NUCLEAR WEAPON EFFECTS
UNCERTAINTIES IN TACTICAL WARFARE

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

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Director
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Washington, D. C. 20305
NUCLEAR WEAPON EFFECTS UNCERTAINTIES IN TACTICAL WARFARE

Raymond W. Millican and William L. Daugherty

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

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Nuclear Effects Uncertainties
Battlefield Data Collection

The study identifies important uncertainties in regard to tactical nuclear warfare, devises methods for collecting battlefield data on these uncertainties, and proposes plans and procedures for collecting, evaluating, and disseminating the data to important users.
SUMMARY

This research identifies the uncertain major nuclear effects and assesses the feasibility of collecting data on a tactical nuclear battlefield to assist in clarifying these uncertainties. Where collection was feasible, we evaluated the immediate and near-term operational benefits of reducing the uncertainty. For uncertainties that passed both tests (data collection feasibility and operational benefit), we devised plans for collecting the data, analyzing it, and disseminating the analysis to users.

From discussions with Science Application Inc., who are planning for underground testing, and with Stanford Research Institute, who are planning for test readiness, the major uncertainties are:

- Effects of low airburst precursor.
- Effects of blast and ground shock from surface and shallow underground bursts.
- Effects of combined thermal and blast effects on equipment.
- Effects of dust clouds on communications and radar.
- Volume of fireball causing interference to radar and communications.
- Correlations among visible blast damage, casualties, and equipment damage.
- Human response versus time as a function of radiation dose.
• Effects of multiple injuries (blast, thermal, and radiation).
• Radiation from vent stem from shallow to deep subsurface bursts.
• Adequacy of fallout prediction system.
• Loss of effectiveness of U.S. units by type as a function of percentage of casualties.*
• Same for enemy units.

A. **Wars Involving U.S. Forces**

We investigated the means that are likely to be available for collecting nuclear effects data in a tactical nuclear environment involving U.S. forces. This investigation was based on current organization and plans. We then analyzed (Section III) each of the listed effects uncertainties to determine:

- The data required to dispel or reduce the uncertainty.
- The feasibility of collecting the data.
- The immediate operational benefits of dispelling the uncertainty.

In six cases, it was judged feasible to collect the necessary data. There also appeared to be a significant immediate operational benefit from reducing the uncertainty involved. These were to:

- Develop human response versus time as a function of radiation dose.

*Percent casualties that would prevent mission performance.
• Determine effects of multiple injuries to personnel.
• Determine loss of effectiveness of U.S. units as a function of casualties.
• Determine adequacy of current fallout prediction system.
• Determine combined thermal and blast effects on aircraft.
• Determine loss of effectiveness of enemy units as a function of casualties.

Collection of data on these uncertainties requires the following positive actions:

• Issue gamma neutron dosimeters which will cover the dose range of interest to selected troops (e.g., every third or fourth man). A small inexpensive type is described in Section III.

• Provide selected NBC personnel at all echelons with concise questionnaires so that, if the situation permitted, they could be sent to interrogate survivors of U.S. units who had suffered high radiation doses and/or multiple injuries.

Develop report procedures from division and/or brigade DCs to corps CBRE of casualties sustained, equipment lost, and recent experiences for units declared combat ineffective.

Develop division CBRC report procedures to corps CBRE for cases where significant fallout occurred outside of the predicted danger areas.

• Instrument aircraft with plastic or paint strip that will indicate thermal exposure by change of color and with deformation type pressure gauge that will record integrated pressure.
• Develop a list of special items to be observed and reported by units attacking enemy forces supported by nuclear fires. These will pertain to enemy units becoming ineffective.

• Develop special questions for POW interrogators that will seek to determine casualties and damage sustained by enemy units that become combat ineffective.

• Prepare fill-in-the-blank type messages directing changes in the service weapons employment manuals (e.g., Army Field Manual 101-31), which could be dispatched to all units in the event findings regarding effects uncertainties required a change in employment planning or procedures.

It would be advantageous to have the collected data analyzed at the Corps CBRE, since they are moderately close to the data sources; this would also provide redundancy (there are currently two U.S. corps in Europe). An exception is that data relating to the vulnerability of USAF aircraft should be analyzed at the Direct Air Support Center (DASC). Findings on most uncertainties should be cross-checked among corps CBREs and with Army CBRE and, if they appear valid, should be disseminated via the preplanned messages to all TOCs, DASCs, and FSCCs involved in nuclear planning or targeting. Any findings on aircraft vulnerability to combined blast and thermal effects should also be reported to all USAF and Army units operating, controlling, or requesting aircraft.

B. Wars Involving Non-U.S. Forces

Sections II, III, and IV of this report cover wars involving U.S. forces. Section V covers wars in which the United States is not involved. In the latter investigation we assume (1) that a
tactical nuclear war has been concluded between two (or more) lesser nuclear powers and (2) that the United States has been allowed to send a team of observers to that nuclear arena. The question is "What could the U.S. team learn about the uncertainties that would be of significant benefit?"

Collection of data on many of them would require instrumentation that would probably not be present on foreign battlefields. In cases where the United States is providing military assistance to potential participants, it might be possible to incorporate some instrumentation in the equipment being furnished.

However, even with no instrumentation some useful observations could be made:

- Medical officers might provide data on the frequency of combined blast and burn injury and on the typical casualty rates. By the time the U.S. team arrived on the scene, some symptoms of radiation would probably have been diagnosed, giving approximate received doses; hence, there might be some data on the frequency of total combined injury.

- Discussions with operational commanders and staff could provide data on the loss of unit effectiveness as a function of percentage of casualties.

- If the battlefield had not been policed and if a collaborating former participant would disclose where specific yields had been used, it might be possible to reconstruct the scene and glean useful data on the vulnerability of certain equipment to blast. Even without collaboration, an analysis of residual neutron induced radiation could provide an estimate of weapon yield and ground zero (GZ).
Prior planning would be most important in attempting to collect information from someone else's war. Hence, a study should be made to examine:

- The likely areas of occurrence and differing degrees of cooperation that U.S. personnel might encounter.

- The key personnel who should be questioned, their attitudes toward the United States, and the questions to be asked.

- The number of observers desired, their qualifications, and the required training.

- The instruments and other equipment needed and requirements for stockpiling.
PREFACE

This research was performed to identify important uncertainties in tactical nuclear warfare, to devise methods for collecting battlefield data on these uncertainties and to propose plans and procedures for collecting, evaluating and disseminating the data to important users. The work was a scoping effort which has provided some insights that should stimulate thoughts in this area. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either express or implied, of the Defense Nuclear Agency or the U. S. Government.
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I INTRODUCTION

This research identifies the important effects of nuclear uncertainties, to assess the feasibility of collecting battlefield data that would clarify or dispel those uncertainties, and where collection of data from the battlefield was possible and there were significant benefits, to devise plans for collecting, evaluating, and disseminating the data. Emphasis was placed on cases where increased knowledge would result in more effective weapon employment with the time span of a very short war.

It was assumed that any interference with the combat effort would be prohibited, that data collection would require a minimum of additional equipment, if any, and that the resources devoted to this effort would be austere.

The original concept was to collect data on a U.S. battlefield. However, at the client's suggestion, a supplemental concept was added—that of what could be learned by a team of U.S. observers visiting the scene of a tactical nuclear war or battle that did not involve U.S. forces.
II EFFECTS DATA AVAILABLE FROM CURRENTLY PLANNED SYSTEMS

A principal source of burst data (location and yield) will be the Nuclear-Biological-Chemical (NBC) reports. The system based on these reports is completely dependent on human observations made with instruments that are usually present on the battlefield (e.g., aiming circles and compasses). In Appendix A, we present an analysis of the inaccuracies that might be expected from this system. Except when there is a visible crater, the errors in the location of ground zero (GZ) can be on the order of from 100 to 400 meters.

Height of burst (HOB) will be largely unknown--reporting procedures distinguish primarily between air and surface bursts. If the estimated yield is based on measurement of cloud diameter, the error can be on the order of ±50%. If based only on cloud stabilization altitude, one sigma accuracy will be about +120%, -70%.

The army is developing an automatic nuclear burst detection system (NBDS). Conceivably such a system could provide burst data (GZ, HOB, and yield) with sufficient accuracy to dispel certain

* References are listed at the end of the report.
+ By a detailed survey of neutron-induced radiation, or by careful photo interpretation, GZ could be located to within 50 to 100 meters. However, the basic approach in this study is to see what could be learned and used quickly. This concept does not permit prolonged, costly redigestion of data.
effects uncertainties (e.g., precursor effects). To avoid classification of this report, the specified accuracies for burst data from the NBDS are not given. However, these location accuracies will not be a substantial improvement over those that might be possible with the manual (NBC) system now in use.

The Army has radiac instruments and is developing improved ones for monitoring fallout. The issue is generally six to eight for company-sized units. These instruments can be used for static monitoring or for making radiological surveys. Hence, there is (and will be) a capability for monitoring that will hopefully verify the accuracy of fallout predictions. There is also a fountain-pen-sized dosimeter that will measure received-radiation doses of up to 600 rad (tissue) gamma, either initial gamma radiation or fallout. The basis of issue is two per platoon. As is discussed later, 600 rad (tissue) gamma excludes important neutron radiation and does not cover the dose range needed to investigate radiation related effects uncertainties.
III EVALUATION OF THE FEASIBILITY OF DATA COLLECTION ON UNCERTAINTIES AND RESULTANT OPERATIONAL BENEFIT

In this section, we (1) list the data required to decrease uncertainties of effects, (2) evaluate the feasibility of collecting that data on the battlefield, and (3) assess the operational benefit of decreasing the uncertainty. Findings regarding uncertainties were considered to be of high operational benefit—if they could significantly change damage criteria.* The results of this evaluation are summarized on Table 1.

As was anticipated, in many cases we found that either it would not be feasible to collect data on the uncertainty or that, given the data, the tactical benefit would be small. To emphasize the positive aspects of the findings, the analyses of those uncertainties that might be decreased with definite tactical benefit are presented first.

A. Human Response Versus Time as a Function of Radiation Dose

The uncertainties about human response as a function of radiation dose relate to what dose will incapacitate a person in what time, the degree of incapacitation, and the time the person is

* Damage criteria specifies the level and type of damage that the planner seeks to inflict on a target.
**TABLE I. SUMMARY OF UNCERTAINTY ANALYSES**

<table>
<thead>
<tr>
<th>UNCERTAINTIES</th>
<th>DATA REQUIRED</th>
<th>FEASIBILITY OF COLLECTION</th>
<th>OPERATIONAL BENEFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human response versus time as a function of radiation dose.</td>
<td>Chronological description of impairment experienced by a number of men who have received a wide range of doses.</td>
<td>Feasible, providing troops are equipped with gamma neutron dosimeters.</td>
<td>High—could cause significant change in damage (or targeting) criteria.</td>
</tr>
<tr>
<td>Effects of multiple injuries (blast, thermal, and radiation).</td>
<td>Chronological description of impairment experienced by a number of men who have suffered a range of injuries.</td>
<td>Feasible, with some proviso as above plus a survey team capable of diagnosing degree of burns and nature of basic blast injuries.</td>
<td>High—same as above.</td>
</tr>
<tr>
<td>Loss of effectiveness of U.S. units by type as a function of percentage of casualties.</td>
<td>Percentage of casualties and recent experience of U.S. units declared combat ineffective.</td>
<td>Feasible—data are available at Bde and Div CPs.</td>
<td>High—could significantly change targeting criteria.</td>
</tr>
<tr>
<td>Same for enemy units.</td>
<td>Same as for U.S. units above.</td>
<td>Feasibility is doubtful; but answer is important and some data available from POW interrogation.</td>
<td>High—enemy unit response may differ from U.S. response.</td>
</tr>
<tr>
<td>Combined thermal and blast effects on equipment.</td>
<td>Calories/cm², static and dynamic pressures, and damage.</td>
<td>Possibly feasible, with special instrumentation on selected equipment.</td>
<td>Small to medium—effects on aircraft could require special safety measurements.</td>
</tr>
<tr>
<td>Adequacy of fallout prediction system.</td>
<td>Predicted pattern versus pattern actually experienced.</td>
<td>Feasible—CBRC does prediction and also plots actual events from monitoring reports.</td>
<td>Small to medium, in unlikely event that current prediction system is not sufficiently conservative.</td>
</tr>
<tr>
<td>Low airburst precursor effects.</td>
<td>Burst data (x, y, z, and yield), static and dynamic pressures.</td>
<td>Not feasible—burst data inexact and pressures would require instrumented battlefield.</td>
<td>Small</td>
</tr>
<tr>
<td>Shock from surface and shallow underground bursts.</td>
<td>Burst data, velocities and accelerations.</td>
<td>Same as above.</td>
<td>Small</td>
</tr>
<tr>
<td>Blast effects from surface and shallow underground bursts.</td>
<td>Same as for precursor effects.</td>
<td>Same as above.</td>
<td>Small</td>
</tr>
<tr>
<td>Effect of dust clouds on communications and radar.</td>
<td>Reports of interference in presence of dust clouds, type and frequency of equipment.</td>
<td>Feasible.</td>
<td>Small—effect is transitory and remedial actions are limited to those possible within existing nets.</td>
</tr>
<tr>
<td>Fireball volume causing interference to radar and communications.</td>
<td>Measurements by radars of cluttered area, reports of interference in presence of fireball, type and frequency of equipment.</td>
<td>Feasible.</td>
<td>Small to medium—chief benefit would be appreciation of radar blackout problem. Communications impact same as for dust cloud.</td>
</tr>
<tr>
<td>Correlation between visible blast damage, casualties, and equipment damage.</td>
<td>Counts of casualties, survivors, and equipment damage with associated distances from GZ to outer limit of visible damage.</td>
<td>Feasible; however, it would require significant manpower and there is high error potential.</td>
<td>Small—it is doubtful that a battlefield survey would develop a significantly different correlation than one computed based on EM-1.</td>
</tr>
<tr>
<td>Radiation from vent stem from shallow to deep, subsurface bursts.</td>
<td>Burst data and doses received at a number of points.</td>
<td>Feasible, assuming either the thermal luminescent dosimeters or the current issue dosimeter.</td>
<td>Medium—would increase confidence in troop safety distances.</td>
</tr>
</tbody>
</table>
incapacitated. A cause for the uncertainty is that most current data are based on experiments with monkeys and is limited even there. Predictions of human response based on monkey response may have significant error. A chronological description of the impairment experienced by a number of men who have received a wide range of doses is required to fill this void.

Within a troop unit subjected to or near to a nuclear attack, there will be considerable differences in the doses received, because of variations in the postures of the men at the time of attack and their distances from GZ. Even men subjected to a dose causing immediate transient incapacitation (and ultimately death) will have a period of partial recovery. At lesser doses, even though those doses may ultimately be fatal, there may not be even a temporary loss of capability. Hence, it appears feasible to interview men who have been exposed to radiation to determine the time history of their responses.

A major limitation to such an approach is the fact that the dosimeter now issued to troop units only reads to 600 rad (tissue) gamma. No neutron dose is measured. Also, the basis of issue is two per platoon and, depending on their posture, the doses received by the two men carrying the dosimeters might not be representative of the entire platoon. Because of the variances in individual exposures that might occur, it would be desirable to have at least every third or fourth man instrumented. To overcome these limitations it would be necessary to have dosimeters that would measure both gamma and neutron doses and cover the dose range of interest.

*An early incapacitation followed by a temporary period of recovery.
and to have a representative sample of men instrumented. Any
dosimeter that would permit meeting these requirements would suf-
fice. It is known that the U.S. Army has dosimeters under develop-
ment; however details as to cost, size, and range of doses read are
not known. As a matter of interest a small, cheap dosimeter used
by ERDA is described below.

Based on information from a radiological safety expert in the
Hazards Department at Lawrence Livermore Laboratory, it would be
quite simple and cheap (about 20¢ per dosimeter) to equip every
third or fourth man with a thermal luminescent dosimeter that could
read to $10^4$ rad (tissue). The part of the dosimeter that absorbs
the radiation and provides the reading is a small cylinder of
special material about 1 mm in diameter and 10 mm long. This cyl-
inder could be enclosed in plastic and hung on a man's dog-tag chain.
Since the cost of these tiny cylinders is insignificant, it would
probably be desirable to enclose four cylinders in the plastic case,
thus making a dosimeter set consisting of:

- Two dosimeters reading gamma dose—one up to $10^4$ and
  one up to $10^3$ rad (tissue).
- Two dosimeters reading neutron dose—same levels as
  above.

Supplemental equipment is needed to read a dosimeter, but it is
packageable in a size about as big as a cased typewriter and could
readily be used in the field. Because the actual reading must be
taken at a site remote from the wearer of the dosimeter (and be-
cause the cost is small), it would be desirable to have replace-
ment dosimeter sets available. This would permit detaching one
set for reading and leaving a new unexposed one with the man.
Given gamma neutron dosimeters, it appears feasible to collect data on the variation of disability with time as a function of dose. Doctrine requires that irradiated personnel continue to fight until too sick to do so. Ultimately, however, the men who have received high doses and survived, at least temporarily, may be evacuated to an aid station or collected in a holding area, probably near an aid station. More often than not the tactical situation may preclude any attempt to interview survivors. However, interviewing a huge sample of cases is probably not necessary. With some additional training and with the provision of a questionnaire, the NBC personnel at company, battalion, and brigade could be used to interview survivors. The questionnaires would be similar to the one shown in Table 2. If data were being collected on radiation effects only, the interviewers would have to be careful to confine their examinations to men who had suffered only radiation exposure—avoiding men suffering from multiple effects.*

The time history of the impairment experienced by a man who has suffered both burns and an initial radiation dose cannot be used as an input to a study of the impairment caused by radiation alone. A questionnaire would be filled out for each man interviewed and a dosimeter or a reading considered representative would be attached to a group of questionnaires. Depending on the time lapse since the burst, the interview team might need to remain at the aid station or holding area for some time to observe and note the onset of delayed responses. The NBC personnel

*The next part of this section covers collection of data on the effects of multiple injuries. If this were done the data collection would cover both radiation response and multiple injuries. The difficulty in finding radiation-only casualties suggests that examining multiple injuries would be preferable.
would return to their bases, the dosimeters would be read (probably at brigade), and the dose recorded on the appropriate questionnaire.

TABLE 2. ILLUSTRATIVE QUESTIONNAIRE FOR INTERVIEWING RADIATION VICTIMS

Were you ever unconscious?
If so, do you know how long?
Were you nauseated or did you vomit after the attack?
How long?
Were you dizzy or unstable?
Did you notice any other specific debilitations?
Were you burned or injured by the blast?
In the period immediately following the attack, did you notice any impairment of your ability to perform any of the following functions; if so, how long did the impairment last?

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>NATURE OF PROBLEM</th>
<th>DURATION TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire a rifle or carbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operate crew served weapon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use binoculars or other surveillance device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive a vehicle or tank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read a map</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operate a radio</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Did you observe impairments such as the above in others?
Who and nature?
The questionnaires could then be analyzed to determine what doses would cause:

- Immediate permanent incapacitation for demanding tasks.
- Immediate transient incapacitation (and time duration).
- No incapacitation.

If the sample of men interviewed was adequate, variances could also be determined.

The development of reliable data on the time variance of human capabilities as a function of dose could have great operational benefit. For example, if it was discovered that a particular level of incapacitation could be achieved with 2000 rad (tissue) in contrast to, say, 8000 rad (tissue), the yield used could be decreased by about a factor of four. In some cases this could be achieved by using a smaller yield option within a single weapon system; in other cases this could be achieved by using a different, smaller weapon system. Use of the smaller yield would reduce collateral damage and would permit an attack on targets closer to our own troops. This would be an example of criteria that were too stringent.

There is some uncertainty as to whether neutron doses and gamma doses are equal in causing rapid incapacitation. Thus, it is conceivable that the battlefield data collection and analysis could show that 8000 rad (tissue) are needed to achieve what we expected to do with 3000 rad (tissue). In this case, yield would have to be appropriately increased. In all cases, given proven data, we could operate with increased confidence.
In sum, the collection of battlefield data on the variation of human response versus time as a function of dose is both feasible and potentially of significant operational benefit. Accordingly plans should be devised to collect, evaluate, and disseminate such data.

B. Effects of Multiple Injuries on Personnel

To assess the potential importance of multiple injuries, a separate analysis was made of the significance and frequency of multiple injuries. This analysis is presented in Appendix C. In this analysis we found that multiple injuries increased the probability of death, and that there would be numerous multiple injuries.

This uncertainty is actually an extension of human response versus time as a function of radiation dose. In this extension we consider blast injuries and thermal effects (burns), as well as radiation dose. The data required are:

- A chronological description of the impairment experienced by a number of men who have received combinations of
  - A wide range of radiation doses.
  - A range of percentages of their bodies subjected to second and third degree burns.
  - A range of blast injuries (both as to type and cause).
- Unit activity and individual posture at the time of attack.
As is described in Appendix C, when a unit is subjected to nuclear attack, it is likely that men will be injured by blast, some will be burned, and some irradiated. By our doctrine we tend to target for a single effect—blast, thermal (rarely), or radiation. Considering only the one effect, we may seriously underestimate the total damage inflicted. Hence, knowledge of multiple injuries could give us valuable insight into the real status of an enemy unit we have attacked or one of our units attacked by the enemy.

In some ways it may be more feasible to collect the data needed to solve this uncertainty than it was for the previous uncertainty, which was only concerned with radiation dose. As we pointed out, a time history of the impairment suffered by a man who has received an initial radiation dose and whose body has suffered significant burns (or whose arm is broken) cannot be used as an input to human response versus time as a function of radiation dose. However, if the collecting team interviews an adequate number of men whose bodies have suffered 0%, 10%, 20%, and so on second and third degree burns (and similar varied levels of blast injury), the data generated may dispel both uncertainties. The data from the men with 0% burns and no blast injury will be used to answer the question of impairment versus time as a function of radiation dose, while the data from those burned and injured by blast will help to dispel uncertainties on combined effects. Because we would then be measuring percentage and degree of body burns and diagnosing blast injuries, the qualifications for the interview team would increase. The team members must be able to distinguish between degrees of burns and
estimate the percentage of the body that the burns cover, and they
must be able to identify the nature and severity of blast injuries.

Analysis and evaluation of the data collected will be somewhat
more complex than in "initial radiation only" cases. With the data
collected here, one can estimate the percentage of a troop unit ex-
posed to thermal radiation as a function of unit activity and the
variance in that percentage. Also, the data concerning 0% burn and
zero blast injury cases can be segregated to provide answers for
questions in "radiation only" cases.

The operational benefit would be greater than that for human
response versus time as a function of radiation dose. Given re-
liable data on multiple injury effects and on the expected percent-
age of a unit exposed to thermal effects, we could take into ac-
count thermal effects and multiple injury effects in our targeting
and in post strike analyses. Thus, all of the operational benefits
described under the previous uncertainty would be realized, and the
accuracy of our planning should be greatly increased.

C. Loss of Effectiveness of U.S. Units as a
Function of Casualties

Probably commencing with ORO-T-289, a number of studies have
sought to determine the percentage of casualties that a unit must
suffer to cause it to lose its combat effectiveness. This original
study examined cases of U.S. infantry battalions in WWII and ar-
rived at percentages of casualties for two types of offensive ac-
tion breaking points and one defensive action breaking point.
Other similar studies examined Korean and Vietnam experience and
arrived at rather similar findings. Despite the caveats in the ORO study, its results (slightly modified) were assimilated into U.S. Army targeting practices. In fact, an aura of near magic attaches to a casualty figure of between 30% and 40%, and few users are familiar with the source studies on which these numbers are based.

There are several resultant weaknesses in our targeting. All of the case histories that served as inputs to these studies involved nonnuclear war, and the casualties were sustained over a period of from a number of hours to as long as two weeks. In contrast, casualties caused by a nuclear attack would in large part be virtually instantaneous. (The realization and recognition of all initial or residual radiation casualties would last for days.) Secondly, casualties in conventional conflict are often not directly associated with equipment damage (tanks being an exception) whereas most nuclear attacks that caused significant casualties would also damage equipment—thus increasing loss of effectiveness. Finally, despite the fact that the principal source study focused on infantry battalions, the 30% to 40% figure has been used on units ranging from platoon to theater forces; it seems very unlikely that the criteria that defeats a battalion will also apply to the defeat of a platoon or a theater force. Thus, there are major uncertainties regarding what level of nuclear-inflicted casualties will cause various types and sizes of units to lose their combat effectiveness.

The data required to resolve these uncertainties are:

- A listing of units (designation, type, and size) that are declared combat ineffective, the percentage
of casualties that each suffered, and description of equipment damage.

- A brief description of the near-term prior experience of these units (prior casualties, exhaustion, and the like).
- For each unit, the time at which it was declared ineffective and the time (if ever) that it was again considered combat effective.

Most of the foregoing data could be collected from regular reports that would be received at brigade and division command posts. It would probably be desirable in selected cases to visit the stricken units to verify the casualty figures and equipment damage. In the confusion of such a situation, the reporting might well be inaccurate. However, if the focus of the effort were on units declared ineffective even though they had suffered less than 50% casualties, it should be possible to collect the essential data.

The Technical Project Monitor suggested that a unit's breaking point might be from equipment damage as well as casualties. However, two factors argue that this investigation should be in terms of percentage of casualties. First, there will often be a close correlation between percentage of casualties and damage to equipment; hence, making the assessment in terms of casualties does not ignore equipment damage. Second, the operational reports concerning the nuclear attack and the damage inflicted will tend to be more accurate on casualties than on equipment—a commander's first concern is his men. Therefore, the basic concept of indexing the breaking point to casualties is retained.
The operational benefit could be significant. Our targeting criteria might be far too stringent. In that case, assuming that enemy unit response was similar to ours, smaller yields could be used, and collateral damage and risk to our forces would be reduced. Conversely, if we found that current criteria were inadequately low, we could use larger yields. In either case, we would gain increased confidence in our targeting. The findings would also provide some quasi-quantifiable data on the psychological impact of nuclear weapons.

D. Loss of Effectiveness of Enemy Units as a Function of Casualties

Since an enemy unit's response to sudden, heavy casualties might not be similar to that of a U.S. unit,* it would be desirable to have separate data on the percentage of casualties that would cause enemy units to become combat ineffective, and for how long. The type of data required would be essentially the same as that required to determine the breaking point for U.S. units.

Collecting meaningful data on loss of effectiveness on enemy units would be difficult. Even in the uncertain event that U.S. forces overran major enemy headquarters, there would be no

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*At any given time in history, the combat performance and stamina of troop units varies considerably with nationality. For example, during WWII Wavell, with 36,000 Commonwealth forces, virtually destroyed an Italian force of 2250,000. Yet, the subsequent injection of two German divisions into that theater nearly reversed the course of that war.
assurance that the pertinent records would be recovered and properly interpreted. Some relevant information could probably be obtained in POW interrogations. Also, when U.S. units mounted counterattacks supported by nuclear weapons, enemy casualties could be estimated with some accuracy and correlated with the effectiveness of enemy opposition to the attack. Even though the ability to acquire sufficient data from which to form accurate conclusions is uncertain, the cost of attempting to acquire it is small. Some key questions could be asked by POW interrogation teams and certain relevant matters would be in after-action reports.

If the data were obtained, the operational benefit would be high because we could then target the enemy with more confidence. Hence, plans should be made to collect pertinent data.

E. Combined Thermal and Blast Effects

Equipment that has been heated by thermal effects may become more vulnerable to blast. The data required for a variety of equipments are:

- Calories/cm²
- Overpressure and dynamic pressure.

Strips of paint on equipment or attached pieces of plastic that change color with heat could permit the amount of thermal exposure to be determined. Crush or deformation type gauges could be attached to permit the reading of the total or integrated pressure experienced. Damage would, of course, be observable.
IV PLANS FOR BATTLEFIELD COLLECTION, ANALYSIS, AND DISSEMINATION

A. Collection

In the preceding section, we analyzed the feasibility of battlefield collection of data on the identified uncertainties and examined the possible operational benefit of dispelling the uncertainty. In this part of this section, we will develop specific plans for data collection on those uncertainties that passed the tests of collection feasibility and operational benefit. The findings are summarized on Table 3.

1. Human Response Versus Time as a Function of Radiation Dose

After a troop unit has suffered a nuclear attack there probably will be men who have sustained high-radiation doses who temporarily survive and can be interviewed. If they are equipped with the thermal luminescent dosimeters, their radiation exposure can be measured and correlated with their descriptions of their response.

In many cases the tactical situation will preclude such interviews. However, a review of thousands of cases is probably not necessary. If 600 to 1000 men who had received a range of doses could be interviewed, the uncertainties regarding radiation response could be considerably reduced. In past wars the tactical
TABLE 3. COLLECTION OF DATA ON EFFECTS UNCERTAINTIES

<table>
<thead>
<tr>
<th>UNCERTAINTY</th>
<th>PROPOSED METHOD OF COLLECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human response versus time as a function of radiation dose.</td>
<td>Equip selected men with gamma neutron dosimeters. When the tactical situation permits, dispatch trained interview teams from brigade or division to collect dosimeters and interview survivors. Read dosimeters and analyze data at the appropriate echelon and analyze data.</td>
</tr>
<tr>
<td>Effects of multiple injuries to personnel (combination of blast, thermal, and radiation).</td>
<td>Same as above plus interview team diagnoses and records extent of burns and blast injuries for each man interviewed.</td>
</tr>
<tr>
<td>Loss of effectiveness of U.S. units as a function of percentage of casualties.</td>
<td>At Bde and Div CPs, record percentage of casualties and prior recent history for U.S. units declared combat ineffective. Make some on-scene surveys to verify percentage of casualties. Also record time to return unit to combat effective.</td>
</tr>
<tr>
<td>Adequacy of current fallout prediction system.</td>
<td>CRDC at Div TOC takes fallout predictions and receives and plots actual monitoring and survey reports. Compare actual with predicted doses and note discrepancies.</td>
</tr>
<tr>
<td>Combined thermal and blast effects on aircraft.</td>
<td>Instrument aircraft with plastic or paint strip that will change color with thermal exposure, and a deformation type pressure gauge. Read instrumentation on planes that have survived nuclear environments.</td>
</tr>
</tbody>
</table>
battlefield has tended to move in spasms and this may also be true of a tactical nuclear battlefield. Thus, in the ebb and flow of the battle there may well be opportunities for interviewing radiation victims.

If each U.S. echelon (division to company) trained selected NBC personnel, an interviewing team could be formed when needed. The team could be sent to the holding area where the irradiated survivors were located to collect the dosimeters and fill out questionnaires (similar to Table 2) on the survivors' description of their response history. The dosimeters could then be read and the dose readings could be correlated with the response descriptions and forwarded to the Corps CBRE for analysis.

Summarizing, the actions required to make collection feasible would be to:

- Procure and issue the gamma neutron dosimeters to be carried or hung from dog-tag chains.
- Equip appropriate echelons with the devices needed for reading the dosimeters (if required).
- Designate and train selected NBC personnel at each echelon to act as interviewers.

2. Effects of Multiple Injuries to Personnel

Basically the same plan of collection as that described above (for radiation) would be used for collecting data about injuries. Variations needed would be the following:
• The interview team will have to be trained to diagnose and describe burn and blast injuries.

• Because of the increased scope, the survey teams should be increased to ten men each.

• The questionnaire would need to be expanded.

3. Loss of Effectiveness of U.S. Units as a Function of Casualties

In general, a unit will be declared combat ineffective by its superior echelon (possibly on recommendation of the unit commander). Whenever such a declaration is made, there will be messages to the brigade and division TOCs stating the designation of the unit, the nature of the catastrophe, the damage sustained by personnel (and possibly to equipment), and the expected time of return to some level of effectiveness. Hence, what is required to collect data on this uncertainty is that brigade and division TOCs forward copies of these messages to corps CBRE, adding a brief description of the unit's recent experience—prior casualties, fatigue, and so on. In cases where the data seem abnormal, the corps CBRE—after a suitable interval and during a lull in the action—should query the originating TOC as to whether there have been revisions in the estimated damage.

4. Adequacy of Current Fallout Prediction System

As was previously indicated, a concern is whether or not a predicted pattern does in fact cover all of the danger areas. Current doctrine already provides for the division CBRC making
fallout predictions and plotting actual fallout based on monitoring and surveys made by division units. Thus the necessary data can be obtained by simply requiring division CBRCs to report to corps CBRE any instances where local areas of intense radioactivity occur outside of the predicted danger zones.

5. **Combined Thermal and Blast Effects on Aircraft**

Does thermal exposure weaken aircraft components to the point where their resistance to blast is significantly reduced? To answer this question, the plan developed in this report is to instrument aircraft with a strip (paint or plastic) that will change color with thermal exposure and a deformation type gauge that will measure total pressure. When a plane returns to base after being exposed to a nuclear environment, this instrumentation would be examined. If there were positive readings they would be taken and reported together with any damage noted--the U.S. Air Force probably reporting to the DASC (and possibly numbered Air Force) and the Army to corps CBRE. The instrumentation would then be replaced. These readings would show what combinations of effects will not kill the aircraft.

6. **Loss of Effectiveness of Enemy Units as a Function of Casualties**

To explore the uncertainty about the breaking point of enemy units as a function of casualties, the collection concept is to use POW interrogations and after-action reports from U.S.
units that have attacked enemy forces with nuclear fire support.

The actions required to provide for such a collection are to:

- Develop special questions for POW interrogators that will probe this point--e.g., How many casualties did your unit take? Was it then out of action? How long?
- Develop a list of items to be observed and reported by units exploiting nuclear fires--e.g., estimated nuclear casualties in enemy units overrun, estimated equipment damage, and effectiveness of enemy resistance.

B. **Analysis and Dissemination**

From the reporting procedures already described, it will be apparent that it is planned to have most of the data analyzed at corps CBREs. This echelon was selected for several reasons. It is far enough to the rear to provide some safety, yet far enough forward to have fairly ready access to the fighting units. Being well forward also simplifies communications. Putting the responsibility at corps level, rather than at field army level, also provides some redundancy (i.e., there are two U.S. Corps in NATO). Finally, the staff at the corps CBR should be somewhat larger than at division and should thus have a better capability for making the analysis.

One exception is the analysis of data concerning the combined effects of thermal radiation and blast on aircraft. That portion of these data that relates to USAF aircraft will originate at USAF bases. Because of communications, familiarity with the problem,
and proprietary interest, these data should be analyzed at the DASC. The Army portion of these combined effects data should be analyzed at the corps CBRE; however, a knowledgeable army aviator from the corps aviation section should either assist or supervise the analysis.

When a corps CBRE makes a finding concerning an uncertainty, it should be cross checked with an adjacent corps CBRE and with the Army CBRE to make certain that there are not conflicting findings. If there are no conflicts and the Army CBRE approves, the findings should be immediately disseminated. Findings on those uncertainties that pertain primarily to ground targeting should go to all staff elements involved in nuclear planning or targeting, namely all TOCs, DASCs, and FSCCs. Findings on uncertainties relating to army aircraft vulnerabilities should go to all army aviation units and to those TOCs and FSCCs that may request or control army aviation elements.

Similarly, when a DASC has findings on USAF aircraft vulnerability, it should cross check with another DASC and the TACC. With no conflict, and with TACC approval, the finding should be reported to all air bases and all TACPs. (TACC will probably report the finding to all number air forces.)

To the extent possible, the findings should be anticipated and plans should be made to make appropriate changes in doctrine. These could be in the form of change pages to service weapon employment manuals (e.g., Army FM 101-31). However, in a battle area it would probably be more expeditious to have prepared
fill-in-the-blank type messages which could be sent at once to all interested headquarters. Examples are:

"Battlefield data indicates that _______ rad (tissue) are required to cause immediate transitory incapacitation."

"Experience thus far indicates that the infliction of _______ % nuclear casualties on a _______ size infantry unit will cause loss of combat effectiveness in the attack."

but entry might be possible within a useful time after the battle. In the third situation, data could be obtained only through use of remote sensing techniques, such as drones, cameras, satellites, or radio monitoring.

For the purposes of this report, the question is "What could observers who were permitted on scene learn that would benefit our knowledge of nuclear effects uncertainties?" Reexamining Section IV, in which we developed plans for data collection on uncertainties in a situation where the United States was involved, it is evident that many of the collection plans entailed some instrumentation—dosimeters and deformation gauges. Manifestly these could not be applied ex post facto. However, if the United States was providing military assistance to one of the participants, it could furnish aircraft equipped with deformation gauges and thermal exposure indicators. Thermal luminescent dosimeters could conceivably be imbedded in military web equipment or buttons. The political implications of such acts would have to be carefully assessed.

If allowed to interview medical officers, our observers might get interesting data on the frequency of combined effects injuries. If sufficient time had elapsed before our observers' arrival, and if it was within the competence of the medical corps of the country, medical officers might have diagnosed from symptoms what approximate radiation doses various patients* had received. Thus it might be

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*The patients might be from the medical officer's own forces, or POWs.
possible to get quite useful data on the frequency of various combined effects. Also, medical officers might be able to furnish good descriptions of the total casualty situation within units that had been hit—the total picture might be more interesting and important than its parts.

If allowed, discussions with operational commanders and staff might furnish valuable insight on unit losses of effectiveness with casualties. After a unit was hit, suffering X percent casualties, did the survivors panic or fight on? How effective was their resistance?

It would also be interesting to visit the battlefields. It is doubtful that they would have completely policed the battle area, and much of the damaged equipment would still be in place. If a collaborating former participant would provide data on what yields were used where, and at what height of burst, it might be possible to reconstruct the battle scene. An air photo would show the location of the derelict equipment relative to GZ, and a ground survey could record the damage. Such a survey could produce excellent data on the vulnerability of the equipment present. These data would be particularly interesting if the damaged equipment had been furnished by a potential U.S. enemy or if it was equipment of U.S. manufacture that had not previously been tested in a nuclear environment.

Even if the participants were unwilling to furnish weapon and burst data, a careful analysis of the residual-induced radiation would provide an estimate of the yield and the location of GZ.
Thermal, and possibly neutron, shadows might permit estimating height of burst. All of this, of course, assumes free access to the battle area.

To a great extent our ability to obtain useful information from a non-U.S. tactical nuclear war would depend on the effectiveness of our prior planning. It would be valuable to make a study examining:

- The likely areas where tactical nuclear wars without U.S. involvement might occur and, for each area, the probable rules that would govern U.S. observer access to data.
- The key commanders and medical officers who should be interrogated, if possible, and their political leanings to include their attitude toward the United States.
- The questions that should be asked of key participants.
- The number and types of observers and equipment that it would be desirable to send to each of the potential areas, based on the anticipated access to data rules.
- The training required for candidate observers.
- The instruments and other equipment that should be stockpiled and where.
REFERENCES

1. "Chemical, Biological, Radiological and Nuclear Defense," Field Manual, F-3-12, Headquarters, Department of the Army, WDC (May 1971). (NBC1 report used by a reporting unit is specified in FM 3-12 and conforms to the nuclear part of STANAG 2103.)


SUPPLEMENTAL BIBLIOGRAPHY
