RADIATION EXPOSURE CONTROL

ON THE

NUCLEAR BATTLEFIELD

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The opinions and conclusions expressed herein are those of the individual student author and do not necessarily represent the views of either the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

Ground forces operating in the nuclear environment will face exposure to radiation as a normal hazard of battle. Commanders must consider the effects of radiation on the combat efficiency of their units and their ability to accomplish assigned missions. Radiation will influence the commanders' decisions on the battlefield; a system of radiation exposure control is necessary to permit an evaluation of relative hazards. The fundamental requirements of a radiation exposure control system are the abilities to determine radiological status of a unit prior to exposure, to measure or predict any new dose to a unit with accuracy, and to assess the effect of any new exposure upon the previous radiological status in terms of unit effectiveness. This, in turn, requires a method of determining basic radiation exposure data, a system of recording this data, and a system of utilization to permit assessment of the effect of subsequent radiation on unit effectiveness. The capability of measuring radiation exposure is severely handicapped by the inability of the current tactical dosimeter, the IM-93/UD, to measure neutrons, a significant contributor to initial radiation. Since "type classification" of a replacement dosimeter is at least five years in the future, there is a requirement for an interim system which utilizes current measurement capability. The best approach appears to be the application of tabulated "neutron weighting factors" which, when multiplied by the gamma dose readings, will provide an indication of total dose. The distribution

of dosimetric devices within units is subject to question and requires further analysis. The system of recording, based on troop test experience, is judged to be adequate. The system for utilization of the measured and recorded data suffers from a serious defect. The determination of company and particularly of battalion radiation status provides no useful information for the commander and worse, may lead him to an incorrect conclusion. Since the battalion radiation status normally is the only radiation exposure information provided to brigade and division commanders, this deficiency is a serious problem. The addition of a fourth radiation status category, as proposed in a Combat Developments Command Institute of Nuclear Studies report, only serves to further complicate the current system. The best format of transmission of radiation exposure data to higher headquarters appears to be as the radiation status of the basic data-measuring unit, currently the platoon. This requirement for transmission of platoon data suggests consideration of basic reorganization of the combat structure with the platoon as the basic unit, attached to company headquarters based upon the requirements of the mission, to include anticipated radiation exposure. Finally, a lack of detailed medical knowledge of the effects of radiation limits the validity of guidance provided by the radiation exposure control system. Lack of information on recovery from radiation injury prohibits valid assessment of residual injury from previous exposures, the effect of chronic or protracted doses and the effect of recovery or repair in determining future vulnerability. This limitation, along with lack of ability to accurately assess partial-body irradiation results in a system employing conservative medical criteria and relying heavily on the medical judgment of the surgeon, which in part must be based on close association with the exposed personnel. Recent centralization of battalion surgeons at division level appears to have a potentially deleterious effect on the provision of required radiation advice to the battalion commander. The overall conclusion of the thesis is that the current system of radiation exposure control is incapable of providing the commander on the nuclear battlefield with the required information.

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INTRODUCTION

THE NEED FOR RADIATION EXPOSURE CONTROL

Ground forces operating in a nuclear environment must expect exposure to radiation. Operations may dictate such exposure as a normal hazard of battle. Commanders of units operating in a nuclear environment must therefore consider the effects of radiation on the combat efficiency of their units and their ability to accomplish an assigned mission.[1]

In order to function efficiently and effectively a commander needs information on both the present and future effectiveness of his command. One of the vital determinants of unit effectiveness is the health of the command. While operating in a nuclear environment, the commander must be vitally concerned with the effects of radiation, for exposure to radiation may result in serious diminution of health of the personnel under his control, resulting in loss of ability to conduct effective combat operations.

The control of exposure of personnel to nuclear radiation will affect operations by influencing the commander's decisions in the selection of a course of action and of the units to be employed in a

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[1]Department of the Army. FM 101-31-1, Nuclear Weapons Employment Doctrine and Procedures, 15 February 1968, p. 5-5; see also Department of the Army. FM 100-5, Operations of Army Forces in the Field, 8 September 1968, p. 6-3.

given operation. Continuous evaluation of unit radiation exposure levels is necessary as part of the considerations in making these decisions. Radiation exposure should be controlled to the maximum extent possible consistent with the mission. If exposure control is ignored, the results could be disastrous. On the other hand, the establishment and use of operation exposure guides will aid the commander in keeping radiation casualties at a minimum.[2]

This recognition of the requirement for radiation exposure control is not recent. In early 1961, The Surgeon General of the Army appointed a "task force" from the Medical Field Service School to "derive guidance for the 'reference dose' and for establishing 'operation exposure levels' for medical field units and installations." The report of this task force provided guidelines, as requested, and noted that the guidance would also, for the most part, be just as applicable to other military units.[3]

The dosage guidelines thus developed were subsequently included as part of an Army-wide system in Department of the Army Field Manual 3-12, in January 1963. Subsequently modified in certain aspects, including the treatment of recovery from radiation, the current system is contained in Department of the Army FM 3-12, Operational Aspects of Radiological Defense, 21 August 1968.

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[2]Department of the Army. FM 3-12, Operational Aspects of Radiological Defense, 21 August 1968, p. 6-1.

[3]Donald H. Behrens, LTC, USA. "Radiation Exposure Guidance and the Effectiveness of Irradiated Personnel," Symposium on the Management of Mass Casualties (Fort Sam Houston, Texas: Medical Field Service School, 1964), pp. 145-146.

THE PROBLEM

Preliminary review of the current U.S. Army doctrine for radiation exposure control indicates that inadequacies in the present system may exist; and that these inadequacies may be significant enough to render the overall radiation exposure control system ineffective. The potentially serious consequences of invalid or misleading radiation exposure information being presented to the commander required that a detailed analysis of the current doctrine be made and that deficiencies be identified so that appropriate corrective measures might be initiated.

The problem statement for this thesis is simply the question:

"IS THE CURRENT U.S. ARMY RADIATION EXPOSURE CONTROL SYSTEM ADEQUATE FOR OPERATIONS ON THE NUCLEAR BATTLEFIELD?"

The historical method is used to solve the problem. Current published doctrine, reports on radiation exposure control, dosimetry, biological effects and other pertinent sources of information form the review. To assure validity, analysis is guided by doctrine being developed for tactical nuclear operations.

The tentative hypothesis for this thesis is that current U.S. Army radiation exposure control doctrine is inadequate for operations on the tactical battlefield and that significant changes are required to develop an effective system for the commander.

LIMITATIONS AND CONSTRAINTS

In the development of the problem certain limitations and constraints were necessary in order to restrict the scope of this thesis to permit meaningful analysis. These are discussed in the following paragraphs.

The thesis is unclassified. While this creates some problems, it is not believed to have significant effect on the overall results. The current radiation exposure control system is unclassified as is much of the literature concerning the biological effects of radiation. The major effect is in discussion of radii of radiation effects and the inability to differentiate between weapon designs. Where weapons effect information is used, it is derived from unclassified sources and therefore is general in nature.

The thesis is restricted to application on the tactical battlefield, consistent with doctrine for "the army in the field". Specifically eliminated is consideration of the effects of strategic nuclear warfare, with its attendant civil defense activities.

The purpose of this paper is not to develop or evaluate reference dose criteria. While certain background discussion and comment is presented on exposure criteria, it is beyond the scope of this paper to attempt to evaluate the numerous animal radiation experiments and human exposures in order to analyze reference dose criteria. Thus, while reference doses are part of the radiation exposure control doctrine, detailed consideration is purposely excluded.

Finally, in the analysis, the effect of previous radiation exposure from natural, medical and industrial sources is excluded. This is consistent with nonconsideration of reference dose criteria, and is further justified based on the following considerations:

1. Exposure to natural radiation. All living creatures are always exposed to ionizing radiations from various natural sources, both inside and outside the body. These are chronic exposures, lasting a lifetime. It has been estimated that, during the average lifetime of an individual, he will receive about 10 rads of nuclear radiation over the whole body from natural sources. This dosage can be neglected both from its relatively small intensity over an extended period, and from the fact that it applies to all humans, thus providing the common base upon which the effect of additional exposures is evaluated.[4]

2. Medical Exposure. Normal medical exposures include the common and regularly applied chest and dental x-rays, along with such irregular x-rays as for broken bones, sinus infections, etc. Such exposures can be safely ignored because of their common base, relatively low dosage over an extended period of time (average annual dose from medical radiation currently is about 100 millirem in the United States), and the fact that they are generally partial body exposures whose effects are difficult to pinpoint,

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[4]Department of the Army. Pamphlet No. 39-3, The Effects of Nuclear Weapons, February 1964, p. 585.

in relation to whole body exposures. Further, levels of exposure permitted by all federal agencies, to include the Atomic Energy Commission, have specifically and consistently excluded medical exposures. Those few personnel who have received extensive therapeutic radiation treatments or fluoroscopic diagnoses normally would not be expected to be a part of the rigorous battlefield operation and their physical condition would itself probably cause greater individual variance to additional radiation than would the radiation dose previously absorbed in treatments.[5]

4. Industrial Exposure. Certain Army personnel will have had "occupational exposure" as a result of duties with military reactors and other radiation sources. These personnel are currently few in number and are closely limited by regulation to an average maximum exposure of 5 rem[6] per year. This dosage is relatively small when compared with anticipated battlefield exposures. In addition, those relatively few individuals have a radiation exposure record (DD1141, Record of Occupational

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[5]Sagan, Leonard A., MD. "Medical Uses of Radiation," The Journal of the American Medical Association. 215, 12 (1971), pp. 1977-8; see also U.S. Atomic Energy Commission, AEC Manual Chapter 0524, Standards for Radiation Protection, (Washington: U.S. Atomic Energy Commission, 1968) and U.S. Atomic Energy Commission, Conditions and Limitations on the General License Provisions of 10CFR150.20, (Washington: U.S. Atomic Energy Commission, 1969), p. 2.

[6]NOTE. The terms "rad" and "rem" are used interchangeably in this thesis. Dose in rems equals "Relative Biological Effectiveness" (RBE) times the dose in rads. The rem provides an indication of the extent of biological injury that would result from the absorption of nuclear radiation. The rad is the unit of absorbed dose (liberation of 100 ergs of energy per gram of absorbing material). The relation between the two terms, the RBE, is unity for gamma radiation and the whole-body neutron radiation. See U.S. Naval Weapons Evaluation Facility, Definitions of Nuclear Terms - Including Formulas and Tables (U), Albuquerque, New Mexico: USNWEF, 1967, pp. 207, 214, 220.

Exposure to Ionizing Radiation) as a permanent part of their medical records, thus available to medical personnel for their use in treatment of subsequent exposures. It is not felt that personnel with "occupational exposures" require special treatment in exposure control.[7]

CHARACTERISTICS OF NUCLEAR WEAPONS

An explosion can be defined as a very rapid release of energy within a limited space. This is true for conventional "high explosives" as well as for nuclear explosions, although energy is produced in a different way. The liberation of energy converts materials present into hot compressed gases, which expand rapidly and thus create a pressure wave in the surrounding medium, which, in both nuclear and conventional weapons, is a major cause of destruction.[8]

There are, however, several basic differences between nuclear and high explosive weapons. These are:

1. Nuclear explosions can be many thousands (or millions) of times as powerful as the largest conventional detonations;

2. A large proportion of energy in a nuclear explosion is released in the form of light and heat, generally referred to as "thermal radiation;"

3. A nuclear explosion is accompanied by highly penetrating and harmful invisible nuclear radiations; and

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[7]Department of the Army. AR 40-14, Control and Recurring Procedures, Occupational Exposure to Ionizing Radiation, 29 September 1966, pp. 1-3.

[8]DA Pam 39-3, op. cit., p. 1.

4. Finally, radioactive substances may remain after a nuclear explosion, emitting radiation for an extended period of time. It is these fundamental differences between a nuclear and conventional explosion that require special consideration of the effects of nuclear weapons.[9]

When a uranium or a plutonium nucleus is fissioned or split into two parts by reacting with a neutron, the resulting fission products weigh less when added together than did the original nucleus. The mass which has disappeared has been converted into energy according to Einstein's $E=mc^2$ equation. While the splitting of a single nucleus releases only a comparatively small amount of energy, in a nuclear explosion billions of nuclei are split, resulting in a tremendous release of energy.

If two nuclei of deuterium are brought together and "fused" to produce helium, the resultant helium atom weighs less than the sum of the two hydrogen nuclei. Similar to fission, in fusion the loss of weight is a source of energy and when large numbers of nuclei are fused in a short period of time, an explosion is produced.

The energy produced in nuclear explosions is dissipated in three ways: blast, heat, and nuclear radiation.

As a result of the liberation of a large amount of energy in a very short period of time, all materials in the vicinity, including fission products, bomb casing and other weapon parts are raised to very high temperatures, and are converted into gaseous form resulting in

[9]Ibid., pp. 1-2.

tremendous pressures, probably in the order of many millions of pounds per square inch. Within less than a microsecond of the detonation of the weapon, the extremely hot weapon residues radiate large amounts of energy, mainly x-rays which are absorbed within a few feet in the surrounding atmosphere. This leads to the formation of a hot and highly luminous spherical mass of air and gaseous weapon residues.

The expansion of the intensely hot gases at extremely high pressures in the fireball causes a blast wave to form in the air, moving outward at high velocity. This dense layer of compressed air completely surrounding the fireball travels out in all directions, breaking away from the fireball. At first it travels with a speed greater than sound, eventually decreasing to about the speed of sound. At the same time the energy in the blast wave decreases as the distance away from the burst point increases.

Both personnel and material are affected by blast, both by the high pressures associated with the blast wave and its ability to carry objects along with it.

When the nuclear detonation occurs in air, the soft x-rays in the primary thermal radiation are completely absorbed in a matter of feet. Some of the radiations are degraded to lower energies, e.g., into the ultraviolet region, but most of the energy is converted into kinetic and internal energy of the hydrogen and oxygen atoms and molecules in the air. Part of this energy is reradiated, at a lower temperature, from the fireball and the remainder is converted into blast energy, as previously discussed. Thus, only about 30 to 40 percent of the energy is received at a distance as thermal radiation energy in an air burst although the primary thermal radiation may constitute as much as 70 percent of the total. Because the secondary thermal radiation is emitted at a lower temperature, it lies mainly in the region of spectrum with longer wave lengths, i.e., ultra-violet, visible and infrared. Thermal radiation travels at the speed of light.[10]

Although blast is responsible for most of the destruction caused by a nuclear air burst, thermal radiation will contribute to overall damage by lighting combustible materials. In addition, thermal radiation is capable of causing skin burns and eye injuries in exposed individuals at such distances from the nuclear explosion that the consequences of blast and of the initial nuclear radiation are not significant.

Both blast and thermal radiation can produce significant deleterious results in operations on the nuclear battlefield. This greatly abbreviated treatment of these phenomena is intended only to note the different types of effects produced by nuclear weapons. For detailed discussion, there are numerous references; probably the most accepted is Department of the Army Pamphlet No. 39-3, The Effects of Nuclear Weapons, February 1964, edited by Samuel Glasstone and also published by the U.S. Atomic Energy Commission.

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[10]Ibid., p. 26.

The third effect, nuclear radiation, is the cause of the last two fundamental differences between nuclear and conventional weapons. This phenomena will be discussed in detail in Chapter II.

CHAPTER II

RADIATION ON THE BATTLEFIELD

Nuclear radiation, as it would occur on the tactical battlefield during operations in a nuclear environment, is the weapon effect of concern in this thesis. Therefore a common basis should be established on certain aspects pertinent to radiation exposure. Discussed in subsequent paragraphs is basic radiation phenomenology, including a description of the basic forms of radiation, their military significance and differentiation between initial and residual radiation. In addition, a rather detailed discussion of the biological effects of nuclear radiation is presented. Such a review of biological effects is believed necessary for a proper appreciation of the problem. Without a basic understanding, one may be led to oversimplified and unjustified conclusions. Concluding the chapter is a brief discussion of combat effectiveness.

CHARACTERISTICS OF NUCLEAR RADIATIONS

The four nuclear radiations: alpha particles, beta particles, gamma rays and neutrons produce their various biological effects by the same physical process, the transfer of energy to the target molecules. The biological effect of a given type of radiation depends on the distribution and amount of energy absorbed per unit mass. One of the major effects of radiation on any type of tissue is ionization. Charged particles, i.e., alpha and beta, cause a high concentration of ionization by interacting with orbital electrons along their path through matter. Gamma rays ionize occasional atoms along their paths in matter, but the secondary electrons thus produced, in turn, ionize densely. Neutrons, being uncharged, produce ionization by interacting with atomic nuclei. They may be captured by nuclei, producing an unstable state and subsequent radioactive decay or they may collide with nuclei and transfer to them a portion of their kinetic energy. The nuclei will be displaced from their electron shells, and, since they are charged, will in turn ionize densely along their short paths. Therefore, there is a basic similarity between these radiations and they may all be termed "ionizing". Despite the common factor of ionization, the four radiations do have important differences, warranting separate discussion.[1]

Alpha Particle

Structurally the alpha particle is identical with the nucleus of the helium atom. It contains two protons and two neutrons for a total atomic mass of four, with a double positive electrical charge.

Alpha particles are emitted by the unfissioned plutonium or uranium of a weapon as a result of the normal radioactive decay of these elements.

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[1]Department of the Army. TM 8-215, Nuclear Handbook for Medical Service Personnel, 30 April 1969, p. 18; see also William J. Price, Nuclear Radiation Detection (New York: McGraw-Hill, 1958), pp. 1-41; or any basic text on nuclear physics.

Compared to the other forms of radiation, the alpha particle is very heavy, highly charged and slow. It ionizes very densely in any target material but has a very short range. In air it travels about five centimeters, but in tissue only a fraction of a millimeter. Because its energy is absorbed by the outermost layer of skin, alpha particles produce no hazard as long as they remain outside the body.

Inhalation or ingestion, with absorption of alpha emitting isotopes into the body may constitute a long range health hazard in industrial environments or at nuclear weapon accident sites, but significant quantities will not occur on the nuclear battlefield even though they are present at the time of detonation and in fallout.[2]

Beta Particle

The physical characteristics of the beta particle are the same as those of the orbital electron even though it originates from the nucleus of a radioactive fission product. Most radioactive elements which result from uranium or plutonium fission are beta emitters.

The beta particle is light (1/7400 the mass of the alpha particle). It may travel initially at speeds up to about 95 percent of the speed of light and has a single negative charge. Being charged, small and fast, it ionizes over greater distances but less intensely than the alpha particles. Its range in air is about five meters, whereas, in tissue, it is a few millimeters or centimeters, depending on its initial energy.

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[2]Ibid.

Beta particles from radioisotopes associated with fallout will penetrate into the superficial cell layers of skin, producing "beta burns" after prolonged contact. The military hazard of beta radiation is small compared to gamma radiation.[3]

Gamma Ray

Gamma rays are electromagnetic radiations emitted by the nuclei of some radioactive iostopes. The characteristic features of gamma radiation are its electromagnetic nature and its ability to penetrate and ionize many materials. Since it is an electromagnetic radiation, it travels at the speed of light.

Gamma radiation of high energy (average four MEV for nuclear weapons) is produced as a result of fission and comprises a large part of the initial radiation. Also, many fission products and their daughter products emit gamma rays, lower in energy (average 0.7 MEV). Since gamma rays are not charged particles, they ionize directly by producing energetic electrons in the material in which they are absorbed. The energy of these electrons is then dissipated by intense localized interaction with matter. Because the attenuation per unit length of path of the primary gamma ray is relatively small, these secondary electrons may be produced at considerable depth in the target.[4]

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[3]Ibid., pp. 18-19.

[4]Ibid., p. 19.

Neutron

The neutron is an electrically neutral (uncharged) particle, approximately one atomic mass unit in weight. It is a normal constituent of all atomic nuclei except that of the common isotope of hydrogen. It is produced during the fission reaction along with fission products and kinetic energy. Some of the neutrons produced will go on to cause other fission reactions which are necessary to sustain the reaction of a nuclear explosion. Others will be lost to the environment as part of the initial radiation. Fusion of the heavier isotope of hydrogen produces helium, free neutrons and energy.

Since neutrons are produced in enormous numbers, mainly during the actual reactions of fission or fusion, they contribute only to the initial or prompt radiation hazard. Their contribution to the fallout problem can be significant, however, because of their ability to induce certain materials to become radioactive. Non-fissionable portions of the bomb structure, air atoms, and certain elements in soil and water are some of the substances in which radioactivity can be induced. These, with all the other materials in the near vicinity of the detonation are vaporized and become a part of the fallout.

Since neutrons have no electrical charge, they do not ionize by interaction with orbital electrons. Fast or high energy neutrons produced during fission or fusion lose energy to and ionize target atoms primarily by "collision" with the nuclei of those atoms, especially hydrogen. After "collision" the neutrons and the target nuclei (protons in the case of hydrogen) "recoil" in a manner that has been likened to the action of billiard balls. The target protons are stripped of their orbital electrons by this process and are, therefore, ionized. Since they are charged particles, the resulting protons cause dense concentrations of secondary ionizations along their short paths in the target material. Protons ionize more densely than do beta particles and less densely than alpha particles. The protons may be produced at considerable depth in tissue by this collision process. Therefore fast neutrons qualify as penetrating radiations, somewhat similar in this respect to gamma radiation.

When the target atoms are heavier than hydrogen, the neutrons lose less energy with each collision. If the target nuclei are quite heavy, essentially no energy is lost by the neutrons, and they are only scattered. Therefore shielding made of lead or other heavy materials does not significantly impede neutrons although it will scatter them widely.

Very slow, low energy neutrons (the end result of many collisions and termed "thermal neutrons") interact with matter finally by nuclear capture. This can occur with a great variety of target elements, resulting in the formation of unstable radioactive isotopes. These isotopes, in turn, emit beta particles and/or gamma rays as they decay.

Whole body radiation injury from neutrons is about equivalent to that produced by absorption of an equivalent amount of energy from gamma radiation. However, for specific tissues, for example the lens of the eye or the gastrointestinal mucosa, neutrons are more injurious than are gamma rays of equal absorbed dose.[5]

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[5]Ibid., pp. 19-20.

INITIAL AND RESIDUAL NUCLEAR RADIATION

Ionizing nuclear radiation is a phenomenon entirely different from any encountered with conventional weapons. It is emitted in its various forms during and after a nuclear detonation. Nuclear radiation resulting from a nuclear explosion has been, for convenience, divided into two categories:

1. Initial radiation, which is emitted during the first minute and which results almost entirely from the nuclear processes in the detonation.

2. Residual radiation, which is emitted after one minute and which is derived predominantly from decay processes of isotopes produced during the detonation.

Initial Nuclear Radiation

During the nuclear detonation, the nuclear material present within the warhead undergoes either fission or fusion reactions resulting in the emission of highly energetic ionizing nuclear radiations. These consist primarily of neutrons and gamma rays and lesser amounts of beta radiation. The neutrons and some of the gamma rays are produced almost instantly by fission and fusion processes while the remaining gamma and the total beta contribution result from decay of fission products with short half lives. Alpha radiation is also present and is primarily the product of either the decay of the unfissioned uranium or plutonium or the fusion process when a fusion stage is included in the warhead.

The ranges of alpha and beta particles are comparatively short and they cannot reach the surface of the earth from an airburst. Even if the fireball touches the ground, the alpha and beta particles are not very important. The initial nuclear radiation thus is considered as consisting only of the gamma rays and neutrons produced during a period of 60 seconds after the nuclear explosion.[6]

Certain characteristics of neutrons and gamma rays have been considered previously. However, there are several common characteristics of the initial nuclear radiations which should be mentioned, since exposure to both radiations happens simultaneously on the battlefield and their ultimate effects on man are much the same.

1. They travel extremely fast. Gamma rays travel at the speed of light, while neutrons travel at an average speed of about 10 percent of that speed, depending on their energy. Thus personnel are exposed to initial nuclear radiation almost instantaneously, depending on yield and range.

2. They travel essentially along straight lines, although a large portion of the total radiation is scattered at the ranges normally of interest. Gamma rays and neutrons, while passing through the atmosphere, are scattered, especially by the oxygen and nitrogen in the air. Consequently, they reach a particular individual on the ground from many

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[6]Department of the Army. Pamphlet No. 39-3, The Effects of Nuclear Weapons, February 1964, pp. 369-370.

directions. Most of the dose received will come from the direction of the explosion, but a considerable amount will arrive from other directions.

3. A portion is absorbed by the atmosphere through which they travel. The denser air at sea level absorbs more radiation than does the thinner air at high altitudes.

4. They have a very high penetrating power. While it is not possible to absorb these radiations completely, they can be reduced to negligible proportions.

5. They travel considerable distances. The distance the initial nuclear radiations travel is measured in hundreds and thousands of meters, depending upon yield, height of burst, weather and other factors.

6. Emission time of initial nuclear radiation increases with yield. Although most neutrons are emitted in less than one second after the burst, the initial gamma radiation is received by a target over a period of time, depending on the weapon yield. With low yield weapons, this time is extremely short, less than one second for most of the initial gamma radiation to be delivered.[7]

The intensity of the initial nuclear radiation decreases with distance from the point of the burst. This is due to the spread of the radiation over larger and larger areas as it travels away from the explosion and to the absorption, scattering and capture (neutrons) by the atmosphere. The following table exemplifies this reduction.

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[7]Edward Marks, LTC, USA. "Initial Nuclear Radiation as a Wartime Hazard," Symposium on the Management of Mass Casualties (Medical Field Service School, Fort Sam Houston, Texas: January 1964), pp. 83-84.

Table 1

Initial Nuclear Radiation Slant Distances (Meters)
For Various Doses and Weapon Yields[8]

	Yield				
Dose	1 KT	10 KT	100 KT	1 MT	10 MT
100 rads	1,100	1,600	2,100	2,900	3,900
500 rads	1,000	1,300	1,800	2,400	3,400
1000 rads	800	1,100	1,600	2,300	3,200

It should be noted that a distance of 300 meters (low yield - 1 KT) to 700 meters (high yield - 10 MT) decreases the radiation by a factor of ten. Note also that the range is extended by a factor of 3.4 to 4.0 for a 10,000 fold increase in yield. By dispersing troops the effects of initial radiation can be significantly reduced.

Shielding can influence the amount of radiation received by personnel considerably. Any solid material will absorb some nuclear radiation. Because of the very high penetrating power of neutrons and gamma rays, large amounts of material are required to provide significant protection. Dense materials such as lead, steel, concrete and earth offer the best protection against gamma rays. Materials such as water or concrete offer the best protection against neutrons. Earth is a fair neutron shield.

A rough approximation of the percentage of the outside dose of initial gamma and neutron radiation shielded from military personnel in various types of protection is shown in Table 2 below.

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[8]DA Tm 8-215, op. cit., p. 37.

Table 2

Battlefield Protection-Initial Nuclear Radiation[9]

	Percent Effectiveness of Protection	
	Gamma	Neutron
Armored Carrier	30	30
Foxhole	80	70
Earth 91 cm (3 ft.)	98	95
Light Tank	80	70
Medium Tank	90	70
Vehicle	0	0

Note that shielding against neutrons is more difficult to achieve than is shielding against gamma rays.

Near the explosion center, the contribution of neutrons to the total dose received is greater than that of gamma rays. With increasing distance, the neutron dose falls off more rapidly than does that of the gamma radiation, so that beyond a certain point the gamma rays predominate. Ultimately the neutrons become negligible in comparison with gamma irradiation. This phenomenon will be discussed in more detail later in this paper.

As stated previously, the emphasis in this paper is on nuclear radiation. Thus, although the effects of blast and thermal radiation are generally ignored, one should not lose sight of the fact that these effects

[9]Ibid., p. 38.

may predominate, especially at the higher yields. Many comparative graphs have been formed to demonstrate which effect predominates, for certainly the control of radiation exposure becomes unnecessary if the individual soldier is already dead from other causes. Yet protection from blast and thermal radiation can be provided to the degree that, even for higher yield weapons, the exposure to additional radiation may be the dominant effect. Thus the author has placed no self-imposed restrictions on consideration of the radiation of the tactical battlefield as a function of weapon yield.

Residual Nuclear Radiation

Residual radiation includes neutron induced radioactivity in the soil and material near to detonation, and fallout, which may be distributed over many square kilometers and at great distances from the point of detonation.

Neutron induced radioactivity occurs when free neutrons from the detonation interact with elements in the atmosphere and ground in the vicinity of the detonation, making them radioactive. Most of these radioactive elements decay rapidly, emitting both gamma and beta radiations. The resulting gamma intensity can be as serious as that due to fallout and can be great enough to deny access to the contaminated area. However, the geographical area in which this induced radioactivity is produced is many times smaller than that usually involved in fallout since it is limited to an area immediately around ground zero.

Fallout is the process in which radioactive material rises with the fireball of a nuclear detonation into the upper atmosphere and then falls back to earth over a variable period of time due to gravity, rain-out or snow. Fallout is composed of several different radioactive materials, as follows:

1. Unfissioned uranium or plutonium from the weapon.

2. Fission products which are generally elements with atomic weights about one-third to two-thirds that of uranium or plutonium.

3. Weapon debris, soil, water and other material in which radioactivity has been induced by neutrons.

The particles suspended initially in the rising fireball settle to earth eventually by gravity. The rates and patterns of settling depend upon the yield of the weapon, the height of burst, the particle size distribution and meteorological conditions.

Fallout in a given area presents three hazards: beta contamination of the skin, irradiation of the body or organs by isotopes taken into the body, and external whole body gamma irradiation. Whole body gamma irradiation results from the exposure of the individual to penetrating gamma radiation from material dispersed on the ground in an area contaminated by fallout. It is by far the most important of the three fallout hazards. Beta skin burns generally are not serious injuries, prevention is easy and it is considered to be of minor significance in combat operations. The internal hazard (inhalation, ingestion or absorption through wounds) is normally long term and therefore not of immediate importance on the battlefield.

The whole body gamma radiation hazard results from the total body exposure to radiation coming from some distance around an individual in a fallout area. Essentially all of the dose to which an individual may be exposed is a summation of gamma radiations from the contamination around him to a radius of approximately 100 meters. Fifty percent of the dose comes from a circular area having a radius of approximately ten meters. The individual receives this radiation from all directions, including from above. Gamma radiation is scattered through the atmosphere just as are other electromagnetic radiations, such as visible light. Therefore a small but significant amount of gamma radiation can be received in the form of "skyshine". If a soldier is in a foxhole, he will be shielded from most of the gamma radiation which comes from the surrounding ground; however, he will still receive the gamma radiation from above unless he interposes some cover of earth.

Almost all protective measures and operational decisions with residual radiation are ultimately based on the concept of radioactive decay. All radioactive materials decay or lose radioactivity with the passage of time. Many of the fission products lose radioactivity very rapidly in the first few hours after a detonation. After a day or two, the rapidity of decay slows down considerably, creating a rapid shrinking of a fallout pattern during the first day or two after a burst with a much slower shrinkage after the second day.

Several methods, of varying degrees of complexity, have been established for predicting fallout patterns. Department of the Army, TM 3-210, Fallout Prediction, 3 December 1967, describes the systems currently used in the U.S. Army.

An important factor in determining the distribution of fallout within an area, as well as the area covered by appreciable fallout, is the wind pattern from the ground up to the top of the radioactive cloud. The direction and speed of the wind at the cloud level will influence the motion and extent of the cloud itself. In addition, the winds at lower altitudes, which may change both in time and space, will cause the fall-out particles to drift one way or another while they descend to earth. Thus actual fallout patterns may be quite irregular and present little physical resemblance to the idealized fallout predictions. The situation may be further complicated by the effect of rain and or irregularities in the terrain. These, as well as irregular distribution of activity in the cloud and fluctuations in the wind speed and direction, will contribute to the development of "hot spots" of much higher activity in the immediate surroundings.[10]

BIOLOGICAL EFFECTS OF RADIATION

It has long been known that exposure to radiations which are capable of producing ionization can cause injury to living organisms. After discovery of x-rays and radioactivity toward the end of the nineteenth century, it became increasingly apparent that a element of danger was associated with

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[10]DA Pam 39-3, op. cit., pp. 439-442.

exposure to ionizing radiations. In spite of the growing awareness by physicians of the hazards inherent in many radiation sources, there were some excessive exposures.[11]

However, before the nuclear bombings of Hiroshima and Nagasaki, radiation injury was a rare occurrence and relatively little was known of the phenomena associated with whole body radiation injury. In Japan, however, a large number of individuals were exposed to doses of radiation ranging from insignificant quantities to amounts which proved fatal. The effects were often complicated by other injuries and shock, so that symptoms of radiation sickness could not always be isolated. Because of the great number of patients and the lack of facilities after the explosions, it was impossible to make detailed observations and keep accurate records. Nevertheless certain important conclusions have been drawn from Japanese experience with regard to the effects of nuclear radiation.[12]

Since 1945, further information on this subject has been gathered from other sources. These include:[13]

1. Accidents in industry or laboratories. There have been a number of recorded cases of persons exposed to significant doses in

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[11] Ibid., p. 577.

[12] Ibid., p. 588.

[13] Eugene P. Cronkite and Victor P. Bond. Radiation Injury in Man. (Springfield, Illinois: Charles C. Thomas, 1960), pp. 113-6.

laboratory radiation accidents. However, out of forty-six cases, only four resulted in death. The range in dosage in these cases was from a low of eleven rads to a high of approximately 5,000 rads.

2. Pacific Testing Ground accidents involving exposure to fallout radiations. In only one of these accidents did anyone receive more than eighty rads. In the one major accident, sixty-four Marshallese in the Rongelop Atoll received an estimated 175 rads of whole body radiation.

3. Medical exposure of patients to whole body (or near whole body) radiation for therapy. These dosages are generally rather low, although they represent a rigidly controlled exposure and therefore can provide some significant data. One inherent problem with this source, however, is that the personnel receiving therapeutic exposures are already sick, thus requiring careful analysis in eliminating this effect in extrapolating to healthy people.

4. Extrapolation to man of observations on animals. As a result of the limited data available and the obvious impossibility of using healthy humans in experiments, working with animals has dominated recent research. The validity of extrapolation from animals to man is the subject of some controversy. Major Robert A. Flory in a 1968 study concluded that no meaningful comparison can be made between the data obtained from animals and data obtained in man (from the limited radiation accidents) at the present time. The basic reason for this conclusion was the vast difference between animals and man in the post-irradiation behavioral environment. Thus under current experimental conditions which involve varying amounts

of uncontrolled post-irradiation stress, he concluded that meaningful extrapolation was neither feasible or possible.[14]

On the other hand, extrapolation from animals is the only available source of information on man, particularly on doses of over 200 rad, and careful extrapolation, primarily of primates, generally is currently accepted.

Since no single source of data directly yields the relationship between the physical dose of ionizing radiation and the clinical effect in man, there is not complete agreement concerning the effect associated with a specific dose or dose range. Numerous studies have been made on the radiation syndrome in man and other studies have attempted to correlate individual studies. (See Bibliography.) Fortunately Department of the Army Technical Manual 8-215, Nuclear Handbook for Medical Service Personnel, 30 April 1969, has been recently revised and provides an excellent presentation of information that is available. This manual is used as the basic reference for subsequent discussion on radiation injury. For the reader who would like to review biological effects in greater detail, the bibliography contains references on this subject.

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[14]Robert A. Flory, MAJ, USA. "Is the Extrapolation to Man of Animal Radiation Dose vs. Incapacitation Data Feasible?" (Unpublished Treatise, US Army Command and General Staff College, 1968), p. 26.

Radiation Injury

Radiation injury to man results in a variety of patterns, depending on the interaction of several variables. These include the amount of body exposed, the physical nature of the radiation, the total dose received, the dose rate and number of exposures and the physiological state of the exposed man.

Whole body and partial body radiation. The proportion of the body which is exposed to radiation is a major factor in determining the nature and degree of illness and the probability of mortality. The most serious clinical disturbances and the highest probability of death follow whole body irradiation such as might result from exposure to the gamma rays and neutrons emitted at the instant of weapon detonation or from gamma rays in a residual radiation field.

Partial body irradiation will cause a variety of clinical effects depending on the ratio of exposed tissue and the sparing or nonsparing of critical tissue. The less tissue exposed, the less severe will be the morbidity, the less likely will be death and the higher will be the dose per gram of tissue which can be tolerated. Personnel in foxholes, in vehicles and in buildings will all be shielded to some extent. The most critical tissue is the bone marrow and an individual subjected to half-body irradiation, lower or upper, could have a significant sparing of his bone marrow. If the total dose of radiation received is not in the very high or supralethal range, such an individual could develop significant symptoms of radiation injury and still survive. His clinical condition during much of this illness could not be distinguished easily from whole body irradiation with a probability of death close to 100 percent.

Physical nature of radiation. The differences in the physical nature of the various forms of radiation were discussed previously in this chapter.

The dose of radiation. Both the type of radiation syndrome and its severity are dose dependent. Detailed consideration of these syndromes and the dosages associated with them are presented subsequently.

Dose rate and number of exposures. The dose rate of the radiation will determine the amount of energy required to produce equal biological effects. As the dose rate of radiation increases, the amount of energy to produce a given effect decreases. This is particularly true of gamma radiation, but less so of neutron irradiation. In combat, the difference between the high dose rate of the mixed radiation emitted on detonation, and the variable but lower dose rates of the gamma component of fallout fields could be large enough for a dose rate effect to be present. However, the clinical patterns which irradiated personnel would show, and upon which treatment would be based, would not give a clue as to the dose rate of exposure.

Fractionation of irradiation into several separate doses will be characterized by a certain amount of recovery or repair between doses. The longer the time intervals, the more the recovery or repair. There is an irreducible minimum of injury which remains after each dose and which accumulates with each successive dose. This phenomenon has been seen experimentally with both neutron and gamma irradiation.

Physiological factors. The physiological state of an individual when exposed has a variable effect upon the morbidity and probability of death. Both the very young and the very old are more sensitive than are healthy young adults. Moderate to severe physical stress, prior to radiation, which is well tolerated, may increase resistance to radiation injury. Poorly tolerated or post-irradiation stresses tend to increase the severity of the response to radiation injury. The timing of the stress in relation to radiation exposure and the degree of stress are both highly critical. In combat, with its multiple stresses, the result would be increased variability of response to given doses.

The interaction of radiation with concurrent or pre-existent disease is largely unknown, although it is reasonable to expect that the addition of radiation injury to the burden of pre-existing disease would be deleterious.

The Acute Radiation Syndrome

As noted above, the effect of nuclear radiations depends not only on the total dose, but also on the rate of absorption, i.e., whether it is an acute or chronic dose. A dose is described as acute if it is either a single dose or one received in a short time, defined as 24 hours or less. A chronic dose (also termed a protracted dose) is the total dose accumulated in time periods greater than 24 hours. In the literature, acute and chronic doses normally are treated separately. Most dose effects information available is for acute exposures, simply because more valid and reliable information is available for acute exposures.

Three syndromes are normally used to describe the characteristics of whole body irradiation. (Partial body irradiations can often result in similar patterns.) These syndromes, which are dose dependent, are termed the Central-Nervous, Gastrointestinal, and Hematopoietic Syndromes. While these syndromes are dose related, the dose effect relationship will be modified by the variables previously discussed. This variability reduces the value of dosimetry data when diagnostic or treatment decisions are made by medical personnel on individual patients.

Central nervous system syndrome. Very high (supralethal) whole body doses will result in symptoms reflecting severe effects on the central nervous system. The minimum dose required (for single, acute, high dose exposure) is estimated at about 3,000 to 5,000 rad for man. The dosage above which death essentially becomes instantaneous and is no longer due to central nervous system effects is unknown for man, but is speculated to be in the region of 50,000 rad or greater.

The physical causes of this syndrome are not known. Typically victims have an early transient phase of incapacitation with marked ataxia (lack of voluntary muscle coordination) lasting a few minutes to less than an hour. It is followed by a variable period of lucidity. Sometime, during the next two hours to three days, a severe, rapid, clinical deterioration would begin with alternating periods of lethargy and hyperactivity, and with grand-mal convulsions and ataxia. This would be followed by a period of deepening coma culminating in cardiovascular collapse and death. The total period of time is highly variable, from as short as a few hours to as long as three days.

The mortality in patients with the central nervous system syndrome is 100 percent, regardless of treatment.

Gastrointestinal syndrome. Radiation dosages in the range of 750 rads to 3,000 rads will result in a characteristic syndrome of bloody diarrhea, fever and dehydration. Causes include inflammation and necrotic (death of tissue) changes in the gastrointestinal tract, seen during the first week after exposure.

During the first few hours after radiation, there may be a short period of time during which nausea, vomiting and malaise may occur. This may be followed by a period of relative well-being. The actual symptomatic phase of the gastrointestinal syndrome would begin between the third and seventh day. This is the time when the denudation of the gastrointestinal mucosa would result in fluid losses and hemorrhage severe enough to incapacitate the individual.

Partial body irradiation or diarrheal disease due to infection may present symptoms similar to severe radiation injury. Personnel who have the gastrointestinal syndrome due to whole body irradiation have little chance for survival. If the individual survives the first few days, he will enter a period of bone marrow depression with its attendant syndrome of hemorrhage and susceptibility to infection discussed below. The probability of lethality remains very high under the most favorable circumstances, since the degree of bone marrow depression will be severe.

Hematopoietic syndrome. This syndrome occurs when individuals receive doses of radiation too low to cause the gastrointestinal syndrome or when patients are in the latter phase of a gastrointestinal syndrome. This syndrome is seen over a wide range of doses, both lethal and sublethal. Personnel with even very low levels of whole body irradiation with a high degree of survival will still show some degree of bone marrow depression.

The hematopoietic syndrome may be divided into the following phases:

1. Exposure Phase. The exposure phase is the time during which the radiation is received.

2. The Delay Time. The delay time refers to the period of time from exposure to the onset of initial symptoms of the initial or prodromal reaction. This delay time will last a few hours.

3. The Initial or Prodromal Phase. This phase is characterized by a prodromal reaction (nausea, vomiting and fatigue), usually lasting one to three days. This reaction may be mild and may not even occur.

4. The Latent Phase. The period from the subsidence of the initial or prodromal symptoms, if they occur, to the onset of overt hypoplastic anemia is called the latent phase and is usually up to three weeks long. It is most probable that casualties will not become medical patients until they are past the latent phase.

5. The Secondary Phase of Overt Hypoplastic Anemia. This phase occurs three to six weeks following radiation exposure. Epilation (loss of hair), which usually occurs about two weeks following exposure to 300 rads or more, will frequently herald the onset of this phase of the injury. If epilation occurs, the victim may develop a significant hematopoietic syndrome. Medically, this is the most important phase, requiring treatment to counter the problem of hemorrhage and susceptibility to infection.

6. The Convalescent Phase. This final phase begins approximately three months after exposure. By this time, hematopoietic recovery will usually have progressed to such a point that the threat of complications has subsided and the individual no longer requires hospitalization or frequent medical observation.

Figure 1 summarizes the effects of single, high dose rate exposures of whole body radiation to healthy adults.[15]

The following table indicates additional guidance provided medical personnel by the U.S. Army Medical Field Service School.

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[15] DA TM 8-215, op. cit., p. 30.

DOSE (RANGE)		0-100 RADS (SUBCLINICAL RANGE)	100-200 RADS	100-1000 RADS (SUBLETHAL RANGE) 200-600 RADS	600-1000 RADS	OVER 1000 RADS (LETHAL) 1000-3000 RADS	OVER 3000 RADS
INITIAL PHASE	NAUSEA AND VOMITING	NONE	5-50%	50 - 100%	75 - 100%	100%	
	TIME OF ONSET	—	APPROX 3-6 HRS	APPROX. 2 - 4 HRS	APPROX. 1 - 2 HRS	LESS THAN 1 HR	
	DURATION	—	LESS THAN 24 HRS	LESS THAN 24 HRS	LESS THAN 48 HRS	LESS THAN 48 HRS	APPROX 48 HRS.
	COMBAT EFFECTIVENESS	100%	100%	CAN PERFORM ROUTINE TASKS. SUSTAINED COMBAT OR COMPARABLE ACTIVITIES HAMPERED FOR 6-20 HRS.	ONLY SIMPLE ROUTINE TASKS. SIGNIFICANT INCAPACITATION IN UPPER PART OF RANGE. LASTS MORE THAN 24 HRS.	PROGRESSIVE INCAPACITATION FOLLOWING AN EARLY CAPABILITY FOR INTERMITTENT HEROIC RESPONSE.	
LATENT PHASE	DURATION		MORE THAN 2 WEEKS	APPROX 7-15 DAYS	NONE TO APPROX 7 DAYS	NONE TO APPROX 2 DAYS	NONE
SECONDARY PHASE	SIGNS AND SYMPTOMS	NONE	MODERATE LEUKOPENIA	SEVERE LEUKOPENIA; PURPURA; HEMORRHAGE; INFECTION; EPILATION ABOUT 300 RADS.		DIARRHEA; FEVER; DISTURBANCE OF ELECTROLYTE BALANCE.	CONVULSIONS; TREMOR; ATAXIA; LETHARGY
	TIME OF ONSET	—	2 WKS OR MORE	SEVERAL DAYS TO 2 WEEKS		2 - 3 DAYS	
	CRITICAL PERIOD	—	NONE	4 - 6 WEEKS		5-14 DAYS	1 - 48 HRS
	ORGAN SYSTEM	NONE		HEMATOPOIETIC TISSUE		GASTRO-TRACT	CENTRAL NERVOUS
HOSPITALIZATION	PERCENTAGE	NONE	< 5%.	90%	100%	100%	100%
	DURATION	—	45-60 DAYS	60 - 90 DAYS	90 - 120 DAYS	2 WEEKS	2 DAYS
INCIDENCE OF DEATH		NONE		0 - 80%	90 - 100%	90 - 100%	
AVERAGE TIME OF DEATH		—		3 WEEKS TO 2 MONTHS		1-2 WEEKS	2 DAYS
THERAPY		NONE	REASSURANCE; HEMATOLOGIC SURVEILLANCE.	BLOOD TRANSFUSION; ANTIBIOTICS.		MAINTENANCE OF ELECTROLYTE	SEDATIVES

FIGURE 1. ACUTE CLINICAL EFFECTS OF SINGLE HIGH DOSE RATE EXPOSURES OF WHOLE BODY IRRADIATION TO HEALTHY ADULTS.

Table 3

Guidance for Acute Doses[16]

Acute Dose	Probable Effects
100 rad or less in 24 hours.	No ineffectiveness.
100-200 rad in less than 24 hours.	Spectrum of response from 0 to temporary illness assuming no previous radiation. No evacuation for temporary illness.
Greater than 300 rad delivered in less than an hour	90 percent vomiting in 6 hours. (If no vomiting within 6 hours, probably under 300 rads.)
500-1000 rad in 24 hours.	50 percent require medical evacuation in less than 24 hours. All in medical channels after 24 hours.

Chronic Radiation and Recovery

In contrast to the rather detailed guidance available for acute exposures, there is essentially none available for chronic or prolonged exposures. There are several reasons for this lack. Most human data comes from radiation accidents. Acute exposure accidents are conceivable and do occur, but it is difficult to see how an accident resulting in continuing and prolonged exposure could occur with all the controls and safeguards which govern all current activities involving radiation. Human exposures in radiation therapy might provide useful human effects data; however, those receiving radiation therapy are not well to begin with and as indicated

[16]US Army Medical Field Service School Instructional Material, "Command Guidance," M90-330-415-1/119. (Fort Sam Houston, Texas: undated) (Mimeographed), p. 1.

previously, the physiological results are usually questionable. Also therapeutical exposures are usually partial body exposures, not whole body exposures. Animal research in the prolonged area is not widespread. The closure of the Navy Radiological Defense Laboratory at San Francisco eliminated the activity doing more of this type research than any other research facility. With this source of information gone, there is little to encourage others to work in the area. This type of study is expensive and is not popular with researchers.[17]

The ability of the human body to recover from radiation injury is obviously closely related to the effects of prolonged radiation exposures, and there are serious deficiencies in knowledge on radiation recovery. There is ample evidence that recovery does take place, but the rate and degree is questionable. There is also reasonable certainty that some residual injury remains after recovery but once again there is insufficient evidence at this time to state how much. Recovery rates now in use are little more than educated guesses. Recovery rates have been variously estimated to be 2.5 percent to 10 percent of the unrecovered portion of the injury per day. The residual unreparable injury is variously considered to be from zero to 10 percent of the total original exposure.[18]

Years ago more precise answers were available. Paradoxically, the current inability stems from increased knowledge. While recovery was

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[17]US Army Medical Field Service School Instructional Material, "Command Guidance in Irradiated Personnel," M90-330-415/040. (Fort Sam Houston, Texas: undated) (Mimeographed).

[18]E. S. Shapiro. Operational Significance of Biological Recovery from Chronic Radiation: A Comparison of Several Recovery Theories. USN RDL-TR-421. (San Francisco: US Naval Radiological Defense Laboratory, 1960); see also George M. Angleton, Radiation Recovery Studies. AFWL-TR-66-161. (Kirtland AFB, New Mexico: Air Force Weapons Laboratory, 1967).

once considered to be exponential, current evidence does not support a simple mathematical course. Thus the current philosophy is that recovery should be disregarded entirely in estimates of troop effectiveness and that recovery which does occur should be accepted as a bonus or "built-in" safety factor.

In general, several conclusions can be drawn with respect to recovery and the effect of chronic doses:[19]

1. Any whole body gamma dose delivered over a protracted period of time will have a lesser effect than that same dose delivered in a 24-hour period. Therefore lives and morbidity may be saved by spreading out radiation exposures in time and among different groups when the tactical situation permits.

2. Recovery from radiation injury is probably never complete.

3. Recovery from high level exposures is slower than from low.

4. Partial recovery of effectiveness takes place even at supralethal dose levels.

COMBAT EFFECTIVENESS

When a commander employs radiation exposure control, his concern is for the effectiveness of his unit and for individual members of his unit. In order to discuss the application of exposure controls, review of what is meant by combat effectiveness is necessary.

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[19] DA TM 8-215, op. cit., p. 59.

First consider the effectiveness of individuals. Generally, when one speaks of an effective individual, he refers to one who is capable of carrying out an assigned mission or task. Certainly, if he is to be considered effective, he must be an asset to his unit rather than a liability. To be meaningful, however, effectiveness should be related to the task that the individual is expected to perform. Some tasks require a high degree of effectiveness while others a relatively low degree. A group of military combat arms officers was asked by the Medical Field Service School to select representative combat tasks and to determine the degree of physical effectiveness required to perform each task. The typical military combat tasks they agreed upon and the degree of physical effectiveness required are shown below:

Table 4

Degree of Effectiveness Required to Perform Various Combat Tasks[20]

Task	Degree of Effectiveness
Fire a preplaced weapon	10 percent
Operate radio communications	20 percent
Drive a vehicle	50 percent
Aim a weapon	80 percent
Assault a position	90 percent
Hand-to-hand combat	90+ percent

[20]DA TM 8-215, op. cit., p. 59; see also Donald H. Behrens, LTC, USA, "Radiation Exposure Guidance and the Effectiveness of Irradiated Troops," Report of the Fourteenth Army Medical Service Instructors Conference, 14-17 April 1964, (Medical Field Service School, Fort Sam Houston, Texas, 1964), pp. 47-48.

The range of physical effectiveness required for satisfactory performance of these tasks is significant.

The degree of effectiveness also varies, of course, with the mental as well as the physical requirements of the task. Some tasks require a high degree of mental alertness and capacity. Certain staff officers and the commanders themselves would probably lose effectiveness with lesser doses of radiation than that required to incapacitate a truck driver. Others must maintain a high degree of skill or mechanical proficiency to remain effective. Helicopter pilots, surgeons, certain electronic equipment operators, etc., must retain nearly complete use of their facilities in order to remain fully effective. Any attempt to relate radiation dose to individual effectiveness must consider the task for which effectiveness is being determined.

Although individual effectiveness may be of concern, commanders at higher levels are more likely to be interested in the effectiveness of units rather than individuals. The commander will want to know what will happen to the unit if certain radiation exposures occur. This may influence the selection of courses of action. The commander will also want to know what is likely to happen to the unit as a result of exposures already received, or the penalty to be paid in unit effectiveness for working troops during latent periods and periods between exposure and the onset of symptoms in emergency situations. In the broader sense, the relationship between various radiation exposures and unit effectiveness will be fundamental to planning and even to development of doctrine on the nuclear battlefield.

How many individuals need be noneffective in order to make the unit ineffective? Our service schools and even weapons employment doctrine teach that ten percent prompt casualties will neutralize a unit while thirty percent render the unit "destroyed".[21]

But just as in the case of individual noneffectiveness, in considering unit noneffectiveness, it is not possible to define the term absolutely by means of a simple number or set of numbers applicable to all units. It is not always a matter of how many noneffectives there are in a unit, but rather who the ineffectives are. If all the command and staff elements of a combat unit are ineffective, that entire unit may be ineffective as a military entity, even though the bulk of the personnel are still completely effective. If the surgeons of a mobile surgical hospital are noneffective, that unit is totally ineffective as a surgical hospital. If the pilots of an aviation unit are incapacitated, the unit is noneffective. For some types of units, one percent noneffectives might make that unit noneffective, if they were the right one percent.

The currently used fractional loss criteria were developed on the basis of historical statistical analysis of land battles in previous wars to determine the point at which a force capitulates from all causes. There is no prior reason to assume that in a nuclear exchange one side will capitulate when it has suffered losses of thirty percent or even fifty percent. It

[21]Department of the Army. FM 101-31-1, Nuclear Weapons Environment Doctrine and Procedures, 15 February 1968, p. 3-7.

would appear that such a criteria would depend on a variety of factors and would vary with the type of force.[22]

When thirty percent losses are incurred in conventional warfare, one can infer something about the weight of the opposing forces. It would seem logical that, under such circumstances, on the average, the defender could not hope to change the tide of battle, and the effectiveness of the remaining forces, particularly in land combat, could be questioned. This is probably reflected in the historical data on which the thirty percent criterion is based. In the case of nuclear exchange, however, because of the area coverage properties of nuclear weapons, and the effectiveness of the side with the strike-first capability, thirty percent losses could be incurred by the defender as a result of chance events and not necessarily because of a preponderence of attacking force. However, as long as the defender has a viable nuclear retaliatory capability, he knows he can be effective and perhaps survive, irrespective of fractional losses.[23]

In the final analysis, it appears that, after all, it is the commander of the unit who will know how many and which individual noneffectives would make his unit noneffective in a particular situation. Unfortunately, this conclusion does not lend to a neat presentation of numbers to be used in analysis on the nuclear battlefield.

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[22]W. Mostow. An Analytical Methodology for Estimating the Relative Magnitude of Prompt and Delayed Casualties in Nuclear Land Combat, USNRDL-TR-895 (San Francisco: US Naval Radiological Defense Laboratory, 1965), pp. 5-6.

[23]Ibid.

CHAPTER III

COMMANDERS REQUIREMENTS FOR RADIATION EXPOSURE CONTROL

This chapter establishes the requirements for a radiation control system. These requirements are viewed from the eye of the commander and are general in nature, reflecting the broad knowledge needed by the commander, without regard to feasibility of obtaining the information. The requirements determined in this chapter will form the basis for evaluation of the current system and discussion in subsequent chapters.

In Chapter I, the need for a radiation control system was discussed. This need revolved about the simple fact that, on the nuclear battlefield, radiation can be expected to be a serious casualty producer and neglect in providing a system to enable the commander to exercise control over exposure to radiation would produce unnecessary casualties and jeopardize mission accomplishment.

Having established the need for a system of control, one must then determine what specific information is necessary for the commander in order to make timely and judicious decisions.

In 1969, Major Bobby G. Robinson, then a student at the U.S. Army Command and General Staff College, requested comments from a number of general officers on radiation dosage information requirements.[1]

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[1]Bobby G. Robinson, MAJ, USA. "Radiation Dosage Control and Reporting in the ROAD Division," (Unpublished treatise, U.S. Army Command and General Staff College, 1969), p. 10.

Three responses are especially pertinent to determination of the requirements for the ideal radiation exposure control system. Portions of these replies are quoted in the following paragraphs.

Lieutenant General J. L. Throckmorton provided his views on requirements as follows:

> Tactical decisions in a radiation environment are very complex and cause concern among all troop commanders. Before employing forces in a radiation environment I would require answers to at least the following questions:
>
> a. What is the radiation exposure history of each unit in my command?
>
> b. What opportunities has each unit had to recover from past radiation exposure?
>
> c. What radiation exposure should I expect the unit conducting the mission to receive and what dosage am I willing to accept (considering the tactical importance of my mission)?
>
> d. What is the status of nuclear defense training in each of my units?
>
> e. What equipment is available to each unit of my command to assist in providing protection from radiation hazards encountered in a nuclear environment (e.g., tanks, armored personnel carriers, radiation detection equipment)?
>
> f. What effect will the expected radiation exposure have on the committed unit?
>
> g. What effect will radiation casualties have on the overall combat effectiveness of my command?
>
> h. Is my combat service support (medical facilities, evacuation channels, transportation) prepared to handle expected radiation casualties in addition to normal battle casualties?
>
> i. What is the radiation history status of available replacement personnel?[2]

From this list of requirements by LTG Throckmorton, the answers to questions in paragraphs a, b, c, f, g, and possibly i, would be expected

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[2]J. L. Throckmorton, LTG, USA, HQ Third U.S. Army, personal letter to Major Bobby G. Robinson, undated.

to be provided by the radiation exposure control system. The remaining questions, while pertinent, would be answered by other sources.

Major General Delk M. Ogden included in his response:

> As a matter of preference I would prefer no radiation and no radiation problems. If, however, I were a commander in a nuclear environment I would need an estimate of the probability of success and the consequences to be expected in each proposed course of action. I would need this information on support elements as well as maneuver elements. Specific dosage levels in units and key individuals would be necessary if a "close decision" is required. I would expect the estimate to include the following:
>
> a. Dose criteria and effective strength for each element of the command.
>
> b. Total dose expected for each unit as a result of each proposed course of action.
>
> c. A tabulation of the radiation casualties, by percent and type, to be expected in each unit as a result of following each course of action.
>
> d. Expected effect on morale and on future operations.[3]

The need indicated by MG Ogden roughly parallels that of LTG Throckmorton.

Finally, Lieutenant General Harry H. Critz comments on radiation dosage information required by commanders:

> In order for a commander to make valid decisions regarding the tactical employment of forces in a radiation environment, he must have the following radiation dosage information:
>
> a. The radiation exposure status of the command.
>
> b. The location and intensity of the radiological contamination in his area of responsibility or operation.
>
> c. An estimate of the effects that further exposure to radiation may have on the commands combat effectiveness and mission accomplishment.[4]

The requirements for radiation exposure control, as expressed by these general officers, are essentially the same. They cover the three time

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[3]Delk M. Ogden, MG, USA, HQ U.S. Army Aviation School, personal letter to Major Bobby G. Robinson, 29 January 1969.

[4]Harry H. Critz, LTG, USA, HQ Fourth U.S. Army, personal letter to Major Bobby G. Robinson, 4 February 1969.

periods surrounding the possible exposure of concern: the past, the present, and the future.

The "past" is concerned with the previous radiation exposure of the unit. In order to determine the effect of subsequent radiation exposure of a unit, there must be a basis for evaluating previous exposure. This basis for establishing the vulnerability to effects of additional radiation should include:

1. A method of determining, by instrument readings or other means, the radiation previously absorbed, which is representative of exposure of the unit.

2. Having established a valid "average" unit exposure, a system of recording must be used so that exposure may be considered with all other exposures, previous and subsequent.

3. Finally, a system must be available to permit ut[illegible]ion of the previously determined and recorded radiation exposures to enable timely prediction of the effects of future doses.

If one cannot determine the radiological status of a unit with some degree of assurance, whatever else may be done toward developing sound radiological guidance will be of limited usefulness to the commander.

The "present" involves the determination, by instruments or other means, of the "new" radiation which the unit receives.

The "future" is the assessment, in terms of future unit effectiveness, of "new" radiation exposure superimposed on the previous radiological status.

Selected as the fundamental requirements for a radiation exposure control system are the requirements to:

1. Determine the radiological status of the unit prior to exposure.

2. Measure or predict any new dose to the unit with accuracy.

3. Assess the effect of any new exposure upon the previous radiological status in terms of unit effectiveness.

This selection of fundamental requirements for a radiation exposure system coincides with that utilized by the U.S. Army Medical Field Service School.[5]

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[5]U.S. Army Medical Field Service School Instructional Material. "Command Guidance on Irradiated Personnel (2 hours)," LP 90-330-415/040. (Fort Sam Houston, Texas: undated) (Mimeographed).

CHAPTER IV

ANALYSIS OF CURRENT RADIATION EXPOSURE CONTROL SYSTEM

This chapter presents an analysis of the current radiation exposure control system against the previously developed commanders requirements. It begins with a description of the current system, followed by an analysis of the various facets, including the type and distribution of dosimetry devices, the system of recording exposure and the placing of units in radiation status categories.

THE CURRENT SYSTEM

The current U.S. Army system for radiation exposure guidance and control is basically promulgated in Department of the Army Field Manual 3-12, Operational Aspects of Radiological Defense, 21 August 1968. Corollary guidance also can be found in Department of the Army Field Manual 21-40, Chemical, Biological, Radiological and Nuclear Defense, 20 December 1968 and in various additional field and technical manuals.

Categories of Exposure

Basic to the current system, in order to effectively use radiation exposure records for rapid determination of a unit's potential to operate in a radiologically contaminated area, is the establishment of categories of exposure. Three Radiation Status Categories have been established and are defined as follows.

Radiation Status - 1 (RS-1). This radiation status applies to a unit which has no dose or has militarily negligible radiation exposure history (total dose of less than 75 rads).

Radiation Status - 2 (RS-2). RS-2 applies to a unit that has received a significant but not a dangerous dose of radiation (total dose of 75 to 150 rads). This category may include a dose range in which most personnel are just below the threshold sickness for most personnel. Doctrine indicates that, if the situation permits, units in this category should be exposed less frequently and to smaller doses than RS-1 units.

Radiation Status - 3 (RS-3). This status applies to a unit that has already received a dose of radiation which makes further exposure dangerous (total dose greater than 150 rad). Doctrine indicates that this unit should be exposed only if unavoidable, because additional exposure in the immediate future would result in sickness and probably some deaths.

Degrees of Risk

In conjunction with the Categories of Exposure, a "degree-of-risk" exposure criteria is furnished to assist the commander in minimizing the number of casualties from nuclear radiation and in establishing an operational exposure guide for a particular operation, especially in contaminated areas. The degrees of risk are established as negligible, moderate and emergency. The basic definition and applicatory guidance for these degrees of risk are:

Negligible Risk. For negligible risk conditions from single exposure to our own weapons, troops are completely safe, with the possible exception of temporary loss of night vision or dazzle. A negligible risk is possible only when a unit has an insignificant accumulated radiation dose history that will cause no decrease in combat effectiveness. Negligible risk should not be exceeded unless significant advantages will be gained.

Moderate Risk. For moderate risk conditions from single exposure to our own weapons, anticipated effects on troops are tolerable or, at worst, minor nuisance. A moderate risk prevails either when a unit has a significant radiation exposure history but has not yet shown symptoms of radiation sickness, or when a planned single dose is sufficiently high that exposure up to four or five such cases, alone or in conjunction with previous exposures, would constitute a significant radiation exposure history. A moderate risk is considered acceptable in close support operations; for example to create a gap in enemy forward positions or to halt an enemy attack. A moderate risk should not be exceeded if troops are expected to operate essentially at full efficiency after a friendly burst.

Emergency Risk. For emergency risk conditions from single exposure to our own weapons, anticipated effects should never be extensive enough to neutralize a unit. Emergency risk prevails either when a unit has a radiation exposure history that is at the threshold (150 rads) for onset of combat ineffectiveness from radiation sickness, or when a planned single dose is sufficiently high that exposure up to two or three such doses, along with or in conjunction with previous exposures, would approach or exceed the threshold for combat ineffectiveness from radiation sickness. An emergency risk should be accepted only when absolutely necessary, and should be exceeded only in extremely rare situations that might be called disaster situations.

Table 5 presents the current nuclear radiation degree-of-risk exposure criteria. The notes accompanying this figure merit particular attention.

Collecting, Recording and Reporting

FM 3-12 notes that the operation exposure guide concept requires that radiation exposure records be maintained on all units. It goes on to state:

> The most realistic unit exposure data are based on readings obtained at the platoon level because companies are often so deployed that the platoons may not be located in areas of equal radiation dose rates or remain in these areas for like periods of time.[1]

Currently, unit dosage is measured by the IM-93( )/UD tactical dosimeter. This dosimeter is issued on the general basis of two per platoon or the smallest operational unit of interest. Present concepts indicate that the platoon-size unit is the optimum size in which to maintain the radiation status.

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[1]Department of the Army. FM 3-12, Operational Aspects of Radiological Defense, 21 August 1968, p. 6-3.

Table 5

Nuclear Radiation Degree-of-Risk Exposure Criteria[2]

Radiation Status[1,2]	Total Past Cumulative Dose[3]	Single Exposure Criteria[4,5]
RS-1 Units	<75 rad	Negligible Risk ≤5 rad Moderate Risk >5 rad, ≤20 rad Emergency Risk >20 rad, ≤50 rad
RS-2 Units	75-150 rad	All further exposure considered Moderate or Emergency Risk Moderate Risk ≤5 rad Emergency Risk >5 rad, ≤20 rad
RS-3 Units	>150 rad (Threshold for onset of combat in-effectiveness)	All further exposure considered Emergency Risk

Table Notes:

1. Radiation status categories are based on previous exposure to radiation.

2. Reclassification of units from a more serious radiation status category to a less serious one is done by the commander upon advice of the surgeon after ample observation of actual state of health of the exposed personnel has been made.

3. All exposures to radiation are considered to be total body and simply additive. No allowance is made for body recovery from radiation injury.

4. For operations in radiologically contaminated areas, the operation exposure guide established by the commander can be any number in the risk range appropriate to the unit's mission and radiation status.

5. Risk levels are graduated within each status category in order to provide more stringent criteria as the total radiation dose accumulated becomes more serious.

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[2]Ibid.

A step-by-step procedure for the handling of dosimeter information of an infantry platoon is provided in FM 3-12, with the note that similar procedures would be applicable to other organizations. The basics of these procedures are:

1. The tactical dosimeters are read daily or more often as the situation dictates.

2. The net readings of the two platoon dosimeters will be averaged, rounded off to the nearest 10 rad, and reported to the company. If only one dosimeter is felt to be representative of the platoon, due to location or shielding, then the reading from that dosimeter is used. The reading reported is the net dosage, that is, the amount accumulated since the last readings.

3. Platoon readings are reported daily by radio or telephone to the battalion S-3 as part of an established operational type report required by Unit S.O.P. An exception is when the operation exposure guide has been exceeded, in which case the report is forwarded without delay.

4. Unit radiation exposure records are normally maintained at battalion and higher level because of the lack of capability to evaluate at lower levels. Battalion maintains radiation exposure records down to and including the organic and attached platoons. A chart is maintained at battalion depicting that radiation status of each platoon and company. The radiation status category for each platoon is determined from its total accumulated dose and entered on the chart. The RS numbers for all organic and all attached platoons in any one company are summed and based on this

sum, and the number of platoons with that company, the company radiation status is determined. Table 6 presents a sample Radiation Dose Status Chart. Table 7 provides the doctrine for determination of Company and Battalion Radiation Status.

5. Reports on the radiation exposure status of small units are not normally forwarded higher than battalion. Battalion forwards its own radiation status, based on the radiation status of organic and attached companies and using Table 7 as the guide, through brigade to the CBRE in the division TOC. If these Commanders desire more specific information, it is obtained at the Commander's request. The battalion radiation status "will assist both the division commander and the brigade commander in establishing operation exposure guides, degrees of risk and composition of task forces for missions requiring further radiation exposure".[3]

CONSIDERATIONS IN ANALYSIS

In Chapter III, the fundamental requirements for a radiation exposure control system were established as the need to:

1. Determine the radiological status of the unit prior to exposure;
2. Measure or predict any new dose to the unit with accuracy; and
3. Assess the effect of any new exposure upon the previous radiological status in terms of unit effectiveness.

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[3] Ibid., pp. 6-4, 6-5.

Table 6

Radiation Dose Status Chart, Month 6[4]

Platoon	Company	Date 1	2	3	4	5	6	30	Present Radiation Status	Remarks
A 1		||	|||	|		||	|		RS-2	RS-1 on 1 Jun RS-2 on 5 Jun
A 2		||	||	|	||	||	|		RS-2	RS-1 on 1 Jun RS-2 on 5 Jun
A 3		||	||||	|||		|			RS-2	RS-1 on 1 Jun RS-2 on 3 Jun
A 4		|	||				|		RS-1	RS-1 on 1 Jun
Engineer Platoon						||	|		RS-1	Had received no radiation when attached on 3 Jun
	A								RS-2	RS-1 on 1 Jun RS-1 on 3 Jun RS-2 on 5 Jun

Each tally mark represents 10 rads.

[4] Ibid., p. 6-4.

Table 7

Determination of Company/Battalion Radiation Status[5]

Number of Platoons in Company or Companies in Battalion	2	3	4	5	6	7
Company or Battalion RS Category	Sum of RS Numbers of All Organic and Attached Platoons or Companies					
RS-1	2	3-4	4-5	5-7	6-8	7-10
RS-2	3-4	5-7	6-9	8-12	9-14	11-17
RS-3	5-6	8-9	10-12	13-15	15-18	18-21

Prior to examining the current system, further discussion of these broad basic requirements is necessary, in terms of their inherent and more specific characteristics and requisite conditions.

The first broad requirement involves determination of the prior radiation status of the unit. To intelligently appraise the future status of a unit implies historical perspective. To determine the effect of subsequent radiation exposure on a unit, there must be a basis for evaluating previous exposure.

This basis for determining the radiological vulnerability of a unit, or its susceptibility to new radiation exposure embodies the following characteristics:

1. There must be a method of measuring or otherwise determining, the basic data which is the radiation exposure of the unit.

[5]Ibid.

2. Having measured the basic data, a system of recording must be established so that any exposure may be considered with all the other exposures, previous and subsequent.

3. Finally, a system must be developed to utilize the radiation exposure data, which have been measured and recorded, to permit the assessment of the effects of subsequent radiation on unit effectiveness.

One can see that the essential ingredients of the first basic requirement essentially encompass all three basic requirements; for a radiation exposure system must by definition be continuous, taking the most recent or perceived radiation exposure, and integrating it with previous exposures, while all the time providing the commander with guidance on the effect of subsequent exposures.

Therefore, in this analysis of the current system, the means of measuring radiation data (dosimetry), the system of recording and the system for utilization will be examined.

DOSIMETRY

In the evaluation of the adequacy of the current dosimetric system, two major aspects will be examined. The first is instrument capability or the capacity of the dosimetric instrumentation to provide the basic data necessary for radiation exposure control. The second aspect is the capability of the dosimetry system to provide needed information; and specifically: "Is the distribution of measurement devices adequate?"

In Chapter II, in the description of nuclear radiation on the battlefield, it was pointed out that, for convenience, radiation from nuclear weapons is divided into two categories: initial radiation and residual radiation. These two categories of radiation will be considered separately in subsequent discussion.

Instrument Capability

Radiation cannot be detected by the senses. This means complete dependence on instruments for the detection and measurement of radiation. In the laboratory, this presents no great problem. Highly trained personnel, space, adequate power supply and sophisticated instruments which are usually expensive and rather fragile, make possible the fulfillment of the major criterion of lab instruments: the detection and very accurate measurement of radiation, even in very small amounts. However, in addition to sensitivity and accuracy in field instruments, additional criteria are necessary. Since emphasis is on mobility, equipment must be light and compact as possible. Limited training of operator personnel necessitates an instrument that is relatively simple to operate, calibrate and maintain. Field conditions require ruggedness inconceivable in laboratory instruments, complicated further by extremes of temperature, humidity and atmospheric pressure. In addition there is one additional criterion: it is highly desirable that these instruments be low in cost. These requirements make the development of ideal field instruments a formidable task.[6]

While recognizing that instrumentation must meet the basic requirements for field operation, for purposes of this analysis the requirements are over-simplified to two requirements:

1. Detect and measure, with reasonable accuracy, the militarily significant radiation in the environment in which the instrument is used.

2. Provide the measurement data on a timely basis to permit its use in the radiation exposure control system.

The current tactical dosimeter in the U.S. Army is the Radiacmeter, IM-93( )/UD, which is designated as the primary source of radiation exposure data for the current system. This instrument is a pocket dosimeter, of about fountain pen size, using ionization to indicate total dose. It is gamma sensitive with a range of 0 - 600 roentgens, has a calibration accuracy of ±5 percent, is small, compact and fairly inexpensive ($5.00). It is a fairly rugged instrument; however, the quartz fiber electroscope is not a sturdy apparatus. Heavy blows or the shock from dropping can damage or knock the indicator off scale. Since the scale is built into the dosimeter it can be read directly; therefore requiring no extensive special training in its operation. One significant disadvantage is that a certain amount of the "charge" on the instrument will leak off. If this leakage exceeds ½ percent (3 roentgen) per day of the total scale reading,

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[6]Edgar H. Eckermann, Major, VC. "Radiac Instruments," Symposium on the Management of Mass Casualties, (Fort Sam Houston, Texas: Medical Field Service School, 1964), p. 175.

the instrument is to be replaced. A detailed description of the instrument can be found in Department of the Army Technical Manual 11-6665-214, Operator's Manual, IM-9E/PD, IM-93/UD, IM-93A/UD and IM-147/PD, 27 November 1962.[7]

How does the Radiacmeter IM-93( )/UD meet our oversimplified requirements? First, consider the ability to detect and measure the radiation of interest. As was pointed out in Chapter II, initial radiation consists of militarily significant components of both gamma rays and neutrons. The current radiac equipment does not have the capability to measure the neutron component. Since the neutron component can be a substantial portion of the dose, in effect initial radiation exposures cannot be measured at all.

With residual radiation, the picture is brighter. Gamma radiation is the significant component of residual radiation and is measurable by the current instrument.

Do we have "reasonable" accuracy? "Reasonable" is a delightfully ambiguous term. Personnel who have worked with the instrument describe the accuracy range from between ±5 percent (the published calibration accuracy) to ±25 percent. An accuracy in this range is certainly not laudatory; subsequently developed instruments certainly must improve this characteristic. However, consideration must be given to the accuracy of the data analysis before placing stringent requirements on the accuracy of the measured data itself. Some of the uncertainties and difficulties in analysis will be expanded in subsequent discussion. The point is that one should not conclude

[7]Ibid., pp. 176-8.

that the radiation exposure system, for residual radiation, is limited by instrument accuracy.

The second requirement for instruments is the capability to provide the data in a timely manner. Since the IM-93( )/UD is self-reading, the data is immediately available to the commander and staff, limited only by communications, and this requirement is met.[8]

Thus, with the current radiac instrument, the IM-93( )/UD the following has been noted:

1. The lack of capability to measure neutrons negates usefulness in measuring initial radiation.

2. Residual radiation may be measured, with some reservations on the accuracy of such measurement.

3. The self-reading characteristic satisfies the requirement for immediately available data.

Distribution

The second consideration in evaluating the adequacy of the dosimetry system is the capability of the system to provide the information that is required. This goes beyond the capacity of the physical instrumentation and questions whether the dosage data measured actually represents the dose received by the unit.

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[8]NOTE: Arguments are made that the psychological effect on the uninformed individual who suddenly discovers he has been exposed to radiation may make the self-reading feature a disadvantage rather than an advantage. The answer seems to be in the word "uninformed". In the author's opinion, the uninformed on the nuclear battlefield will find more psychological problems in the unknowns than in the knowns. Knowledge is essential and training should be so oriented.

As discussed previously in Chapter II, the commander is basically concerned with the combat effectiveness of his unit. While this relates to individual effectiveness, it is the effectiveness of the unit which must be evaluated. In order to assess "unit effectiveness" to radiation exposures, one requires measurement of "unit dose". "Unit dose" is probably best represented by an "average" unit exposure, i.e., a radiation exposure reading or combination of readings which provides a figure which best represents the dose to the unit.[9]

Factors which affect the validity of a representative average are the effect of partial body shielding, the geometry of exposure and the number (distribution) of instruments. The effect of partial body shielding and geometry of exposure cannot be reasonably evaluated on the battlefield. The varying attitudes and locations of individuals, including the dosimeter wearer, provide an infinite number of combinations. Certainly, the reading on a dosimeter worn by one individual will not apply specifically to other individuals and probably does not exactly represent the whole body dose even to the wearer.

Even the selection of personnel to wear the instruments will have its effect. A platoon sergeant may be required to move throughout the platoon a great percentage of the time, thus subjecting himself and the dosimeter to a maximum exposure. On the other hand, a squad leader may spend most of his time in a foxhole thus subjecting himself and his dosimeter to a minimum exposure. Within various units and associated with

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[9]NOTE: The author recognizes the impreciseness of the word "average". However, he is not prepared to argue the desirability of average, median, mean, etc., in this application. The determination of the optimum "average" would be necessary in a detailed study on instmment distribution.

various positions there are many variations in degree of exposure which may be related to the type of position.

Can the variation in body shielding and individual exposure geometry be neglected? It appears that there is little choice, for there is no obvious reasonable solution. (Ideas to eliminate partial body shielding, as well as the shielding effect of the body itself, by providing multiple "around-the-belt" dosimeters are rejected intuitively from the standpoints of simplicity and cost.) One receives little consolation from observing that, for a large number of exposures, an average may be approached; such a number of exposures probably also would achieve an "average" lethality.

As previously noted, the current system provides for the issue of tactical dosimeters on the general basis of two per platoon (or the smallest operational unit of interest). The readings in the platoon are averaged, or if one dosimeter is adjudged to be not representative because of shielding or location, then only the readings from the representative dosimeter would be used. This could, with clairvoyance in the midst of battle, assist in eliminating gross variations due to shielding and exposure geometry.

During the period 1-10 October 1964 the 4th Infantry Division conducted a troop test (USACDCCBRA 65T6) at and in the vicinity of Yakima Firing Center, to evaluate a proposed tactical dosimetry system under simulated nuclear combat conditions. The concept tested was that proposed in Study Project Report USACDC Number CMLCD 62-8, U.S. Army Radiation Dosimetry System (The Division), 8 December 1963, the basis of the current system.

One of the objectives of this troop test was to evaluate the basis of issue of unit dosimetry equipment (IM-93/UD). This objective, however, was actually never attempted. The plan of test established the criterion "If there are two individuals in the unit who have an 84 percent assurance of being with the unit 80 percent of the time, the proposed basis of issue of IM-93's is adequate."[10]

The test was carried out on this basis, evaluating 158 type TOE officer and NCO positions and determined that 91.77 percent of these positions met the criterion and therefore would be "suitable carriers for the two unit dosimeters". In addition, it concluded that all units tested, except the communications platoon of the infantry battalion headquarters, have two or more positions suitable for the incumbents to carry the unit dosimeter. Thus, based on the criterion "84 percent assurance of presence in the immediate unit area 80 percent of the time" the basis for issue of the unit dosimeter, IM-93, was found to be adequate.[11]

However, the report recognized "that the established criterion is based on the assumption that all personnel in a platoon, because of the relatively small area they occupy compared to the gross area of the contamination to be encountered, are subjected to approximately the same exposure. This assumption is probably not valid, since individual job requirements associated with positions may make a significant difference in the degree of exposure."[12]

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[10]Fourth Infantry Division, Troop Test USACDCCBRA 65T6, Radiation Dosimetry System (The Division), (Fort Lewis, Washington: 4th Infantry Division, 1964), p. 5.

[11]Ibid., pp. A-3, 4, 32. [12]Ibid., p. A-4.

The report's analysis of the platoon leader recommendations as to the various individuals who should carry the dosimeters, indicated that none of the respondents considered the possibilities of significant variations in exposure based on routine differences in protective positions and activity, but rather used as the basis the responsibility associated with the position, convenience for daily reporting of net dose or routine close physical association with platoon members. Of the 113 replies, percentages were distributed as follows: squad leaders - 27 percent; platoon sergeants - 24 percent; platoon leaders - 15 percent; section leaders - 14 percent; and 20 percent of miscellaneous replies of frequencies below three.[13]

The report concluded that:

> Because of the high probability of such significant variations in the degree of exposure among members of a platoon, it cannot be stated that the proposed system of unit dosimetry is any more accurate than the expedient method of estimating troop exposure based on time of entry and time of stay in contaminated areas. However it does give a more specified basis for a relative comparison of one unit with another concerning exposure. It provides no basis for predicting extent of biological damage, if any, or for anticipating casualties due to radiation. Further, any conclusion concerning the adequacy of the basis of issue and the recommended distribution based on time studies alone must be qualified.[14]

A generalized example of the variance in dose with location on the ground provides additional appreciation of the problem. As with instrument capability, it is convenient to consider initial and residual radiation separately.

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[13]Ibid., p. A-I-1.

[14]Ibid., p. A-4.

Consider a platoon defense position (part of a forward rifle company in defense). Width of the position (physically occupied) is taken as 400 meters, depth as 200 meters, including supplementary positions. These distances are currently applicable for ideal terrain.[15]

Figure 2 presents the distance from a nuclear detonation, as a function of the yield of the weapon, for three different doses of initial radiation, 100 rads, 500 rads, and 1000 rads. Of particular note is the parallelism between the dose lines as the yield varies, so that the distance between 100 rads, 500 rads and 1000 rads is essentially independent of yield. Actually the distances between the dose lines would be expected to be less at smaller yields. However, if one accepts the presentation of this unclassified figure for the current analysis, if for no other reason than for simplicity, the following figures can be excerpted:

Distance Differential	Dose Boundaries
150 meters	1000 rad & 500 rad
300 meters	500 rad & 100 rad
450 meters	1000 rad & 100 rad

for weapon yields from 2 KT to 100 KT.

Imposing these dose-distance relationships over the platoon position provides the arrangement presented in Figure 3. The difference in initial radiation dose over the platoon is roughly a factor of ten. This is the difference between life and death; for at 1000 rads 100 percent lethality

[15]Department of the Army. FM 7-15, Rifle Platoon and Squads, Infantry, Airborne and Mechanized, March 1965, pp. 103-6.

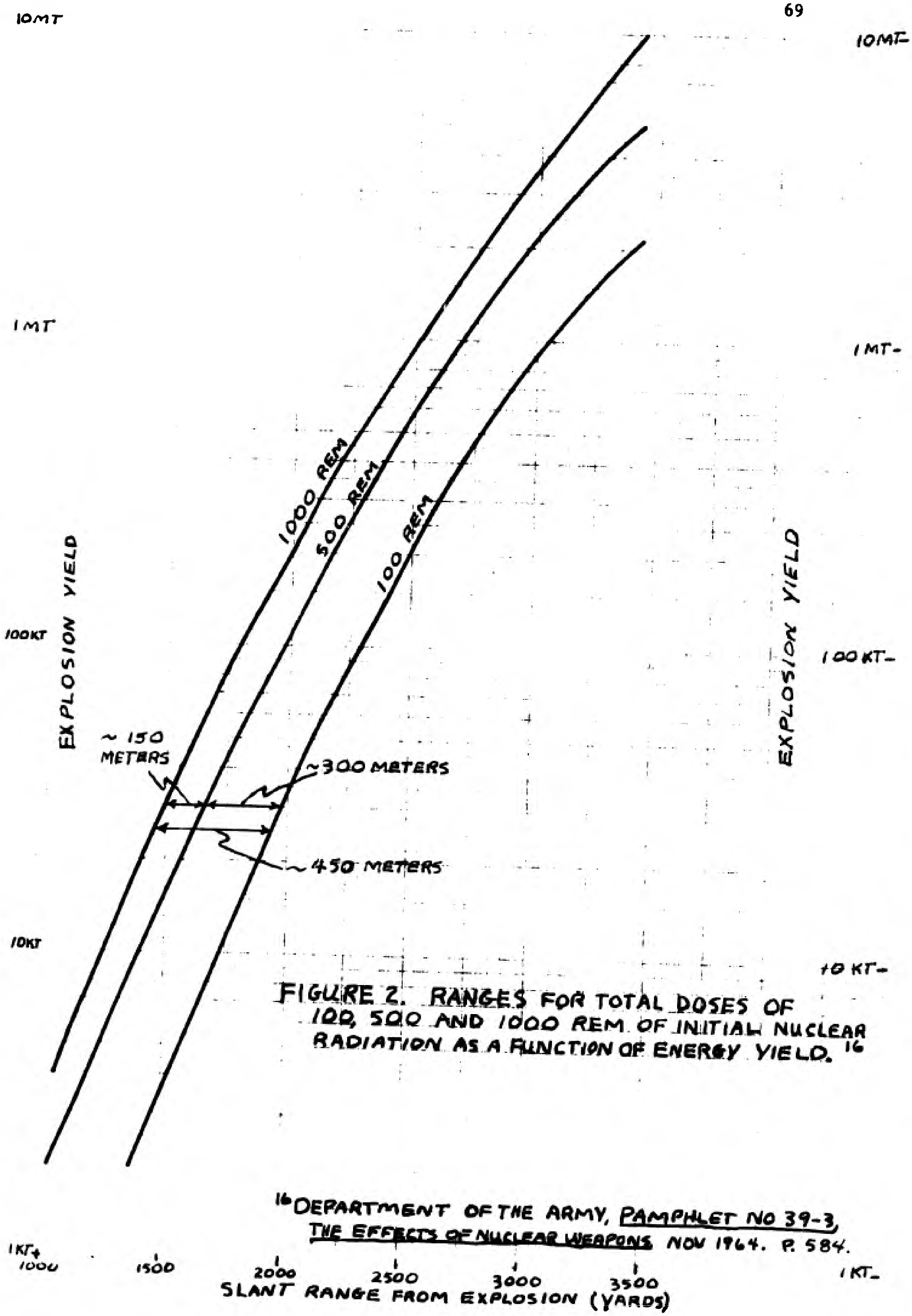

FIGURE 2. RANGES FOR TOTAL DOSES OF 100, 500 AND 1000 REM OF INITIAL NUCLEAR RADIATION AS A FUNCTION OF ENERGY YIELD.[16]

[16] DEPARTMENT OF THE ARMY, PAMPHLET NO 39-3, THE EFFECTS OF NUCLEAR WEAPONS, NOV 1964. P. 584.

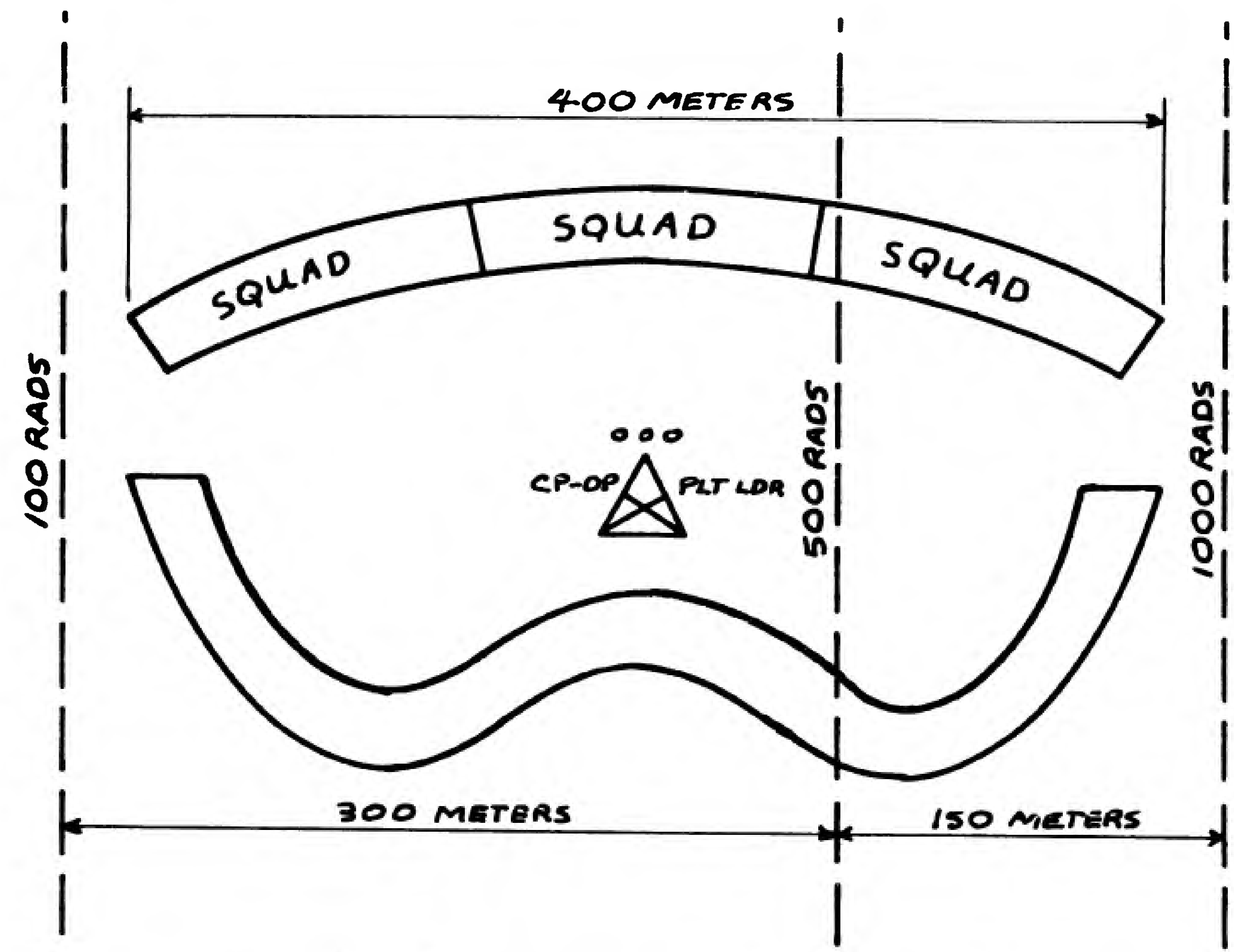

FIGURE 3. INITIAL RADIATION ON PLATOON DEFENSIVE POSITION.

can be expected while a dose of 100 rads, depending on previous radiation history could have a negligible effect on combat effectiveness.

In this particular example the radiation dose varies significantly over short distances and members of the platoon are not exposed to the same dose. While one can theorize over possible locations of the dosimetry devices and the difference in the average dose reported as a result, there remains the inescapable conclusion that, for the hypothesized situation, no single "average" platoon dose determination can properly represent the dose received by individuals within the platoon, regardless of the number of instruments used.

In Chapter II it was noted that the whole body gamma radiation from residual radiation comes from a finite area about an individual of approximately 100 meters. Fifty percent comes from a circular area having a radius of approximately ten meters. Thus the radiation source area for different members of the platoon will vary considerably with the possibility of significant variation in dose among squads and even individuals within the platoon.

There is a serious question as to whether two dosimeters per platoon is the optimum distribution for determination of platoon "average". It appears that a detailed analysis, to include field tests, is desirable to determine the optimum distribution or reaffirm the current basis of issue. This conclusion is not new; the 1968 study of Major Bobby G. Robinson had a similar recommendation.[17]

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[17] Bobby G. Robinson, Major. "Radiation Dosage Control and Reporting in the ROAD Division," (Unpublished treatise, U.S. Army Command and General Staff College, 1969), p. 27.

However, the intuitive and unsupported judgment of the author is that two dosimeters per platoon will prove to be a valid distribution. If the variation in dose received over the platoon areas is so great as to require additional instruments to provide a valid average, the concept of a "platoon average" becomes invalid.

SYSTEM FOR RECORDING

Once the basic radiation exposure data has been collected, a system of reporting and recording must be established to permit timely consideration of this information in conjunction with previous and subsequent exposures.

The current reporting and recording system was described previously in this chapter.

Again the results of the 4th Infantry Division troop test provides insight on the adequacy of the system. A basic objective of the best was evaluation of procedures for collecting, recording, processing, transmitting, and analyzing dosimetry data. Pertinent subobjectives and results are shown below:

Subobjective 1: To determine the mean time required to transmit and the mean time required to process dosimetry data for each step in the dosimetry system. Results were obtained from 98 company trials, adjusted to obtain 84 percent assurance (addition of one standard deviation), and presented as follows:

Step 1 - Company receives all platoon averages -------------- 1 hr, 26 min

Step 2 - Battalion receives platoon averages ---------------- 1 hr, 18 min

Step 3 - Battalion determines percentage summary[18] ---------- 1 hr, 49 min

Step 4 - Brigade receives battalion percentage summaries[18] -- 1 hr, 2 min

Total time from first reading of first unit dosimeter until battalion has platoon percentage summaries determined -------------------- 3 hr, 40 min

Total time from first reading of first unit dosimeter until brigade has battalion percentage summaries -------------------------------- 4 hr, 39 min[19]

The report takes special note that these times do not necessarily represent the actual time to accomplish the tasks, since the times recorded during the test and analyzed represented the time from the start to the completion of each step. Consequently the times shown include time consumed by distractions and higher priority matters due to exigencies in the tactical situation. However, it was noted that such distractions occur on the tactical battlefield and therefore the report concluded that the times were realistic.[20]

A partial explanation of the time factors is evident in commander's preferences for the method of transmitting dosimeter readings. The platoon leaders, for submitting readings to company, indicated the following preferences: 43 percent preferred messenger, 34 percent radio and 21 percent wire. From company level to battalion, preferred methods were 46 percent radio, 39 percent wire and 15 percent messenger, while at battalion level, for forwarding to brigade and division all three methods were about equally

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[18]NOTE: The system tested required determination of the percentage of platoons in each RS category in lieu of company and battalion statuses.

[19]Troop Test, op. cit., pp. 8, A-25-7.

[20]Ibid., p. 8.

recommended. In the comments received from all levels, security appeared to take precedence over speed of reporting. Lack of urgency also was a factor. One battalion commander commented: "Should not tie up radio nets, command or admin with information which cannot be of immediate value."[21]

While some of the times seem to be excessive, the report concluded that: "these times were found to be sufficiently short to provide timely information at the levels of command where it is useful."[22]

Subobjective 2: To determine the number of errors which occur during transmission of dosimetry data between units, and which occur during processing of dosimetry data. The following are results, with 84 percent assurance that the given percentage of errors will not be exceeded:

	Percent of Errors
Reporting Platoon Averages to Company	1.61
Reporting Platoon Averages to Battalion	1.76
Posting Platoon Averages to Battalion Chart	1.42
Determining Platoons Radiation Status	1.04[23]

The report concludes that "the small percentage of errors in transmitting and processing dosimetry data indicates that the system contains no particularly difficult steps which cause an inordinate amount of errors."[24]

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[21]Ibid., p. A-I-6.

[22]Ibid., p. 9.

[23]Ibid., p. A-31.

[24]Ibid., p. A-30.

Subobjective 3: To determine what use commanders made of the information generated by the dosimetry system. The after-action reports by commanders indicated that they considered it important to know the radiation status of their units. The radiation status of elements of the command were presented at staff briefings at each level and in two instances, during the exercise, the status of certain units caused a change in unit missions in order to minimize risk of higher exposures to some units. More important to the discussion was the fact that commanders were unanimous in stating that the information generated by the system is useful and that "its usefulness and importance far outweighs the small additional administrative and communications effort."[25]

The conclusions drawn from the report of the troop test which measured the adequacy of the reporting and recording system were quite satisfactory, and provided good evidence that this portion of the radiation exposure control system is adequate.

SYSTEM FOR UTILIZATION

Having measured, reported and recorded the radiation exposure data, evaluation of the system established to utilize this information remains.

Basically, what is required of the utilization system is the ability to take radiation exposure data, integrate it with the effects of previous exposures to provide the commander with timely guidance on what the effects of it and subsequent radiation exposure will be.

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[25] Ibid., p. 9.

Review of this aspect will be divided into two areas:

1. The capacity of medical knowledge in assessing the effect of exposures; and

2. The validity of the specific method of classifying units in Radiation Status Categories.

Medical Analysis

One of the most valid criticisms of the current radiation exposure control system is that it provides no reference as to how the exposure was accumulated. Each dose received is considered to be an acute dose and the dosage is simply added to previously accumulated dosages. No allowance is made for recovery from radiation injury.

As pointed out in Chapter II, most current medical guidance is directed toward acute doses. There is simply not enough information available on recovery from radiation exposure to make valid estimates.

It should be noted that lack of recovery guidance prohibits positive assessment of:

1. The residual injury from previous exposures.

2. The effect of protracted doses and/or mixed acute and protracted doses.

3. The effect of recovery or repair of damage in assessing future vulnerability.

The lack of applicable recovery data seriously limits the validity of the radiation exposure control system. Because of the uncertainty as to recovery and residual injury, the current doctrine specifies disregarding recovery entirely (see Table 5, Note 3) thus requiring acceptance of whatever recovery that occurs as a bonus or built-in safety factor. This bonus effect probably is extremely significant.

Another serious deficiency in medical knowledge of the effect of radiation is the effect of partial-body irradiation. Inability to relate and integrate partial-body radiation exposures with whole-body exposures again necessitates a significant safesiding practice; that of regarding all exposures as whole-body irradiation.

Associated with both of these deficiencies is the concept of reclassification of units. The current system specifies that units can be reclassified to less serious radiation status categories by the commander upon advice of the surgeon, after ample observation of the actual state of health of the exposed personnel has been made. Thus the surgeon plays a decisive role, as would be expected.

Serious absence of detailed medical knowledge on certain aspects of radiation injury, especially recovery, make efficient utilization of radiation exposure information difficult if not impossible. The result is a system employing conservative medical criteria and relying heavily on the clinical judgment of the surgeon both in treating individual patients and providing guidance to the commander.

Unit Classification

The validity of the system of classifying units into radiation status categories is of primary importance, since it is this classification system which changes the radiological data into a form which is to be used by Commanders and their staffs at the various levels.

Platoons are classified into the three radiation status categories based on the data provided in Table 5. As pointed out in the introduction, this report does not consider the basic radiation reference dose criteria in its analysis. However, in reviewing the basic classification system and associated dosage numbers, one aspect stands out strongly and deserves comment: the single exposure criteria is excessively safe-sided. For example, a moderate risk is applied "when a planned single dose is sufficiently high that exposure up to four or five such doses, alone or in conjunction with previous exposures constitute a significant exposure history." An emergency risk prevails "when a planned single dose is sufficiently high that exposure up to two or three such doses, alone or in conjunction with previous exposures would approach or exceed the threshold for combat ineffectiveness from radiation sickness."[26]

It could be desirable to have exposure criteria which safe-sides radiation exposures by factors of 2, 3, 4, or 5 *if* these limits normally permitted mission accomplishment. In reality, however, one would expect radiation exposure limits to be one of the strongest limiting factors on the nuclear battlefield.

The hazard from radiation is only one of the aspects which the Commander must measure in determining his course of action. Other aspects

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[26]DA Fm 3-12, op. cit., p. 6-3.

include the blast and thermal radiation from nuclear weapons, as well as the normal conventional aspects of warfare. To provide the commander with information on one aspect which is "safe-sided" significantly does him a major disservice, for it restricts him in achieving a valid measurement of the comparative hazards of the operation and could lead him to a decision which actually involves greater risk, both to mission accomplishment and the future effectiveness of his command.

Fortunately, a study has recently been completed which evaluates and updates radiation exposure criteria. In applying the new data, this multiple safe-siding was recognized and new criteria have been proposed. This criteria is presented in Chapter V.

The classification of Company and Battalion size units requires a careful examination. The basic requirement of the classification of the higher level units is the same as that of the platoon: the radiation status category must provide the Commander with information which enables him to judge the radiation vulnerability of the unit.

The current criteria for determination of Company/Battalion Radiation Status is shown in Table 7. The system is basically one of "averaging" platoon readings to provide a Company Status and of "averaging" Company Statuses to determine the Battalion Status. The problem with this system is that it does not work. It does not provide the Commander with the information necessary to make decisions.

This can be demonstrated amply with a simple example. Consider a hypothetical battalion consisting of three companies, each with three platoons. The battalion has a radiation status of RS-2. What does this mean to the brigade and division Commanders who are concerned with employment of the battalion?

A detailed analysis proves enlightening. Since the battalion is RS-2 and has three companies, one notes from Table 7 that the sum of the RS numbers from the three companies is either 5, 6, or 7. What combination of company radiation statuses provide this sum? The following table indicates the possible combinations.

Table 8

Company Radiation Status Distribution for 3-Company Battalion in Radiation Status-2

Sum of Company RS Numbers	Number of Companies RS-1	RS-2	RS-3
5	2	0	1
	1	2	0
6	1	1	1
	0	3	0
7	1	0	2
	0	2	1

Thus radiation status of the companies in the battalion could be any of six possible combinations. There obviously is quite a range in the exposure vulnerability.

But the platoon is the basic unit for radiation exposure. What is the possible distribution of platoons within the battalion? Since in the Company Radiation Status distribution there are RS-1, RS-2 and RS-3 units to be considered, an expansion of Table 8 is necessary to consider platoon radiation status categories.

Table 9 is this expanded table.

Table 9

Platoon Radiation Status Combinations
3-Platoon Company

Company Status	Sum of Platoon RS Numbers	Number of Platoons RS-1	RS-2	RS-3
RS-1	3	3	0	0
	4	2	1	0
RS-2	5	2	0	1
		1	2	0
	6	1	1	1
		0	3	0
	7	1	0	2
		0	2	1
RS-3	8	0	1	2
	9	0	0	3

The next step is to combine Table 8 and Table 9. The results produce 33 possible combinations of platoon radiation status. The extremes are shown in Table 10 where "least severe" means the minimum indication of radiation and "most severe" the maximum.

Table 10

Extremes of Platoon Radiation Status Combinations
(RS-2 Bn, 3 Co, 3 Plt)
(Number of Platoons)

Least Severe RS-1	RS-2	RS-3	Most Severe RS-1	RS-2	RS-3
7	0	2	2	0	7
6	2	1	1	2	6
5	4	0	0	4	5

Three possible combinations are indicated in both the least severe and most severe categories, since in a particular operation the commander might find it more restrictive, for example, to have four RS-2 and five RS-3 platoons than two RS-1 and seven RS-3 platoons.

The results of this classification system become apparent. The brigade or division commander is only able to discern that, of the nine platoons in the RS-2 battalion, up to seven platoons (78%) may be in a RS-3 status, that is, "all further exposure considered Emergency Risk"; or perhaps no platoons are in RS-3 status; or perhaps seven platoons are in the RS-1 status (militarily negligible radiation exposure history).

This, to say the least, is an unsatisfactory variation in perceivable status of a subordinate unit. In an operation where radiation exposure was a factor, the commander would have <u>no</u> meaningful guidance available.

CHAPTER V

CDCINS PROPOSED REVISION OF RISK CRITERIA

Before proceeding on to further discussion of the current radiation exposure control system, it is necessary to present, in brief, at least part of the contents of a Combat Developments Command Institute of Nuclear Studies report, which was published subsequent to the inception of this thesis.

The Coordination Draft of ACN 4260, Personnel Risk and Casualty Criteria for Nuclear Weapons Effects, was published by CDCINS on 9 November 1970. The objective of this report is to establish revised personnel risk and casualty criteria for nuclear weapons effects. During the past several years a considerable body of experimental data had been developed, particularly in the area of radiation effects, which had cast some doubt on existing criteria, particularly on the time response to large doses of radiation which is used for casualty assessment of enemy troops. In addition to recommending revision of response to large doses, the report also examines personnel risk criteria.

The report points out that the current single-shot nuclear radiation troop safety criteria do not correspond to the levels of injury which are associated with the current blast and thermal troop safety criteria. It notes that the cumulative nature of radiation has been taken into account in the development of the single-shot criteria and had also been accounted for by the use of radiation status categories.

A consistent risk criteria is established (re-established) for each of the three casualty producing effects of nuclear weapons. Those risk criteria are:

Risk	Incidence of Casualties	Incidence of Nuisance Effect
Negligible	1%	2.5%
Moderate	2.5%	5%
Emergency	5%	No Limit

where (1) the casualty criterion is the level for a particular physical parameter at which permanent combat ineffectiveness will occur in 50 percent of the population exposed to that level; and (2) a nuisance effect is an injury which may cause a significant degree of performance decrement in a soldier, but will not result in a casualty.[1]

A comprehensive study on the effects of intentional therapeutic whole body irradiation in men was referenced wherein medical case studies of 163 patients had been subjected to an analysis to determine dose response relationships for the various symptoms of the prodromal response and for hematological death. A procedure was accepted which permitted adjustment to allow for the symptoms of the patients illness which could not be distinguished from prodromal responses. However, the report notes that the dose-response relationship probably underestimates the doses necessary to produce the indicated results in normal, healthy combat troops, due to a

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[1]U.S. Army Combat Developments Command Institute of Nuclear Studies. Personnel Risk and Casualty Criteria for Nuclear Weapons Effects (U), ACN 4260, CONFIDENTIAL, (Fort Bliss, Texas: USACDCINS, 1970), p. A-3-5.

lack of knowledge as to what degree interaction between radiation and illness affects the results. The dose response relationship for the prodromal symptoms of anorexia, nausea, fatigue, vomiting and diarrhea are shown in Figure 4. The dose is expressed as the average absorbed dose in rads to a 26 cm diameter sphere of tissue in the human epigastrum and is assumed equivalent to the mid-trunk dose.[2]

As noted previously, risk criteria are based upon evidences of either a nuisance effect or casualties. Of the prodromal responses, anorexia and nausea were judged insufficient to cause a significant performance decrement in typical combat tasks and therefore did not qualify as nuisance effects. Fatigue may result in performance decrement if performance is demanded for extended periods of time. Vomiting may cause performance decrement, particularly in more difficult tasks and yet is generally insufficient to cause casualties. Diarrhea is generally related to supralethal doses and consequently was judged too severe a sign to be considered a nuisance effect. Therefore, of the prodromal symptoms, vomiting is chosen as the suitable nuisance effect.[3]

Figure 5 presents the dose-response relationship for incidence of vomiting and percent combat ineffectiveness. Combat effectiveness, defined as "ineffective in performing assigned duties", is a safe-sided measure of effectiveness in the post exposure final phase. A band, determined by the limit of each dose range was included to indicate the magnitude of uncertainties in the dose-response relationship.[4]

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[2] Ibid., p. B-36 [3] Ibid., p. B-39. [4] Ibid.

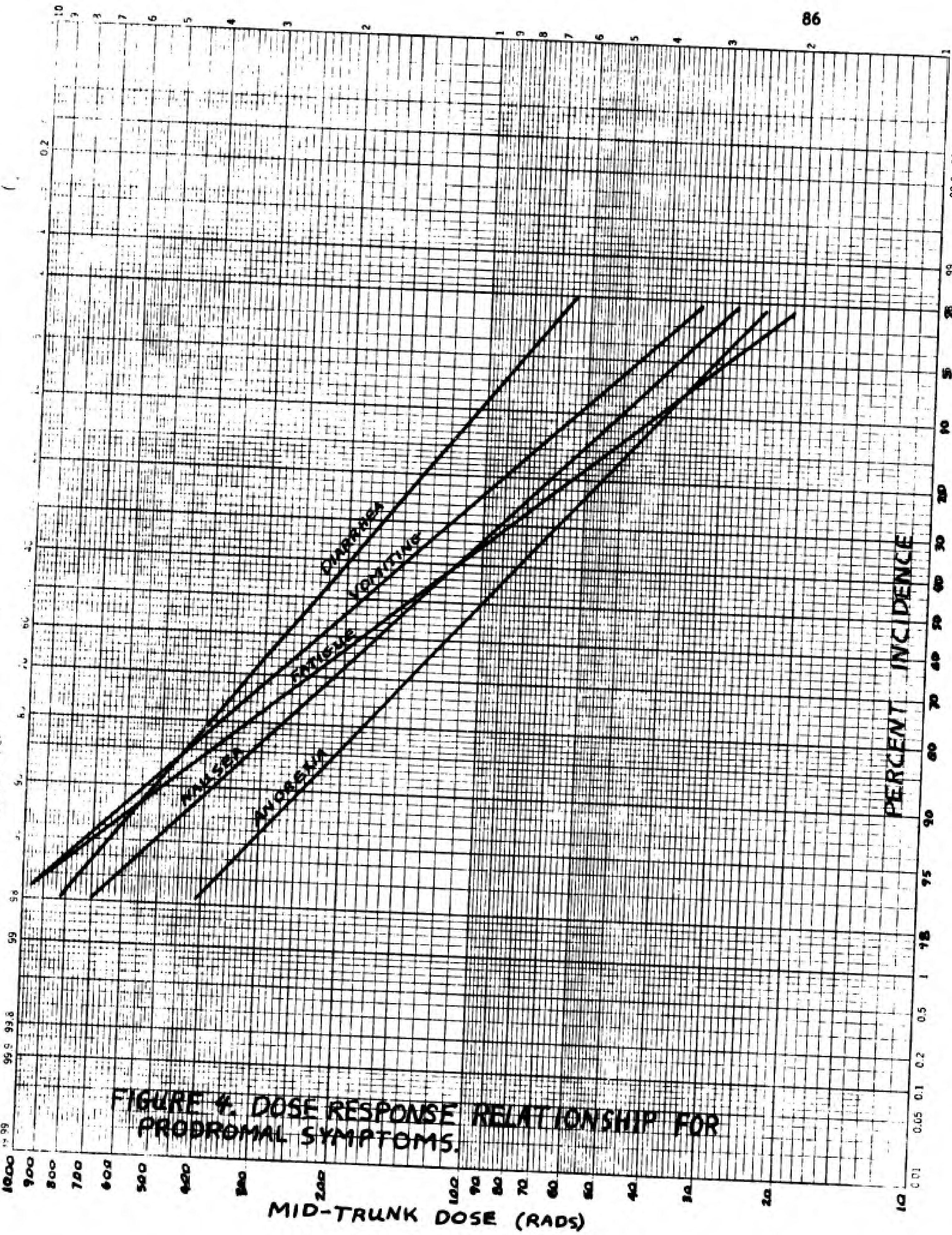

FIGURE 4. DOSE RESPONSE RELATIONSHIP FOR PRODROMAL SYMPTOMS.

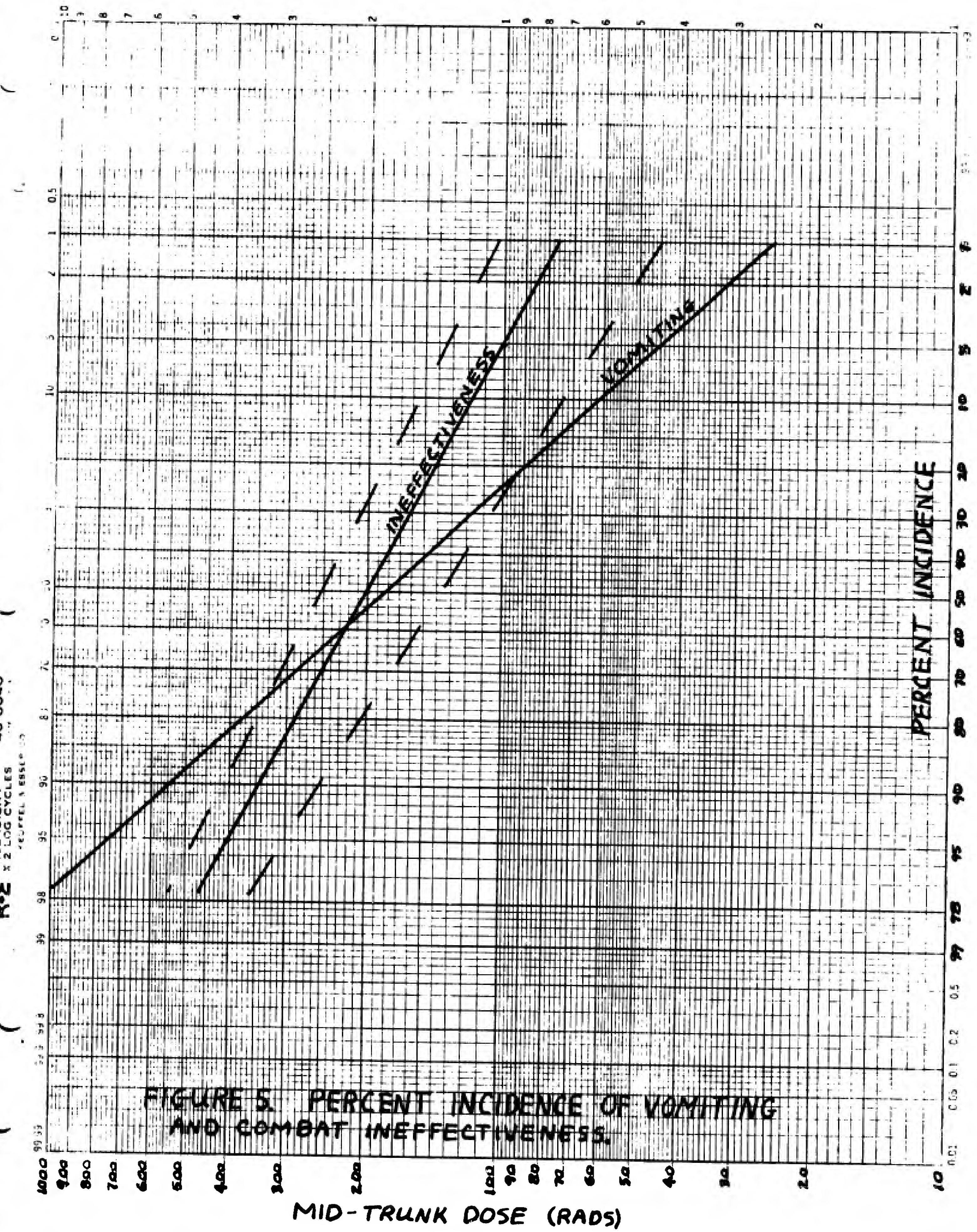

FIGURE 5. PERCENT INCIDENCE OF VOMITING AND COMBAT INEFFECTIVENESS.

Risk criteria on the governing effect between nuisance effect or casualties were taken from Figure 5 for each of the three degrees of risk. The dose necessary to cause a 2.5 percent incidence of vomiting (35 rad) is less than the dose required for one percent combat ineffectiveness (77 rad) and thus vomiting governs and a 35 rad mid-trunk dose is chosen as a negligible risk. Similarly, a mid-trunk dose of 45 rad is chosen as a moderate dose. An emergency dose is defined only by a 5 percent incidence of combat ineffectiveness (nuisance effect is unrestricted) and a mid-trunk dose of 100 rad was selected. Converting these mid-trunk doses into midline doses (free-in-air) gives risk criteria of 50, 70 and 150 rad for negligible, moderate and emergency risks, respectively.[5]

As a result of the differences between old and new risk criteria, it was necessary to establish new criteria for radiation status categories. The new single-shot risk criteria, 50, 70, and 150 rads, correspond to negligible, moderate and emergency risk, respectively, only when personnel have received no previous radiation dose. Personnel with no exposure history are classified in the category RS-0. Units with accumulated doses of from greater than zero to less than or equal to 70 rads are classified in category RS-1. In addition, it is noted that 70 rads is within the dose range (50-100 rads) of the threshold for significant blood changes to occur and consequently is a significant dose. The category RS-2 is defined by previous doses totaling to greater than 70 rads but less than or equal to 150 rads. Units which have received greater than 150 rads are classified RS-3.

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[5]Ibid., p. B-40.

The report recognizes that while a desirable property of risk is the existence of precise correspondence between a particular degree of risk and an expected level of nuisance effect or casualties, regardless of the radiation status of the unit, this is not possible because radiation status categories are defined by a dose range while risk criteria are definite dose values. However, an approximate correspondence is obtained by choosing risk criteria for each radiation status category such that a correspondence between effect and risk level exists for personnel with past accumulated doses which are in the middle of the dose range defined by each radiation status category. A negligible risk for troops in RS-0, 50 rads, would entail the same risk as a negligible risk dose for troops with a past accumulated dose in the middle of the dose range defined by RS-1 or 40 rads. (Since doses are rounded off to the nearest 10 rad in the field, RS-1 includes the range 10 rads through 70 rads, the median of which is 40 rads.) Consequently, a dose of 10 rads is chosen as a negligible risk dose for troops in RS-1. In the same manner risk criteria are specified for other risk levels and radiation status categories.[6]

Table 11 presents the proposed table of risk criteria as a function of radiation status category.

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[6]Ibid., p. 43.

Table 11

Proposed Radiation Status Categories[7]

Radiation Status Categories	Total Past Dose (rad)	Single Exposure Risk Criteria		
		Neg	Mod	Emerg
RS-0	0	50	70	150
RS-1	$> 0, \leq 70$	10	30	110
RS-2	$> 70, \leq 150$	--	--	40
RS-3	> 150	--	--	--

It is evident that the proposed radiation status category criteria are significantly different than the current criteria, both in the number of radiation status categories and the recommended dosages within each category. Discussion of the former is included in the next chapter.

[7]Ibid.

CHAPTER VI

DISCUSSION

Three aspects developed during the analysis are selected for expanded development and discussion in this chapter. These are: the deficiency in dosimetry which precludes measurement of initial radiation, the inability of the method for determination of battalion radiation status to provide meaningful information and the role of the surgeon in providing radiation advice to the Commander.

DOSIMETRY

During review of the capabilities of the IM-93/UD, the current tactical dosimeter and basic instrument for collecting data for the radiation exposure control system, one serious shortcoming was noted: the lack of capability to measure the neutron component of initial radiation.

This lack of capability for neutron measurement effectively negates the system's capability to perform adequately in the initial radiation environment, and thus limits the overall usefulness to the commander. This instrumentation deficiency has been long recognized. In July 1961, Department of the Army approved military characteristics for a new tactical dosimeter. These military characteristics were subsequently revised and in March 1965 were restated as a "Qualitative Material Requirement for a Tactical Dosimeter". The Qualitative Material Requirement (QMR) requires that the tactical dosimeter be a high-range, direct reading device measuring both gamma and neutron radiation to provide a means for rapid determination of the total cumulative gamma and neutron dose received by personnel from nuclear weapons (initial radiation) and gamma radiation from radioactive materials (radioactive fallout, induced radiation and radiological agents). This dosimeter is to be organic to all combat, combat support and combat service support units and will provide commanders with an indication of total cumulative dose of gamma and neutron radiation to which their units have been exposed. Information from the dosimeters is to assist commanders in assessing troop potential. The dosimeter shall be of such size, weight and shape as to be worn on the individuals clothing or person. This dosimeter will replace the IM-93/UD dosimeter.[1]

From this description of the development requirements, it appears that the Radiacmeter, IM-185( )/UD, as it has been designated, has been pointed in the right direction.

The technical approach taken is to exploit the SEMIRAD (Secondary Electron Mixed Radiation Dosimeter) principle for detection and measurement. In this technique, a vacuum chamber with secondary electron emitters are used as the sensitive element. Primary electrons resulting from gamma radiation and recoil protons resulting from neutron radiation cause low energy

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[1]U.S. Army Electronics Command. Technical Development Plan, Part B, Radiacmeter IM-185( )/UD and Charger PP-4370( )/PD, (Fort Monmouth, New Jersey: U.S. Army Electronics Command, 1967), p. 29.

secondary electrons to be emitted from the walls of the vacuum chamber. These secondary electrons are collected, causing a quartz-fiber electroscope to discharge. The responses to radiation are completely independent of the incident dose rate.[2]

Technical difficulties have caused significant slippage in the development of the IM-185( )/UD. Recent contact with the U.S. Army Electronics Command provided the following anticipated phasing.[3]

Engineering/Service Test: Start September 1974.

Type Classification: October 1976.

However, this schedule must be recognized as highly dependent on available funding, as well as solving of technical problems.

It is believed, based upon the recognition of the deficiency in the measurement of neutrons and the subsequent development action, that one can conclude that necessary cognizance and action is being taken to develop a tactical dosimeter which will adequately meet the requirements of the radiation exposure control system.

In the meantime, which could range for a number of years past type classification, there remains the problem of adequate measurement of initial nuclear radiation. One possible "interim" solution is the use of a "weighting factor" which could be applied in the field to give credit for the neutron portion of the dose.

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[2]Ibid., pp. 30-31.

[3]U.S. Army Electronics Command. Personal conversation with Mr. P. Brown.

It should be noted, prior to discussion, that the figures developed were based on unclassified sources, and therefore have definite limitations both in scope and accuracy. More precise numbers must be obtained for any expansion of this concept.

Basically the procedure is to determine and apply the gamma to neutron ratio as a function of distance from the nuclear detonation. The best method available to the author proved to be a purely empirical extraction of values from Figure 11.91, DA Pamphlet 39-3, which is reproduced in Figure 6. This data is for a 1 kiloton burst at 0.9 sea level air density. The curve showing the total biological dose is obtained by adding the separate initial gamma-ray and neutron doses at distances from the explosion. Although the nuclear radiation doses are not strictly proportional to the energy yield of the explosion, the general conclusions are not basically affected if such proportionality is assumed.[4]

An examination of the gamma ray and neutron dose curves shows that near the explosion the neutron dose is the greater of the two. However, with increasing distance, the neutron dose falls off more quickly than does that of gamma radiation, so that beyond a certain point the gamma rays predominate. Ultimately the neutrons become negligible in comparison.

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[4]Department of the Army. Pamphlet No. 39-3, The Effects of Nuclear Weapons, April 1962, pp. 582-3.

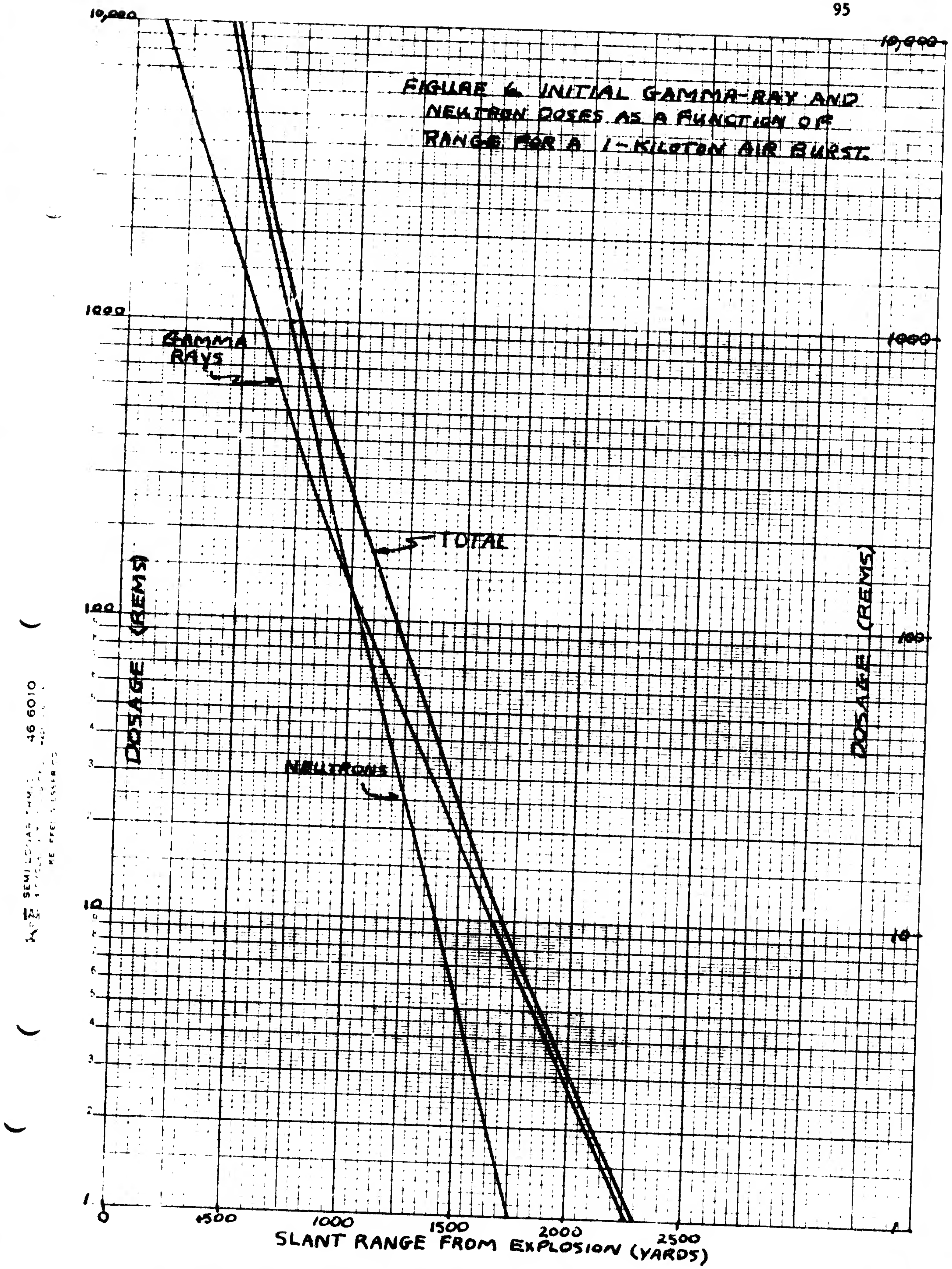
FIGURE 6 INITIAL GAMMA-RAY AND NEUTRON DOSES AS A FUNCTION OF RANGE FOR A 1-KILOTON AIR BURST.
10,000
1000
100
10
1
GAMMA RAYS
TOTAL
NEUTRONS
DOSAGE (REMS)
0
500
1000
1500
2000
2500
SLANT RANGE FROM EXPLOSION (YARDS)

Table 12 presents values of gamma and neutron radiation extracted from Figure 6:

Table 12

Gamma and Neutron Dose Relationships

Range (yards)	Neutron Dose (rads)	Gamma Dose (rads)	Neutron Dose/ Total Dose	Total Dose/ Gamma Dose
500	4700	1500	0.76	4.1
1000	130	130	0.50	2.0
1500	5.5	18.5	0.23	1.3
2000	0.25	2.85	0.08	1.2

An attempt also was made to develop a "simple" formula to express the neutron-gamma relationship. While this approach was doomed to failure, from a practical standpoint, the results are interesting and are thus presented.

It is possible to derive a simple semi-empirical analytical expression for initial gamma ray exposure as a function of distance from a nuclear explosion. If the distances of interest are large in comparison with the size of the nuclear burst, the source of gamma rays may be treated as a point source emitting a total quantity 'A' of gamma radiation. If the radiation distribution is isotropic, the amount received per unit area at distance 'D' normal to the direction of propogation will be:

$$I_o = \frac{A}{4\pi D^2}$$

if no attenuation in the air is assumed. Attenuation is included, using a linear absorption coefficient, u, in $I = I_0 e^{-uD}$ so that the radiation dose received at a distance D can be represented by

$$I = \frac{A}{4\pi D^2} e^{-uD}$$ where u is obtained from

actual experiments on initial gamma radiation and represents an empirical mean of photon energies.

However, this equation oversimplifies the conditions existing close to the explosion center and applies only for distances greater than 1200 yards. For a one kiloton weapon airburst at 0.9 sea level air density u has a value of 1/360 $yards^{-1}$ and the equation can be represented by:[5]

$$I = \frac{3.2 \times 10^9}{D^2} e^{-D/360}$$ rad, where D is measured in yards.

For weapon yields of less than 20 kilotons, the total initial gamma radiation is approximately proportional to the energy yield and the general equation for initial gamma radiation at a distance D yards from an explosion of W kilotons at a range of over 1,200 yards and for air of 0.9 normal density is:[6]

$$I = \frac{3.2 \times 10^9 W}{D^2} e^{-D/360} \text{ rads.}$$

A similar expression can be developed for neutrons, again treating the explosion as a point source:

$$N = \frac{B}{4\pi D^2} e^{-wD}.$$

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[5]Ibid., p. 408. [6]Ibid., p. 409.

From empirical data and assuming proportionality with weapon yield, at air of 0.9 sea level density, the neutron flux can be represented by:

$$N = \frac{8.6 \times 10^{18} W}{D^2} e^{-D/210} \text{ neutrons/cm}^2$$

where D is in yards. For a typical fission weapon, an integrated flux of 1 neutron/cm^2 is equivalent to an absorbed dose of 1.8×10^{-9} rad, for neutrons with energies greater than 200 electron volts. Thus the expression for neutron dose becomes:[7]

$$N = \frac{1.55 \times 10^{10} W}{D^2} e^{-D/210} \text{ rads.}$$

The "weighting factor" or value that one would multiply times the directly read gamma dose in order to obtain the total dose is:

$$\frac{\text{Total Dose}}{\text{Gamma Dose}} = \frac{N + I}{I}$$

Combining the previously determined equations for gamma and neutron dose, one obtains the weighting factor "$1 + 4.84\ e^{-D/504}$". Applying this within the range for which the gamma relationship is valid (over 1200 yards):

Range (yards)	$1 + 4.84\ e^{-D/504}$
1500	1.25
2000	1.09

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[7]Ibid., pp. 411, 581.

These values agree quite closely with the data taken from the curves in Figure 7. Unfortunately, the limitation as to range prevents usage at ranges of greatest concern, where the neutron contribution is the greatest.

Based on the values presented in Table 12, an increase in measured gamma dosages by the Total Dose/Gamma Dose factor is indicated, as a function of range from the explosion, a factor which should not be difficult to at least approximate. Weighting factors appropriate to unshielded conditions are presented in Table 13:

Table 13

Neutron Weighting Factors (Unshielded)

Range (meters)	Weighting Factor
500	4
1000	2
1500	1.3
2000	1.1

Distances beyond 2000 meters would not have an adjustment, since less than 10 percent error would result, which is within the gamma dose measurement error range. It should be noted that a translation to meters from yards was accomplished without exact conversion. This is a safe-sided adjustment; exact conversion is not warranted by the accuracy of the data used.

This adjustment applies for 0.9 sea level air density, for which the values used were derived. But different shielding substances attenuate gamma rays and neutrons at different rates. Even the difference in air density at sea level will have an effect. To see the effect of various shielding materials, as related to tactical situations, the following radiation transmission data are used:[8]

Protection	Transmission Factor Gamma	Transmission Factor Neutron
Armored Carrier	70%	70%
Foxhole	20%	30%
Earth 91 cm (3 feet)	2%	5%
Light Tank	20%	30%
Medium Tank	10%	30%
Vehicle	100%	100%

Applying these transmission factors with neutron and gamma dosages at the various ranges and regrouping produces the following table.

Table 14

Neutron Weighting Factors (Shielded)

Range (meters)	Unprotected Vehicles Armored Carriers	Foxhole Light Tanks	Earth (91 cm)	Med Tanks
500	4	5.7	8.8	10.4
1000	2	2.5	3.5	4.0
1500	1.3	1.5	1.7	1.9
2000	1.1	1.1	1.2	1.3

[8]Department of the Army. TM 8-215, Nuclear Handbook for Medical Service Personnel, 30 April 1969, p. 38.

As one can see, the factor needed to adjust for the effect of neutrons varies significantly, depending on the relative efficiency of the shielding as well as the range. Thus, in order to have an effective "neutron adjustment" factor one must use a table or other presentation which compensates for these differences.

Perhaps of greater significance, however, is the recognition of the increased requirement for radiation dosage adjustment in the shielded environment. The shielded environment is precisely the same environment that will provide protection against the effects of blast and thermal radiation and make important the consideration of the effects of nuclear radiation.

Application of neutron weighting factors must be basically compatible with the current system. It was noted previously that, due to lack of capability at the lower units, the basic platoon exposure data is forwarded to the battalion where platoon, company and battalion statuses are all computed. Consistent with this rationale, the application of neutron weighting factors and subsequent adjustment of dosage should also occur at battalion.

The platoon would immediately, upon receipt of the initial radiation from a nuclear burst, or as soon as practicable thereafter, read its dosimeters and forward the net reading to battalion along with that additional information necessary for the application of the weighting factor, i.e., estimated range to explosion, shielding at the time of explosion and the location of the dosimeter at the time the initial radiation was received.

Battalion would verify the information, to include the location of the platoon in relation to the nuclear detonation, and would apply the correct weighting factor to determine the total dose received by the platoon.

There exists the possibility that if the platoon were operating in a residual radiation environment, the dosimeter reading would include previously received residual radiation, that is, radiation which is not appropriate for the application of neutron weighting. Inaccuracy due to the inclusion of residual radiation could be reduced by increasing the frequency of reading of platoon dosimeters to at least once every four hours, or possibly even more frequently in a residual radiation field of relatively high intensity. The reduced span of time between readings would serve to limit the possible error; the dose from residual radiation over the shorter period of time should not be significant in relation to the initial radiation dosage. The additional readings would be a simple task due to the self-reading characteristic of the dosimeter. Results would be kept in the notebook maintained for that purpose. However, more frequent communication of net radiation doses than normally required would not be needed except in the case of receipt of initial radiation. Of course, to measure the initial radiation from planned "friendly" nuclear explosions, instruments would be read immediately before and after the explosion occurs.

The development and planned use of "weighting factors" for neutron radiation as a function of shielding and distance would appear to be warranted in view of the serious misrepresentation given by the current tactical dosimetry devices and the delay in final development and distribution of neutron reading devices.

UNIT CLASSIFICATION

In Chapter IV it was demonstrated that the system for determination of the Company/Battalion Radiation Status did not, at least for the example cited, provide a responsive indication to the Brigade and the Division Commander of the true radiation status of his units.

As previously noted, the basis for determination of Company/Battalion Radiation Status is the following table (Table 7 reproduced for convenience):

Number of Platoons in Company or Companies in Battalion	2	3	4	5	6	7
Company or Battalion RS Category	Sum of RS Numbers of All Organic and Attached Platoons or Companies					
RS-1	2	3-4	4-5	5-7	6-8	7-10
RS-2	3-4	5-7	6-9	8-12	9-14	11-17
RS-3	5-6	8-9	10-12	13-15	15-18	18-21

This table is represented in graph form in Figures 7 and 8. Figure 7 presents the sum of RS numbers versus the number of platoonsor companies. While only integral values of RS numbers and units are applicable, lines have been drawn for better visualization. As one would expect, RS-1

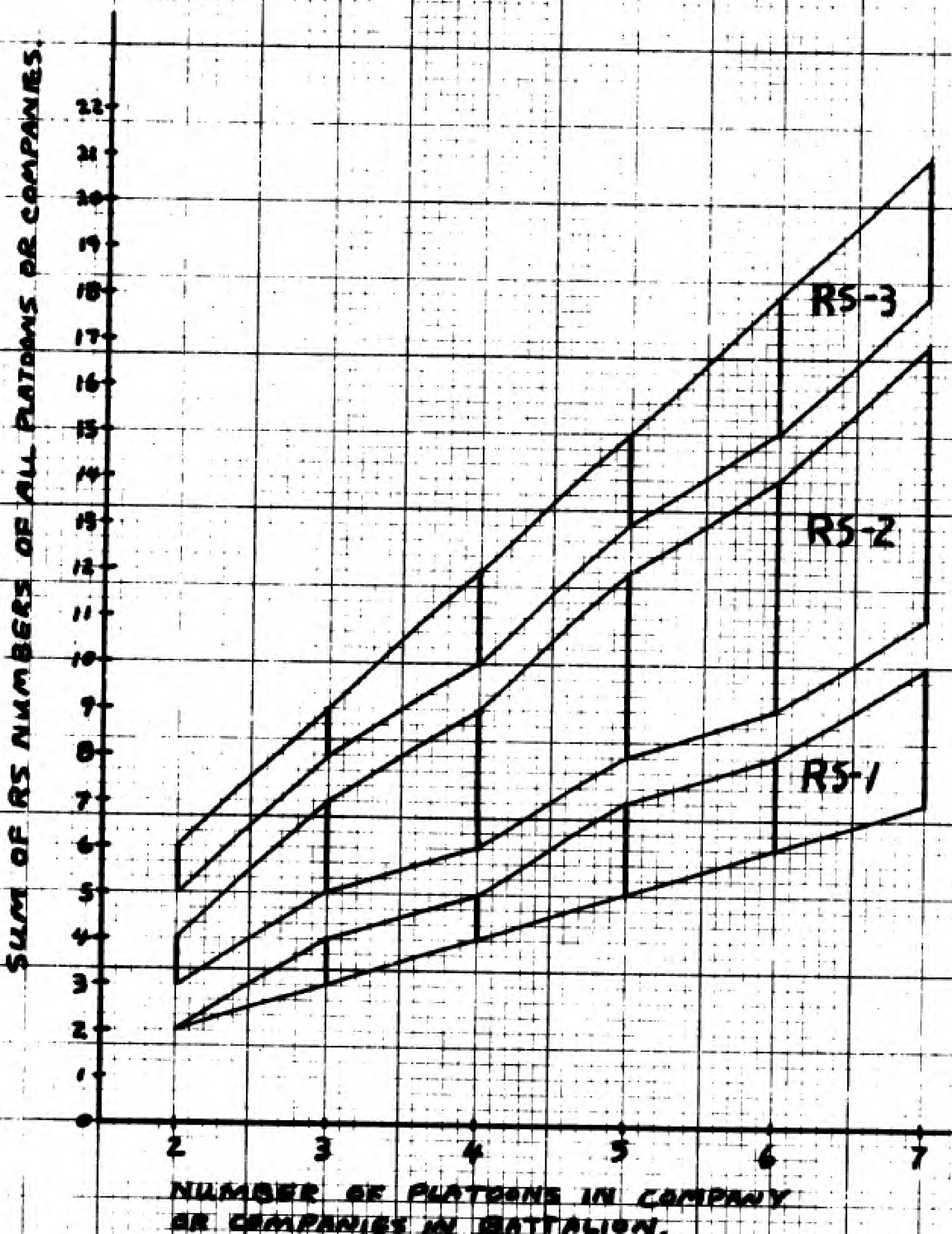

FIGURE 7. DETERMINATION OF COMPANY/BATTALION RADIATION STATUS — SUM OF RS NUMBERS VS. NUMBER OF UNITS.

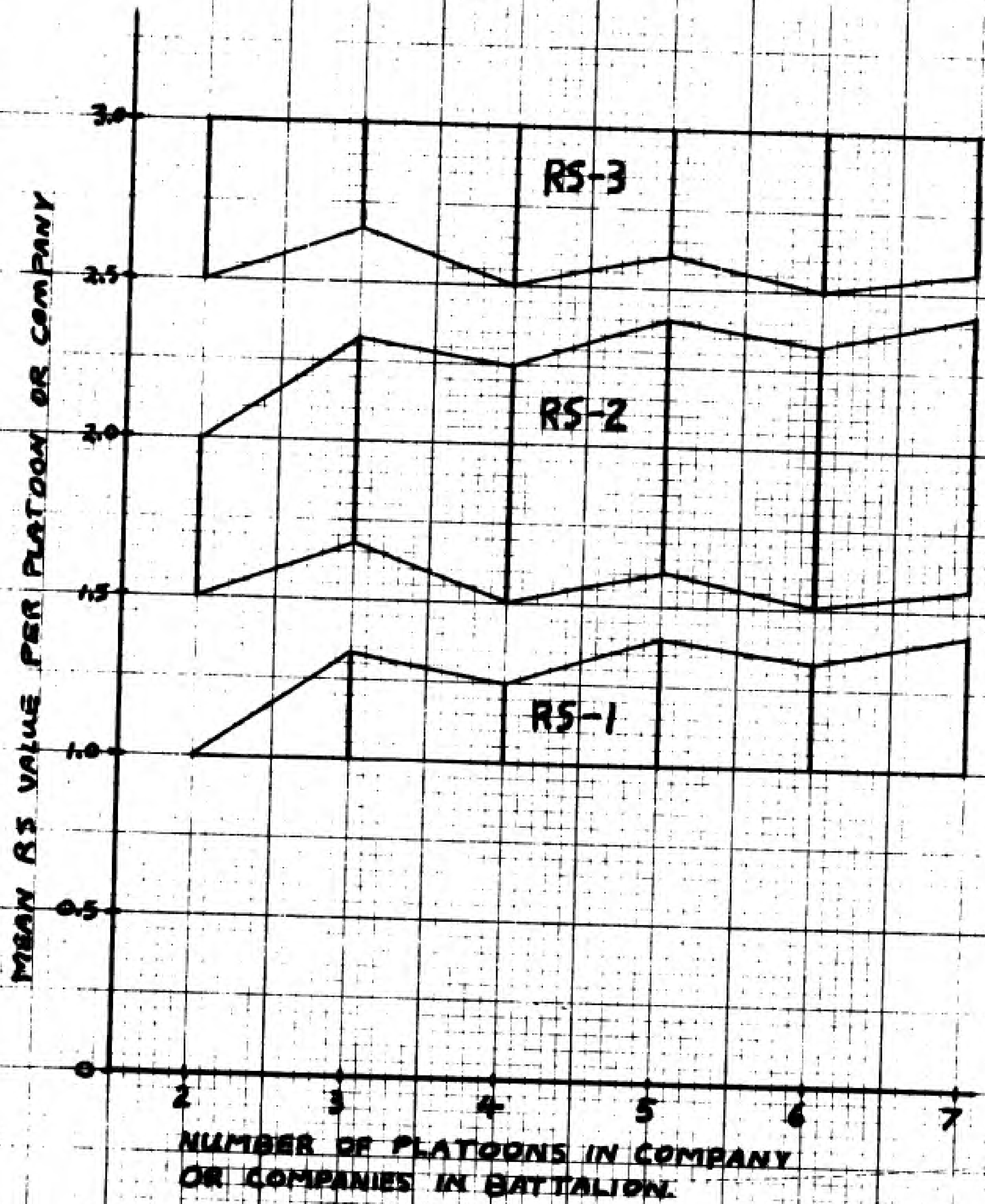

FIGURE 8. DETERMINATION OF COMPANY/BATTALION RADIATION STATUS – MEAN RS VALUE RANGE VS. NUMBER OF UNITS.

corresponds to lower sums of RS numbers and RS-3 to the higher sums. The range in RS sums expands as the number of units increase and the range in RS sums for RS-2 appears approximately double the range for either RS-1 or RS-3.

Figure 8 plots the mean RS value per platoon or company against the corresponding number of platoons or companies. From this figure the basis for the table becomes apparent; the mean radiation status for company or battalion is simply rounded off to the nearest integer or category, with the 1.5 and 2.5 figures rounded up. This can be summarized as follows:

$1.0 \leq \text{RS-1} < 1.5$

$1.5 \leq \text{RS-2} < 2.5$

$2.5 \leq \text{RS-3} \leq 3.0$

In order to provide a broader base for a conclusion on the system, a further look at the information provided the commander is desirable. This analysis centers around the battalion radiation status which is provided to the brigade and division commanders for their use. There is no problem at the battalion command level, for the doctrine provides that the platoon dose readings are forwarded to battalion, where the platoon radiation status is determined, the company radiation status is computed and both are placed on the battalion radiation status chart. Thus the battalion commander has all the radiation dose information available within the system.

However, at brigade and division level the picture is different. As noted in Chapter IV, the current doctrine provides that the battalion forward its own radiation status, based on the radiation status of organic and attached companies using the guidance contained in Table 7, and that, if more specific information is required it is obtained at the higher commanders request. Thus the radiation status information about the battalion that "normally" would be used is a simple RS-1, RS-2, or RS-3.

In order to evaluate the effectiveness of the system, several hypothetical battalion organizations are considered. The first and simplest battalion structure considered is a battalion consisting of three companies, each company having three platoons, i.e., a nine-platoon battalion. (A portion of the results were reported in Chapter IV.) Possible minimum or maximum radiation statuses for each Battalion Radiation Status are presented:[9]

Battalion Status: RS-1.

Company Status

Minimum: All three companies RS-1.

Maximum: Two companies RS-1; one company RS-2.

Platoon Status

Minimum: All nine platoons RS-1.

Maximum:

1. Five platoons RS-1; two platoons RS-2; two platoons RS-3; or

2. Four platoons RS-1; four platoons RS-2; one platoon RS-3.

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[9]NOTE: Minimum and maximum refer to minimum and maximum radiation exposure indicated to have been received. Where multiple radiation statuses are presented for a single category, no determination could be made of relative severity. The current tactical situation would dictate the most or least favorable combination of units in various radiation statuses.

Battalion Status: RS-2.

Company Status

Minimum:

1. Two companies RS-1; one company RS-3; or

2. One company RS-1; two companies RS-2.

Maximum:

1. One company RS-1; two companies RS-3; or

2. Two companies RS-2; one company RS-3.

Platoon Status

Minimum:

1. Seven platoons RS-1; two platoons RS-3; or

2. Six platoons RS-1; two platoons RS-2; one platoon RS-3; or

3. Five platoons RS-1; four platoons RS-2.

Maximum:

1. Two platoons RS-1; seven platoons RS-3; or

2. One platoon RS-1; two platoons RS-2; six platoons RS-3; or

3. Four platoons RS-2; five platoons RS-3.

Battalion Status: RS-3.

Company Status

Minimum: One company RS-2; two companies RS-3.

Maximum: All three companies RS-3.

Platoon Status

Minimum:

1. Two platoons RS-1; two platoons RS-2; five platoons RS-3; or

2. One platoon RS-1; four platoons RS-2; four platoons RS-3.
Maximum: All nine platoons RS-3.

When the brigade or division commander receives the battalion radiation status, it should provide him with some definitive information upon which he can base a decision. However, what information does the battalion radiation status actually provide?

If the battalion is RS-1, then it is possible that no platoon has received any significant radiation exposure; <u>or</u> that four platoons have received significant exposure and one platoon has received over 150 rads; <u>or</u> that four platoons have received significant exposure and two platoons have received over 150 rads (any further radiation would be an emergency dose with anticipated radiation casualties).

If the battalion is RS-2 the brigade or division commander can ascertain that seven platoons have had no significant exposure and two have received 150 rads or more; <u>or</u> no platoons have received 150 rads; <u>or</u> up to seven platoons have received 150 rads or more; <u>or</u> something in between. (As expected from Figure 8, the RS-2 category provides the widest divergence.)

An RS-3 battalion could either have all nine platoons at the RS-3 level; <u>or</u> perhaps five of the platoons are RS-1 and RS-2 and therefore possibly could take part in an operation involving some radiation exposure with assurance that there would not be significant radiation casualties.

The conclusion which is evident is that the battalion radiation status provides the brigade and division commanders with insufficient information upon which they can make their estimate of the situation and decision on a course of action.

A relatively simple task organization for a battalion has been examined. Is the effect the same for a larger battalion, perhaps with five companies, each with five platoons, which would be more representative of a battalion with organic and attached companies and platoons?

With the risk of boring the reader, the results of a similar analysis with a "5 x 5" battalion are presented, if for no other purpose than of reinforcing the seriousness of the problem:

<u>Battalion Status: RS-1</u>.

Company Status

Minimum: All five companies are RS-1.

Maximum:

1. Four companies RS-1; one company RS-3; or

2. Three companies RS-1; two companies RS-2.

Platoon Status

Minimum: All 25 platoons RS-1.

Maximum:

1. Fourteen platoons RS-1; two platoons RS-2; nine platoons RS-3; or

2. Thirteen platoons RS-1; four platoons RS-2; eight platoons RS-3; or

3. Twelve platoons RS-1; six platoons RS-2; seven platoons RS-3; or

4. Eleven platoons RS-1; eight platoons RS-2; six platoons RS-3; or

5. Ten platoons RS-1; ten platoons RS-2; five platoons RS-3; or

6. Nine platoons RS-1; twelve platoons RS-2; four platoons RS-3.

Battalion Status: RS-2.

Company Status

Minimum:

1. Three companies RS-1; one company RS-2; one company RS-3; or

2. Two companies RS-1; three companies RS-2.

Maximum:

1. One company RS-1; one company RS-2; three companies RS-3; or

2. Three companies RS-2; two companies RS-3.

Platoon Status

Minimum:

1. Nineteen platoons RS-1; three platoons RS-2; three platoons RS-3; or

2. Eighteen platoons RS-1; five platoons RS-2; two platoons RS-3; or

3. Seventeen platoons RS-1; seven platoons RS-2; one platoon RS-3; or

4. Sixteen platoons RS-1; nine platoons RS-2.

Maximum:

1. Three platoons RS-1; three platoons RS-2; nineteen platoons RS-3; or

2. Two platoons RS-1; five platoons RS-2; eighteen platoons RS-3; or

3. One platoon RS-1; seven platoons RS-2; seventeen platoons RS-3; or

4. Nine platoons RS-2; sixteen platoons RS-3.

Battalion Status: RS-3.

Company Status

Minimum:

1. One company RS-1; four companies RS-3; or

2. Two companies RS-2; three companies RS-3.

Maximum: All five companies RS-3.

Platoon Status

Minimum:

1. Nine platoons RS-1; two platoons RS-2; fourteen platoons RS-3; or

2. Eight platoons RS-1; four platoons RS-2; thirteen platoons RS-3; or

3. Seven platoons RS-1; six platoons RS-2; twelve platoons RS-3; or

4. Six platoons RS-1; eight platoons RS-2; eleven platoons RS-3; or

5. Five platoons RS-1; ten platoons RS-2; ten platoons RS-3; or

6. Four platoons RS-1; twelve platoons RS-2; nine platoons RS-3.

Maximum: All twenty-five platoons RS-3.

The reader is left to his own war gaming. Certainly the type of information provided the commander is grossly inadequate. For example an RS-2 battalion may have nineteen platoons (76 percent) either with no previous significant radiation <u>or</u> in an RS-3 category, with an accumulated dose of 150 rads or more. The previous conclusion is affirmed: the system is unsatisfactory.

One further examination is necessary. The Combat Developments Command Institute of Nuclear Studies proposed, as discussed in Chapter V, revised radiation status categories. Added was an additional category, RS-0, with the meaning that no previous radiation has been received by the unit. While not arguing that increased fractionalization will not increase accuracy due to reduction in the range that certain radiation statuses will encompass, the question arises as what the effect is of adding an additional category to the usefulness of the Company/Battalion radiation status.

Since there was no proposed table in the CDCINS report for the determination of Company/Battalion radiation status, an assumption must be made on the range for the RS-0 category. Based on the analysis of the current table, the following breakdown appears logical:

Table 15

Range for Proposed Radiation Status Categories

(Mean RS numbers for platoon or company)

$0 \leq RS\text{-}0 < 0.5$

$0.5 \leq RS\text{-}1 < 1.5$

$1.5 \leq RS\text{-}2 < 2.5$

$2.5 \leq RS\text{-}3 \leq 3.0$

Using this range, a table, similar to Table 7, but incorporating all four radiation status categories can be constructed.

Table 16

Determination of Company/Battalion Radiation Status Using Four RS Categories

Number of Platoons in Company or Companies in Battalion	2	3	4	5	6	7
Company or Battalion RS Category	Sum of RS Numbers of All Organic and Attached Platoons and Companies					
RS-0	0	0-1	0-1	0-2	0-2	0-3
RS-1	1-2	2-4	2-5	3-7	3-8	4-10
RS-2	3-4	5-7	6-9	8-12	9-14	11-17
RS-3	5-6	8-9	10-12	13-15	15-18	18-21

The RS-2 and RS-3 values in Table 16 are identical with those in Table 7. The RS-0 and RS-1 values are new because of the addition of the RS-0 category and its encroachment into the old RS-1 area.

Using this expanded table as the basis, the four radiation status category system is examined in the same format as was the three category system. Chosen for this analysis is the more simple "3 x 3" battalion.

Battalion Status: RS-0.

Company Status

Minimum: All three companies RS-0.

Maximum: Two companies RS-0; one company RS-1.

Platoon Status

Minimum: All nine platoons RS-0.

Maximum:

1. Five platoons RS-0; three platoons RS-1; one platoon RS-3; or

2. Five platoons RS-0; two platoons RS-1; two platoons RS-2.

Battalion Status: RS-1.

Company Status

Minimum:

1. Two companies RS-0; one company RS-2; or

2. One company RS-0; two companies RS-1.

Maximum:

1. One company RS-0; one company RS-1; one company RS-3; or

2. One company RS-0; two companies RS-2; or

3. Two companies RS-1; one company RS-2.

Platoon Status

Minimum:

1. Seven platoons RS-0; two platoons RS-2; or

2. Six platoons RS-0; two platoons RS-1; one platoon RS-2; or

3. Five platoons RS-0; four platoons RS-1.

Maximum:

1. Two platoons RS-0; three platoons RS-1; four platoons RS-3; or

2. Two platoons RS-0; two platoons RS-1; two platoons RS-2; three platoons RS-3; or

3. Two platoons RS-0; one platoon RS-1; four platoons RS-2; two platoons RS-3; or

4. Two platoons RS-0; six platoons RS-2; one platoon RS-3; or

5. One platoon RS-0; four platoons RS-1; one platoon RS-2; three platoons RS-3; or

6. One platoon RS-0; three platoons RS-1; three platoons RS-2; two platoons RS-3; or

7. One platoon RS-0; two platoons RS-1; five platoons RS-2; one platoon RS-3; or

8. Five platoons RS-1; two platoons RS-2; two platoons RS-3; or

9. Four platoons RS-1; four platoons RS-2; one platoon RS-3.

Battalion Status: RS-2.

Company Status

Minimum:

1. One company RS-0; one company RS-2; one company RS-3; or

2. Two companies RS-1; one company RS-3; or

3. One company RS-1; two companies RS-2.

Maximum:

1. One company RS-1; 2 companies RS-3; or

2. Two companies RS-2; 1 company RS-3.

Platoon Status

Minimum:

1. Four platoons RS-0; three platoons RS-2; two platoons RS-3; or

2. Three platoons RS-0; two platoons RS-1; two platoons RS-2; two platoons RS-3; or

3. Three platoons RS-0; one platoon RS-1; four platoons RS-2; one platoon RS-3; or

4. Two platoons RS-0; four platoons RS-1; one platoon RS-2; two platoons RS-3; or

5. Two platoons RS-0; three platoons RS-1; three platoons RS-2; one platoon RS-3; or

6. Two platoons RS-0; two platoons RS-1; five platoons RS-2; or

7. One platoon RS-0; six platoons RS-1; two platoons RS-3; or

8. One platoon RS-0; five platoons RS-1; two platoons RS-2; one platoon RS-3; or

9. One platoon RS-0; four platoons RS-1; four platoons RS-2.

Maximum:

1. Four platoons RS-2; five platoons RS-3; or

2. One platoon RS-1; two platoons RS-2; six platoons RS-3; or

3. Two platoons RS-1; seven platoons RS-3.

Battalion Status: RS-3.

Company Status

Minimum: One company RS-2; two companies RS-3.

Maximum: All three companies RS-3.

Platoon Status

Minimum:

1. One platoon RS-0; three platoons RS-2; five platoons RS-3; or

2. Two platoons RS-1; two platoons RS-2; five platoons RS-3; or

3. One platoon RS-1; four platoons RS-2; four platoons RS-3.

Maximum: All nine platoons RS-3.

Comparison of the four radiation status category system with the three category system in the determination of a meaningful battalion radiation status shows no advantage for the more fractionated system. The additional category only presents a wider range of possible platoon and company radiation status configurations without providing more specific guidance for the brigade and division commander. The additional "battalion RS-0" category is, as are the other three categories, vague enough in the multiplicity of possible interpretations so as to negate its usefulness.

Thus one comes to the conclusion that, while admittedly providing a more specific categorization at the platoon level, the addition of a fourth radiation status is not desirable because of the increased vagueness (if this is possible) caused in the subsequent determinations of company and particularly battalion radiation statuses.

The foregoing analysis is believed to amply demonstrate that the current system for determination of company and battalion radiation statuses is unsatisfactory. There is little cause for concern on the company radiation status, for this status normally never goes past battalion. The fact that the basic radiation exposure data is available at battalion permits whatever analysis is necessary at that level to be accomplished. Where the problem becomes severe is in the determination of the battalion radiation status and its subsequent use at the higher levels of command.

In an attempt to determine a "better" system, various methods of combining platoon radiation statuses were analyzed. The best approach appeared to be a more restrictive criteria rather than just rounding the mean of the sum of radiation units to the nearest integer. The most restrictive possibility is to categorize the company or battalion at the highest platoon status. This is extremely safe-sided and does not present a valid picture for the commander. A twenty-five platoon battalion would be classified as RS-3 simply because of the exposure of four percent of the battalion.

Similarly, narrowing the range for the lower RS-1 category, e.g.:

$$1 \leq \text{RS-1} < 1.2$$

$$1.2 \leq \text{RS-2} < 2.2$$

$$2.2 \leq \text{RS-3} \leq 3.0$$

proved to be unduely safe-sided and restricted the range of the lower radiation status at the expense of the higher. Placing an arbitrary restriction that no unit will have more than one sub-unit of higher radiation status than the parent's status was unwieldy and also did not provide necessary information.

Some improvement can be obtained by requiring the battalion, in the computation of its own radiation status, to utilize directly the platoon radiation status. In the current system, where the mean platoon radiation status determines each company status and then the mean company status finally provides the battalion status, the end result is a battalion radiation status whose mean platoon radiation status varies beyond the values obtained by simply rounding their mean to the nearest integer. This multiplicity of averaging contributes to the range of possible combinations of platoon status; however, the improvement obtained by a "direct averaging" process is not sufficient to make the system meaningful.

The conclusion is reached that, even at brigade and division level, radiation status should be presented in units in which the basic radiation measurements had been made, i.e., the platoon.

With this concept the battalion radiation status for the "5 x 5" battalion could be forwarded in a direct format such as:

12 platoons RS-1

6 platoons RS-2

7 platoons RS-3

An alternative is to report the battalion in percentage of platoons in each radiation status:

48% RS-1

24% RS-2

28% RS-3

Now the proposed four radiation status category system has specific merit, for a better defined platoon status can be utilized at higher levels.

The method of reporting radiation status by percentage of platoons is not novel. In the 1964 troop test of the radiation dosimetry system this was the prescribed format to be used. As indicated in Chapter IV this information was found to be useful during the test. It did provide the brigade and division commander with an indication of the percentage of troops in the battalions which were in each radiation status category. It is difficult to see how the current system of reporting the battalion radiation status could be so classified.

The major derogatory comment, in the troop test report, on reporting the battalion radiation status by percentage of platoons was that it did not provide information on the status of companies, since no specific companies were associated with the platoons in each status and the company was felt to be the basic combat unit. Under current techniques of organization this is a valid criticism. (It should be noted that the current system does not provide valid company information either.)[10]

This observation indicates a requirement for reevaluation of the current concepts of organization. If, as stated in FM 3-12, present concepts indicate that the platoon-size unit is the optimum size on which to maintain the radiation status, it is possible that the platoon itself should be the basic combat unit for the Army.

Consider the following: Companies are simply a command and control headquarters for individual platoons (with administrative and logistical functions as required). Platoons would be individually formed and designated, and attached to the company headquarters on the basis of the mission to be performed, much in the way that battalions within the division are attached to brigades for specific operations.

It is beyond the scope of this thesis to attempt a detailed evaluation of such a system. Certainly many problems could be presented. It would seem that a significant portion of these problems, such as billeting, messing, training, etc., would be primarily non-combat problems, solvable by relatively stable non-combat organization.

Several significant advantages for a platoon-base organization for the nuclear battlefield are evident. The first is the optimum flexibility in organization available to the battalion commander to best successfully

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[10]Fourth Infantry Division. Troop Test USACDCCBRA 65T6, Radiation Dosimetry System (The Division). (Fort Lewis, Washington: 4th Infantry Division, 1964), p. A-I-3.

complete his assigned mission. On the nuclear battlefield, the battalion commander will be hard-pressed on how to best use a company with platoons which have different radiation statuses. For example, how does the battalion commander deploy the company which has two RS-1 platoons and two RS-2 platoons? Significant additional radiation exposure may eliminate half of the company from further effectiveness, yet the commander may not be able to afford not to use all of the combat power which he has available. Advantage could be gained by reorganizing companies by radiation status category so that, for example, two companies might be RS-1, one company RS-2, and one company RS-3, with the platoons within each company having a corresponding radiation status. Courses of action could be developed commiting companies whose radiation histories are appropriate to the anticipated additional radiation exposure of the operation. It appears that such reorganization on the nuclear battlefield would be a practical necessity, so why not develop the organizational base as part of the basic combat unit structure?

A second, and complementary, advantage involves the problem of replacements. On the nuclear battlefield individual replacement may not be feasible because of large losses of both personnel and equipment. Doctrine proposed for the nuclear battlefield visualizes the more common form of replacement will be unit replacement.[11] What unit would be more appropriate for the basic replacement unit than the platoon, made up of

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[11]U.S. Army Combat Developments Command Institute of Combined Arms Support. "FM 100-30, Tactical Nuclear Operations," DRAFT, December 1970, pp. 4-18.

individuals of similar radiation history? The individual replacement platoon would not need be assigned to any specific company but rather to a battalion to be used as the mission requires. The replaced unit, if replaced because of radiation exposure, could retire to a radiation safe area for recovery, and after medical examination, reclassification. A platoon size unit, separate and integral, could be handled with efficiency and flexibility, and after recovery, assigned to any battalion, again based on the current situation.

Thus it appears that there is a basis, considering employment on the tactical nuclear battlefield, for a platoon based combat organization. Whether such an organizational concept is valid deserves a thorough and complete study.

THE ROLE OF THE SURGEON

Examination of the radiation exposure control system would not be complete without discussion on the role of the surgeon.

As pointed out previously, to function efficiently and effectively, a commander needs information on both the present and future health of his command. On the battlefield, health is affected by both trauma and disease. Evaluating the present health of a command is not particularly difficult. It requires a tabulation of the daily reports of the battle and non-battle casualties of subordinate units. Predicting the future health of a command, however, requires a reliable past experience factor. For conventional battle trauma this experience factor exists. For example, in World War II, it was found that a Division in the attack can expect four to seven percent casualties in the first 24 hours. The ability of the surgeon to predict the effect of a given disease in a command is not so clear cut. Individual sensitivity and the number of agents with varying potency makes this at best a frustrating game. One time an influenza virus may severely affect 90 percent of a command. Another time, another strain may pass unnoticed.[12]

Radiation sickness is a disease. Few physicians have a thorough understanding of the physics and biology of the disease. Fewer still have had personal experience with radiation sickness. There is almost no backlog of military experience, as such. The surgeon, therefore, is forced to start from scratch. He studies nuclear weapons effects, literature on radioactive experiments with animals, the results of radiation accidents and radiation therapy. Out of this a pattern develops. The surgeon will try to distinguish the parts that are valid for him, the parts that point a direction and those that are invalid or not applicable to military problems. Most importantly, he will recognize the problem areas and will be able to comment intelligently and reliably on his advice.[13]

Currently accepted military medical information is, at least in part, presented in Chapter II. Clearly the uncertainties are significant, particularly in judging the effects of protracted radiation doses and recovery.

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[12]Roger E. Linneman, MD. "Command Radiation Guidance," Military Medicine, 133, 9 (1968), p. 711.

[13]Ibid.

In lieu of more experience, any radiation advice must be based, not on generalities, but on examination of each situation. Where exposure dose information is available and reliable, data such as Figure 1 and Table 3 provide acceptable, simplified medical guidelines. Using such guidance, and modifying it with his most meaningful asset, experience and medical evaluation, the surgeon can give meaningful advice to the commander.[14]

There are two situations in which the surgeon will be required to provide radiation guidance:

1. Troops exposed to unplanned radiation, normally initial radiation resulting from an enemy nuclear explosion.

2. Troops exposed to a planned radiation exposure, which can be either initial radiation from a "friendly" nuclear weapon or residual radiation environments.

In the first case, the surgeon's advice will of necessity be after the fact. The knowledge that 200 rads will result in hospitalization or that 50,000 rads will cause instantaneous total incapacitation is interesting but of little practical value. The first reaction of a commander whose unit has just received a nuclear strike will be: "Am I okay?" His second reaction is: "How effective is my unit?" In a committed, pressing situation the commander will use every able-bodied man to repulse or carry on the attack. In situations of lesser urgency, an immediate casualty and damage assessment will determine unit effectiveness. By evaluating the number of radiation casualties, the onset, type and degree of symptoms, the surgeon can offer the most meaningful guidance possible.

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[14]Ibid., p. 714.

Unlike unplanned radiation situations, the commander who is planning an operation, which will involve planned radiation exposure, has a great deal of control over the radiation exposure to his troops. Against the operational choices of a commander will be tabulated a series of predicted exposure doses. The surgeon may use various exposure tables and the history of the unit. The strength of his advice, however, must lie on medical evaluation. He will know his unit. He can give a general impression of the unit's ability to perform a particular mission by observing the past and present performance, by observing the sick call rate and the type and number of symptoms. As with any disease the surgeon alerts the commander to the deteriorating health status in his command and the anticipated reduction in effectiveness of personnel due to the planned exposure to radiation.[15]

Particularly with the current radiation exposure control system, the commander must rely heavily on the advice of his surgeon. Inaccuracies in the physical measurement of radiation exposure, due to such factors as instrument capability and the effects of geometry of exposure and partial body shielding, the uncertainty of validity of the platoon average dose, and the lack of guidance in assessing partial body irradiation and the recovery from radiation injury, all combine to discourage acceptance by the commander of the literal results of the current system. The uncertainties in medical knowledge itself has generated criteria which is significantly conservative or safe-sided.

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[15]Ibid., see also DA FM 3-12, op. cit., p. 6-6.

The compensating factor for these uncertainties must be, from the commander's point of view, the advice and reliable comment from his surgeon on the actual physical state of health of his command. The commander will place his credence in this advice, for it will provide him the staff guidance, from a medical standpoint, as to which units to employ, including the advisability of reclassification or reorganization, and even the capability of the command to accomplish the assigned mission.

Thus, in the nuclear environment, the commander will look directly to his staff surgeon for current vital information prior to making battlefield decisions. However, a reorganization of the medical structure promulgated in the recently issued H-series of Tables of Organization and Equipment removes the "battalion surgeon" from the combat battalion and places him at division level. Based on the previous discussion of the role of the surgeon, this centralization of medical expertise will have a deleterious effect on the ability of the commander to obtain accurate and timely guidance pertinent to his unit. For the battalion surgeon would have known his unit and would have been able to base his guidance partly on the intangible medical evaluation which comes from day to day association with the men of the unit.

Current planning is in process for substitution of a non-physician "clinical warrant officer" for the battalion surgeon. He will receive comprehensive and appropriate training corresponding to duties encompassing supervision of enlisted aid men, the establishment of evacuation priorities and the care of troops with minor diseases and injuries.[16]

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[16]Hall B. Jennings, LTG, USA. "Remarks of the Federal Medical Chiefs, Department of the Army," Military Medicine, 136, 4 (1971), pp. 336-7.

In testimony before the Senate Appropriations Committee, LTG Walter T. Kerwin said that the physician's aide "would relieve the physician of the burden of routine examinations and tests which do not require his level of expertise and would permit the doctor to spend more time performing only those duties which require a full medical education."[17]

The lack of detailed guidance and widespread expertise in radiation injury requires each situation to be evaluated on a case by case basis. Such evaluation would appear to require the maximum amount of medical education and expertise available. The surgeon has received lengthy and detailed specialized education on the response of the human body to disease. He is best capable, especially when the specific biological response is not well known and medical "judgment" must prevail, to provide the needed guidance to the commander on the capability of his unit to operate in radiological environments. Perhaps, when the biological response to radiation becomes more exactly known and tabulated, someone with less than a full medical education, such as the "clinical warrant officer" will be able to provide adequate advice to the commander.

Meanwhile, although it is appreciated that the shortage of surgeons in the Army may necessitate reorganization toward a more centralized organization, it should be recognized that this will decrease the validity of medical guidance on the nuclear battlefield, with its attendant and potentially very significant ramifications.

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[17]"Army Proposes Use of WO Doctors Aides," Army Times, 31, 41 (1971), 10.

CHAPTER VII

SUMMARY AND CONCLUSIONS

In this concluding chapter, the approach and results obtained will be presented in condensed form, so as to provide a concise summary of the investigation. Highlighted are what are considered to be the significant aspects, pointing toward the conclusions which are reached. The chapter terminates with a presentation of these conclusions.

SUMMARY

The problem statement for the thesis is the question: "Is the current U.S. Army radiation exposure control system adequate for operations on the nuclear battlefield?"

Affirmed initially is the need for radiation exposure control. Commanders of units operating in a nuclear environment must consider the effects of radiation on the combat efficiency of their units and their ability to accomplish an assigned mission. Radiation will influence the commanders decisions on the battlefield and a continuous evaluation of unit radiation exposure levels is necessary to assist him in making these decisions.

Considerable background is provided in the first and second chapters on nuclear weapons characteristics and particularly radiation on the battlefield. Presentation of characteristics of the four types of nuclear radiation, on initial and residual radiation, on the biological effects of radiation and on combat effectiveness provides a common basis for the subsequent analysis and discussion. Of significance to conclusions subsequently reached is the "state of the art" of medical knowledge with regards to radiation injury, particularly on protracted exposures and recovery.

The requirements for a radiation control system are determined. Selected as the fundamental requirements are the requirements to:

1. Determine the radiological status of the unit prior to exposure.

2. Measure or predict any new dose to the unit with accuracy.

3. Assess the effect of any new exposure upon the previous radiological status in terms of unit effectiveness.

These requirements for the radiation control system are subsequently translated to the following necessary characteristics: There must be a method of measuring or otherwise determining and collecting the basic data which indicates the radiation exposure of units. Having collected the basic data, a system of recording must be established so that any exposure may be considered with all the other exposures, previous and subsequent. Finally a system must be developed to utilize the radiation exposure data which have been measured and recorded, to permit assessment of the effects of subsequent radiation on unit effectiveness. Thus the analysis of the current system includes the means of collecting radiation data (dosimetry), the system of recording and the system for utilization.

Dosimetry is evaluated from two aspects, the physical capability of the current instruments to measure the radiation of concern and the capability of the dosimetry system, specifically the distribution of instruments, to provide the necessary information.

The capability of the current tactical dosimeter, the IM-93/UD, to measure initial radiation was found to be inadequate because of the lack of capability for measurement of neutrons, a significant contributor to initial radiation dosage. Residual radiation, however, is characterized by gamma rays which are adequately detected and measured by the instrument.

The adequacy of the current basis of distribution of the tactical dosimeters (normally two per platoon) is questioned but not resolved. Particularly in the initial radiation environment erroneous interpretation of dosimetry measurements is possible because of the rapid fall-off of dose with distance from the nuclear detonation and the anticipated wide dispersal of personnel on the nuclear battlefield. Additional detailed study and test are indicated as necessary to determine the optimum distribution of devices.

Analysis of the system of recording radiation exposure data principally was based on the results of a 1964 troop test. While certain reaction times appeared to be excessive, overall assessment of the recording system is that it provides adequate procedures for collecting, recording, processing and transmitting dosimetry data.

Analysis of the system for utilization of the radiation exposure data is divided into two areas: The capacity of medical knowledge in assessing the effect of exposures and the validity of the specific method of classifying units in radiation exposure categories.

In assessing the capacity of medical knowledge, it is noted that all doses are considered to be acute doses and that there is a lack of recovery guidance, prohibiting valid assessment of the residual injury from previous exposures, the effect of protracted doses or mixed acute and protracted doses, and the effect of recovery or repair in determining future vulnerability. This limitation, along with lack of ability to assess partial body irradiation, seriously limits the validity of the radiation exposure control system and results in a system employing conservative medical criteria and relying heavily on the clinical judgment of the surgeon, both in the treatment of personnel and the provision of advice to the commander.

The system of radiation status category classification for battalion size units, normally the only data passed on to brigade and division commanders, is found to be grossly unsatisfactory. The combination of platoon radiation status categories into company categories and hence into battalion categories provides at best uninterpretable and at worst misleading advice to higher commanders.

A recently published Combat Developments Command Institute of Nuclear Studies report proposing revision of personnel risk and casualty criteria for nuclear weapons effects is presented in part, with emphasis on those portions which would change the current radiation exposure control system. Proposed changes include the establishment of new reference doses and the addition of a fourth radiation status category, for units with no previous radiation history.

Finally three aspects are chosen for additional development and discussion. The first concerns the instrument measurement deficiency, i.e., the lack of capability to measure neutrons. A new dosimeter, currently under development, is discussed and the delay prior to field distribution is noted. An interim concept is presented wherein a tabulated "weighting factor" is applied to the directly read gamma dose so as to provide a means of determining the total dose from initial radiation.

The second aspect analyzed in greater detail is the inadequate method of determination of battalion radiation status categories. Detailed presentation of results of analysis of nine and twenty-five platoon battalions using the three radiation status categories and of a nine platoon battalion using the four radiation status categories proposed in the CDCINS report. The system, after this more extensive analysis, is reaffirmed to be unsatisfactory. The best alternative appears to be the transmission of platoon radiation exposures to higher headquarters without any "averaging" consolidation. This requirement for transmission of platoon data suggests consideration of basic reorganization of the combat structure with the platoon as the basic unit, attached to company headquarters based upon the requirements of the mission. One consideration in such attachment would be the radiation status of the platoon.

Third, the role of the surgeon is examined from the standpoint of the commander's reliance on the surgeon's advice and the surgeon's reliance, when it comes to the effects of radiation, on his medical evaluation and the knowledge of his men. The deleterious effect of the recent restructuring of medical personnel within the division is noted.

CONCLUSIONS

The overall conclusion of this thesis is that the current system of radiation exposure control is incapable of providing the commander on the nuclear battlefield with the required information. The basic deficiencies which seriously limit the usefulness of the system are:

1. There is no instrument capability of measuring initial radiation. While recognized as a problem, the distribution of redesigned tactical dosimeters is years in the future. There is a need for an interim system, such as the application of a tabulated "neutron weighting factor" to permit use of current gamma ray dosage measurement capability.

2. The distribution of current tactical dosimetry to provide accurate platoon exposure data has been questioned. Detailed tests and analysis should be conducted to reaffirm the current basis of issue.

3. The system for determination and use of battalion radiation status categories is unsatisfactory. The most appropriate means of providing exposure data appears to be by use of basic-unit measurements. Consideration for reorganization of combat units so that the platoon is the basic unit is strongly suggested.

4. Lack of certain medical knowledge on the effects of radiation places emphasis of the medical judgment of the surgeon and his detailed knowledge of his men. Recent centralization of battalion surgeons at division level appears to have a deleterious effect on the provision of required radiation advice to the battalion commander.

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