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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 intense energy field that can instantly overload or disrupt numerous electrical circuits at a distance. Modern high technology microcircuits are especially sensitive to power surges, and the possible vulnerability of U.S. civilian computer systems to the effects of EMP has been discussed in the media. EMP can be produced on a large scale using a single nuclear explosion, and on a smaller, non-nuclear scale using a device with batteries or chemical explosives. 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 computers, communications systems, or parts of the U.S. critical infrastructure.

The threat of an attack against the United States involving EMP 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 a single, specially-designed low-yield nuclear explosion high above the United States, or over a battlefield, can produce an EMP effect that results 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) does the level of vulnerability of U.S. civilian and military electronics to large-scale 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 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] A recent briefing given to the Securities Industry Automation Corporation (SIAC) by panel members from the commission reportedly highlighted what they termed as deficiencies in the U.S. government's readiness to protect against a high-altitude nuclear burst which could emit electromagnetic energy powerful enough to permanently disable many critical infrastructure computers. At a July 22, 2004 hearing before the House Armed Services Committee, panel members from the commission reportedly stated that as U.S. military weapons and control systems become more complex, they may also 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

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[1] Michael Sirak, "U.S. vulnerable to EMP Attack," *Janes'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 Electomagnetic 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.

an EMP attack may create a new incentive for other countries to develop or acquire a nuclear capability.

Questions about Vulnerability to EMP

Some analysts discount the likelihood of a large-scale EMP attack against the United States in the near term, and the extent of 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 reportedly 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.[4] However, other analysts reportedly state 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 predict 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.[5]

Electromagnetic Pulse Weapons

An electromagnetic pulse (EMP), characterized as an energy weapon potentially threatening to national security, usually is created by two methods. High-Altitude Electromagnetic Pulse (HEMP) is an 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) is an electromagnetic pulse produced with special equipment that transforms power from batteries, or from a chemical 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, involve a much lower level of technology, and may be within the capability of many non-state organizations. HPM can cause damage to computers similar to HEMP, although the effects are limited to a much smaller area. The

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

[5] Lowell Wood, Statement before the House Military Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, Oct. 7, 1999; Jack Spencer, "America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse," *The Heritage Foundation Backgrounder*, 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].

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 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.[6] 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 throughout 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)[7], 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.

Description of High-Power Microwave

HPM is a non-nuclear radio frequency energy field. It can be produced as a weapon when a powerful chemical detonation is instantly transformed by a special coil device, called a flux compression generator, into a strong electromagnetic field of microwave energy.[8] Other methods, such as powerful batteries, 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, but only within a very limited range. Unlike HEMP, however, HPM radiation is comprised of shorter wave forms at higher-frequencies, which make it highly effective against electronic equipment and more difficult to harden against. A mechanically simple, suitcase-sized device, using a chemical explosive and special focusing antenna, might

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[6] 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].

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

[8] 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].

theoretically produce a one-time, instantaneous HPM shockwave that could disrupt many computers within a 1-mile range.[9] 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.[10]

Disruptive Capabilities of HEMP and HPM Weapons

Studies related to the effects of electromagnetic weapons have been published infrequently, or remain classified.[11] Nevertheless, it is known that a powerful HEMP field as it radiates outward can interfere with radio frequency links and disrupt 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 Unites 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.[12] 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.[13]

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[9] Dr. Robert C. Harney, Naval Postgraduate School, Apr. 12, 2004, personal communication.

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

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

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

[13] 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*, Nov. 2003, [http://www.spectrum.ieee.org/WEBONLY/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

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To produce maximum HEMP, 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.[14] 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.[15]

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 fail minutes, days, or even weeks later. Recently, a U.S. Commanche helicopter, flying in New

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[13](...continued)
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*, Oct. 7, 1999.

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

[15] 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.

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 an airport in Albany, New York.[16]

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.[17]

Hardening Against HEMP and HPM Weapons

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.[18]

Hardening most military systems, and mass-produced commercial equipment including PCs and communications equipment, against HEMP or HPM reportedly would add from 3% to 10% to the total cost, if the hardening is engineered into the original design. To retro-fit existing military electrical equipment with hardening would add about 10% to the total cost.[19]

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[16] 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].

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

[18] 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].

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

DOD Applications of HEMP and HPM

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.[20] 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 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.[21]

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.[22] The term "non-kinetic" is sometimes used to describe the group of weapons with the above capabilities. This term includes weapons designed to emit directed energy that, in short pulses, may disable computer circuitry, or in other applications, may cause temporary physical discomfort.

HPM can sometimes injure persons in the path of the instantaneous microwave power beam, or can be fatal if persons are too close to the energy-focusing antenna.[23]

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[20] Associated Press, "Experts Cite Electromagnetic Pulse as Terrorist Threat," *Las Vegas Review-Journal*, Oct. 3, 2001.

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

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

[23] Victorino Matus, "Dropping the E-bomb," *The Weekly Standard*, Feb. 2, 2003,

Testing has been done for microwave weapons that can be used for controlling or dispersing crowds without killing people. These types of weapons reportedly create microwave energy of longer duration that causes a painful burning sensation on the skin, but no long-term physical damage.[24]

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 the Air Force Conventional Air-Launched Cruise Missile system. By 2010, DOD reportedly plans to field several air-launched UAVs using disposable and reusable HPM weapons to disrupt enemy computers.[25]

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.[26] Other nations that could possibly develop a capability for HEMP operations over the next few years include United Kingdom, France, India, Israel, and Pakistan.

According to a recent DOD report, China is actively pursuing the development of electromagnetic pulse weapons, and is devoting significant resources to development of other electronic warfare systems and laser weapons. The report also notes that China's leaders view offensive counter space weapons and other space-based defense systems as part of inevitable scenarios for future warfare. The report notes that China could have 30 ICBMs capable of striking the United States by 2005, and as many as 60 by the end of the decade. Also, China may reportedly replace 20 of its current ICBMs with a longer-range version by the end of this decade, or sooner.[27]

Vladimir Lukin, the former Soviet Ambassador to the United States, and former Chairman of the International Affairs Committee for the Russian Parliament,

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[23](...continued) [http://theweeklystandard.com/Utilities/printer_preview.asp?idArticle=2209&R=9F0C225C3].

[24] David Ruppe, "Directed-Energy Weapons: Possible U.S. Use Against Iraq Could Threaten International Regimes," *Global Security Newswire*, Aug. 16, 2002, [http://www.globalsecurity.org/org/news/2002/020816-dew.htm].

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

[26] 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.

[27] 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].

reportedly has stated that Russia currently has a capability to create a HEMP effect over the United States.[28] 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.[29] 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.[30]

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.[31]

As the Cold War ended, the U.S. military took steps to reduce its nuclear arsenal and associated infrastructure.[32] 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

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[28] The statement was reportedly made on Apr. 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, Oct. 7, 1999, [http://commdocs.house.gov/committees/security/-has280010.000/has280010_0.HTM].

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

[30] 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].

[31] Rosalie Bertell, "Background on the HAARP Project," *Global Policy Forum*, Nov. 5, 1996, [http://www.globalpolicy.org/socecon/envronmt/weapons.htm].

[32] 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].

resistant to EMP, and offers more flexibility than GWEN because the equipment is lightweight, transportable, and interoperable with DOD satellite networks.[33]

Policy Analysis

Private Sector Vulnerability

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 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 and incapable of supporting a sustained military campaign? During such time, would the United States be capable of a making an effective response should other nations chose to make military advances in other parts of the world?

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.[34] Officials of several U.S. power stations and public utilities have stated that their electrical systems currently have no protection against electromagnetic pulse.[35] However, electric power and telephone utilities have been known to fail as a result of solar storms which cause effects similar to, but less severe than HEMP from a nuclear blast. Commercial electronic surge arresters used for lightning strikes reportedly do not clamp fast enough to protect against the instantaneous effects of electromagnetic pulse, and some may also not have great enough current carrying capacity.[36]

Military Vulnerability

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

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

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

[35] Associated Press, "Experts Cite Electromagnetic Pulse as Terrorist Threat," *Las Vegas Review-Journal*, Oct. 3, 2001.

[36] 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*, Apr. 15, 2001, Chapter 27, [http://www.usace.army.mil/publications/armytm/tm5-692-2/chap27VOL-2.pdf].

Special Weapons Agency, and is 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 most U.S. weapons systems used for the battlefield do not, and that this uneven protection is undoubtedly known to our potential adversaries.[37] 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 are retrofitted to increase resistance to EMP.[38] However, there is disagreement among observers about whether test procedures used by the U.S. military may have been flawed, leading to erroneous conclusions about the effects of electromagnetic pulse on commercial electronics.[39]

The U.S. military has adopted a policy where possibly vulnerable 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.[40] Many commercial communications satellites, particularly those in low earth orbit, reportedly may degrade or cease to function shortly after a high altitude nuclear explosion.[41] However, some observers believe that possible HEMP and HPM vulnerabilities of military information systems are outweighed by the benefits gained through access 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.

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[37] 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*, Oct. 7, 1999.

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

[39] Lowell Wood, statement before the House Military Research and Development Subcommittee, hearing on *EMP Threats to the U.S. Military and Civilian Infrastructure*, Oct. 7, 1999; and Jack Spencer, "America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse," *The Heritage Foundation Backgrounder*, 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].

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

[41] 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.

New Incentive to Develop a Nuclear Capability

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 newer 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?

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 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. would likely not retaliate with a nuclear salvo that would destroy 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 warfare capability of the U.S. military, and gain maximum battlefield advantage from an existing supply of smaller nuclear warheads?[42]

Terrorist Use of HPM

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.[43] Recently, 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.[44] Aside from specially-trained dogs, experts reportedly say

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

[43] 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*, Nov. 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].

[44] 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].

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.[45]

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 increasingly become aware of the growing advantages from an attack launched against U.S. critical information systems. In addition, the use by a terrorist group 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.[46]

Additionally, the explosives used in a smaller, or suitcase-sized HPM device could simultaneously be used to disperse radioactive materials, making it a so-called "dirty bomb". This combination would offer a possible two-for-one effect, where the dispersed radioactive materials could generate immediate near-panic, while the HPM-damaged computers might not be noticed until days later. This potential double effect could improve the attractiveness of using an HPM device as a terrorist weapon.

Human Rights Objections

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

Legislative Activity

In 1997, the House National Security Committee held a hearing on the Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure, [47] and in 1999, the House Military Research and Development

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[45] Tim Starks, "High-Tech Fixes for Low-Tech Warfare, Experts Say," *CQ Homeland Security - Technology*, Aug. 3, 2004.

[46] 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.

[47] U.S. Congress House National Security Committee, *Threat Posed by Electromagnetic Pulse (EMP) to U.S. Military Systems and Civil Infrastructure*, No. 105-18, July 16, 1997,

(continued...)

Subcommittee held a hearing on the potential threats to United States civilian and military systems from and electromagnetic pulse attack.[48]

A Commission to Assess the Threat from High Altitude Electromagnetic Pulse was established by Congress in FY2001 after several experts expressed concern that the U.S. critical infrastructure and military were vulnerable to EMP attack.[49] Seven of the Commission members were appointed by the Secretary of Defense and two by the Director of the Federal Emergency Management Agency. On July 22, 2004, the Commission presented a report to the House Armed Services Committee, stating that EMP is capable of causing catastrophe for the nation.[50] However, the report, which focuses mainly on the effects of HEMP and not necessarily on HPM, also states that such a catastrophe can be prevented by following recommendations made by the Commission. Testimony during the presentation raised 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 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?

CRS Products

CRS Report RL32114. *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*.

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[47](...continued)
[http://commdocs.house.gov/committees/security/has197010.000/has197010_0.HTM].

[48]U.S. Congress, House Armed Services Committee, *Electromagnetic Pulse Threats to U.S. Military and Civilian Infrastructure*, No. 106-31, Oct. 7, 1999, [http://www.fas.org/spp/starwars/congress/1999_h/has280010_0.htm].

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

[50] 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].