U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

AD-A023 775

THE ELECTROMAGNETIC PULSE (EMP)

ARMY NUCLEAR AGENCY

JUNE 1974

NUCLEAR NOTES NUMBER 1

THE ELECTROMAGNETIC PULSE

(EMP)

NUMBER ONE IN A SERIES OF INFORMATION PAPERS ON TOPICS ASSOCIATED WITH NUCLEAR WEAPONS, PRINCIPALLY DESIGNED FOR USE BY TRADOC SCHOOL INSTRUCTORS AND MAJOR COMMAND STAFF OFFICERS.

CAC NUA

JUNE 1974

PREPARED BY THE

UNITED STATES ARMY NUCLEAR AGENCY
FORT BLISS, TEXAS 79916

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

The US Army Nuclear Agency recommends that issues of Nuclear Notes be retained and filed in a loose leaf binder.

Local reproduction and distribution is authorized; but headquarters that do so are requested to maintain a record of internal distribution so that changes, up-dates, and corrections may be properly disseminated.

115277

June 1974

FOREWORD

The series of papers, "Nuclear Notes," prepared by the US Army Nuclear Agency is intended to clarify and explain various aspects of nuclear weapons phenomenology and usage. These papers are prepared in as non-technical a fashion as the subject matter permits. They are oriented toward an audience assumed to be responsible for teaching or in some way evaluating the tactics and techniques of employing nuclear weapons in a conflict situation. Their dissemination will hopefully provide to the US Army accurate, up-to-date information of critical importance to a reasoned understanding of nuclear weapons on the battlefield.

The material in this paper reflects the ideas and findings of the principal author, CPT E. J. Gaul, and the US Army Nuclear Agency. It is not to be construed as an official position of any other element of the US Army unless otherwise indicated. Comments and views of readers are desired and should be forwarded to: Commander, US Army Nuclear Agency, Fort Bliss, Texas 79916.

ROY E. LOUNSBURY
COL, IN
Commanding

The Electromagnetic Pulse (EMP)

One tends to think of the effects of a nuclear detonation in terms of blast, thermal radiation, and nuclear radiation. However, the one effect which may be most critical to the Army in the field is the Electromagnetic Pulse (EMP). Commanders, tacticians, and analysts at all levels must have a clear understanding of EMP if the Army is to function effectively prior to or in a tactical nuclear war. Many misconceptions about EMP seem to be floating about in the Army community, e.g., EMP will wipe out all the communications no matter what we do; or, our lightning protection will protect us against EMP. The purpose of this paper is to present EMP for what it is and what it is not, with a minimum of technical details.

The electromagnetic pulse is critical because of its unique properties and effects:

1. It does not affect people, just equipment; in particular command, control, and communications (C^3) equipment and electrical and electronics systems.

2. The EMP's large "killing" range -- hundreds of kilometers from a high altitude nuclear burst; perhaps tens of kilometers from a surface nuclear burst.

3. The EMP is capable of causing disruption or damage to electronics from a burst at distances where other weapons effects such as nuclear radiation, blast, and thermal radiation effects are not important as damage mechanisms.

4. Modernized C^3 is feeding the threat. The EMP affects electronics, the most susceptible being the complex systems utilizing semiconductor technology. The Army's increasing dependence on sophisticated command, control, and communications (C^3) systems enhances the EMP threat proportionally.

The magnitude of the EMP threat is best visualized by comparing it to other electromagnetic phenomena. Table 1 lists several electromagnetic energy requirements.

Table 1 - Electromagnetic Energy Comparison

Power/Energy Source	Power Density (Watts/square meter)
Typical Radio Receiver	0.001
Typical Radio Transmitter	100
Directional Pulse Radar	1,000
EMP	1,000,000

The complete quantification of the EMP threat and its impact on doctrine and tactics is not on hand at the present time. Two statements can be made about the EMP:

1. The EMP threat is solvable; a Gordian Knot perhaps, but not a sorcerer's curse.

2. Enough scientific and engineering knowledge is currently available to attack the vulnerability and survivability of C^3 systems to EMP*.

This paper provides a survey of the EMP situation which includes defining what the phenomenon is, why it occurs, how it can damage Army equipment, and what can be done to overcome the threat. This is important to a commander because without this knowledge, he could easily cause his communications systems to be knocked out at a time when it is most critical to be able to communicate.

Definition: The EMP is a broad bandwidth electromagnetic energy pulse of short duration produced by the interaction of nuclear radiation (from a nuclear burst) with the atmosphere, or the atmosphere and the earth's surface.

---

*See reference 1 for a detailed discussion of EMP and its effects.

Preceding page blank

One is tempted to think of the electromagnetic aspect of EMP in terms of lightning. Although the simile of being electromagnetic in nature is valid, they should be handled as two separate electromagnetic phenomena, and both require protective measures.

EMP is best considered at its beginning, i.e., the interaction of nuclear radiation from a nuclear burst with the atmosphere. Figure 1 is a representation of a nuclear weapon detonation showing the forms of energy release, namely blast, thermal, and nuclear radiation.

Nuclear radiation consists of gamma rays (γ), x rays, and neutrons (n) which emanate from the point of detonation. Gamma rays are the dominant source of radiation which leads to the production of the EMP, and the EMP results from a nuclear detonation at any altitude from subsurface to exoatmospheric. Figure 2 shows the burst height altitude regimes from an "EMP production and propagation" viewpoint. The regimes are exoatmospheric, air, surface, near-surface, and subsurface heights of burst (HOB).

A nuclear burst at any altitude produces two kinds of electromagnetic fields in two different regions as shown in Figure 3; the source field region or volume, and a radiated field. One can think of this in terms of a super large antenna; antennas have strong electromagnetic fields within and radiate an electromagnetic field.

The EMP source region is physically defined by the volume of atmosphere in which the gamma-ray interactions take place with air molecules. This produces strong electric currents, and, just as in an antenna, if the currents are produced asymmetrically, a radiated field is launched. The radiated energy propagates away from the source region, and is called radiated EMP. The strength and area coverage of both types of EMP (source region and radiated) depend on height of burst and yield of the weapon.

Figure 4 pictorially demonstrates the effect of height of burst on the size of the EMP source region, the degree of asymmetry of the source region currents, and thus the strength of the radiated EMP. Note that the high altitude source region is pancake in shape and very large. This results in the large area coverage on the ground of its radiated EMP.

Table 2 summarizes the strength and area coverage of the source and radiated fields, from different heights of burst. These strengths are what a land-based Army system would experience. Note that the source region in some HOB cases is low strength or no effect. This occurs only because the source region is not touching or connected with the ground so its effect on land based systems can be neglected. The same applies to weak radiated fields. An examination of

Table 2 - Strength and Area Coverage of EMP on Land Systems

	Source Region		Radiated	
	Strength	Area (km^2)	Strength	Area (km^2)
Exoatmospheric	NA	NA	High	1,000,000
Air	NA	NA	NA	NA
Near-Surface	Low-High	10	Low	50
Surface	High	10	Low	50
Subsurface	High	<1	NA	NA

Table 2 shows that there are two critical cases to land systems:

1. Radiated field from an exoatmospheric burst.
2. Source region fields from surface/near-surface bursts.

The area coverage of the EMP on the ground is also critical; an area of tens of thousands of square kilometers resulting from the exoatmospheric burst, and tens of kilometers from the surface/near-surface burst. Reference 1 contains a detailed description of exoatmospheric and surface burst generated EMP.

How does EMP affect equipment? Before discussing the effects of EMP on equipment, it is necessary to understand the composition of the EMP. As stated in the definition, the EMP is

NUCLEAR BURST ENERGY RELEASE

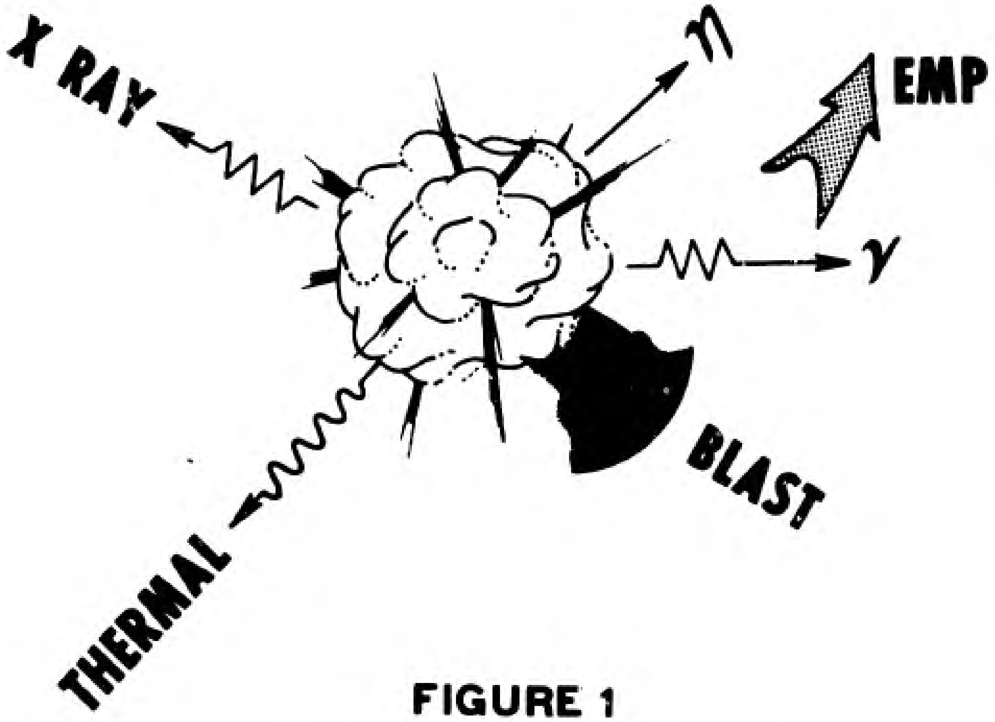

FIGURE 1

EMP ALTITUDE REGIMES

EXOATMOSPHERIC

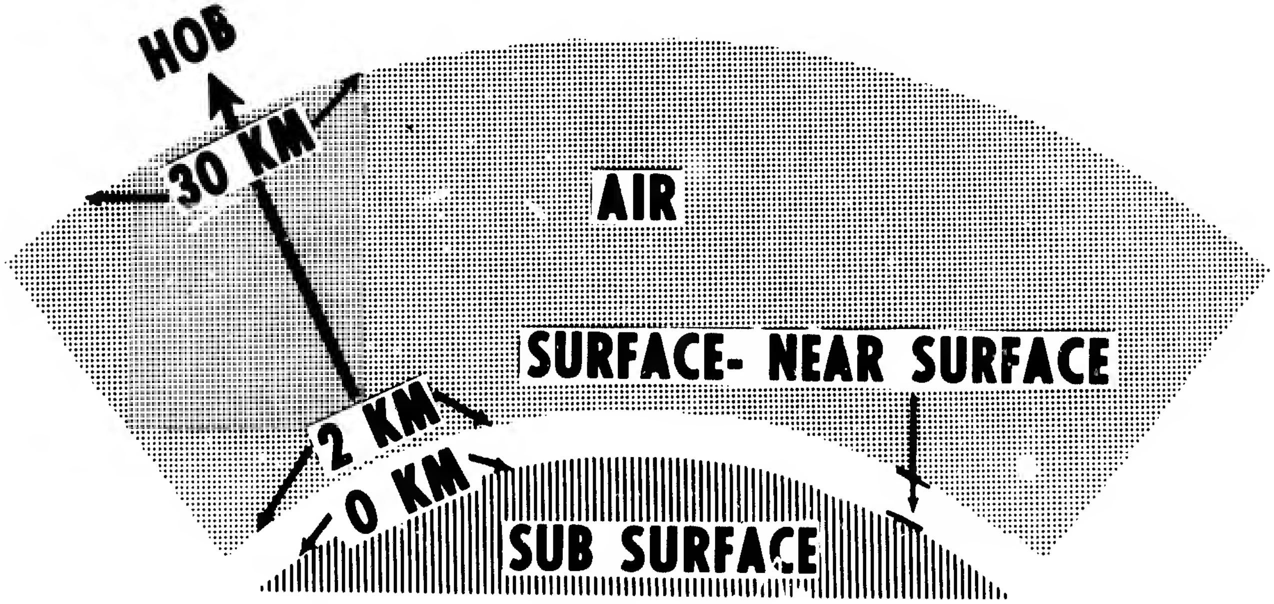

FIGURE 2

SOURCE REGION AND RADIATED EMP

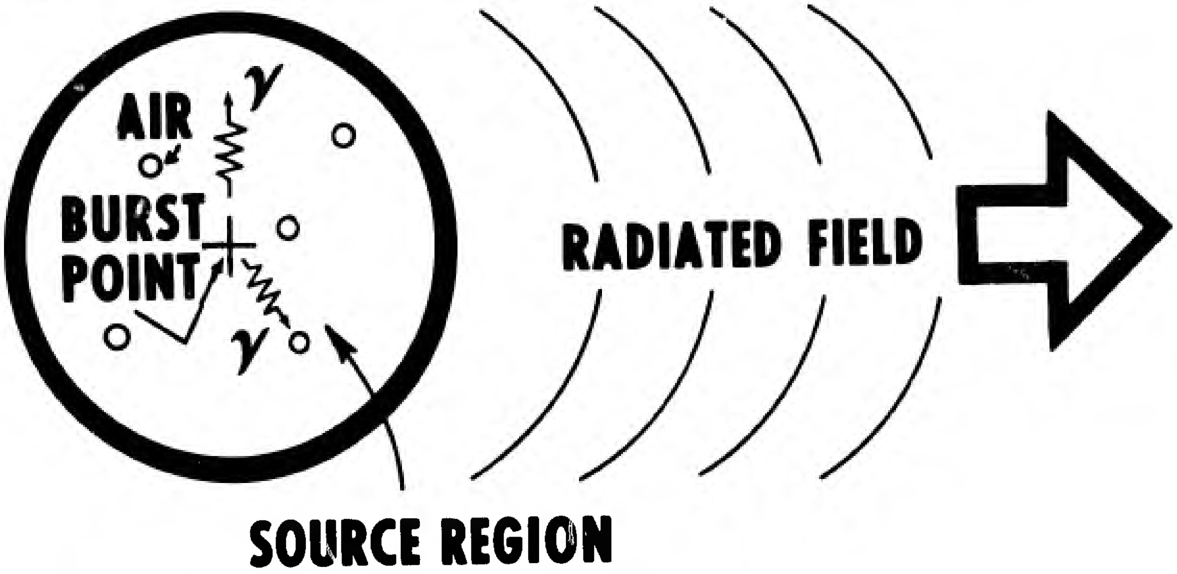

FIGURE 3

SOURCE EMP- RADIATED EMP

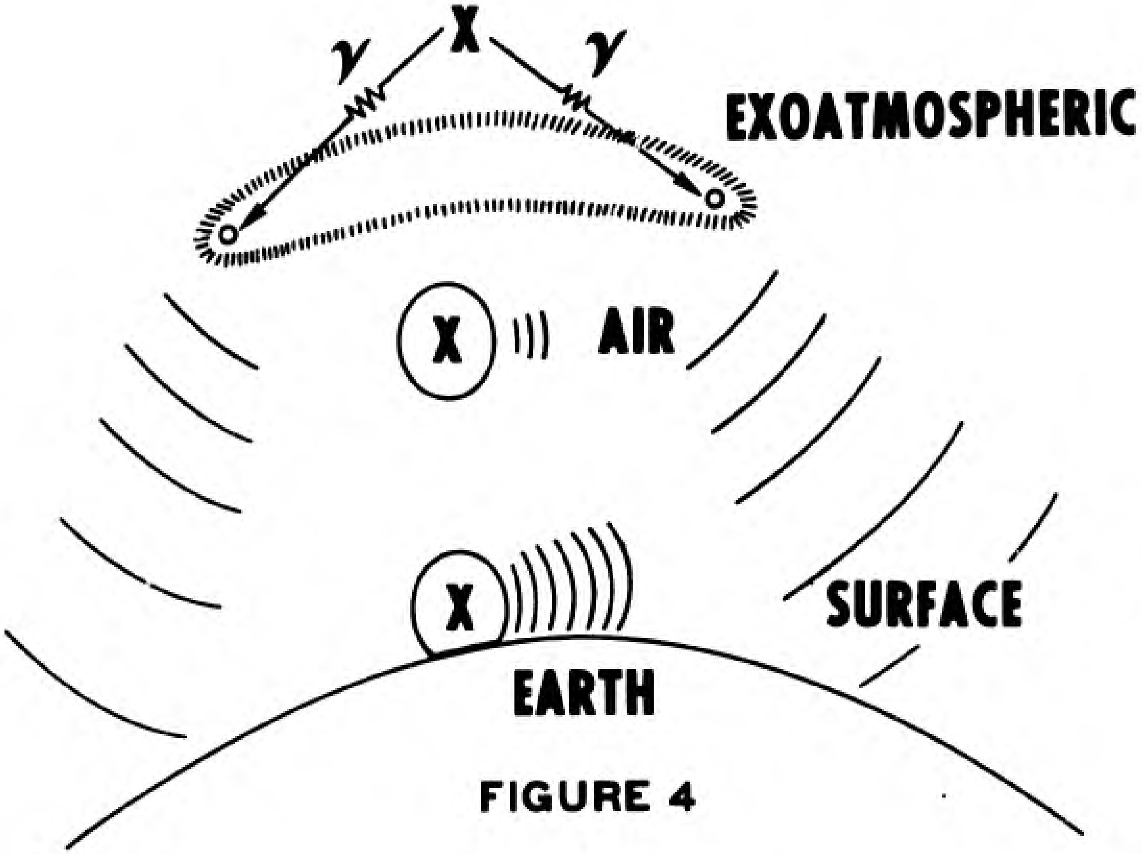

FIGURE 4

broadband or, composed of a wide range of frequencies. The analogy diagrammed in Figure 5 may help to provide an insight into the frequency composition of an electromagnetic pulse. Consider a large number of high power radar and radio transmitters, no two operating at the same frequency, all turned on to full power at time zero and turned off a few microseconds (μ seconds) later. The result would be a block of electromagnetic energy several microseconds in duration, composed of many frequencies, each frequency having a considerable amount of electromagnetic energy associated with it. This fairly well characterizes the make-up of the EMP; a high energy pulse of electromagnetic energy composed of a broad band of frequencies.

Materiel with good electrical conduction properties, e.g., cables, wires, antenna, and metal structures, all absorb EMP energy to a varying degree. The degree of absorption depends on the electrical properties, size, and shape of the materiel. This is analogous to the design and operation of a typical field radio. One tunes the radio to amplify the operating frequency desired. But if the wrong antenna is used, the desired frequency may come in weak. Using the correct antenna allows a sufficient amount of the signal to be picked up or absorbed and amplified within the radio.

All electrically conducting parts have this characteristic of absorbing some ranges of frequencies better than others, and to a varying degree of efficiency. The term usually used is "coupling" and materiel which couples with electromagnetic energy may absorb a sufficient amount of energy from the EMP. This induces voltages and currents in the materiel and should the materiel be connected with a component, device, or system which is voltage or current sensitive, damage could result.

Modern communications and electronics equipment are sensitive due to the extensive use of microcircuit transistor technology. These devices cannot normally handle the voltage and current surges that result from EMP coupling without special design considerations.

An example of the EMP Environment-Coupling-Equipment Damage chain for a hypothetical piece of electronics equipment is presented in Figure 6. EMP may couple into cables, wires, antennas, and metal enclosures which can transmit the energy to sensitive electronics within. Burn out of transistors, upset of digital functions, or equipment performance degradation would result. Extensive test and analysis can determine the extent of EMP energy coupling and the resultant performance degradation levels. Possible locations for design or retrofit procedures to correct the vulnerability are shown by the X's in Figure 6 and include:

a. Protective devices installed in cables, wires, and antenna lead ins.

b. Replacement of damageable transistors by less susceptible transistors (usually more expensive).

c. Modification of grounding techniques.

d. Electrically shielding the metal enclosure.

It must be stressed that it is not possible to determine "a priori" what the quantitative effects of EMP on a complicated piece of communications or electronics will be. However, the Army has developed a nuclear survivability program to protect critical equipment against EMP. This program requires the specification of nuclear survivability criteria and a comprehensive design, test, and analysis program against these criteria.

The Army Nuclear Agency specifies nuclear survivability criteria for Army equipment (reference 2). Figure 7 is a flow chart which indicates the critical points in the equipment development process, with respect to EMP. It begins with an equipment concept in a Required Operational Capability (ROC) document where the need for nuclear survivability criteria should be established. EMP survivability is then obtained by integrating EMP design, subsystem test and analyses, system test and analyses, redesign, and production control into the normal developmental cycle.

Figure 7 demonstrates the amount of testing that may be required in an EMP survivability program. It includes testing of individual electronic components, electrical circuits, subassemblies, end items, and full scale system tests. The latter are performed at large EMP simulator facilities such as the Defense Nuclear Agency (DNA), Transportable EMP Simulator (TEMPS). Figure 8 is a sketch of a threat level EMP simulator and a system test. For a missile system, this would include missile and launcher, and integral command, control, and communications subsystems. The total system test is required since EMP energy can be transferred back and forth through interconnecting cables and the grounding scheme. Once equipment is fielded, there must

EMP FREQUENCY CONTENT

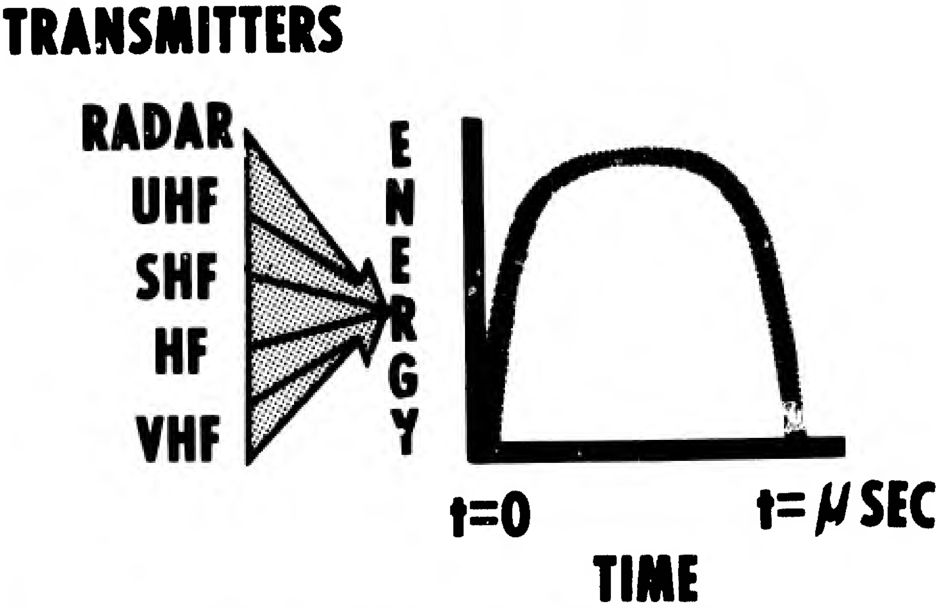

FIGURE 5

EMP DAMAGE CHAIN

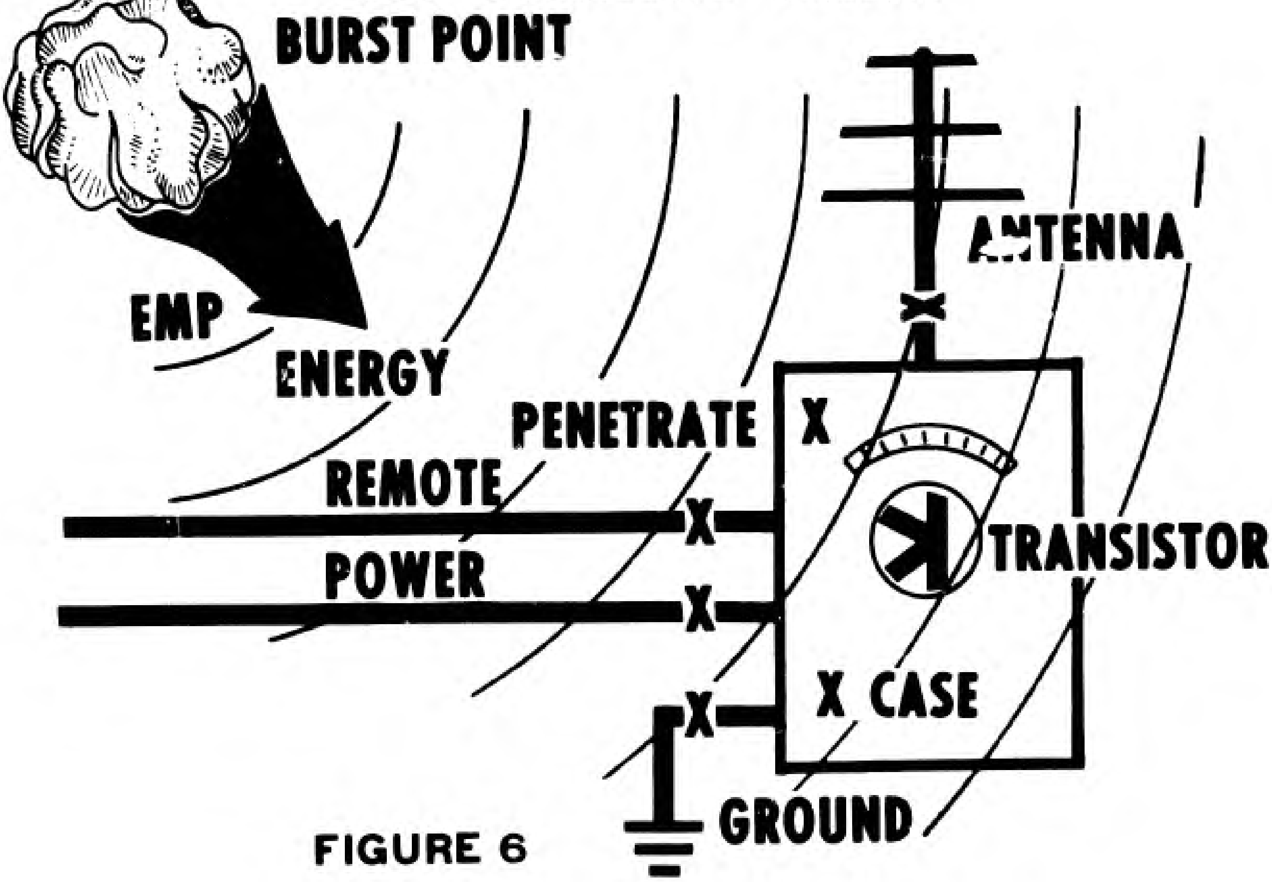

FIGURE 6

EMP CRITICAL POINTS

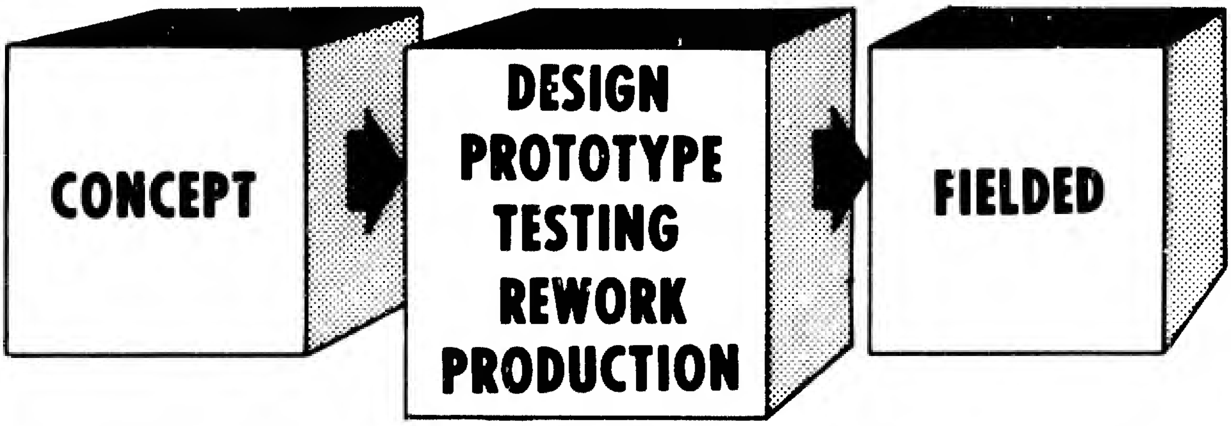

FIGURE 7

SYSTEM EMP TEST

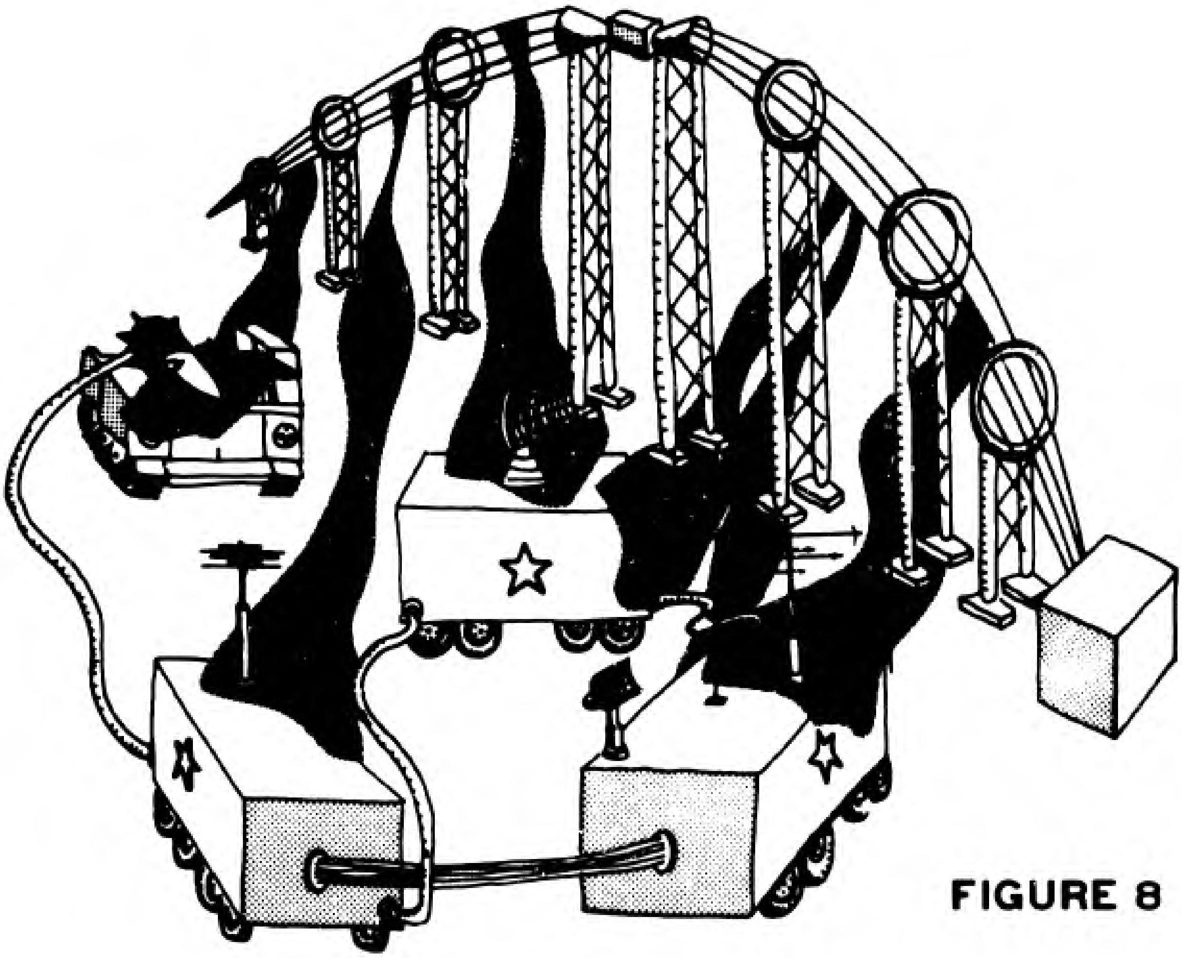

FIGURE 8

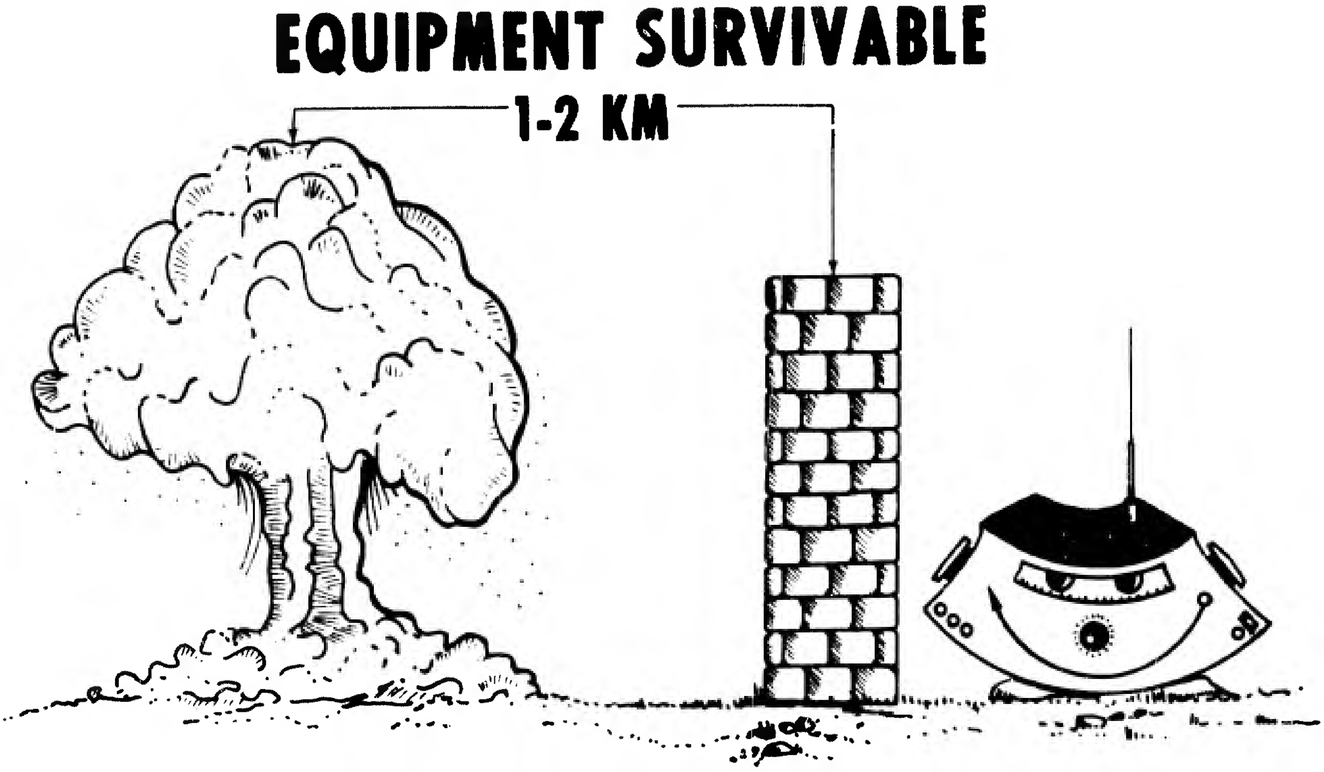

FIGURE 9

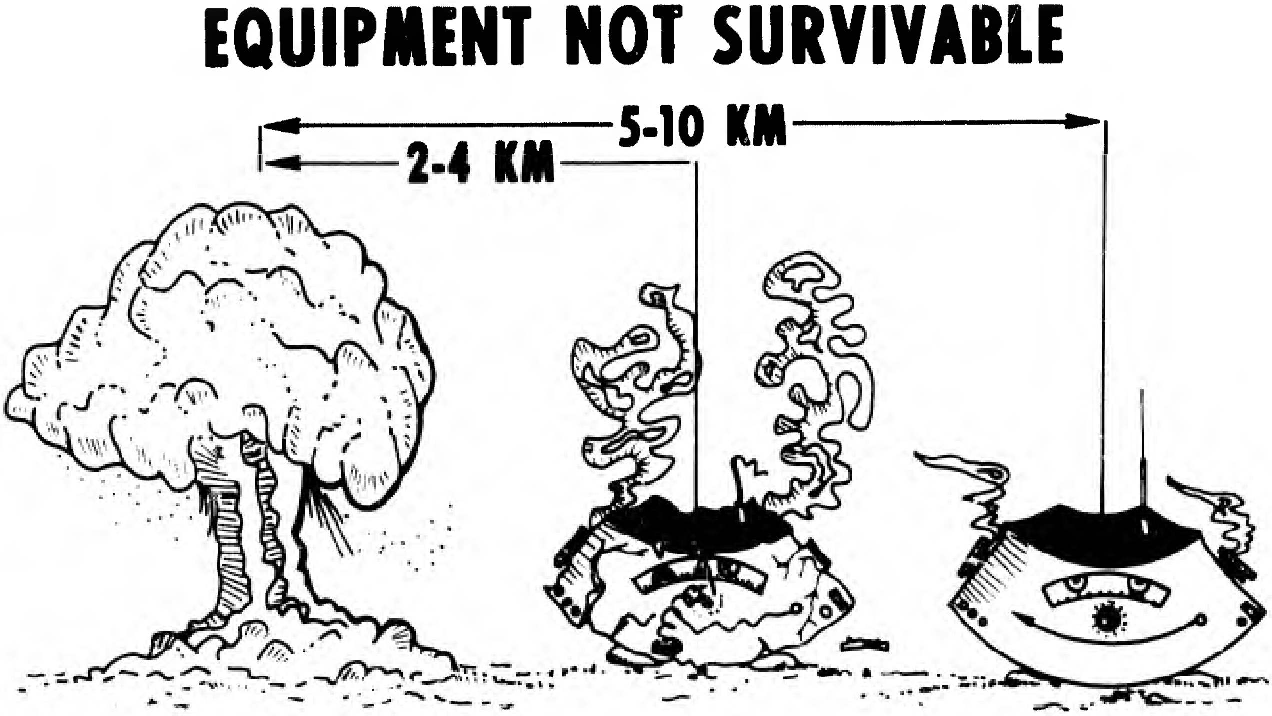

FIGURE 10

also be testing of some sort in order to preclude designed hardening measures from being degraded in field use.

Tactical operations and equipment nuclear survivability. The implications of equipment nuclear survivability on the theater of operations depend on the enemy nuclear threat. If high altitude, large yield nuclear bursts are postulated, then all theater unhardened C^3 equipment might be vulnerable. This follows from the preceding discussion on high altitude burst area coverage (Table 2) which showed an EMP area coverage on the ground of thousands of square kilometers.

The impact of enemy surface nuclear bursts is more subtle. Consider Figure 9 which graphically illustrates what equipment survivability "buys" for commanders in a tactical nuclear war. The first case of interest -- equipment is designed nuclear survivable -- is shown by the "protective brick wall." The tactical commander knows that his people and equipment will survive at distances of 1-2 km from a nuclear burst.

What happens if the equipment is not EMP hardened (Figure 10)? Past experience indicates that other weapons effects (blast, thermal, radiation) lose their sting at 2-4 km from a burst, while EMP vulnerability may exist 5-10 km away. What do these facts tell a tactical commander -- only that he may lose some of his critical electronics at some distance, perhaps up to 10 km from a nuclear burst.

Conclusions. EMP is a critical effect because of the energy involved, the area of coverage, and the possibly large vulnerability radius of modern electronics.

EMP protection requires a comprehensive design - test - analysis - field test program. If EMP protection is integrated into a system from the conceptual stage, the costs are low compared to having to retrofit EMP protection to fielded systems.

A nuclear survivability program provides information to the commander with which tactics and operations can be planned and implemented with a degree of confidence.

REFERENCES

1. DNA 2114H, DNA EMP (Electromagnetic Pulse) Handbook (U), -1 Design Principles (U), November 1971 (CONF); -2 Analysis and Testing (U), November 1971 (CONF); -3 Environment and Applications (U), May 1972 (S-RD); -4 Resources (U), November 1971, Defense Nuclear Agency, Washington, DC. (CONF)

2. Nuclear Survivability Criteria for Army Tactical Equipment, (US implementing document for QSTAG 244), in press, Office of the Deputy Chief of Staff for Research, Development and Acquisition, Department of the Army, Washington, DC. (CONF)