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TIME DISTORTION IN NUCLEAR WAR

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Abstract

Past considerations of nuclear war, particularly those involving battlefield use, have not taken into account a major factor: the time-dependent nature of the human body's response to radiation. This factor is likely to introduce changes in the temporal nature of warfare as profound as the spatial changes associated with the increased explosive power of nuclear munitions. High fatality rates will last for days following a nuclear event and must be taken into account. Continued lack of attention to this aspect of nuclear warfare is likely to result in inappropriate choices of military posture, doctrine, and equipment.

General Discussion

Today increasing attention is devoted to concepts involving the tactical or battlefield use of nuclear weapons. Compared to similar studies of nonnuclear war, the key input parameter changed in such studies is explosive power. Account is thus taken of the much greater radius of destruction that can be achieved by a warhead of given weight using nuclear rather than chemical explosives. This change alone gives nuclear studies a much different character from those involving solely nonnuclear (or conventional) weapons. For example, massing of forces is generally useful for penetration when solely conventional fires are considered; this practice may create extremely attractive targets for nuclear fires.

Somewhat awed by the nature of the changes thus implied, scientists have tended to look no further—to try only to cope with this vastly increased explosive power. This approach turns out to be quite difficult. Yet, since no one has experience with tactical nuclear war, it would not be surprising to discover that there are other nuclear battlefield effects of equal or larger significance. If so, many current studies of tactical nuclear war may be incorrect or misleading in the outcomes they predict. This in turn could lead to an incorrect posture, doctrine, and choice of equipment. It could even result in an inappropriate response to enemy threats and to lessened military effectiveness should the need ever arise for the United States to use nuclear weapons on the battlefield.

With these considerations in mind, it is interesting to note how common it has been to picture nuclear battles as if they would start and stop with a temporal sharpness analogous to nonnuclear battles. The earliest scenarios of massive nuclear strategic exchange were couched in terms of strike, followed by survivors retaliating, followed by both sides proceeding to further actions. Implicit was a notion that with the strike over the damage was done. Later, more sophisticated studies included such effects as fallout. However, even in these studies a clear distinction was usually made between "prompt" fatalities and those deaths occurring much later because of the "lingering" effects of radioactive debris.

More recently a concept of incisive but limited nuclear strikes of short duration (a few hours) has received much discussion. In such discussions the effects produced are frequently assumed to be coincident with, or at least promptly following, the execution of the nuclear strike as is usual with conventional ordnance. Numerous gaming studies involving nuclear war have now been completed. In many cases the win/defeat criteria or hostilities cut-off has been set by a calculation of prompt fatalities. This may be appropriate for battles involving nonnuclear weapons, but is it valid when nuclear fires are involved?

There are many reasons for believing that the temporal impact of effects of using nuclear ordnance on the battlefield will in practice be quite different from those associated with nonnuclear ordnance. There are, most obviously, the time factors noted above associated with the deposition of residual radioactivity by fallout or precipitation scavenging and the time required after deposition for significant doses to be accumulated. These are difficult effects to quantify and ones which may be greatly reduced by the avoidance of ground bursts or through weapon design. It may also be true that leadership decisions will be made slowly or haltingly since battlefield nuclear warfare will be a totally new experience. This is nearly impossible to quantify. Certainly, however, to assume a lack of speed and determination by an enemy is not a sound basis for military planning. Finally, where nuclear weapons are used for deep interdiction, their military utility will only fully be assessible as the impact on engaged forces occurs.

This paper proposes, however, that even if all of these factors do influence the temporal nature of nuclear war, they do not include the most important factor. That factor is the time dependent nature of the human body's response to a dose of radiation; that response will result in continuing fatalities over long periods following a nuclear explosion. Looked at from the fatalities viewpoint, nuclear engagements will perforce tend to be long-drawn-out affairs lasting for days.

Not only will the spatial character of nuclear war be different from that of conventional war, the temporal nature will be different in an at least as significant a way. To demonstrate and illustrate this situation, a specific case has been worked out in some detail. The next section of this paper describes a model situation evaluated and the data used in the calculations. The following section explains the calculation and presents the results. The final section suggests certain consequences that may be derived from this observation about nuclear warfare.

Model and Data

The specific situation evaluated by this paper involves the air burst of a one-kiloton, all-fission, nuclear weapon over a uniformly populated plain. It focuses on radiation as the primary kill-mechanism because in this case, as for all air-burst nuclear weapons of less than several tens-of-kilotons yield, radiation will be the kill-mechanism with the largest lethal radius against exposed personnel. The calculation is done in terms of percentage of total fatalities and, as will be shown, the results are valid for any uniform density. In fact, it will be seen that the most interesting results have a general validity not greatly dependent on the details of the calculation model.

Calculation of fatalities as a function of time involves the following quantities:

$D(R)$ = radiation dose at range, R
$P_\kappa(D)$ = probability of ultimate death given dose, D
$T_\kappa(D)$ = time-to-death given dose, D, for those killed
N = population density (per unit area)
$F(t)$ = total fatalities up to time, t, after exposure

Noting the radially symmetric nature of the exposure field, the total number of fatalities occurring up to time t, F (t), is expressed by:

$$F(t) = \int_0^{R_t} 2\pi R \cdot N \cdot P_\kappa(D)\, dR$$

$$= 2\pi N \int_0^{R_t} R \cdot P_\kappa\{D(R)\}\, dR,$$

where R_t is implicitly defined by:

$$t = T_\kappa(D) = T_\kappa\{D(R_t)\}.$$

The fraction of the total ultimate fatalities occuring by time, t, is expressed by:

$$\frac{F(t)}{F(t=\infty)} = \frac{\int_0^{R_t} R \cdot P_\kappa\{D(R)\}\, dR}{\int_0^{\infty} R \cdot P_\kappa\{D(R)\}\, dR} \qquad (1)$$

As noted earlier, this ratio is independent of the population density, N.

It is also of interest to calculate the average time-to-death from $t = 0$ of those who survive for some time, τ, after exposure, but ultimately die as a direct result of the radiation exposure. This quantity, written as $\bar{T}(\tau)$, is expressed by:

$$\bar{T}(\tau) = \frac{\int_{R_\tau}^{\infty} R \cdot P_\kappa\{D(R)\} \cdot T_\kappa\{D(R)\}\, dR}{\int_{R_\tau}^{\infty} R \cdot P_\kappa\{D(R)\}\, dR} \qquad (2)$$

Evaluation of this quantity permits improved understanding of the characteristic time periods for delayed fatalities—that is, after the early deaths have occurred.

Evaluation of $F(t)/F(t=\infty)$ or $\bar{T}(\tau)$ requires a knowledge of three relationships: $D(R)$, $P_\kappa(D)$, and $T_\kappa(D)$.

The first of these relationships is well known. The case calculated here uses the dose vs. range given in Figure 11.91 of the 1962 Edition of *The Effects of Nuclear Weapons.* This gives total rems vs. slant range for a one kiloton (fission) weapon air burst. For the ranges of importance herein the slant range can be used as range from ground zero with negligible imprecision. At the acute radiation effects levels-of-interest (death), there is a unit relationship between rems and rads (p. 580, same reference). The data used are shown in Figure 1 and tabulated below.

Dose (Rads)	Range (Yards)
10000	445
5000	530
2000	650
1000	750
500	875
200	1000
100	1200

As has been widely noted, available data at fatal dose levels for man are sparse; most of the data quoted are derived from nonhuman exposures. Furthermore, none of these data takes precisely into account differences in levels of health or nutrition, extent of medical care, or other possibly significant factors. Fortunately, the general insight sought in this paper does not require precise knowledge of the relationships

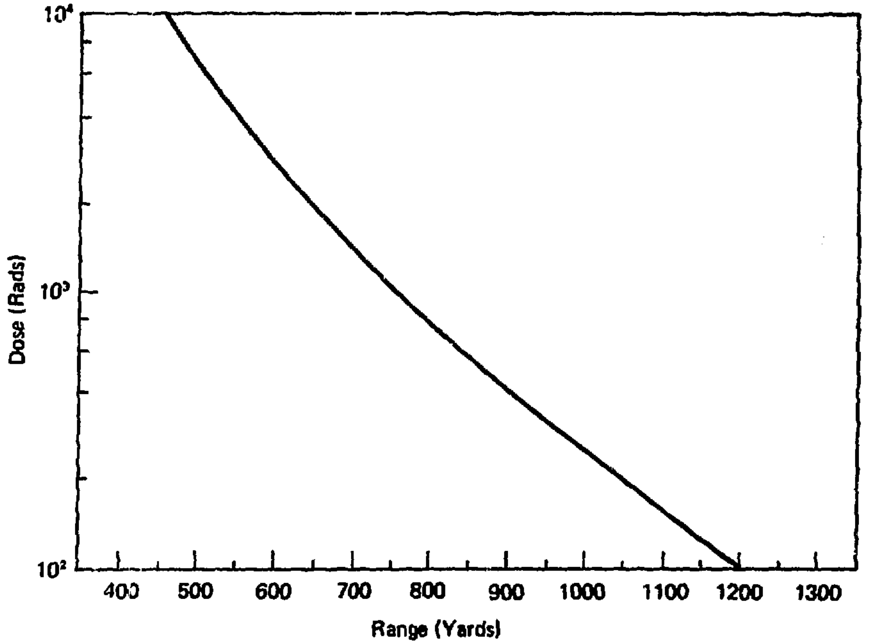

Fig. 1. Dose vs. Range for 1 Kiloton (Fission) Airburst

$P_\kappa(D)$ and $T_\kappa(D)$. Various sources have been compared to derive the data used below with special reliance placed on Table 11.111 of The Effects of Nuclear Weapons and Table 10-2 of Defense Nuclear Agency Effects Manual Number 1.

The relationship between percentage of fatalities and whole body dose was constructed using the following data points.

Dose (Rads)	% Fatalities
600	90
450	50
400	30
200	1

As seen in Figure 2, when these points are plotted on probability paper, a straight line results. It is not clear to the author that this is entirely fortuitous.

Time-to-death data for those who die from whole body radiation exposure are even more sparse; only ranges can be established. Again using the references noted above, the values tabulated above represent best estimates:

Dose (Rads)	Time-to-Death (Hours)
5000	10 - 25
1000	150 - 350
600	300 - 1000
400	500 - 2000

These data are plotted in Figure 3 along with a solid line described by the equation: $T_\kappa = 2.5 \times 10^7\ D^{-5/3}$, where T_κ is the time-to-death in hours and D is the dose in rads. This line appears to fit the available data adequately. No theoretical reason is apparent for this formulation and, therefore, it should not be applied outside the range of 200 to 10,000 rads.

Calculations and Results

Figures 1, 2, and 3 provide the relationships necessary for computation. The easiest procedure is to integrate numerically the numerator and denominator of equation (1) to obtain values of $F(t)/F$ $(t = \infty)$ for various values of t. This is the procedure used to obtain the values tabulated above for the fraction of total ultimate fatalities which occur by time, t.

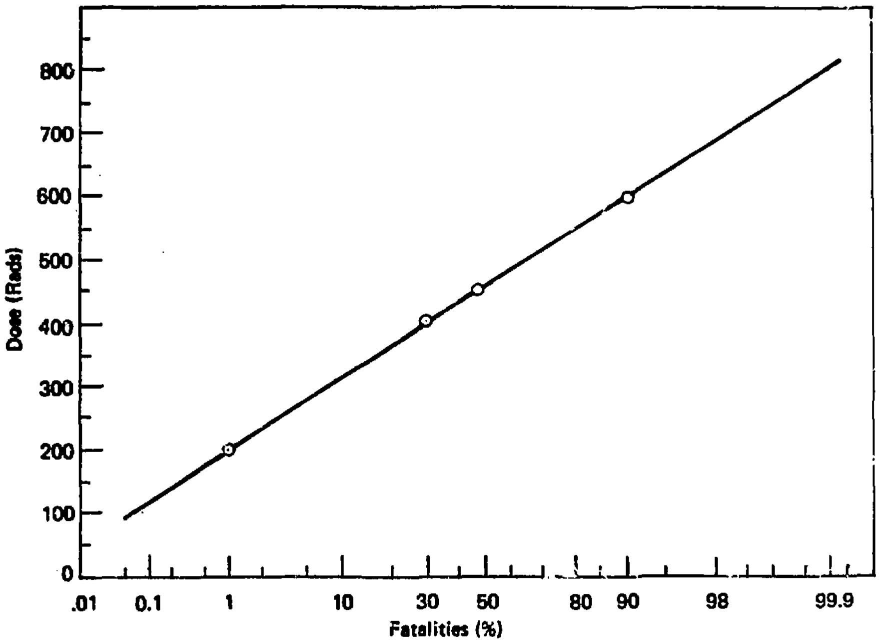

Fig. 2. Dose vs. Fatalities

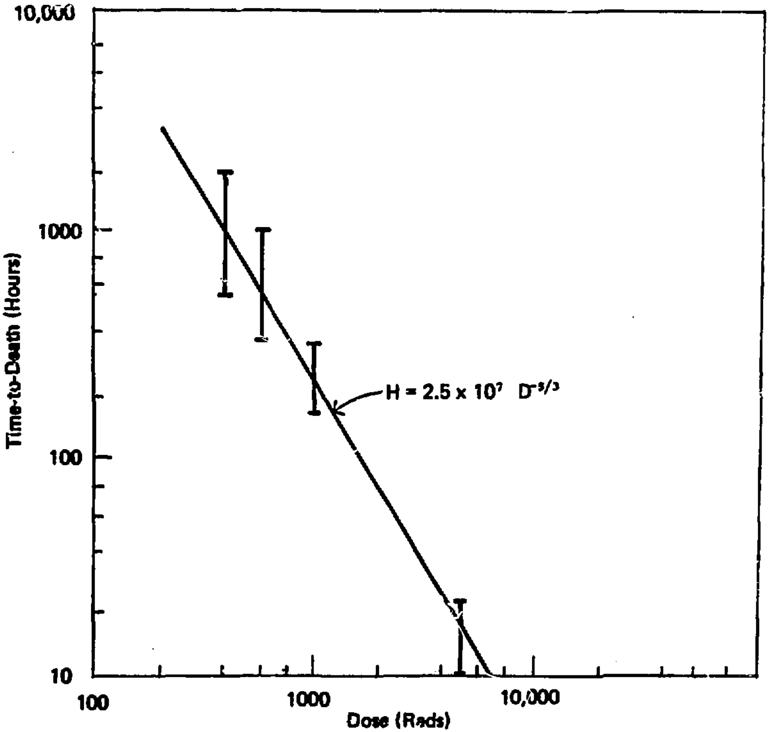

Fig. 3. Time-to-Death vs. Dose

t, hours	10	20	40	60	80	100
F(t)/F(t = ∞)	0.33	0.39	0.47	0.52	0.56	0.59

t, hours	100	200	400	600	800	1000
F(t)/F(t = ∞)	0.59	0.71	0.83	0.92	0.96	0.98

Figures 4 and 5 show F(t)/F(t = ∞) as a function of time using both logarithmic and linear time scales.

Values of $\bar{T}(\tau)$, the average time-to-death from t = o of those who survive for some time τ after the explosion, have also been computed using equation (2). Note that the average survival time is measured from the time of the explosion or exposure but only those who survive beyond time τ yet ultimately die from the radiation exposure are included in the average:* thus $\bar{T}(\tau) > \tau$.

τ, hours	0	10	50	100	500	1000
$\bar{T}(\tau)$, hours	235	300	390	460	800	1300

Examination of these results leads to a number of specific observations.

- Total deaths at early times is likely to be a misleading indicator of ultimate fatalities. For example, after 10 hours only about one-third of those who will ultimately die will actually be dead. In fact, because of the biological processes involved, many of those who ultimately will die will "feel" much better than they did during the first hours after exposure.
- Reports from the exposure zone will be especially easy to misread. In the region around 800 yards from ground zero, twenty-four hour reports will indicate <1% fatalities. However, >99% of the people in that region will die with most of the fatalities occurring more than two weeks later.
- The effects in terms of fatalities will be relatively long term. Half of the deaths will occur more than two days after exposure.
- For those who do die from radiation exposure, the average time of survival will be a surprisingly long 235 hours—almost ten days.
- The median lifetime and average lifetime differ greatly: 50 hours versus 235 hours. At 50 hours, when half the total number of fatalities have occurred, the average additional lifetime for those remaining will be 340 hours—more than 2 weeks.

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*This is analogous to evaluating for a population group the average age at death for those who survive to some minimum age. Early deaths (infant mortality for example) can thus be removed from the averaging for age-at-death. Clearly, the average age-at-death for those that live for at least, say, 20 years must be greater than 20.

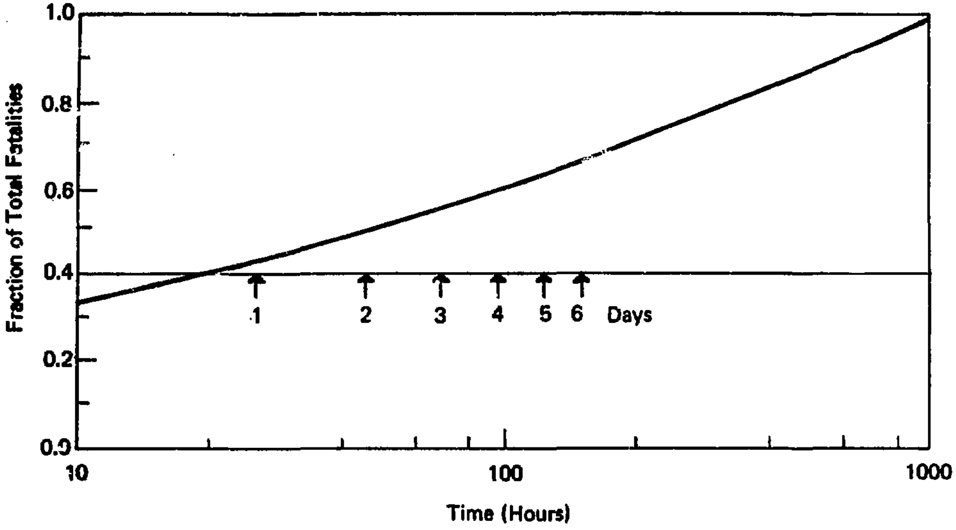

Fig. 4. Fraction of Total Fatalities vs. Time

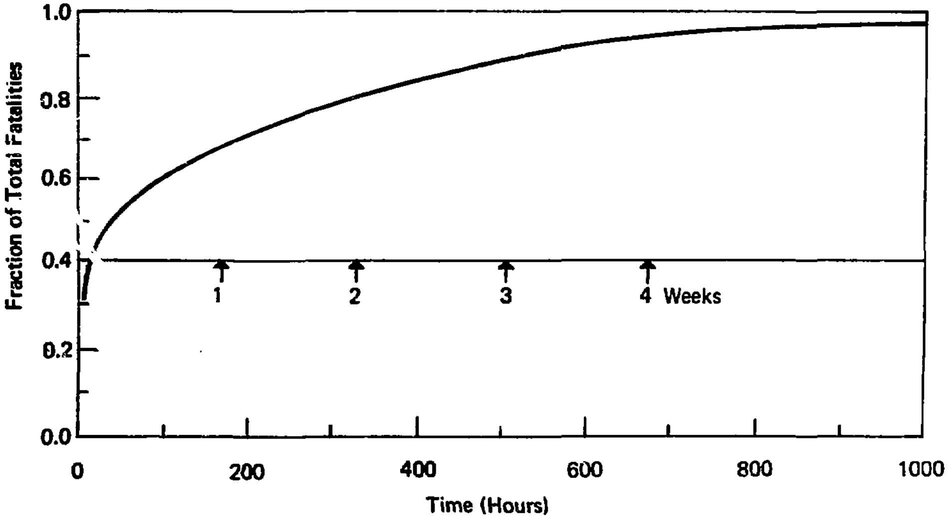

Fig. 5. Fraction of Total Fatalities vs. Time

While these observations are only valid in detail for the case calculated, their general implications will most likely prove valid over a range of conditions. In particular, they are unlikely to be much altered by changes in yield of a few fold, by shielding, or by deriving part of the explosive yield from fusion rather than fission. While detailed calculations for a wide variety of situations using the best available data are certainly worthwhile, the general conclusion will not be significantly affected; that the deaths from nuclear weapons having low-to-moderate yields will occur over many days following the explosion.

Consequences

The observation that the radiation deaths from nuclear weapons having less than several tens-of-kilotons yield will take place over a period of days has a number of interesting and important consequences. Discussion of a few of these will clarify the significance of this aspect of nuclear war. This discussion also suggests some areas that merit additional study.

Perhaps clearest is the fact that on the nuclear battlefield there will be a new class of personnel: those who, while not incapacitated, have received doses of radiation which will ultimately prove lethal. The nature of the effect of large (hundreds of Rads) instantaneous radiation doses on the human body is that an initial period of depressed capability is followed by a period of recovery. The time to recover is often less than one hour. There then follows a period which may last for many days during which the exposed personnel can perform substantially as well as they could prior to exposure. This period is ended by an accelerating decline in capabilities and, in some cases, death. For example, at the 800 rad level the post-exposure period of substantial capability is on the average about ten days to two weeks, but only one in one thousand will ultimately survive. Whether considered in terms of military (or nonmilitary) personnel or objectives, this constitutes a most unusual population group.

It is questionable that members of this group can be identified or that individuals will know the levels of their own exposures. Even if one sets aside psychological factors and considers only military personnel, the options available and appropriate command actions are not clear. Furthermore, there could be considerable disparity between Pact and NATO views on such an issue as well as important differences between the actions appropriate for an attacker as opposed to a defender.

Some of the most interesting and difficult problems suggested by this paper arise when concrete application is made to limited use situations. Consider, for example, the problem of using a limited number of nuclear weapons to counter a massed enemy attack. The defenders resort to nuclear weapons to reduce the unfavorable force ratio caused by enemy massing. But the defender might also decide that to do much more than restore the status quo ante of approximate force equivalence would lead to escalation by the attacker rather than to war termination. However, as has been illustrated, the use of nuclear weapons introduces a transient which lasts many days. Thus, if the defender uses a set of strikes of sufficient nuclear firepower to regain force balance within a few hours, he is likely to have created a situation in which the attacker sees himself being put at grave risk a few days later when all of the resulting fatalities have occurred. But for the defender to use much less force denies him the ability to stop or resist the immediate attack.

Such considerations lead to a perception of how much the introduction of nuclear weapons may change the way in which time must be considered on the battlefield. Once the attacker's forces have been exposed to radiation, delay may result in reduced available forces even though the defender takes no further action. Or the defender, once subjected to nuclear fire, may find his position deteriorating even though the attacker has taken no further action. The whole notion of reserves can be given a different meaning: namely, those who have not been exposed to significant radiation. Mobility could become important in the unusual sense of being able to usefully shift troops having limited life expectations.

The nature and scope of this limited set of possible consequences call attention to a number of important matters. If an understanding of the doctrine, posture, and equipment appropriate for nuclear war is to be achieved, the full spectrum of the changes resulting from the introduction of nuclear weapons must be considered. Certainly the impact on time, as well as on space, resulting from the introduction of nuclear weapons must be comprehended.