

NUCLEAR EXPLOSIONS IN SPACE:

THE THREAT OF EMP (ELECTROMAGNETIC PULSE)

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AUTHOR:

George N. Chatham

Science Policy Research Division

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## ISSUE DEFINITION

A high-altitude nuclear explosion produces electrons which may be caught by the Earth's magnetic field and convert their energy into radio waves. The net effect is a microsecond burst of intense, broad frequency radio wave energy, which is one form of an Electromagnetic Pulse or EMP. Although EMP does not threaten living things, it can disrupt or destroy unprotected solid state electronics, including those used in radio and telephone services, computers and computer magnetic memory banks, aircraft instrumentation and flight controls, ignition and control modules in automobiles, protective devices which sustain electric power distribution in the United States, and satellites and their ground stations. At issue is the vulnerability of the Nation and the measures that can be implemented to minimize the damage that can be caused by EMP.

## BACKGROUND

### History

The high-altitude EMP was first encountered during nuclear testing over Johnson Island in the Pacific in 1958. During this test period, 1958-1963, EMP was not a threat to the relatively primitive vacuum tube electronics nor to the electromechanical relays of telephone systems. It was regarded as a mystery and an "interference." In 1962 the Rand Corporation in California published an explanation of how the pulse was generated along with its approximate magnitude.

Electronic vulnerability to the EMP emerged in the next decade with the electronic revolution which began in the early 1960s. The vacuum tube era gave way to solid state electronics. Only milliwatts of power could perform electronic tasks which required watts using the older technology.

As efficiency rose, sensitivity to transient surges of current also rose. The solid state circuitry, almost universal by 1970, proved to be a thousand to a million times as easily damaged by an EMP as the older vacuum tube technology.

The growth of understanding within the military establishment of EMP effects as well as the problems of EMP countermeasures is revealed in the history of the Safeguard antiballistic missile (ABM), a system of radars, computers, and nuclear-armed interceptor missiles to have been deployed at twelve sites across the United States starting in the early 1970s. As an understanding of EMP developed in the military, protective measures ("hardening") and EMP simulation equipment became a major cost in the Safeguard project. Although the missiles and ground control systems were hardened, the possibility was recognized that the explosion from the Safeguard or Soviet nuclear warhead might isolate the site from all communication. Essential links to NORAD (the North American Defense Command) and NORAD's links to the President could be terminated by the pulse. The extent to which Safeguard might impair the overall defensive capability remained a debate throughout the life of the project (1969-1976).

Ironically, the threat posed by Safeguard was significantly reduced by the May 1972 anti-ballistic missile treaty with the Soviet Union. The treaty

permitted two ABM sites; a 1974 protocol to the treaty reduced that number to one. A single Safeguard base became operational in April 1975 but closed in February 1976, primarily due to concern that the utility of a single ABM site could be nullified by the growing Soviet missile force. Concern over the loss of communications to EMP remained.

Solid state electronics initiated several trends in the early 1960s which began to accelerate and still continue to do so today. Circuitry is now more compact by six or seven orders of magnitude compared to vacuum tube technology. Power consumption has decreased by a similar amount. The cost of circuitry has also decreased by five to six orders of magnitude. This combination of factors has led to a geometric growth of tasks and capabilities. Small electronic chips now control and monitor vehicle engines, provide instrument displays, and provide \$20.00 pocket calculators the mathematical power that would have cost over a million dollars in the late 1950s. They control and program factory machines, home kitchen equipment, toys and games.

Along with this revolution their sensitivity to transient charges of electricity has risen in about the same proportion. Modern circuitry is about a million times as easily destroyed by an EMP as the older vacuum tube systems. This sensitivity may be expected to rise steadily along with growth of the role played by electronics.

#### The EMP Phenomenon

The gamma ray flash from a high-altitude nuclear explosion produces a spherical wave front. The portion of this sphere expanding toward the Earth impacts the upper atmosphere tearing loose a heavy charge of electrons. The free electrons are immediately captured by the Earth's magnetic field. They dissipate their velocity by spinning around the magnetic field lines, converting their energy into radio waves. The net effect is a microsecond burst of intense, broad frequency radio wave energy, which is one form of an Electromagnetic Pulse or EMP.

Since the EMP contains a broad spectrum of frequencies, an electrical conductor of any length can serve as an antenna. The heaviest jolt is received from the electrical service lines. However, wiring internal to electronic equipment also receives and conducts the surge directly into the circuitry.

The disruptive capability of the EMP is due more to its shape than to the total energy it contains. The duration of the pulse is about a millionth of a second (a microsecond) but the peak power density is nearly instantaneous -- a few billionths of a second (about 10 nanoseconds). The total energy received from a nominal one-megaton burst above the atmosphere is small -- about half a joule per square meter. The peak power density, however, reaches 6 megawatts per square meter. The onset of the peak power density is a hundred times more rapid than that of lightning. As a consequence, conventional lightning surge protective devices are not effective against the EMP.

Any electrical conductor may serve as an antenna for the pulse, even short lengths of internal wire. All electronic circuitry more advanced than that using vacuum tubes may be affected by the pulse. This may include all communication networks, transmitters and receivers, and all telephone systems except those in which glass fiber has been substituted for wire. Computers

may be destroyed and magnetic tapes and discs erased. Machines and vehicles which employ electronic modules in their operation would be disabled. Electronic instruments such as aircraft NAVCOM and flight control systems may be destroyed.

Satellites exposed to the expanding spherical wave front of gamma and x-rays could also receive a crippling or destructive EMP. The radiation could free electrons from the metal skin of the satellite, creating an electric charge. The intensity of the charge could reach a million volts per meter. The electronic payload would then receive large induced currents, not unlike a lightning strike. This effect is called a system-generated EMP or SGEMP.

Protection or hardening against SGEMP presents a problem which is not entirely solved. Even a double walled satellite would not be immune to a pulse strong enough to induce a charge in the inner shell. A single nuclear warhead could conceivably disable all satellites not shielded by the Earth. This would include synchronous, as well as low altitude civil and military satellites. Defensive systems such as laser battle stations and offensive systems such as killer satellites or enroute missiles could also be disabled or damaged by the SGEMP.

#### The Effect of EMP

A nuclear explosion 150 miles above the geographic center of the country is too distant to inflict direct damage or threaten life. However, at this altitude, the expanding sphere of gamma radiation would excite a lens shaped segment of the upper atmosphere several thousand square miles in area. The resulting EMP would cover most of the United States.

Large-scale power blackouts could occur. Power plants could automatically shut down as the pulse triggered fault sensors. The power distribution grid would then be imbalanced causing many more generating facilities to shut down in response to surges and overloads. However, with no additional EMP's, power distribution could be restored in a matter of hours or a day.

More serious would be the destruction of electronic circuitry. On line equipment would receive the EMP through the electrical service connection. New equipment in stores or warehouses would receive the pulse through wire leads which would serve as antennae.

In brief the main effects of the EMP would be temporary, large-scale power losses followed by longer-duration communications effects. Computer dependent banking functions, air fleet operations, and surface transportation systems could all be affected. There are concerns that defensive and retaliatory capability as well as the operation of military communication systems could also be disrupted.

#### Protection from the EMP

The word "harden," borrowed from the military, has come to mean "protect." For example, a computer which has been "hardened" is shielded or otherwise protected against the EMP. Protection from the pulse is simple in principle. Conductors such as power cables or antenna leads may be fitted with surge arrestors or filters designed specifically for the fast rise time of the pulse. Other than this, the equipment may be either encased in metal (a

Faraday Shield) or simply taken deep underground. New equipment, stores, and spares could be protected by the use of a continuous metal covering, possibly a foil, applied as part of the packaging process.

Some protection for large open networks such as electrical power and telephone grids could be achieved by replacing the systems now in use with underground networks or by protecting the networks above ground. Such procedures are generally considered too costly for practical consideration. Advancing technology may eventually reduce the EMP as a threat to the telephone as copper conductors are replaced by optical fibers. However, optical fiber systems have terminals and repeaters which must also be hardened.

Military hardening began in aircraft strategically important in conducting a retaliatory strike or serving as an aerial command post. This includes most aircraft in the Strategic Air Command. Unhardened aircraft in which the pilot's input to the control surfaces is electronic ("fly-by-wire") may be disabled by the EMP, but there are only a few of these.

Further hardening is now underway to protect surface installations and military communication networks. Continuity of electric power in missile launching facilities is being assured by the installation of fuel cells as well as auxiliary generators. Optical fiber cables are replacing conventional telephone networks for local communication. Information on the hardening status of long distance military communication networks is not available.

Since total hardening of civil and military resources against EMP is not possible, decisions on protection must weigh threat assessment, cost, and consequences. In the case of the military, the deterrent value of an immune retaliatory force is also a consideration.

### Issues

1. The number of space-capable launchers increases with time and some may become commercially available during this decade. Can a threat assessment be made of the prospect of a hostile nation or group inflicting an EMP in the manner of a terrorist blow, not as an opening to war?

2. Should governing bodies be encouraged to protect their own computer capabilities and magnetically recorded data? Should financial institutions and communication networks?

3. Should systems of protective packaging for electronic goods be developed and their use encouraged?

4. Should industrial and public educational programs be initiated which encourage hardening of electronic circuitry in vehicles, factory equipment and possibly in the home?

5. When a power plant generator is started, it will not produce current until an outside electrical source is applied to initiate the formation of its magnetic field. Once formed the generator sustains its own field. This means that in a total shut down, the plant remains off-line until electricity can be brought in from another plant or generator. Have utilities made adequate provision to reduce down time in the event of widespread total shut-downs (such as by keeping small auxiliary generators on hand)?

6. Should the replacement of copper telephone lines with cables of optical fiber, at least over trunk lines, be encouraged or somehow accelerated?

7. To what extent should orbiting equipment, civil as well as military, be protected against SGEMP?

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