the potential vulnerability of U.S. military forces and civilian critical infrastructures to EMP, it is necessary to be mindful of the complex interdependencies of these highly-networked systems, because EMP upset and damage of a very small fraction of the total system can cause total system failure.*

*Real world failures of electric grids from various causes indicate that a nuclear EMP attack would have catastrophic consequences. Significant and highly disruptive blackouts have been caused by single-point failures cascading into system-wide failures, originating from damage comprising far less than 1 percent of the total system. For example:*

*--The Great Northeast Blackout of 2003--that put 50 million people in the dark for a day, contributed to at least 11 deaths, and cost an estimated \$6 billion—originated from a single failure point when a powerline contacted a tree branch, damaging less than 0.0000001 (0.00001%) of the system.*

*--The New York City Blackout of 1977, that resulted in the arrest of 4,500 looters and injury of 550 police officers, was caused by a lightning strike on a substation that tripped two circuit breakers.*

*--The Great Northeast Blackout of 1965, that affected 30 million people, happened because a protective relay on a transmission line was improperly set.*

*--India's nationwide blackout of July 30-31, 2012—the largest blackout in history, effecting 670 million people, 9% of the world population—was caused by overload of a single high-voltage powerline.*

*--India's blackout of January 2, 2001—effecting 226 million people—was caused by equipment failure at the Uttar Pradesh substation.*

*--Indonesia's blackout of August 18, 2005—effecting 100 million people—was caused by overload of a high-voltage powerline.*

*--Brazil's blackout of March 11, 1999—effecting 97 million people—was caused by a lightning strike on an EHV transformer substation.*

*--Italy's blackout of September 28, 2003—effecting 55 million people—was caused by overload of two high-voltage powerlines.*

*--Germany, France, Italy, and Spain experienced partial blackouts on November 4, 2006—effecting 10-15 million people—from accidental shutdown of a high-voltage powerline.*

*--The San Francisco blackout in April 2017 was caused by the failure of a single high voltage breaker.*

*In contrast to the above blackouts caused by single-point or small-scale failures, a nuclear EMP attack would inflict massive widespread damage to the electric grid causing millions of failure points. With few exceptions, the U.S. national electric grid is unhardened and untested against nuclear EMP attack.*

*In the event of a nuclear EMP attack on the United States, a widespread protracted blackout is inevitable.*

Source: Excerpt from Statement for the Record by Dr. William R. Graham, Chairman, and Dr. Peter Vincent Pry, Chief of Staff, Congressional EMP Commission, “North Korea Nuclear EMP Attack: An Existential Threat” Hearing “Empty Threat Or Serious Danger: Assessing North Korea’s Risk to the Homeland” before the House Committee on Homeland Security, Subcommittee on Oversight and Management Efficiency (October 12, 2017).

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### **DR. WILLIAM A. RADASKY**

Dr. William A. Radasky holds the Lord Kelvin Medal for Electromagnetic Protection Standards and is one of the few people who has actually designed national electric grids to be protected from EMP. Dr. Radasky's work has been foundational to advancing Department of Defense scientific and technical understanding of HEMP phenomenology and the vulnerability of military and civilian critical infrastructures. Dr. Radasky served on the Congressional EMP Commission as senior scientific and technical staff. He has worked on high power electromagnetic applications for more than 44 years, beginning his career at the Air Force Weapons Laboratory in 1968 where he evaluated the threat of the high-altitude EMP to U.S. military systems. He has published over 400 reports, papers, and articles dealing with electromagnetic environments, effects and protection during his career. In recent years, he has worked extensively in performing assessments for critical infrastructures to the threats from HEMP, IEMI, and severe geomagnetic storms. He is Chairman of IEC SC 77C (EMC: High Power Transient Phenomenon), Chairman of IEEE EMC Society TC-5 (High-Power EM), and a working group convener for Cigre C4. Dr. Radasky founded Metatech Corporation in 1984 in California and is the President and Managing Engineer. He received his B.S. in Electrical Engineering and Engineering Science from the U.S. Air Force Academy in 1968; his M.S. in Electrical Engineering from the University of New Mexico in 1971; and his Ph.D. in Electrical Engineering from the University of California at Santa Barbara in 1981.

### **DR. PETER VINCENT PRY**

Dr. Peter Vincent Pry is Executive Director of the EMP Task Force on National and Homeland Security, a Congressional Advisory Board dedicated to achieving protection of the United States from electromagnetic pulse (EMP), cyber-attack, mass destruction terrorism and other threats to civilian critical infrastructures on an accelerated basis. Dr. Pry served as Chief of Staff of the congressional Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack (2001-2017); as Director of the United States Nuclear Strategy Forum, an advisory board to Congress on policies to counter Weapons of Mass Destruction; and on the staffs of the Congressional Commission on the Strategic Posture of the United States (2008-2009); the Commission on the New Strategic Posture of the United States (2006-2008); the House Armed Services Committee (1995-2001); and the CIA (1985-1995).

Dr. Pry served as Professional Staff on the House Armed Services Committee (HASC) of the U.S. Congress, with portfolios in nuclear strategy, WMD, Russia, China, NATO, the Middle East, Intelligence, and Terrorism. While serving on the HASC, Dr. Pry was chief advisor to the Vice Chairman of the House Armed Services Committee and the Vice Chairman of the House Homeland Security Committee, and to the Chairman of the Terrorism Panel. Dr. Pry played a key role: running hearings in Congress that warned terrorists and rogue states could pose an EMP threat, establishing the Congressional EMP Commission, helping the Commission develop plans to protect the United States from EMP, and working closely with senior scientists who first discovered the nuclear EMP phenomenon.

Dr. Pry was an Intelligence Officer with the Central Intelligence Agency responsible for analyzing Soviet and Russian nuclear strategy, operational plans, military doctrine, threat perceptions, and

developing U.S. paradigms for strategic warning. He also served as a Verification Analyst at the U.S. Arms Control and Disarmament Agency responsible for assessing Soviet compliance with strategic and military arms control treaties.

Dr. Pry has written numerous books on national security issues, including: *Will America Be Protected? (Volumes I and II)*; *The Power And The Light: The Congressional EMP Commission's War To Save America*; *POSEIDON: Russia's New Doomsday Machine*; *The Long Sunday: Nuclear EMP Attack Scenarios*; *Blackout Wars*; *Apocalypse Unknown: The Struggle To Protect America From An Electromagnetic Pulse Catastrophe*; *Electric Armageddon: Civil-Military Preparedness For An Electromagnetic Pulse Catastrophe*; *War Scare: Russia and America on the Nuclear Brink*; *Nuclear Wars: Exchanges and Outcomes*; *The Strategic Nuclear Balance: And Why It Matters*; and *Israel's Nuclear Arsenal*. Dr. Pry often appears on TV and radio as an expert on national security issues. The BBC made his book *War Scare* into a two-hour TV documentary *Soviet War Scare 1983* and his book *Electric Armageddon* was the basis for another TV documentary *Electronic Armageddon* made by the National Geographic.

DR. PETER PRY



*This recognizes Dr. Peter Pry for his outstanding accomplishments during his 10 years of service at the Central Intelligence Agency. A noted expert in his field, Dr. Pry conducted groundbreaking research that illuminated one of the most important issues of our time—the US-Soviet nuclear competition. On the vanguard of strategic intelligence analysis during the Cold War, he developed much of what the US Government knows about Soviet planning for nuclear war, including Soviet views of the character of war, perceptions of US intentions, assessment of the nuclear balance, and operational plans. In the post-Cold War period, his work has been central to the US Government's understanding of evolving Russian threat perceptions and military doctrine and the construction of new paradigms for strategic warning and stability assessments.*

*Dr. Pry can take pride in knowing that his work has contributed significantly to the security of the United States. He has been a pillar of the Intelligence Community and will be sorely missed. Without a doubt, his continued public service on Capitol Hill will reflect the same expertise, professionalism, and dedication that have characterized his exemplary career at the CIA.*

*We wish him much success in his new endeavor.*

Handwritten signature of Lawrence K. Gershwin in cursive.

Lawrence K. Gershwin

Handwritten signature of Charles E. Allen in cursive.

Charles E. Allen

Handwritten signature of John E. McLaughlin in cursive.

John E. McLaughlin

