Nuclear electromagnetic pulse

This article is about nuclear-generated EMP. For other types, see Electromagnetic pulse

A **nuclear electromagnetic pulse** (commonly abbreviated as nuclear EMP, pronounced /iː.ɛm.piː/, or NEMP) is a characteristic burst of electromagnetic radiation created by nuclear explosions. The resulting rapidly changing electric and magnetic fields may couple with electrical and electronic systems to produce damaging current and voltage surges. The specific characteristics of any particular nuclear EMP event vary according to a number of factors, the most important of which is the altitude of the detonation.

The term “electromagnetic pulse” generally excludes optical (infrared, visible, ultraviolet) and ionizing (such as X-ray and gamma radiation) ranges. In military terminology, a nuclear warhead detonated hundreds of kilometers above the Earth’s surface is known as a high-altitude electromagnetic pulse (HEMP) device. Effects of a HEMP device depend on factors including the altitude of the detonation, energy yield, gamma ray output, interactions with the Earth’s magnetic field and electromagnetic shielding of targets.

1 History

The fact that an electromagnetic pulse is produced by a nuclear explosion was known in the earliest days of nuclear weapons testing. The magnitude of the EMP and the significance of its effects, however, were not immediately realized.[1]

During the first United States nuclear test on 16 July 1945, electronic equipment was shielded because Enrico Fermi expected the electromagnetic pulse. The official technical history for that first nuclear test states, “All signal lines were completely shielded, in many cases doubly shielded. In spite of this many records were lost because of spurious pickup at the time of the explosion that paralyzed the recording equipment.”[2] During British nuclear testing in 1952–1953 instrumentation failures were attributed to "radioflash", which was their term for EMP.[3][4]

The first openly reported observation of the unique aspects of high-altitude nuclear EMP occurred during the helium balloon lofted Yucca nuclear test of the Hardtack I series on 28 April 1958. In that test, the electric field measurements from the 1.7 kiloton weapon went off the scale of the test instruments and was estimated to be about 5 times the oscilloscope limits. The Yucca EMP was initially positive-going whereas low-altitude bursts were negative pulses. Also, the polarization of the Yucca EMP signal was horizontal, whereas low-altitude nuclear EMP was vertically polarized. In spite of these many differences, the unique EMP results were dismissed as a possible wave propagation anomaly.[5]

The high-altitude nuclear tests of 1962, as discussed below, confirmed the unique results of the Yucca high-altitude test and increased the awareness of high-altitude nuclear EMP beyond the original group of defense scientists.

The larger scientific community became aware of the significance of the EMP problem after a three-article series on nuclear EMP was published in 1981 by William J. Broad in *Science*.[1][6][7]

1.1 Starfish Prime

Main article: Starfish Prime

In July 1962, the US carried out the Starfish Prime test, exploding a 1.44 megaton bomb 400 kilometres (250 mi) above the mid-Pacific Ocean. This demonstrated that the effects of a high-altitude nuclear explosion were much larger than had been previously calculated. Starfish Prime made those effects known to the public by causing electrical damage in Hawaii, about 1,445 kilometres (898 mi) away from the detonation point, knocking out about 300 streetlights, setting off numerous burglar alarms and damaging a microwave link.[8]

Starfish Prime was the first success in the series of United States high-altitude nuclear tests in 1962 known as Operation Fishbowl. Subsequent tests gathered more data on the high-altitude EMP phenomenon.

The Bluegill Triple Prime and Kingfish high-altitude nuclear tests of October and November 1962 in Operation Fishbowl provided data that was clear enough to enable physicists to accurately identify the physical mechanisms behind the electromagnetic pulses.[9]

The EMP damage of the Starfish Prime test was quickly repaired because of the ruggedness (compared to today)[10] of Hawaii’s electrical and electronic infrastructure.

The relatively small magnitude of the Starfish Prime EMP in Hawaii (about 5.6 kilovolts/metre) and the relatively small amount of damage (for example, only 1 to 3 percent of streetlights extinguished)[11] led some scientists to believe, in the early days of EMP research, that the problem might not be significant. Newer calculations[10] showed that if the Starfish Prime warhead had been detonated over the northern continental United States, the magnitude of the EMP would have been much larger (22 to 30 kV/m) because of the greater strength of the Earth's magnetic field over the United States, as well as its different orientation at high latitudes. These calculations, combined with the accelerating reliance on EMP-sensitive microelectronics, heightened awareness that EMP could be a significant problem.

1.2 Soviet Test 184

Main article: Soviet Project K nuclear tests

In 1962, the Soviet Union also performed three EMP-producing nuclear tests in space over Kazakhstan, the last in the "Soviet Project K nuclear tests".[12] Although these weapons were much smaller (300 kiloton) than the Starfish Prime test, they were over a populated, large land mass and at a location where the Earth's magnetic field was greater; the damage caused by the resulting EMP was reportedly much greater than in Starfish Prime. The geomagnetic storm–like E3 pulse from Test 184 induced a current surge in a long underground power line that caused a fire in the power plant in the city of Karaganda.

After the collapse of the Soviet Union, the level of this damage was communicated informally to U.S. scientists.[13] After the 1991 collapse of the Soviet Union, there was a period of a few years of cooperation between United States and Russian scientists on the HEMP phenomenon. In addition, funding was secured to enable Russian scientists to formally report on some of the Soviet EMP results in international scientific journals.[14] As a result, formal documentation of some of the EMP damage in Kazakhstan exists[15][16] but is still sparse in the open scientific literature, especially in relation to the level of damage that was indicated in the open reports.

For one of the K Project tests, Soviet scientists instrumented a 570-kilometer (350 mi) section of telephone line in the area that they expected to be affected by the pulse. The monitored telephone line was divided into sub-lines of 40 to 80 kilometres (25 to 50 mi) in length, separated by repeaters. Each sub-line was protected by fuses and by gas-filled overvoltage protectors. The EMP from the 22 October (K-3) nuclear test (also known as Test 184) blew all of the fuses and fired all of the overvoltage protectors in all of the sub-lines.[15]

Published reports, including a 1998 IEEE article,[15] have stated that there were significant problems with ceramic insulators on overhead electrical power lines during the tests. A 2010 technical report written for Oak Ridge National Laboratory stated that "Power line insulators were damaged, resulting in a short circuit on the line and some lines detaching from the poles and falling to the ground."[17]

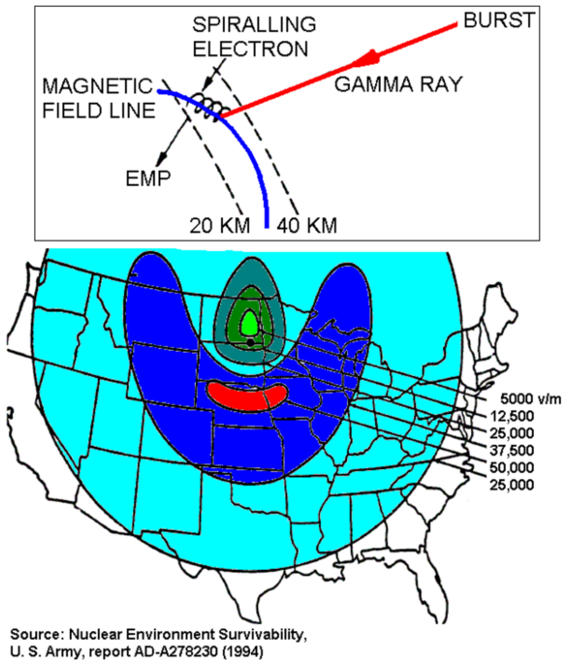
2 Characteristics of nuclear EMP

Nuclear EMP is a complex multi-pulse, usually described in terms of three components, as defined by the International Electrotechnical Commission (IEC).[18]

The three components of nuclear EMP, as defined by the IEC, are called "E1", "E2" and "E3".

2.1 E1

The E1 pulse is the very fast component of nuclear EMP. E1 is a very brief but intense electromagnetic field that induces very high voltages in electrical conductors. E1 causes most of its damage by causing electrical breakdown voltages to be exceeded. E1 can destroy computers and communications equipment and it changes too quickly (nanoseconds) for ordinary surge protectors to provide effective protection against it, although there are special fast-acting surge protectors that will block the E1 pulse.



The mechanism for a 400 km high-altitude burst EMP: gamma rays hit the atmosphere between 20–40 km altitude, ejecting electrons which are then deflected sideways by the Earth's magnetic field. This makes the electrons radiate EMP over a massive area. Because of the curvature and downward tilt of Earth's magnetic field over the USA, the maximum EMP occurs south of the detonation and the minimum occurs to the north.[19]

E1 is produced when gamma radiation from the nuclear detonation ionizes (strips electrons from) atoms in the upper atmosphere. This is known as the Compton effect and the resulting current is called the “Compton current”. The electrons travel in a generally downward direction at relativistic speeds (more than 90 percent of the speed of light). In the absence of a magnetic field, this would produce a large, radial pulse of electric current propagating outward from the burst location confined to the source region (the region over which the gamma photons are attenuated). The Earth’s magnetic field deflects the electron flow at a right angle to the field, leading to synchrotron radiation emitted by the electrons. Because the outward traveling gamma pulse is propagating at the speed of light, the synchrotron radiation of the Compton electrons adds coherently, leading to a radiated electromagnetic signal. This interaction produces a very large, but very brief, electromagnetic pulse over the affected area.[20]

Several physicists worked on the problem of identifying the mechanism of the uniquely large E1 pulse produced by a nuclear weapon detonated at high altitude (HEMP). The correct mechanism was finally identified by Conrad Longmire of Los Alamos National Laboratory in 1963.[9]

Conrad Longmire gives numerical values for a typical case of E1 pulse produced by a second-generation nuclear weapon such as those of Operation Fishbowl in 1962. The typical gamma rays given off by the weapon have an energy of about 2 MeV (mega-electron volts). The gamma rays transfer about half of their energy to the ejected free electrons, giving an energy of about 1 MeV.[20]

In a vacuum and absent a magnetic field, the electrons would travel with a current density of tens of amperes per square metre.[20] Because of the downward tilt of the Earth’s magnetic field at high latitudes, the area of peak field strength is a U-shaped region to the equatorial side of the nuclear detonation. As shown in the diagram at the right, for nuclear detonations over the continental United States, this U-shaped region is south of the detonation point. Near the equator, where the Earth’s magnetic field is more nearly horizontal, the E1 field strength is more nearly symmetrical around the burst location.

At geomagnetic field strengths typical of the central United States, central Europe or Australia, these initial electrons spiral around the magnetic field lines with a typical radius of about 85 metres (about 280 feet). These initial electrons are stopped by collisions with other air molecules at an average distance of about 170 metres (a little less than 580 feet). This means that most of the electrons are stopped by collisions with air molecules before completing a full spiral around the field lines.[20]

This interaction of the very rapidly moving negatively charged electrons with the magnetic field radiates a pulse of electromagnetic energy. The pulse typically rises to its peak value in some 5 nanoseconds. Its magnitude typically decays to half of its peak value within 200 nanoseconds. (By the IEC definition, this E1 pulse ends 1000 nanoseconds after it begins.) This process occurs simultaneously on about 10^{25} electrons.[20] The simultaneous action of the very large number of electrons causes the resulting electromagnetic pulses from each electron to radiate coherently, thus adding to produce a single very large amplitude, but very narrow, radiated electromagnetic pulse.

Secondary collisions cause subsequent electrons to lose energy before they reach ground level. The electrons generated by these subsequent collisions have such reduced energy that they do not contribute significantly to the E1 pulse.[20]

These 2 MeV gamma rays typically produce an E1 pulse near ground level at moderately high latitudes that peaks at about 50,000 volts per metre. This is a peak power density of 6.6 megawatts per square metre.

The ionization process in the mid-stratosphere causes this region to become an electrical conductor, a process that blocks the production of further electromagnetic signals and causes the field strength to saturate at about 50,000 volts per metre. The strength of the E1 pulse depends upon the number and intensity of the gamma rays and upon the rapidity of the gamma ray burst. Strength is also somewhat dependent upon altitude.

There are reports of “super-EMP” nuclear weapons that are able to exceed the 50,000 volt per metre limit by the nearly instantaneous release of a burst of much higher gamma radiation levels than are known to be produced by second-generation nuclear weapons. The reality and possible construction details of these weapons are classified and unconfirmed in the open scientific literature.[21]

2.2 E2

The E2 component is generated by scattered gamma rays and inelastic gammas produced by neutrons. This E2 component is an “intermediate time” pulse that, by the IEC definition, lasts from about 1 microsecond to 1 second after the explosion. E2 has many similarities to lightning, although lightning-induced E2 may be considerably larger than a nuclear E2. Because of the similarities and the widespread use of lightning protection technology, E2 is generally considered to be the easiest to protect against.

According to the United States EMP Commission, the main problem with E2 is the fact that it immediately follows E1, which may have damaged the devices that would normally protect against E2.

The EMP Commission Executive Report of 2004 states, “In general, it would not be an issue for critical infrastructure systems since they have existing protective measures for defense against occasional lightning strikes. The most significant risk is synergistic, because the E2 component follows a small fraction of a second after the first component’s insult, which has the ability to impair or destroy many protective and control features. The energy associated with the second component thus may be allowed to pass into and damage systems."[22]

2.3 E3

Main article: Geomagnetically induced current

The E3 component is very different from E1 and E2. E3 is a very slow pulse, lasting tens to hundreds of seconds. It is caused by the nuclear detonation's temporary distortion of the Earth's magnetic field. The E3 component has similarities to a geomagnetic storm caused by a solar flare.[23][24] Like a geomagnetic storm, E3 can produce geomagnetically induced currents in long electrical conductors, damaging components such as power line transformers.[25]

Because of the similarity between solar-induced geomagnetic storms and nuclear E3, it has become common to refer to solar-induced geomagnetic storms as "Solar EMP."[26] "Solar EMP," however, does not include an E1 or E2 component.[27]

See also: Coronal mass ejection and Solar flare

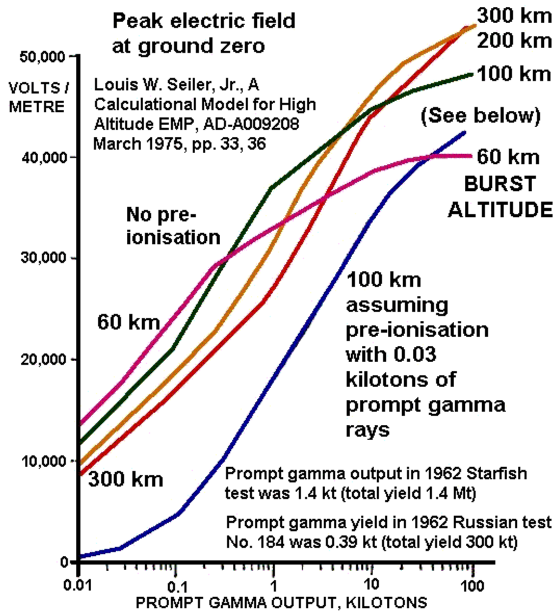
3 Generation

Factors that control weapon effectiveness include altitude, yield, construction details, target distance, intervening geographical features, and local strength of the Earth's magnetic field.

3.1 Weapon altitude

According to an internet primer published by the Federation of American Scientists[30]

> *A high-altitude nuclear detonation produces an immediate flux of gamma rays from the nuclear reactions within the device. These photons in turn produce high energy free electrons by Compton scattering at altitudes between (roughly) 20 and 40 km. These electrons are then trapped in the Earth's magnetic field, giving rise to an oscillating electric current. This current is asymmetric in general and gives rise to a rapidly rising radiated electromagnetic field called an electromagnetic pulse (EMP). Because the electrons are trapped essentially simultaneously, a very large electromagnetic source radiates coherently.*
>
> *The pulse can easily span continent-sized areas, and this radiation can affect systems on land, sea, and air. ... A large device detonated at 400–500 km (250 to 312 miles) over Kansas would affect all of the continental U.S. The signal from such an event extends to the visual horizon as seen from the burst point.*



How the peak EMP on the ground varies with the weapon yield and burst altitude. The yield here is the prompt gamma ray output measured in kilotons. This varies from 0.115–0.5% of the total weapon yield, depending on weapon design. The 1.4 Mt total yield 1962 Starfish Prime test had a gamma output of 0.1%, hence 1.4 kt of prompt gamma rays. (The ***blue*** *'pre-ionisation' curve applies to certain types of thermonuclear weapons, for which gamma and x-rays from the primary fission stage ionise the atmosphere and make it electrically conductive before the main pulse from the thermonuclear stage. The pre-ionisation in some situations can literally short out part of the final EMP, by allowing a conduction current to immediately oppose the Compton current of electrons.)*[28][29]

Thus, for equipment to be affected, the weapon needs to be above the visual horizon.

The altitude indicated above is greater than that of the International Space Station and many low Earth orbit satellites. Large weapons could have a dramatic impact on satellite operations and communications such as occurred during Operation Fishbowl. The damaging effects on orbiting satellites are usually due to factors other than EMP. In the Starfish Prime nuclear test, most damage was to the satellites' solar panels while passing through radiation belts created by the explosion.[31]

For detonations within the atmosphere, the situation is more complex. Within the range of gamma ray deposition, simple laws no longer hold as the air is ionised and there are other EMP effects, such as a radial electric field due to the separation of Compton electrons from air molecules, together with other complex phenomena. For a surface burst, absorption of gamma rays by air would limit the range of gamma ray deposition to approximately

10 miles, while for a burst in the lower-density air at high altitudes, the range of deposition would be far greater.

3.2 Weapon yield

Typical nuclear weapon yields used during Cold War planning for EMP attacks were in the range of 1 to 10 megatons[32] This is roughly 50 to 500 times the size of the Hiroshima and Nagasaki bombs. Physicists have testified at United States Congressional hearings that weapons with yields of 10 kilotons or less can produce a large EMP.[33]

The EMP at a fixed distance from an explosion increases at most as the square root of the yield (see the illustration to the right). This means that although a 10 kiloton weapon has only 0.7% of the energy release of the 1.44-megaton Starfish Prime test, the EMP will be at least 8% as powerful. Since the E1 component of nuclear EMP depends on the prompt gamma ray output, which was only 0.1% of yield in Starfish Prime but can be 0.5% of yield in low yield pure nuclear fission weapons, a 10 kiloton bomb can easily be 5 x 8% = 40% as powerful as the 1.44 megaton Starfish Prime at producing EMP.[34]

The total prompt gamma ray energy in a fission explosion is 3.5% of the yield, but in a 10 kiloton detonation the triggering explosive around the bomb core absorbs about 85% of the prompt gamma rays, so the output is only about 0.5% of the yield. In the thermonuclear Starfish Prime the fission yield was less than 100% and the thicker outer casing absorbed about 95% of the prompt gamma rays from the pusher around the fusion stage. Thermonuclear weapons are also less efficient at producing EMP because the first stage can pre-ionize the air[34] which becomes conductive and hence rapidly shorts out the Compton currents generated by the fusion stage. Hence, small pure fission weapons with thin cases are far more efficient at causing EMP than most megaton bombs.

This analysis, however, only applies to the fast E1 and E2 components of nuclear EMP. The geomagnetic storm-like E3 component of nuclear EMP is more closely proportional to the total energy yield of the weapon.[35]

3.3 Target distance

In nuclear EMP all of the components of the electromagnetic pulse are generated outside of the weapon.[30]

For high-altitude nuclear explosions, much of the EMP is generated far from the detonation (where the gamma radiation from the explosion hits the upper atmosphere). This electric field from the EMP is remarkably uniform over the large area affected.

According to the standard reference text on nuclear weapons effects published by the U.S. Department of Defense, “The peak electric field (and its amplitude) at the Earth’s surface from a high-altitude burst will depend upon the explosion yield, the height of the burst, the location of the observer, and the orientation with respect to the geomagnetic field. As a general rule, however, the field strength may be expected to be tens of kilovolts per metre over most of the area receiving the EMP radiation.”[36]

The text also states that, "... over most of the area affected by the EMP the electric field strength on the ground would exceed $0.5E_{max}$. For yields of less than a few hundred kilotons, this would not necessarily be true because the field strength at the Earth’s tangent could be substantially less than $0.5E_{max}$.”[36]

(E_{max} refers to the maximum electric field strength in the affected area.)

In other words, the electric field strength in the entire area that is affected by the EMP will be fairly uniform for weapons with a large gamma ray output. For smaller weapons, the electric field may fall at a faster rate as distance increases.

4 Effects

4.1 On aircraft

Many nuclear detonations have taken place using aerial bombs. The B-29 aircraft that delivered the nuclear weapons at Hiroshima and Nagasaki did not lose power from electrical damage, because electrons (ejected from the air by gamma rays) are stopped quickly in normal air for bursts below roughly 10 kilometres (6.2 mi), so they are not significantly deflected by the Earth’s magnetic field.[37]

If the aircraft carrying the Hiroshima and Nagasaki bombs had been within the intense nuclear radiation zone when the bombs exploded over those cities, then they would have suffered effects from the charge separation (radial) EMP. But this only occurs within the severe blast radius for detonations below about 10 km altitude.

During Operation Fishbowl, EMP disruptions were suffered aboard a KC-135 photographic aircraft flying 300 km (190 mi) from the 410 kt (1,700 TJ) detonations at 48 and 95 km (30 and 59 mi) burst altitudes.[34] The vital electronics were less sophisticated than today’s and the aircraft was able to land safely.

4.2 Vacuum tube versus solid state electronics

Older, vacuum tube (valve) based equipment is generally much less vulnerable to nuclear EMP than newer solid state equipment.‹See TfD› Soviet Cold War–era military aircraft often had avionics based on vacuum tubes because solid-state capabilities were limited and vacuum-tube gear was believed to be more likely to survive.[1]

Other components in vacuum tube circuitry can be damaged by EMP. Vacuum tube equipment was damaged in the 1962 testing.[16] The solid state PRC-77 VHF manpackable 2-way radio survived extensive EMP testing.[38] The earlier PRC-25, nearly identical except for a vacuum tube final amplification stage, was tested in EMP simulators, but was not certified to remain fully functional.

5 Post–Cold War attack scenarios

The United States military services developed, and in some cases published, hypothetical EMP attack scenarios.[39]

The United States EMP Commission was created by the United States Congress in 2001. The commission is formally known as the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack.[40]

The Commission brought together notable scientists and technologists to compile several reports. In 2008, the EMP Commission released the "Critical National Infrastructures Report".[35] This report describes the likely consequences of a nuclear EMP on civilian infrastructure. Although this report covered the United States, most of the information can be generalized to other industrialized countries. The 2008 report was a followup to a more generalized report issued by the commission in 2004.[24][41]

In written testimony delivered to the United States Senate in 2005, an EMP Commission staff member reported:

> The EMP Commission sponsored a world-wide survey of foreign scientific and military literature to evaluate the knowledge, and possibly the intentions, of foreign states with respect to electromagnetic pulse (EMP) attack. The survey found that the physics of EMP phenomenon and the military potential of EMP attack are widely understood in the international community, as reflected in official and unofficial writings and statements. The survey of open sources over the past decade finds that knowledge about EMP and EMP attack is evidenced in at least Britain, France, Germany, Israel, Egypt, Taiwan, Sweden, Cuba, India, Pakistan, Iraq under Saddam Hussein, Iran, North Korea, China and Russia.
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> Many foreign analysts – particularly in Iran, North Korea, China, and Russia – view the United States as a potential aggressor that would be willing to use its entire panoply of weapons, including nuclear weapons, in a first strike. They perceive the United States as having contingency plans to make a nuclear EMP attack, and as being willing to execute those plans under a broad range of circumstances.
>
> Russian and Chinese military scientists in open source writings describe the basic principles of nuclear weapons designed specifically to generate an enhanced-EMP effect, that they term "Super-EMP" weapons. "Super-EMP" weapons, according to these foreign open source writings, can destroy even the best protected U.S. military and civilian electronic systems.[21]

The United States EMP Commission determined that long-known protections are almost completely absent in the civilian infrastructure of the United States and that large parts of US military services were less-protected against EMP than during the Cold War. In public statements, the EMP experts on the EMP Commission recommended making electronic equipment and electrical components resistant to EMP – and maintaining spare parts inventories that would enable prompt repairs.[24][35][42] The United States EMP Commission did not look at the civilian infrastructures of other nations.

In 2011 the Defense Science Board published a report about the ongoing efforts to defend critical military and civilian systems against EMP and other nuclear weapons effects.[43]

6 Common misconceptions

A 2010 technical report written for the US government's Oak Ridge National Laboratory included a brief section addressing common EMP myths.[44] The remainder of this section is a direct quotation from that Oak Ridge report regarding common HEMP Myths:

> Much of the literature on HEMP is either classified or not easily accessible. Probably because of this, some of what is openly available tends to vary in accuracy – some, especially from the Internet, has major inaccuracies. Some discussions of HEMP have the right words and concepts, but do not quite have them put together right, or have inaccurate interpretations. Here we will discuss some common misunderstandings. HEMP has also appeared in some movies, and there are on-line discussions about possible errors in their depiction of HEMP. Here we will be concerned with E1 HEMP, and ignore misunderstandings about other types of EMP.
>
> **Extremists:** Some general emphasis of comments fall into either "the

world as we know it will come to an end" if there is a high altitude nuclear burst, or the other extreme: "it's not a big deal, nothing much will happen". Since we really have never had a nuclear burst over anything like our current modern infrastructure, no one really knows for sure what would happen, but both extremes are not very believable.

Yield: There appears to be an assumption that yield is important – it is not for E1. The assumption that E1 is an issue only for cold war type situations, but not for terrorists or rogue nations, is false. Very big bombs might have better area coverage of high fields by going to higher burst heights, but for peak fields the burst yield is only a very minor consideration.

1962 experience: Some point to the Starfish event, and the rather minor HEMP effects produced at Hawaii by it. However, there are many problems with extrapolating that experience:

1. That was about half a century ago. Since then, the use of electronics has increased greatly, and the type of sensitive electronics we currently use did not really exist back then.
2. The burst was fairly far away from Hawaii, and the incident E1 HEMP was much less than worst case.
3. The island is small – if over the continental U.S., long transmission lines would be exposed (especially an issue for late-time HEMP). In addition, widely separated substations would have been exposed, although with electromechanical relays (not solid state). Also the yield argument has been used – Starfish was a very big weapon, yet it did very little – see the previous item, yield is not really very significant.

Cars dying: Some say that all vehicles traveling will come to a halt, with all modern vehicles damaged because of their use of modern electronics (and one movie even had a bulk, non-electronic part dying). Most likely there will be some vehicles affected, but probably just a small fraction of them (although this could create traffic jams in large cities). A car does not have very long cabling to act as antennas, and there is some protection from metallic construction. As non-metallic materials are used more and more in the future to decrease weight and increase fuel efficiency, this advantage may disappear.

Wristwatch dying: One movie critic pointed out that electronics in a helicopter were affected, but not the star's electronic watch. A watch is much too small for HEMP to affect it.

Electrons present: One critic, with some awareness of the generation process, said that HEMP could not be present unless there were also energetic electrons present. This is true when one is within the source region, which exists for all types of EMP – there are energetic electrons present. However for the HEMP, the radiation and energetic electrons are present at altitudes of 20 to 40 km, not at the ground.

Turn equipment off: There is truth to this recommendation (if there were a way to know that a burst was about to happen). Equipment is more vulnerable if it is operating, because some failure modes involving E1 HEMP trigger the system's energy to damage itself. However, damage can also happen, but not as easily, to systems that are turned off.

Maximum conductor length: There is a suggestion that equipment will be OK if all connected conductors are less than a specific length. Certainly shorter lengths are generally better, but there is no magic length value, with shorter always being better and longer not. Coupling is much too complex for such a blanket statement – instead it should be "the shorter the better, in general". (There can be exceptions, such as resonance effects, which depend on line lengths.)

Stay away from metal: There is a recommendation to be some distance away from any metal when a HEMP event occurs (assuming there was warning), because very high voltages could be generated. Metal can collect E1 HEMP energy, and easily generate high voltages. However, the "skin effect" (a term not really derived from the skin of humans or any other animal) means that if a human were touching a large "antenna" during an E1 HEMP event, any current flow would not penetrate into the body. Generally E1 HEMP is considered harmless for human bodies.

7 Protecting infrastructure

In 2013, the U.S. House of Representatives considered the "Secure High-voltage Infrastructure for Electricity from Lethal Damage Act" that would allow the Federal Energy Regulatory Commission to order emergency measures to provide surge protection for some 300 large transformers around the country.[45] The bill was introduced and referred to committee, but proceeded no further.[46]

The problem of protecting civilian infrastructure from electromagnetic pulse has also been intensively studied throughout the European Union, and in particular by the United Kingdom.[47][48]

8 In fiction and popular culture

Main article: Electromagnetic pulse in fiction and popular culture

Especially since the 1980s, Nuclear EMP weapons have gained a significant presence in fiction and popular culture.

The popular media often depict EMP effects incorrectly, causing misunderstandings among the public and even professionals, and official efforts have been made in the United States to set the record straight.[44] See, for example, the Oak Ridge quotation in the above section of this article on "Common Misconceptions." Also, the United States Space Command commissioned science educator Bill Nye to produce a video called "Hollywood vs. EMP" so that Hollywood fiction would not confuse those who must deal with real EMP events.[49] The U.S. Space Command video is not available to the general public.

9 See also

- Electromagnetic compatibility (EMC)
- Electromagnetic environment
- Electromagnetic hypersensitivity
- Electromagnetic pulse in fiction and popular culture
- Electromagnetic weapon
- Electromagnetism
- Electronic warfare
- Explosively pumped flux compression generator
- Faraday's law of induction
- Gamma ray burst
- Geomagnetic storm
- High-altitude nuclear explosion
- High-power microwave
- Marx generator
- Operation Fishbowl
- Pulsed power
- Soviet Project K nuclear tests
- Starfish Prime
- Ultrashort pulse

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- Vladimir Gurevich "Cyber and Electromagnetic Threaths in Modern Relay Protection" - CRC Press (Taylor & Francis Group), Boca Raton – New York – London, 2014, 222 p.
- Vladimir Gurevich "Protection of Substation Critical Equipment Against Intentional Electromagnetic Threats" - Wiley, London, 2016, 300 p.

11 Further reading

- ISBN 978-1-59-248389-1 A 21st Century Complete Guide to Electromagnetic Pulse (EMP) Attack Threats, Report of the Commission to Assess the Threat to the United States from Electromagnetic ... High-Altitude Nuclear Weapon EMP Attacks (CD-ROM)
- ISBN 978-0-16-056127-6 Threat posed by electromagnetic pulse (EMP) to U.S. military systems and civil infrastructure: Hearing before the Military Research and Development Subcommittee - first session, hearing held July 16, 1997 (Unknown Binding)
- ISBN 978-0-471-01403-4 Electromagnetic Pulse Radiation and Protective Techniques
- ISBN 978-0-16-080927-9 Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack

12 External links

- Glasstone, Samuel; Dolan, Philip J. (1977). "The Effects of Nuclear Weapons". United States Department of Defense.
- GlobalSecurity.org – Electromagnetic Pulse: From chaos to a manageable solution
- Electromagnetic Pulse (EMP) and Tempest Protection for Facilities – U.S. Army Corps of Engineers
- EMP data from *Starfish* nuclear test measured by Richard Wakefield of LANL, and review of evidence pertaining to the effects 1,300 km away in Hawaii, also review of Russian EMP tests of 1962
- Read Congressional Research Service (CRS) Reports regarding HEMP
- MIL-STD-188-125-1
- Electromagnetic Pulse Risks & Terrorism
- How E-Bombs Work
- Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack
- NEMP and Nuclear plant

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