

CRS Report for Congress

High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments

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High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments

Summary

Electromagnetic Pulse (EMP) is an instantaneous, intense energy field that can overload or disrupt at a distance numerous electrical systems and high technology microcircuits, which are especially sensitive to power surges. A large scale EMP effect can be produced by a single nuclear explosion detonated high in the atmosphere. This method is referred to as High-Altitude EMP (HEMP). A similar, smaller-scale EMP effect can be created using non-nuclear devices with powerful batteries or reactive chemicals. This method is called High Power Microwave (HPM). Several nations, including reported sponsors of terrorism, may currently have a capability to use EMP as a weapon for cyber warfare or cyber terrorism to disrupt communications and other parts of the U.S. critical infrastructure. Also, some equipment and weapons used by the U.S. military may be vulnerable to the effects of EMP.

The threat of an EMP attack against the United States is hard to assess, but some observers indicate that it is growing along with worldwide access to newer technologies and the proliferation of nuclear weapons. In the past, the threat of mutually assured destruction provided a lasting deterrent against the exchange of multiple high-yield nuclear warheads. However, now even a single, specially-designed low-yield nuclear explosion high above the United States, or over a battlefield, can produce a large-scale EMP effect that could result in a widespread loss of electronics, but no direct fatalities, and may not necessarily evoke a large nuclear retaliatory strike by the U.S. military. This, coupled with the possible vulnerability of U.S. commercial electronics and U.S. military battlefield equipment to the effects of EMP, may create a new incentive for other countries to develop or acquire a nuclear capability.

Policy issues raised by this threat include (1) what is the United States doing to protect civilian critical infrastructure systems against the threat of EMP, (2) how does the vulnerability of U.S. civilian and military electronics to EMP attack encourage other nations to develop or acquire nuclear weapons, and (3) how likely are terrorist organizations to launch a smaller-scale EMP attack against the United States?

This report will be updated as events warrant.

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High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments

Background

A Commission to Assess the Threat from High Altitude Electromagnetic Pulse (EMP commission) was established by Congress in FY2001 after several experts expressed concern that the U.S. critical infrastructure and military were vulnerable to EMP attack.¹ At a July 22, 2004, hearing before the House Armed Services Committee, panel members from the EMP commission stated that a high-altitude nuclear burst could emit electromagnetic energy powerful enough to permanently disable many U.S. critical infrastructure computers, and also that as U.S. military weapons and control systems become more complex, they may be increasingly vulnerable to the effects of EMP. The consensus of the commission is that a large-scale EMP attack could possibly cause widespread damage to unprotected civilian and military electronic equipment for an extended period.²

Some observers indicate that the threat of an EMP attack against the United States may be growing along with worldwide access to newer technologies and the proliferation of nuclear weapons.³ A single, specially-designed, low-yield nuclear explosion high above the United States, or over a battlefield, can produce a large-scale EMP effect resulting in widespread loss of electronics, but possibly without direct fatalities. In the past, the threat of mutually assured destruction provided a lasting deterrent against the exchange of multiple high-yield nuclear warheads. However, an EMP attack directed against the United States involving no violent destruction, nor instant death for large numbers of U.S. citizens, may not necessarily evoke massive nuclear retaliation by the U.S. military, where, for example, large numbers of innocent civilians of a nation with a rogue leader might be killed. Today, the perceived lower risk of assured destruction by the United States, and the perceived vulnerability of U.S. civilian and U.S. military computers to the effects of an EMP attack may create a new incentive for other countries to develop or acquire a nuclear capability.

¹ Michael Sirak, "U.S. vulnerable to EMP Attack," *Jane's Defence Weekly*, July 26, 2004, [http://www.janes.com/defence/news/jdw/jdw040726_1_n.shtml].

² Daniel G. Dupont, "Panel Says Society At Great Risk From Electromagnetic Pulse Attack," *Inside the Pentagon*, July 15, 2004, p.1.

³ U.S. Congress, House Armed Services Committee, *Committee Hearing on Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack*, July 22, 2004.

EMP Commission Reestablished for 2006-2007

The EMP commission was reestablished by P.L. 109-163, the National Defense Authorization Act for FY2006. The new Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack (note that the new title no longer includes the phrase “High Altitude”, and adds the new word “Attack”) will continue with the same membership, and the Secretary of Defense is authorized to appoint a new member in the event of a vacancy.⁴ The EMP commission is tasked to monitor, investigate, and make recommendations about the vulnerability of electric-dependent systems of the Department of Defense, government agencies, and the private sector. The EMP commission is also directed to submit a report to Congress by June 30, 2007, to assess progress in protecting these systems from EMP attack, and to make recommendations for better protection of these systems.

As of the date of this report, the Commission is planning to publish an unclassified report on Critical National Infrastructures in April 2008. They are also preparing a review of the DOD response to recommendations made by the Committee.⁵

Committee Hearing

On July 22, 2004, members of the EMP commission testified before the House Armed Services Committee and presented a report consisting of the following five volumes:

- Volume 1 is an unclassified Executive Summary.
- Volume 2 is a classified Threat Assessment.
- Volume 3 is an unclassified Assessment of the U.S. Critical Infrastructure.
- Volume 4 is a classified discussion of Military Topics.
- Volume 5 is a classified Assessment of Potential Threats.

The report stated that High Altitude EMP is capable of causing catastrophic consequences for the nation, and that the current vulnerability of our critical infrastructures, which depend so heavily on computers and electronics, can both invite and reward attack if not corrected.⁶

Specifically referring to the U.S. military, the report states:

... EMP 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

⁴ P.L. 109-163, Section 1052, reestablishes the EMP commission.

⁵ Personal communication with EMP Commission staff, Mar 26, 2008.

⁶ William Graham, et al., *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, Volume 1: Executive Report 2004*, [<http://www.house.gov/hasc/openingstatementsandpressreleases/108thcongress/04-07-22emp.pdf>].

that either now have access to nuclear weapons and ballistic missiles or may have such access over the next 15 years have [sic] combined to place the risk of EMP attack and adverse consequences on the U.S. to a level that is not acceptable.... Our increasing dependence on advanced electronics systems results in the potential for an increased EMP vulnerability of our technologically advanced forces, and if unaddressed makes EMP employment by an adversary an attractive asymmetric option.”⁷

The EMP commission’s report proposed a five-year plan for protecting critical infrastructures from EMP and from other large-scale terrorist attacks. The five-year plan is briefly summarized in Volume 3 of the report. However, some portions of the five-year plan that are related to military equipment may remain classified.

The EMP commission’s 2004 report focused mainly on the effects of High Altitude EMP and not necessarily the effects of High Power Microwave devices (discussed below). Testimony at the 2004 included questions such as (1) how would the United States respond to a limited HEMP attack against the U.S. homeland or against U.S. forces, where there is loss of technology, but no directly caused loss of life; (2) does the current lack of U.S. preparedness invite adversaries to plan and attempt a HEMP attack; and (3) are the long-term effects of a successful HEMP attack, leading to possible widespread starvation and population reduction, potentially more devastating to the U.S. homeland than an attack by surface nuclear weapons?

Private Sector Preparedness

Some assert that little has been done by the private sector to protect against the threat from electromagnetic pulse, and that commercial electronic systems in the United States could be severely damaged by either HEMP or smaller-scale HPM.⁸ Commercial electronic surge arresters used for lightning strikes reportedly do not clamp fast enough to protect against the instantaneous effects of electromagnetic pulse.⁹

In March 2007, a survey of state Adjutants General who oversee National Guard units throughout the country found that most state-based emergency responders are not actively preparing against an attack on the United States by electromagnetic pulse. The survey, entitled *Missile Defense and the Role of the States*, was conducted jointly by the Anchorage-based Institute of the North and the

⁷ William Graham, et. al., Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, Volume 1: Executive Report 2004, [<http://www.house.gov/hasc/openingstatementsandpressreleases/108thcongress/04-07-22emp.pdf>], p.47.

⁸ House Armed Services Committee, *Committee Hearing on Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack*, July 22, 2004.

⁹ Army Training Manual 5-692-2, “Maintenance of Mechanical and Electrical Equipment at Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities, *HEMP Protection Systems*, April 15, 2001, Chapter 27, [<http://www.usace.army.mil/publications/armytm/tm5-692-2/chap27VOL-2.pdf>].

Claremont Institute of Claremont, California. Survey questions were sent to Adjutants General of all 50 states, with more than half responding. Although 96% of state Adjutants General indicated significant concern over an EMP attack, the majority had done little or no analysis of the effects of an overhead EMP attack, and little or no training, or preparation to harden electronic equipment. None of the Adjutants General surveyed indicated that they were actively involved in a formal planning process for response to an EMP attack.¹⁰

Questions About Vulnerability

Some analysts discount the likelihood of a large-scale EMP attack against the United States in the near term, and the extent of possible damage, stating that the critical infrastructure reportedly would survive, and that military communications would continue to operate and a high percentage of civilian phone calls would continue to connect. These analysts state that limited testing has shown that modern commercial equipment may be surprisingly resistant to the effects of electromagnetic pulse, and that some military systems using commercial equipment are also retrofitted to be made more EMP resistant before they are fielded.¹¹ However, other analysts maintain that some testing done by the U.S. military may have been flawed, or incomplete, leading to faulty conclusions about the level of resistance of commercial equipment to the effects of EMP. These analysts point out that EMP technology has been explored by several other nations, and as circuitry becomes more miniaturized, modern electronics become increasingly vulnerable to disruption. They argue that it could possibly take years for the United States to recover fully from widespread damage to electronics resulting from a large-scale EMP attack.¹²

Electromagnetic Pulse and Power

Electromagnetic energy, characterized as weapon potentially threatening to national security, can be created as a pulse traditionally by two methods: overhead nuclear burst and microwave emission. High-Altitude Electromagnetic Pulse (HEMP) is an instantaneous electromagnetic energy field produced in the atmosphere by the power and radiation of a nuclear explosion, and that is damaging to electronic equipment over a very wide area, depending on the design of the nuclear device and altitude of the burst. High-Power Microwave (HPM) electromagnetic energy can be

¹⁰ Press release, *Survey Finds Nation Vulnerable to EMP Attack: States Not Preparing*, Institute of the North and The Claremont Institute, March 7, 2007, [<http://www.institutenorth.org/servlet/download?id=261>].

¹¹ Stanley Jakubiak, statement before the House Military Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

¹² Lowell Wood, Statement before the House Military Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999; Jack Spencer, "America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse," *The Heritage Foundation Background*, No.1372, May 26, 2000, p.6.; and Carlo Kopp, "The Electromagnetic Bomb — A Weapon of Electrical Mass Destruction," *Air and Space Power*, 1993, [<http://www.airpower.maxwell.af.mil/airchronicles/kopp/apjemp.html>].

produced as an instantaneous pulse created through special electrical equipment that transforms battery power, or powerful chemical reaction or explosion, into intense microwaves that are very damaging to electronics within a much smaller area.

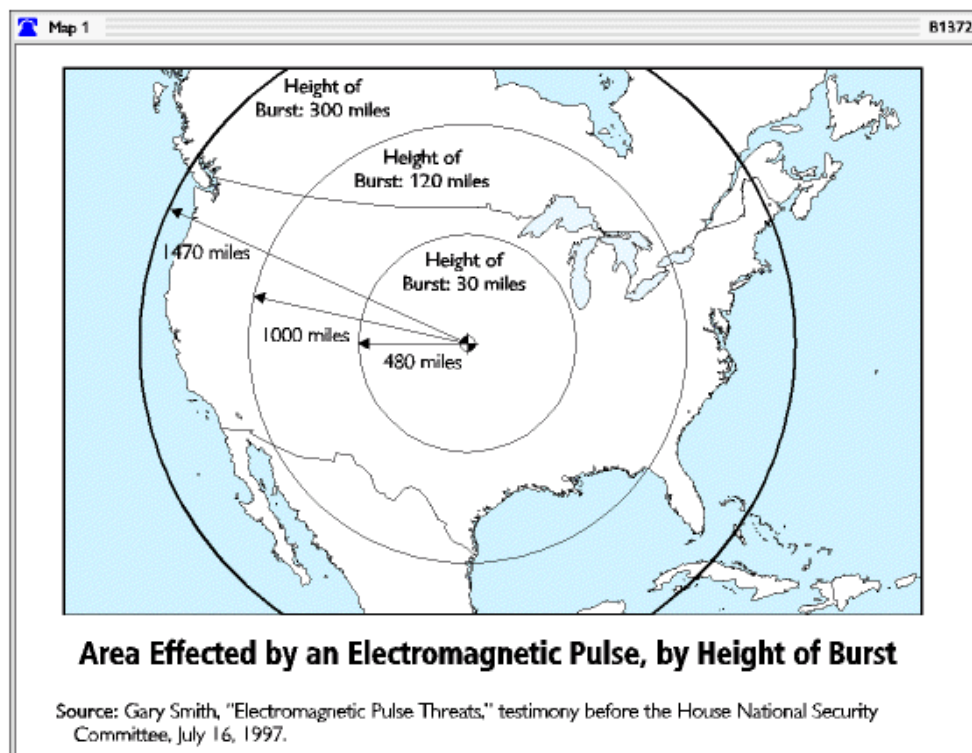
In addition, while HEMP weapons are large in scale and require a nuclear capability along with technology to launch high altitude missiles, HPM weapons are smaller in scale, and can sometimes involve a much lower level of technology, which may be within the capability of some extremist groups or non-state organizations. HPM can cause damage to computers similar to HEMP, although the effects are limited to a much smaller area. The technical accessibility, lower cost, and the apparent vulnerability of U.S. civilian electronic equipment could make small-scale HPM weapons attractive for terrorist groups in the future.

Description of High-Altitude Electromagnetic Pulse

HEMP is produced when a nuclear weapon is detonated high above the Earth's surface, creating gamma-radiation that interacts with the atmosphere to create an instantaneous intense electromagnetic energy field that is harmless to people as it radiates outward, but which can overload computer circuitry with effects similar to, but causing damage much more swiftly than a lightning strike.¹³ The effects of HEMP became fully known to the United States in 1962 during a high-altitude nuclear test (code named "Starfish Prime") over the Pacific Ocean, when radio stations and electronic equipment were disrupted 800 miles away through parts of Hawaii. The HEMP effect can span thousands of miles, depending on the altitude and the design and power of the nuclear burst (a single device detonated at an appropriate altitude over Kansas reportedly could affect all of the continental United States)¹⁴, and can be picked up by metallic conductors such as wires or power cables, acting as antennas to conduct the energy shockwave into the electronic systems of cars, airplanes, and communications equipment.

¹³ A nuclear explosion produces gamma rays, which interact with air molecules in a process called the Compton effect. Electrons are scattered at high energies, which ionizes the atmosphere, generating a powerful electrical field. This EMP effect is strongest at altitudes above 30,000m, and lasts so briefly that current cannot start flowing through a human body to cause harm to people. [<http://www.physics.northwestern.edu/classes/2001Fall/Phyx135-2/19/emp.htm>].

¹⁴ The Federation of American Scientists, "Nuclear Weapons EMP Effects," [<http://www.fas.org/nuke/intro/nuke/emp.htm>].

Figure 1. Estimated Area Affected by High-Altitude EMP

Source: Heritage Foundation, Jack Spencer, *America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse*, Backgrounder #1372, May 26, 2000, [<http://www.heritage.org/Research/MissileDefense/bg1372.cfm>].

Description of High-Power Microwave

Microwaves are characterized by electromagnetic energy with wavelengths as small as centimeters or millimeters, and can be used at moderate power levels for communications or for radar.¹⁵ High Power Microwaves can be produced as a weapon when a powerful chemical detonation is transformed through a special coil device, called a flux compression generator, into a much stronger electromagnetic field.¹⁶ Other methods, such as combining reactive chemicals or using powerful batteries and capacitors, can also be used to create a reusable HPM weapon. HPM energy can be focused using a specially-shaped antenna, or emitter, to produce effects similar to HEMP within a confined area, or over a limited distance. Unlike HEMP, however, HPM radiation uses shorter wave forms at higher-frequencies which make it highly effective against electronic equipment and more difficult to harden against.

¹⁵ For example, microwaves with wavelengths about 5.7 cm long (C-band), or 20 cm long (L-band), or 3 cm long (X-band) are often used for radar or communications.

¹⁶ A Flux Compression Generator consists of explosives packed inside a cylinder, all of which is contained within a cylindrical copper coil structure. The explosive is detonated from rear to front, causing the tube to flare in a wave that touches the copper coil, which produces a moving short circuit. This compresses the magnetic field and creates an electromagnetic pulse that is emitted from the front end, which is then directed by a special focusing antenna. [<http://www.physics.northwestern.edu/classes/2001Fall/Phyx135-2/19/emp.htm>].

A mechanically simple, suitcase-sized device, using a chemical explosive and special focusing antenna, might theoretically produce a one-time, instantaneous HPM shockwave that could disrupt many computers within a 1-mile range.¹⁷ Also, HPM energy at higher power levels (megawatts), and powered for a longer time interval, reportedly could cause physical harm to persons near the source emitter, or possibly in the path of a narrowly focused energy beam.¹⁸

Disruptive Capabilities

Studies related to the effects of electromagnetic weapons have been published infrequently, or remain classified.¹⁹ Nevertheless, it is known that a powerful HEMP field as it radiates outward can interfere with radio frequency links and instantly produce damaging voltage and currents in electronic devices thousands of miles from the nuclear explosion. Effectiveness is increased if the electronic devices are connected to any metal that could also act as an antenna. Because infrastructure computer systems are interconnected, a widespread HEMP effect could lead to possible long-term disruption of power, fuel distribution, transportation systems, food and water supplies, hospitals, and law enforcement communications, as well as military communications systems which utilize the civilian infrastructure.

A HEMP attack directed against the United States continent might involve a one-megaton nuclear warhead, or a smaller one that is specially-designed, using a burst several hundred miles above the mid-western states to affect computers on both coasts.²⁰ However, creating a HEMP effect over an area 250 miles in diameter, an example size for a battlefield, might only require a rocket with a modest altitude and payload capability that could loft a relatively small nuclear device. If a medium or higher range missile with a nuclear payload were launched from the deck of a freighter at sea, the resulting HEMP could reportedly disable computers over a wide area of the coastal United States.

The disruptive effects of both HEMP and HPM reportedly diminish with distance, and electronic equipment that is turned off is less likely to be damaged.²¹

¹⁷ Dr. Robert C. Harney, Naval Postgraduate School, April 12, 2004, personal communication.

¹⁸ Victorino Matus, "Dropping the E-bomb," *The Weekly Standard*, February 2, 2003, [http://theweeklystandard.com/Utilities/printer_preview.asp?idArticle=2209&R=9F0C225C3].

¹⁹ William Graham, *Electromagnetic Pulse Threats to U.S. Military and Civilian Infrastructure*, hearing before the Military Research and Development Subcommittee, House Armed Services Committee, October 7, 1999; and Carlo Kopp, "The Electromagnetic Bomb — A Weapon of Electrical Mass Destruction," *Air and Space Power*, 1993, at [<http://www.airpower.maxwell.af.mil/airchronicles/kopp/apjemp.html>].

²⁰ [<http://www.physics.northwestern.edu/classes/2001Fall/Phyx135-2/19/emp.htm>].

²¹ Experts may disagree on whether the damaging effects of HPM actually diminish following the familiar inverse-square-of-the-distance rule. Michael Abrams, "The Dawn of the E-Bomb," *IEEE Spectrum*, November 2003, [<http://www.spectrum.ieee.org/WEBONLY/>]
(continued...)

To produce maximum coverage for the HEMP effect, a nuclear device must explode very high in the atmosphere, too far away from the earth's surface to cause injury or damage directly from heat or blast. Also, HEMP produced by the nuclear explosion is instantaneous — too brief to start current flowing within a human body — so there is no effect on people. However, microwave energy weapons (HPM) are smaller-scale, are delivered at a closer range to the intended target, and can sometimes be emitted for a longer duration. These capabilities can cause a painful burning sensation or other injury to a person directly in the path of the focused power beam, or can be fatal if a person is too close to the microwave emitter.²² Both HEMP and HPM can permanently immobilize vehicles with electronic ignition and control systems.

A high altitude nuclear explosion (that creates HEMP) produces three major energy components that arrive in sequence, and which have measurably different effects that can be cumulatively damaging to electronic equipment. The first energy component is the initial energy shockwave which lasts about one microsecond, and is similar to extremely intense static electricity that can overload circuitry for every electronic device that is within line of sight of the burst. A secondary energy component then arrives, which has characteristics that are similar to a lightning strike. By itself, this second energy component might not be an issue for some critical infrastructure equipment, if anti-lightning protective measures are already in place. However, the rise time of the first component is so rapid and intense that it can destroy many protective measures, allowing the second component to further disrupt the electronic equipment. The third energy component is a longer-lasting magnetic signal, from about one microsecond to one full second in duration. This geomagnetic signal causes an effect that is damaging primarily to long-lines electronic equipment. A localized magnetic effect builds up throughout the length of the transmission lines and then quickly collapses, producing a magnetohydrodynamic (MHD) “heave,” or “late-time,” power surge that overloads equipment connected to the power and telecommunications infrastructure. This late-time effect adds to the initial HEMP effect, and systems connected to long-lines power and communications systems may be further disrupted by the combined effects. Smaller isolated systems do not collect so much of this third energy component, and are usually disrupted only by the first energy component of HEMP.²³

²¹ (...continued)

publicfeature/nov03/1103ebom.html]. Some experts state that the severity of HEMP effect depends largely on the bomb design, so a specially-designed low yield bomb may pose a larger HEMP threat than a high yield bomb. Lowell Wood, statement before the House Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

²² Victorino Matus, “Dropping the E-bomb,” *The Weekly Standard*, February 2, 2003, [http://theweeklystandard.com/Utilities/printer_preview.asp?idArticle=2209&R=9F0C225C3].

²³ The Federation of American Scientists, “Nuclear Weapons EMP Effects,” [<http://www.fas.org/nuke/intro/nuke/emp.htm>], and Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Vol.1: Executive Report 2004, p.5.

An HPM weapon has a shorter possible range than HEMP, but it can induce currents large enough to melt circuitry, or it can cause equipment to gradually fail over a period of minutes, days, or even weeks. In 2001, a U.S. Comanche helicopter, flying in New York while performing a radar test involving HPM weapons, generated a low-level energy pulse that reportedly disrupted for two weeks the global positioning systems (GPS) being used to land commercial aircraft at a nearby airport in Albany, New York.²⁴

Older electrical components, such as vacuum tubes, are generally built more massively, and are more tolerant of electromagnetic pulse. However, as modern electronics shrink in size, circuitry is becoming increasingly vulnerable to electromagnetic interference. Therefore, countries with infrastructure that relies on older technology may be less vulnerable to the disabling effects of HEMP or HPM than countries that rely on a higher level of technology.²⁵

Hardening Against Attack

Electronic equipment may be hardened by surrounding it with protective metallic shielding which routes damaging electromagnetic fields away from highly sensitive electrical components. This method, known as Faraday cage protection, is traditionally used to protect electronic equipment from a lightning strike. However, power surges HEMP or HPM weapons could possibly involve peak currents of tens of millions of amps which can pass through a protective Faraday cage. Additionally, equipment placed within a Faraday cage may also be made vulnerable by any wires running into to the cage which can conduct the electromagnetic shockwave into the equipment. Depending on the power level involved, points of entry into the shielded cages can sometimes be protected from electromagnetic pulse by using specially-designed surge protectors, special wire termination procedures, screened isolated transformers, spark gaps, or other types of specially-designed electrical filters. Critical systems may also be protected by increasing the number of backup units, and by keeping these units dispersed and out of range of the electromagnetic pulse source emitter.²⁶

Hardening most military systems, and mass-produced commercial equipment including PCs and communications equipment, against HEMP or HPM reportedly would add from 3% to 10% to the total cost, if the hardening is engineered into the

²⁴ Kenneth R. Timmerman, "U.S. Threatened with EMP Attack," *Insight on the News*, May 28, 2001, [<http://www.insightmag.com/news/2001/05/28/InvestigativeReport/U.Threatened.With.Emp.Attack-210973.shtml>].

²⁵ Lowell Wood, statement before the House Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

²⁶ Electrical systems connected to any wire or line that can act as an antenna may be disrupted. [<http://www.physics.northwestern.edu/classes/2001Fall/Phyx135-2/19/emp.htm>]. Army Training Manual 5-692-2, April 15, 2001, "Maintenance of Mechanical and Electrical Equipment at Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities, *HEMP Protection Systems*, Chapter 27, [<http://www.usace.army.mil/publications/armytm/tm5-692-2/chap27VOL-2.pdf>].

original design. To retro-fit existing military electrical equipment with hardening would add about 10% to the total cost.²⁷

DOD Activities

Underground testing of nuclear devices done in 1992 at the Nevada Test Site were designed to research protection techniques to harden military systems against HEMP effects resulting from a nuclear exchange.²⁸ The Limited Test Ban Treaty of 1963 prohibits nuclear explosions in the atmosphere, in space, and under water. Since then, testing to calibrate the effects of large-scale HEMP on the critical infrastructure has been restricted. The design of new simulators to help measure these effects would call for complex computations to represent the large number of possible interactions between components found in the circuit boards, network connections, wireless systems, hardware modules, and operating environments of modern electronic systems that support the critical infrastructure.

DOD research on pulsed-power HPM electromagnetic weapons is currently being done at Kirtland Air Force Base, in Albuquerque, New Mexico. Weapons now being developed by the U.S. military for electronic warfare can disrupt the trajectory of missiles while in flight, and can overpower or degrade enemy communications, telemetry, and circuitry. Other HPM weapons being tested by the military are portable and re-usable through battery-power, and many are effective when fired miles away from a target. These weapons can also be focused like a laser beam and tuned to an appropriate frequency in order to penetrate electronics that are heavily shielded against a nuclear attack. The deepest bunkers with the thickest concrete walls reportedly are not safe from such a beam if they have even a single unprotected wire reaching the surface.²⁹

During Operation Iraqi Freedom, many Iraqi command bunkers and suspected chemical-biological weapons bunkers were deeply buried underground and thought to be difficult to disable using conventional explosives. New HPM weapons were reportedly considered for possible use in attacks against these targets because the numerous communications and power lines leading into the underground bunkers offered pathways for conducting powerful surges of electromagnetic energy that could destroy the computer equipment inside.³⁰

Because instantaneous HPM energy can reflect off the ground and possibly affect piloted aircraft above, much testing currently involves HPM devices on Unmanned Aerial Vehicles (UAVs), and on the Air Force Conventional Air-

²⁷ Lowell Wood, statement before the House Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

²⁸ Associated Press, "Experts Cite Electromagnetic Pulse as Terrorist Threat," *Las Vegas Review-Journal*, October 3, 2001.

²⁹ Michael Abrams, The Dawn of the E-Bomb, *IEEE Spectrum Online*, November 2003, [<http://www.spectrum.ieee.org/WEBONLY/publicfeature/nov03/1103ebom.html>].

³⁰ Will Dunham, "U.S. May Debut Secret Microwave Weapon versus Iraq," *Reuters*, February 2, 2003, [<http://www.globalsecurity.org/org/news/2003/030202-ebomb01.htm>].

Launched Cruise Missile system. By 2010, DOD reportedly will field several air-launched UAVs using disposable and reusable HPM weapons designed to disrupt enemy computers.³¹

Capabilities of Other Nations

Reportedly, several potential U.S. adversaries, such as Russia or China, are now capable of launching a crippling HEMP strike against the United States with a nuclear-tipped ballistic missile, and other nations, such as North Korea, could possibly have the capability by 2015.³² Other nations that could possibly develop a capability for HEMP operations over the next few years include United Kingdom, France, India, Israel, and Pakistan.

In 2005, Iran reportedly acquired several medium and intermediate-range ballistic missiles from North Korea, with a range of 2,500 miles.³³ Also, reportedly, Iran has tested several of their Shahab-3 ballistic missiles, which exploded in mid-flight. While these explosions could have been the result of a missile self-destruct mechanism, Iran has officially described the tests as fully successful. It was noted by witnesses at a recent hearing of the Senate Committee on the Judiciary, Subcommittee on Terrorism, Technology and Homeland Security, that this event could indicate that Iran may be practicing for the execution of an HEMP attack.³⁴ However, other observers caution that these and similar actions might simply be a scare tactic used by Iran, but without much substance.³⁵

According to a 1999 DOD report, China has been actively pursuing the development of electromagnetic pulse weapons, and has devoted significant resources to development of other electronic warfare systems and laser weapons. The report also noted that China's leaders view offensive counter space weapons and

³¹ David Fulghum and Douglas Barrie Farnborough, "Directed-Energy Weapon for UAV, cruise and air-to-ground missile payloads nears production," *Aviation Week & Space Technology*, July 26, 2004, p. 34.

³² Michael Sirak, "U.S. vulnerable to EMP Attack," *Jane's Defence Weekly*, July 26, 2004, [http://www.janes.com/defence/news/jdw/jdw040726_1_n.shtml], and House Armed Services Committee, hearing on *Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack*, July 22, 2004.

³³ Alon Ben-David, *Iran Acquires Ballistic Missiles from DPRK*, Jane's Intelligence and Oversight, December 29, 2005.

³⁴ Senate Committee on the Judiciary, Subcommittee on Terrorism, Technology and Homeland Security, March 8, 2005. Jane's Information Group, *Shahab break-ups suggest possible EMP trial*, May 1, 2005, Jane's Rockets and Missiles. Joseph Farah, *Iran plans to knock out U.S. with 1 nuclear bomb*, April 25, 2005, WorldNewsDaily.com, [http://wnd.com/news/article.asp?ARTICLE_ID=43956].

³⁵ Officials in Iran have also reported that in March 2006, they successfully tested their "Fajr-3" long-range missile, which they claim has a range of 2000 miles, and which is invisible to radar. However, other intelligence sources reportedly argue that the "Fajr-3" is merely an upgraded artillery shell with a very short range. *"Iran Claims Test of Fajr-3 Missile 'Invisible' to Radar, Interceptors"*, April 3, 2006, MissileThreat.com, [<http://www.missilethreat.com/news/200604030826.html>].

other space-based defense systems as part of inevitable scenarios for future warfare. The report noted that China could have as many as 60 ICBMs capable of striking the United States by 2010. Also, China may replace 20 of its current ICBMs with a longer-range missile by the end of this decade, or sooner.³⁶

Vladimir Lukin, the former Soviet Ambassador to the United States, and former Chairman of the International Affairs Committee for the Russian Parliament, reportedly has stated that Russia currently has a capability to create a HEMP effect over the United States.³⁷ During 1962, the then Soviet Union conducted a series of atmospheric nuclear tests and observed HEMP effects that included surge protector burnouts, power supply breakdowns, and damage to overhead and underground buried cables at distances of 600 kilometers. Since then, Russia has reportedly made extensive preparations to protect their infrastructure against HEMP by hardening both civilian and military electronic equipment, and by providing continuous training for personnel operating these protected systems.³⁸ Other sources have reportedly stated that Russia may also have some of the leading physicists in the world currently doing research on electronic warfare weapons and electromagnetic pulse effects.³⁹

Ground Wave Emergency Network

During the Cold War, the US Military designed an innovative communications system to relay emergency messages between strategic military areas in the continental United States, using signals that travel by means of low frequency ground waves — electromagnetic fields that hug the ground — rather than by radiating into the atmosphere. The Ground Wave Emergency Network, or GWEN system, was intended to allow continuous communications despite EMP disruptions. However, the hardware was reportedly transistor based, leaving the system with some level of vulnerability to EMP. In addition, the fixed locations of GWEN sites were known to adversaries, and thus vulnerable to direct attack.⁴⁰

³⁶ FY04 Report to Congress on PRC Military Power, Annual Report on The Military Power of the People's Republic of China, [<http://www.defenselink.mil/pubs/d20040528PRC.pdf>].

³⁷ The statement was reportedly made on April 30, 1999, to a U.S. Congressional delegation that traveled to Vienna to meet with officials from the Russian Duma to discuss a framework for a peaceful solution of the then crisis in Kosovo. Hearing before the Military Research and Development Subcommittee of the Committee on Armed Services House of Representatives, October 7, 1999, [http://commdocs.house.gov/committees/security/-has280010.000/has280010_0.HTM].

³⁸ Lowell Wood, statement before the House Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

³⁹ Barry Crane, a physicist and former F-4 pilot now working at the Institute for Defense Analysis, has visited Russia's top electromagnetic pulse laboratories and design bureaus, and has stated that many Russian electromagnetic pulse specialists may also be now working on contract in China. Kenneth R. Timmerman, May 28, 2001, "U.S. Threatened with EMP Attack," *Insight on the News*, [<http://www.insightmag.com/news/2001/05/28/InvestigativeReport/U.Threatened.With.Emp.Attack-210973.shtml>].

⁴⁰ Rosalie Bertell, "Background on the HAARP Project," *Global Policy Forum*, November (continued...)

As the Cold War ended, the U.S. military took steps to reduce its nuclear arsenal and associated infrastructure.⁴¹ After 1998, the USAF decommissioned GWEN assets and replaced the entire system with the Single Channel Anti-Jam Man-Portable (SCAMP) Terminal. SCAMP uses extremely high frequency (EHF) technology, is resistant to EMP, and offers more flexibility than GWEN because the equipment is lightweight, transportable, and interoperable with DOD satellite networks.⁴²

Policy Analysis

Preparedness

What is the United States doing to protect critical infrastructure systems against the threat of electromagnetic pulse? What is the appropriate response from the United States to a nuclear HEMP attack, where there may be widespread damage to electronics, but relatively little, or possibly no loss of life as a direct result? How could the United States determine which nation or group launched a HEMP attack? After experiencing a HEMP effect, the United States may retain its capability to use strategic weapons for nuclear retaliation, but will the U.S. industrial base and critical infrastructure be crippled or incapable of supporting a sustained military campaign? During such time, would the United States be capable of making an effective response should other nations choose to make military advances in other parts of the world?

The U.S. military has adopted a policy where commercial electronic equipment is now used extensively in support of complex U.S. weapons systems. For example, a large percentage of U.S. military communications during Operation Iraqi Freedom was reportedly carried by commercial satellites, and much military administrative information is currently routed through the civilian Internet.⁴³ Many commercial communications satellites, particularly those in low earth orbit, reportedly may degrade or cease to function shortly after a high altitude nuclear explosion.⁴⁴ However, some observers believe that possible HEMP and HPM vulnerabilities of military information systems are outweighed by the benefits gained through access

⁴⁰ (...continued)

5, 1996, [<http://www.globalpolicy.org/soecon/envronmt/weapons.htm>].

⁴¹ Admiral Richard W. Mies, Commander in Chief, United States Strategic Command, statement before the Senate Armed Services Committee Strategic Subcommittee on Command Posture, July 11, 2001, p.11, [<http://www.defenselink.mil/dodgc/lrs/-docs/test01-07-11Mies.rtf>].

⁴² Federation of American Scientists, *AN/PSC-11 Single Channel Anti-Jam Man-Portable (SCAMP) Terminal*, March 2000 [<http://www.fas.org/spp/military/program/com/an-psc-11.htm>].

⁴³ Jefferson Morris, "DISA Chief Outlines Wartime Successes," *Federal Computer Week*, June 6, 2003; and "GAO: DOD Needs New Approach to Buying Bandwidth," *Aerospace Daily*, December 12, 2003.

⁴⁴ U.S. Congress, House Armed Services Committee, *Hearing on Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack*, July 22, 2004.

to innovative technology and increased communications flexibility that come from using state-of-the-art electronics and from maintaining connections to the civilian Internet and satellite systems.

The effects of large-scale HEMP have been studied over several years by the Defense Atomic Support Agency, the Defense Nuclear Agency, and the Defense Special Weapons Agency, and are currently being studied by the Defense Threat Reduction Agency (DTRA). However, the application of the results of these studies has been uneven across military weapons and communications systems. Some analysts state that U.S. strategic military systems (intercontinental ballistic missiles and long-range bombers) may have strong protection against HEMP, while many other U.S. weapons systems used for the battlefield have less protection, and that this is undoubtedly known to our potential adversaries.⁴⁵

Some analysts reportedly state that limited testing has shown that modern commercial equipment may be surprisingly resistant to the effects of electromagnetic pulse, and in addition to the SCAMP system, some military systems using commercial equipment have been retrofitted to increase resistance to EMP.⁴⁶ However, there is disagreement among observers about whether procedures used by the U.S. military to test EMP survivability may have been flawed, leading to erroneous conclusions about the effects of electromagnetic pulse on commercial electronics.⁴⁷

Nuclear Incentive

A single nuclear device exploded at an appropriate altitude above the continental United States could possibly affect our industrial capacity, economic stability, and military effectiveness. Does knowledge of this vulnerability, combined with the proliferation of nuclear technology, provide a new incentive for potential adversaries to develop or acquire a nuclear weapons capability? Will countries now view the development and acquisition of nuclear weapons, even a small arsenal, as a strategy for cyber warfare?

⁴⁵ Because of the very specialized nature, strategic weapons use essentially no commercial equipment. However, DOD increasingly uses commercial equipment in other tactical weapons. Stanley Jakubiak and Lowell Wood, statements before the House Military Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

⁴⁶ Stanley Jakubiak, statement before the House Military Research and Development Subcommittee, Hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999.

⁴⁷ Lowell Wood, statement before the House Military Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, October 7, 1999; and Jack Spencer, "America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse," *The Heritage Foundation Background*, No.1372, May 26, 2000, p.6.; and Carlo Kopp, "The Electromagnetic Bomb — A Weapon of Electrical Mass Destruction," *Air and Space Power* 1993, [<http://www.airpower.maxwell.af.mil/airchronicles/kopp/apjemp.html>].

During the Cold War, a HEMP attack was viewed as the first step of a nuclear exchange involving many warheads, but the threat of mutually assured destruction provided a lasting deterrent. Today, the proliferation of nuclear technology makes the threat of HEMP attack more difficult to assess. Would the leader of a rogue state be motivated to use a small nuclear arsenal to launch a crippling HEMP strike against the United States, with no resulting fatalities, if it believed the U.S. likely would not retaliate with a nuclear salvo, destroying thousands, or millions of innocent people? Would a HEMP strike over a disputed area during a regional conflict be seen as a way to defeat the communications links and network centric capability of the U.S. military, and gain battlefield advantage from an existing supply of smaller nuclear warheads?⁴⁸

Terrorists

A smaller-scale HPM weapon requires a relatively simple design, and can be built using electrical materials and chemical explosives that are easy to obtain. It is estimated that a limited-range suitcase-sized HPM weapon could be constructed for much less than \$2,000, and is within the capability of almost any nation, and perhaps many terrorist organizations.⁴⁹ In 2001, DOD recruited a scientist to create two small HPM weapons for testing using only commercially available electrical components, such as ordinary spark plugs and coils. One device was developed that could be broken down into two parcels so it could be shipped by regular mail, for example, from one terrorist to another. The second HPM device was constructed to fit inside a small vehicle.⁵⁰ Aside from specially-trained dogs, experts reportedly say there are no scientific methods that currently allow easy detection of an explosive device hidden in a vehicle or inside a suitcase before it can explode.⁵¹

It is difficult to assess the threat of a terrorist organization possibly using a smaller-scale HPM weapon against the United States critical infrastructure. It could be argued that an HPM bomb by itself, may not be attractive to terrorists, because its smaller explosion would not be violent enough, and the visible effect would not be as dramatic as a larger, conventional bomb. Also, constructing an HPM device is still somewhat more technically complex than constructing a conventional bomb. However, observers have reported that the leadership of terrorist organization may

⁴⁸ Jack Spencer, "America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse," *The Heritage Foundation Backgrounder*, No.1372, May 26, 2000, p.3.

⁴⁹ Some experts may disagree about whether most terrorist organizations are capable of building an inexpensive HPM weapon powered by a flux-compression generator. Michael Abrams, "The Dawn of the E-Bomb," *IEEE Spectrum Online*, November 2003, [<http://www.spectrum.ieee.org/WEBONLY/publicfeature/nov03/1103ebom.html>], and Carlo Kopp, "The Electromagnetic Bomb — A Weapon of Electrical Mass Destruction," *Air and Space Power*, 1993, [<http://www.airpower.maxwell.af.mil/airchronicles/kopp/apjemp.html>].

⁵⁰ Kenneth R. Timmerman, "U.S. Threatened with EMP Attack," *Insight on the News*, May 28, 2001, [<http://www.insightmag.com/news/2001/05/28/InvestigativeReport/U.Threatened.With.EMP.Attack-210973.shtml>].

⁵¹ Tim Starks, "High-Tech Fixes for Low-Tech Warfare, Experts Say," *CQ Homeland Security - Technology*, August 3, 2004.

increasingly become aware of the growing advantages from an attack launched against U.S. critical information systems. In addition, the use of a new weapon directed at U.S. information systems would attract widespread media attention, and may motivate other rival groups to follow along a new pathway.⁵²

Human Rights

HEMP and HPM energy weapons primarily damage electronic systems, with little or no direct effect on humans, however, these effects may be difficult to limit or control. As HEMP or HPM energy fields instantly spread outward, they may also affect nearby hospital equipment or personal medical devices, such as pace-makers, or other parts of the surrounding civilian infrastructure. For this reason, some international human rights organizations may object to the development or testing of HEMP or HPM weapons.

Legislative Activity

P.L. 110-181, The National Defense Authorization Act for Fiscal Year 2008, requires the Department of Homeland Security to coordinate efforts with the Commission for work related to electromagnetic pulse attack on electricity infrastructure, and protection against such attack. Funding by provided by the Department of Defense to the Commission for preparation and submission of the final report is limited to \$5,600,000. The deadline for the submission of the final report of the Commission has been extended to November 30, 2008.

CRS Products

CRS Report RL32114. *Botnets, Computer Attack, and Cyber Terrorism: Vulnerabilities and Policy Issues for Congress.*

CRS Report RL32411. *Network Centric Warfare: Background and Oversight Issues for Congress.*

CRS Report RS21528. *Terrorist 'Dirty Bombs': A Brief Primer.*

CRS Report IB92099. *Nuclear Weapons: Comprehensive Test Ban Treaty.*

⁵² Jerrold M. Post, Kevin G. Ruby, and Eric D. Shaw, "From Car Bombs to Logic Bombs: The Growing Threat from Information Terrorism," *Terrorism and Political Violence*, vol. 12, no. 2 (summer 2000), pp.97-122.