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FURTHER EVALUATIONS OF COLLATERAL DAMAGE

Science Applications, Inc.
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This report describes the results of a DNA project which had the objective of developing models and methodologies for the prediction of civilian casualties resulting from conventional weapon attacks. The methods developed and supporting data are detailed in a Handbook (SAI-78-220-LJ) and summarized in this report. This report also contains evaluations of expected civilian fatalities due to conventional and nuclear weapons (over)

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20. ABSTRACT (Continued)

for five theater warfare scenarios. Methodology and computer code improvements are identified.

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EXECUTIVE SUMMARY

This project is a continuation of the Relative Collateral Damage Program sponsored by DNA in 1975. The earlier work investigated and compared the effects of nuclear and non-nuclear weapons on civilian casualties. It became evident form this work that the development of sophisticated analytic procedures over the last 30 years that enables the prediction of casualites due to nuclear weapons was not paralleled by the development of similar techniques that would permit computations of casualties due to conventional weapons. The need for the latter techniques arises from considerations such as selecting between nuclear and conventional weapons for a given attack, assessing the effectiveness of various personnel shelters, the evaluation of the relative merits of various conventional weapons (both existing and conceptual) and in evaluting alternative attack doctrines.

The main purpose of the current project was to develop and validate analytic techniques that would permit the evaluation of collateral casualties associated with the use of non-nuclear munitions. Two documents summarize the results of the work; one is a Handbook containing descriptions of the models and methodologies developed, supporting data and examples of the use of the models, the other, this document, contains a summary of the Handbook, the results of the collateral casualty analysis of five scenarios, and conclusions and recommendations associated with the analysis and with the analysis procedures.

Three models have been developed (or refined) to achieve the objective of the project. The first is a Single Weapon Matrix Model (SIMM) that enables the prediction of civilian casualties due to the detonation of a single conventional munition. Blast and framgentation effects are treated and the results are presented in matrix form from which a civilian casualty function can be derived. The second model, the Multiple Weapon Matrix Model (MUMM), accepts the results of the SIMM (or other historically derived casualty functions), weapon impact distribution and target distribution data as input. The process provides collateral casualty estimates for multiple conventional weapon attacks. This model is appropriate where a relatively small number of weapons are fired against one or more targets. The third model, the Air Base Damage Assessment Model (AIDA) was developed by the Rand Corporation and was applied to the assessment of damage due to a conventional weapon attack on a multielement target such as an airfield. In this project AIDA has been used to size an attack on a tank battal' and can be used for other multielement targets.

In addition to these models that permi' the evaluation of casualties for various sizes of conventional weapon attacks, a Random Bombing Methodology (RBM) was developed to provide an estimate of primary and secondary fatalities resulting from large scale bombing of built up areas. Based on US Strategic Bombing Survey data obtained after World War II, this methodology has permitted an improvement in the assessment of casualties due to nuclear as well as large scale conventional weapon attacks.

Descriptions of these models and the methodology are contained in the handbook along with data for artillery projectiles, aircraft-delivered bombs and submunitions and other weapons which are used as input. Data describing the characteristics of civilians as targets are included.

Five scenarios were selected to evaluate the models and to compare the casualties resulting from nuclear and non-nuclear attacks. Two scenarios from World War II were used for high intensity, large area attacks.

An analysis was performed to determine the number of casualties that might have resulted from a nuclear weapon attack on Hamburg, Germany. The weapon yield (12 KT) was selected on the basis of providing an area of building burn-out equal to that which actually occurred due to a major conventional weapon attack in World War II. It was predicted that the nuclear weapon would have caused about 70,000 fatalities. The conventional weapon attack actually caused about 42,000 fatalities.

Hiroshima, Japan, which was attacked by a single 12 KT weapon at the close of the war, suffered about 66,000 fatalities. An analysis of the fatalities associated with a conventional weapon attack which would cause a building burn-out area equal to that of the nuclear attack indicated that the required 2300 tons of bombs would have killed about 55,000 people.

The Hamburg and Hiroshima analyses provided an insight into the process of estimating total fatalities resulting from nuclear attacks particularly in the area of secondary fatalities due to fires.

The remaining three scenarios investigated and described in this volume involved typical theater warfare situations in which various sizes of attacks would be appropriate. The area in and around Hünfeld, West Germany was selected for the attack location. It has a total population of about 7800 and is near Fulda. The three scenarios included attacks on: an enemy assault unit occupying the south eastern third of the city, a tank battalion in column on a road on the west side of the city and three tanks passing an intersection in the northern part of the city. The first of the scenarios (assault unit attack) involved the use of 750 pound bombs, the second (tanks in column) was assumed to be attacked by Rockeye submunitions and the third involved precision guided MK84 (2000 pound) air-delivered bombs. The fatalities caused by these weapons and by appropriately sized nuclear weapons were estimated. Where possible, the nuclear weapons were offset from the targets to minimize collateral damage while maintaining the required target damage. Civilian fatalities from the conventional weapon attacks were about 370, 230 and 30, respectively for the three scenarios. Fatalities from the nuclear weapons ranged from 5 to 30 times those from the conventional weapons.

The greatest utility for the models and methodologies developed in this program will be to assist analysts in assessing the effectiveness of new or modified conventional weapons, evaluating alternative attack doctrines for minimizing collateral damage, providing a basis for the education of command personnel who might be responsible for target development and in determining the effectiveness of various forms of civilian protection. Eventually it may be desirable to convert the current models to a form applicable for use by the armed services for planning and decision purposes. However, it is suggested that before this is attempted discussions should be held with appropriate military commands to determine their specific needs in assessment of civilian casualties due to conventional weapon attacks. In the meantime, emphasis should be placed on refining the existing models. Detailed recommendations for these improvements are discussed in Section 3 of this report.

PREFACE

The successful completion of this project is due to the able assistance of a number of dedicated people and their help is hereby acknowledged. Mr. Klaus Mueller developed and modified the necessary computer codes for collateral damage assessment and provided the numerical evaluations for the various scenarios. Mr. Duane Taylor organized the handbook, developed the scenarios and several of the methodologies for determining primary and secondary casualties and assisted in directing the project. Mr. John Swenson provided the analysis of civilian characteristics required for the casualty computations. Mr. William Vance assembled the summaries of many of the conventional weapon characteristics and prepared the appendix on West German city characteristics. Mr. William Yengst directed the project and developed many of the conventional weapon scaling laws. The diligence and creativeness of these people is sincerely appreciated.

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1. BACKGROUND AND INTRODUCTION

During the fall of 1975, the Defense Nuclear Agency initiated the Relative Collateral Damage Program for the purpose of investigating and comparing the effects of nuclear and non-nuclear munitions on civilian casualties. In particular, it was noted that although a sophisticated theoretical approach has been developed over the past 30 years for calculating casualties due to nuclear weapon effects, no similar theoretical techniques are available for computing casualties due to non-nuclear munitions. As important, there are no analytic procedures for estimating the effectiveness of new non-nuclear munitions that might be synthesized if the individual weapon effects (blast, fragments, thermal, debris, etc.) and their appropriate combination were more fully understood.

In the past, the effectiveness of non-nuclear munitions against personnel has been derived primarily by empirical techniques using test data and results of accidents or past wars to provide scaling information. The collateral casualties produced by conventional weapons have generally been ignored, largely because (1) the basic weapon effects have not been assessed and (2) such assessments were regarded to be of questionable importance since the delivery accuracy, rather than the relatively small range of effects (per weapon), determine the extent of the collateral damage. However, when large numbers of conventional weapons (and/or poor delivery accuracy) must be used to accomplish a mission there is ample historical evidence that the collateral effects cannot be ignored. Specifically, when bombs and artillery were used to destroy targets in built-up city areas during World War II, the civilian casualties from both prompt weapon effects and secondary effects of fires, building debris and inadequate rescue services or hospitals often exceeded the casualties produced by the nuclear weapons at Hiroshima and Nagasaki.

The purpose of this contract has been to extend the evaluation of the Relative Collateral Damage Project as reported in Reference 1 to a broader class of non-nuclear munition types and to develop the methodology into practical analytic tools. Specific objectives of the current effort are:

- To extend the collection of personnel response data produced by non-nuclear munitions with emphasis on battlefield and area weapons. To use both the microscopic and macroscopic approaches, to formulate an approach for predicting collateral damage when generic weapon parameters are specified.

- To evaluate secondary effects which tend to dominate the collateral casualties for high intensity attacks. Again, using both microscopic and macroscopic approaches, to determine the attack intensity levels (densities of munitions and populations) where secondary effects become important and to generate appropriate methodologies for estimating casualties.

- To develop and verify analytic tools for calculating non-nuclear collateral casualties. This objective involves the development of three different analytic simulations: 1) a microscopic model for combining weapon effects and computing casualties versus radius for a single weapon at or near a specific aimpoint, 2) a multiple weapon model capable of combining the effects of several sets of results from the microscopic model and 3) a macroscopic model for combining multiple weapon effects and computing casualties for an area attack involving random or pattern munition aimpoints.

- To demonstrate relative collateral damage analysis techniques using the analytic simulations which were developed or modified.

In summary, this project was designed to build on the results of past collateral damage efforts. New analytic techniques and simulation tools have been developed and exercised for the estimation of collateral casualties during non-nuclear conflicts. The understanding of weapon effects provided by this project may also prove useful in the synthesis and evaluation of improved conventional munition concepts.

The results of the contract work are reported in two documents. The first is a Non Nuclear Collateral Casualties Handbook[2] and this Final Report is the second. Section 2 of this document summarizes the handbook, defines the scenarios selected for nuclear non-nuclear attack comparisons and presents the results of these comparisons. Section 3 provides conclusions and recommendations concerning the analysis results and the developed computer codes. References are contained in Section 4.

2. TECHNICAL DISCUSSION

2.1 NON-NUCLEAR COLLATERAL CASUALTIES HANDBOOK

The major part of the work performed under the contract involved the preparation of a Non-Nuclear Collateral Casualties Handbook.[2] This handbook provides methods and models for estimating collateral casualties due to conventional weapons. Supporting input data and examples of the use of the methods and models are also included.

The Handbook first describes the primary conventional weapon effects which cause casualties and then suggests procedures for estimating casualty expectancy. Three essential elements involved in estimating casualties are defined. These are:

- Casualty Function - The composite probability of casualty as a function of distance from the burst point of a weapon.
- Accuracy Functions - The statistical description of the expected hit point of the weapons about their aimpoints.
- Target Size Functions - The distribution of the targets in area and value relative to the weapon effects.

Situations of interest are also described. These include a lower bound where only a few weapons are used such as a precision guided weapon attack against a few material targets, an upper bound where large numbers of weapons are used against large target areas such as World War II bombings of cities, and intermediate situations such as a conventional attack against a Company or Battalion operating in or adjacent to populated areas. It is noted that casualty functions are required for all situations; but that the methods for combining the essential elements defined above will depend on the situation under consideration. Since the casualty functions are required in all cases, considerable attention is given to methods for their determination. Empirical and analytic methods are used. Several empirical methods are discussed and examples from World War II data are provided. In the case of analytic methods, attention centers on the Single Weapon Matrix Model (SIMM) which was originally developed by Picatinny Arsenal and later modified by the Rand Corporation under the title, "Modified Full Spray Code."[3] SIMM is an extension to the Modified Full Spray Code. It currently determines blast and fragment effects on personnel based on civilian data for target characteristics. It is expected that SIMM will later be further extended to include additional personnel sheltering conditions and an automatic printout of casualty functions*.

Given that a casualty function can be determined either from historical data or using SIMM, two models and one methodology are discussed and used in the Handbook to estimate civilian casualties for the situations of interest. These are briefly described below.

The MUltiple Weapon Matrix Model (MUMM) will accept the output damage functions from SIMM, the hit point distribution data about the aim point and the target distribution data all in matrix form and will estimate resulting expected collateral casualties. The matrix treatment used in MUMM is compatible with SIMM results and is well suited for handling the irregular casualty functions, accuracy functions and target distributions which are encountered when conventional weapons are used. MUMM makes the same kind of calculations which are carried out for nuclear weapons in TANDEM and AP-550 involving circular coverage functions except that actual irregular distributions are used rather than log normal distributions for casualty functions and circular normal distributions are used for accuracy functions. It is appropriate for situations where a relatively small number of weapons is fired against one or more targets. Attacks on a tank or armoured personnel carrier are example cases.

*The Modified Full Spary Code does not specifically compute a casualty function; however, it provides data from which a casualty function can be determined.

The Air Base Damage Assessment Model (AIDA) was developed by the Rand Corporation(4) to assess damage from a conventional weapon attack on a multielement target such as an air field. Multiple target elements and multiple weapons of different types can be included. AIDA is directly applicable to the estimation of collateral damage resulting from reasonably large scale conventional attacks on targets such as motorized rifle Companies and tank Battalions when civilian targets are appropriately defined. Procedures for obtaining inputs and descriptions of the model are contained in the Handbook and an example of its use is described in Section 2.2 of this report.

The Random Bombing Methodology (RBM) consists of a set of equations that provide first order estimates of fatalities expected as a result of large scale bombing of built up areas. Prompt fatalities and secondary fatalities are included separately. The data from which the equations were derived were based on World War II bombing results as reported in the United States Strategic Bombing Survey.(5) Although there is considerable uncertainty in the use of these equations they permit first order estimates of civilian casualties when the bomb density and target density are high and when the target area is reasonably large. The derivation of these equations is reported in the Handbook.

Methods and models which are recommended in various situations as discussed in the Handbook are shown in Table 1 by check marks. The type of output which is appropriate is indicated in the case of SIMM.

The remaining sections of the Handbook include procedures for describing the vulnerability of civilians to conventional weapons (Section 3), the characteristics of artillery projectiles, aircraft delivered bombs, grenades and mortars, etc. that are needed as inputs to SIMM including scaling relationships for selected weapon classes (Section 4), and an example calculation of collateral fatalities (Section 5). Code descriptions and supporting data are presented in Appendices.

Table 1. Model Application

Typical Situation	Model or Methodology			
	SIMM	MUMM	AIDA	RBM
Small number of similar weapons and targets - e.g. precision guided munition attacks on tanks	Use matrix damage function	x		
Moderate number of different type weapons and targets - e.g. BLU bombs, vs tank Battalion	Use lethal radius		x	
Large number of weapons and large target area - e.g. assault units in builtup a	Use lethal radius			x

2.2 SCENARIOS FOR NUCLEAR VS. NON-NUCLEAR ATTACK COMPARISONS

Part of the contract work involved comparisons between the collateral damage expected as a result of attacks with conventional weapons and attacks with nuclear weapons carried out for essentially the same objective. Specific scenarios have been selected for these comparisons. This section describes the rationale for selecting the scenarios and the scenarios selected for comparative analysis for macroscopic and microscopic cases.

2.2.1 <u>Macroscopic Scenarios</u>

Considerable effort over the past several years has been devoted to developing models for estimating collateral damage resulting from the use of nuclear weapons - particularly in theater war situations. Comparable analysis has not been carried out to estimate collateral casualties resulting from large scale conventional attacks even though World War II proved that a large number of collateral casualties can result from such attacks. This issue is important for two reasons.

First and most important, analysis of large scale attacks with conventional weapons during World War II may permit more realistic estimates of total damage and/or collateral damage from the use of nuclear weapons. This has significance for theater nuclear attacks where collateral damage is of concern and for strategic nuclear strikes where the threat of unacceptable damage is required. In the latter case the objective of the analysis is to reduce the uncertainty of the estimate of total damage resulting from nuclear attacks.

The second reason for estimating civilian collateral damage from conventional attack and nuclear attack against built up areas is to provide a basis for choice between the two alternatives - conventional or nuclear attacks. Even though it is unlikely that a city, per se will be a target in a theater conflict, it is possible that future theater engagements will involve enemy assault units in sections of friendly cities and for these cases, collateral damage associated with the attainment of a military objective would be an issue. Nuclear weapons can be used with offset aim points so that military objectives are just met and collateral damage is minimized and damage from such an option in terms of collateral casualties can be compared to damage from conventional attacks.

Two scenarios have been selected for demonstration of collateral damage associated with conventional attacks and nuclear attacks in the macroscopic context. They are a hypothetical conventional weapon attack on Hiroshima and a hypothetical nuclear attack on Hamburg. These choices are primarily based on the availability of data in the sense that a nuclear attack did occur against Hiroshima and a large scale conventional attack did occur against Hamburg and most of the damage in terms of fatalities resulted from a single raid. Thus, at least one element of the comparison will be based on historical fact in each case. Whether such choices would actually arise in the future would depend on some friendly city having material value to the enemy which would justify a direct city attack with either conventional or nuclear weapons and the desire to minimize the consequences to the civilian population. The amount of collateral damage associated with such an attack would be important.

2.2.2 Microscopic Scenarios

Scenarios much more likely to occur in future theater conflicts involve the amount of collateral damage to be expected caused by strikes against enemy units at the Company and Battalion level operating in or adjacent to population centers. Normally conventional weapons would be employed against such units, however, estimates of the relative collateral damage for conventional and nuclear weapons are of interest since many fewer sorties would be required with the nuclear option in the sense of accomplishing the military objective and allied strike forces may be limited in number. Three scenarios have been selected for analysis and these are discussed below.

The first scenario involves an intersection in a friendly city through which enemy units such as tanks are moving and against which one or more precision guided weapons might be used. Although it is unlikely that a nuclear weapon would be considered in this case, if it were used it would have damage radii from various effects which would considerably exceed the dimension of the city intersection and its adjacent casualties due to nuclear weapons with yields of about .1 KT can be determined.

The second scenario assumes that fighting is progressing in a friendly city and that enemy assault units have occupied a section of the city. The likelihood that military operations in built up areas (MOBA) will occur has been addressed by the Rand Corporation.[6] They also considered the Soviet viewpoint of how such units might be operated, equipped and maintained. Although the Soviets would prefer to avoid MOBA, they recognize that such engagements could occur and have given consideration to how they should be carried out. For example

> "The Soviets found assault detachments, formed mainly of foot soldiers and structured for city fighting, of considerable utility and discovered that small numbers of tanks were helpful in routing the defenders, while massive armor was usually not."*

---

*Reference 6, page vi.

The Soviets have also considered using towed and self propelled artillery pieces to support assault units.

These units would operate autonomously and probably could not be well located by friendly forces. Thus, a likely attack tactic would be barrage bombing of the occupied area with aircraft or artillery; although offset aiming of small nuclear weapons might be considered if collateral damage was not significantly increased.

The third scenario is considered to be a unit such as a tank battalion or motorized rifle battalion moving along a road adjacent to a populated area. Conventional attacks could be employed with BLU anti-tank or anti-BMP weapons; however, with battalion size units the number of required sorties may be large. An alternative might be a single delivered nuclear weapon offset to minimize collateral damage.

An area near Fulda in West Germany has been selected which is appropriate to each of the microscopic scenarios and for which a population data base has been developed under a previous DNA contract.[7] In particular, the town of Hünfeld was selected and grid population data previously developed was used to estimate collateral casualties. The TANDEM-C data base was further processed to provide population data in square cells 250m on a side. This data base can be directly input into the AIDA model and can be modified for input to MUMM and RBM. Figure 1 gives the general area with town outlines, P-95 circles and population data and Figure 2 shows Hünfeld and the grid population data base. Also shown in Figure 2 are locations for the intersection, for the assault units and for a Soviet tank battalion. Population and area data are summarized in Table 2. The population and P-95 radius for each town are listed and the population in 250 meter by 250 meter square cells is shown on the right for the Hünfeld/Nüst area.

2.3 COMPARATIVE ATTACK ANALYSIS

The following analyses were carried out for the five scenarios discussed in Section 2.2 to compare civilian collateral casualties due to nuclear weapons and those due to conventional weapons. It should be noted that in those cases where the SAI DEC 10 computer was used for SIMM, MUMM and/or AIDA calculations, the running time of each case was

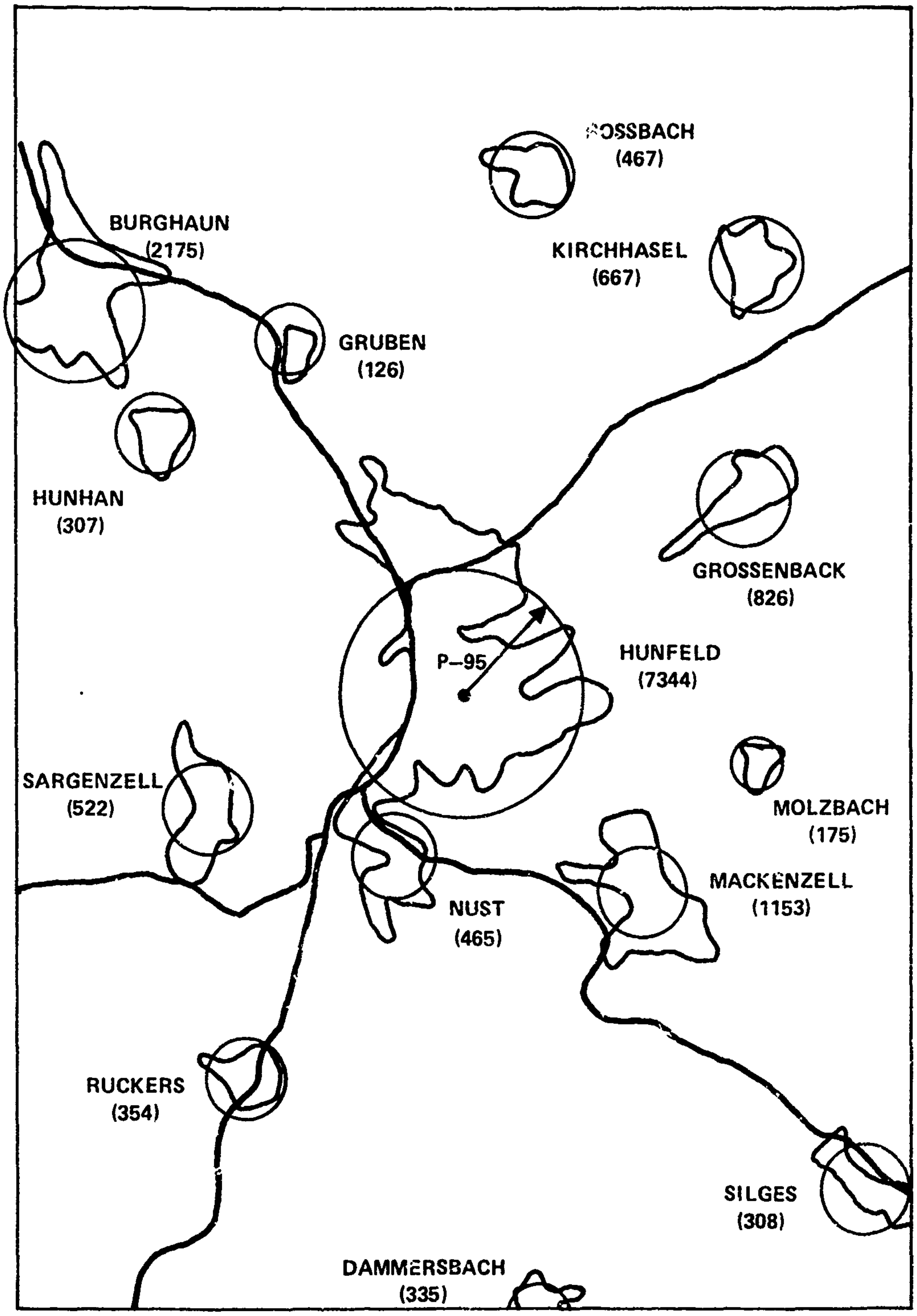

FIGURE 1. HUNFELD AREA

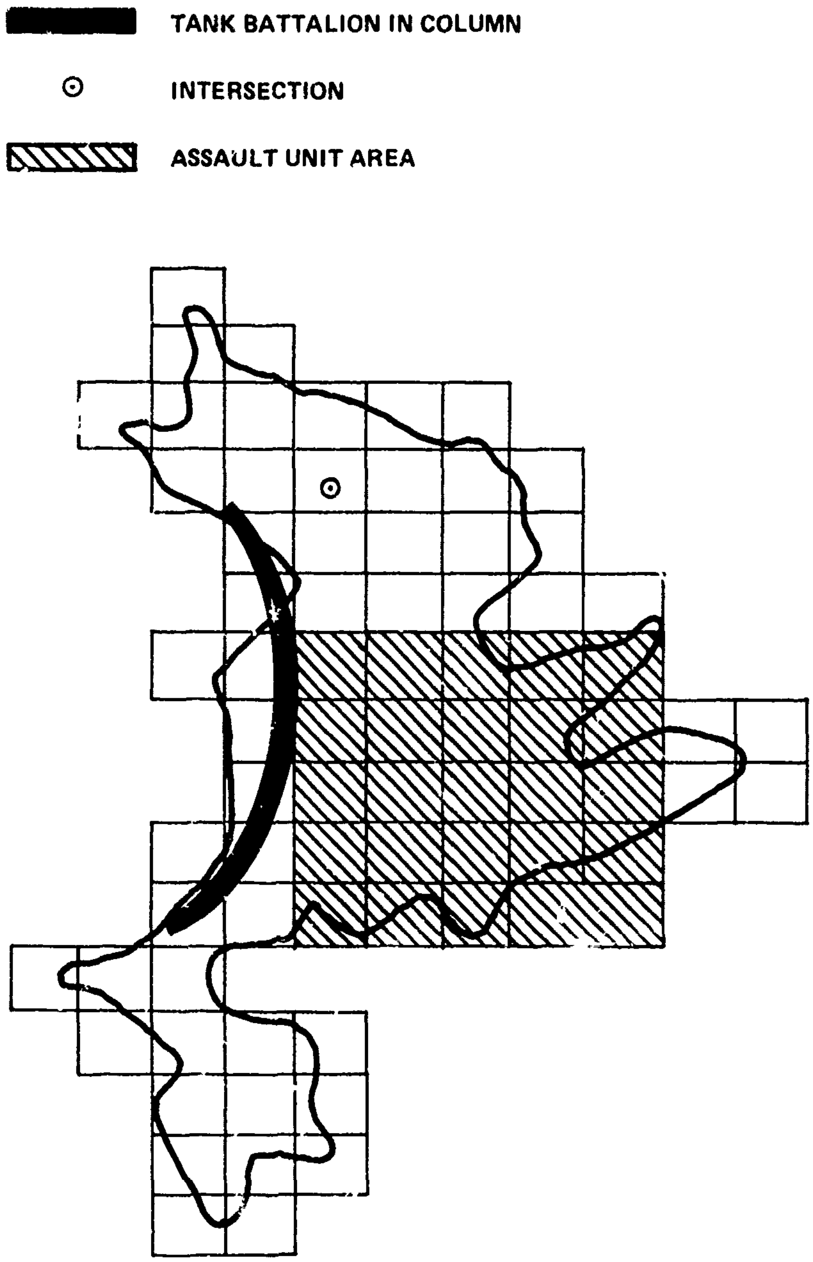

FIGURE 2. SCENARIO LOCATIONS

Table 2. Hünfeld Area Data Base

Town	Population	P-95 Radius (n.mi)
Hünfeld	7,344	.52
Burghaun	2,175	.28
Mackenzell	1,153	.22
Grossenbach	826	.20
Kirchhasel	667	.18
Sargenzell	522	.17
Rossbach	467	.17
Nüst	465	.17
Rückers	354	.16
Dammersbach	335	.16
Silges	308	.16
Hunhan	307	.16
Molzbach	175	.15
Gruben	126	.14
	15,224	

Hünfeld* Data

		73								
		110	55							
	36	129	184	157	46	9				
		110	184	184	184	147	27			
			110	184	184	184	55			
			55	184	147	110	27	36		
		27	129	184	138	138	120	129		
			27	184	184	184	110	92	92	9
			55	184	184	184	175	184	138	9
		36	157	175	184	175	147	55		
		138	147	73	73	120				
48	128	9								
	18	48	59	11						
		44	74	3						
		55	18	14						
		25	3							

*Includes Nüst

on the order of one minute. It is expected that even if very fine grained data were used (large order matrix processing) the time per case would still be well under three minutes per case.

2.3.1 Conventional Attack on Hiroshima

The atomic bomb which was detonated over Hiroshima has been estimated to have a yield of 12 kilotons or 12,000 tons (24,000,000 pounds) of TNT and the area of intense fire which resulted (as determined by the area of burned out buildings) was about 1170 hectare. The approach used in the Random Bombing Methodology is to consider that nuclear attacks and conventional attacks are comparable if the areas of intense fire are the same. This approach will be used in the following example.

The Random Bombing Methodology equations are given in equations 1 to 5.

$$F = F_P + F_S$$

$$A_{IF} = 2.25 \times 10^{-4}\, T^2$$

$$F_P = AN\left(1 - e^{-\frac{MR_L{}^2\pi}{A \times 10^4}}\right)$$

$$F_S = .83 \times 10^{-4}\, NT^2$$

$$R_L = .147\, Y^{.6} \text{ meters}$$

where
F = total fatalities
F_P = prompt fatalities
F_S = secondary fatalities
A_{IF} = area of intense fire, hectare
A = area under attack, hectare
N = population density in area under attack, people per hectare

M = number of weapons dropped
R_L = lethal radius of each weapon dropped, meters
T = tons of bombs dropped, short tons
Y = explosive weight of each bomb, pounds

From Equation (2), 2280 tons of bombs are required to create the area of intense fire of 1170 hectare. If 1000 pound bombs were used, the lethal radius (Equation 5) would be 6 meters and from Equation (3) with N = 115 people per hectare,[8] the number of prompt fatalities would be 5920. From Equation 4, the number of secondary fatalities would be 49,600 and the total fatalities would be 55,500. This compares with 66,000 fatalities which resulted from the nuclear attack on Hiroshima. Thus, it is estimated that about 16 percent fewer fatalities would have resulted if conventional weapons had been used with enough delivered tonnage to create comparable burned out areas.

If, on the other hand, a conventional attack equivalent in tons of TNT delivered were used, 48,000-1000 lb bombs would be required. For this case, prompt and secondary fatalities would account for essentially all of the population within the burned out area and the conventional attack would cause more fatalities than the nuclear attack. Such a large scale conventional attack is not considered reasonable. It would represent about 50 one thousand pound bombs per hectare (one for about every 2000 square feet) which is a bomb density more than an order of magnitude greater than anything experienced in World War II.

2.3.2 Nuclear Attack on Hamburg

Again, it is considered that a nuclear weapon which will cause a comparable area of major building burnout will b equivalent to the conventional weapon attacks. On this basis, the equivalent yield for Hamburg is 12 KT. That is a 12 KT nuclear weapon dropped on Hamburg is estimated to cause the same "area of intense fire" as the 1440 tons used in the single most devastating raid against Hamburg during World War II.

Carrying through the comparison calculations and assuming that people are in basements, the blast radius is 760 meters and the initial nuclear radiation radius is 1150 meters*. Equation (6) is used to determine the composite fatality function where it is assumed that the blast and prompt nuclear casualty functions have a log normal distribution with a sigma of .3 and if the secondary fatality distribution function is proportional to actual building burnout distribution data for Hiroshima. These data suggest that fire damage distribution functions may not be symmetric in that the tail is less than would be expected with a log normal distribution.

A typical composite fatality function has the form:

$$P_F = 1 - (1-P_S)(1-P_B)(1-P_{INR}) \tag{6}$$

where P_F = probability of fatality
P_S = probability of secondary fatality
P_B = probability of blast fatality (prompt)
P_{INR} = probability of initial nuclear radiation (INR) fatality.

The resulting composite fatality function is shown in Figure 3 and the estimated number of fatalities would be about 70,500. Estimated fatalities are determined by numerically integrating the area under the probability function and assuming a uniform population density. This compares with 41,800 killed as a result of the conventional attack on Hamburg or a decrease in fatalities of about 41 percent with the actual conventional attack rather than the hypothetical nuclear attack.

2.3.3 An Intersection in Hünfeld

The first microscopic situation which is considered in comparing collateral damage from conventional and nuclear attack involves elements of an assault group at an intersection in Hünfeld. As was

*These values are taken from Reference 9 under the assumption that people are in home basements.

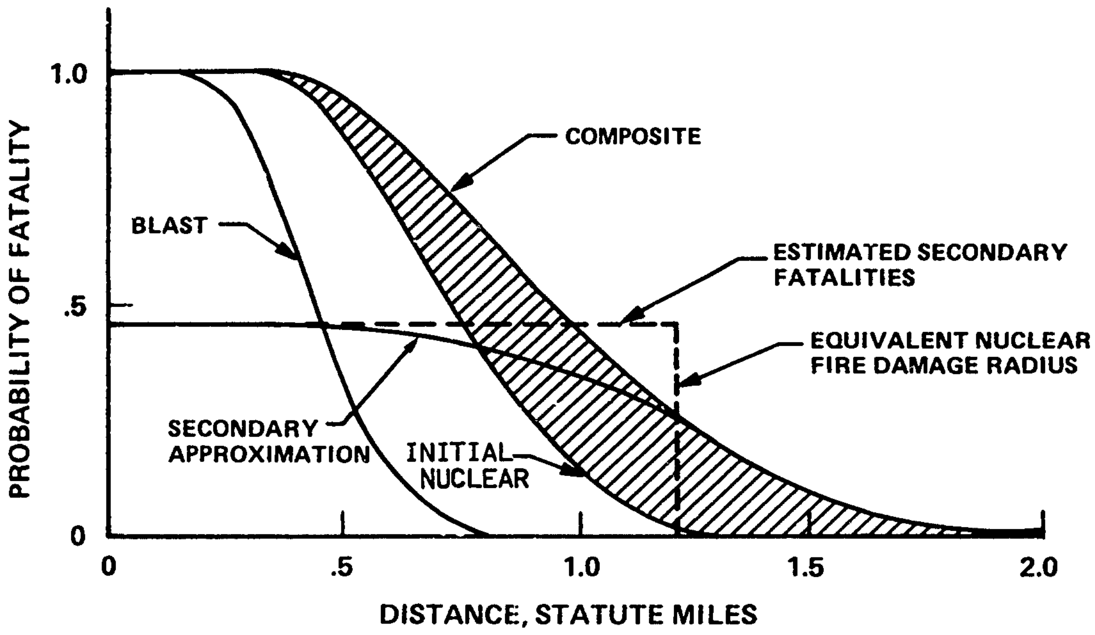

FIGURE 3 COMPOSITE DISTRIBUTION, HAMBURG

discussed in the previous section assault groups are assumed to be autonomous units made up of infantry and related personnel and supported by tanks and artillery units. For this example we have selected three tanks as shown in Figure 4 to represent possible attack points against an assault group. It is assumed that the streets are 60 feet wide and that the civilian population is uniformly distributed in the dwellings at a density of about 120 people per hectare* as shown by the cross-hatched area of Figure 4. Thus there are 62 civilian at risk in the cross hatched area of Figure 4.

It is assumed that a laser guided MK 84 weapon will be launched against each tank. The MK 84 weapon is in the 2000 pound gross weight class, has a CEP of about 10m and the downrange to crossrange dispersion ratio is assumed to be 2 to 1. There are two ways that casualty functions could be determined for civilians in dwellings. One is to use the SIMM model to calculate the damage matrix and the other is to use historical data from German attacks on England during World War II. It was decided that historical data should be most representative of the situation depicted in Figure 4 and that the data on World War II parachute mines (also in the 2000 pound class) would best represent the MK 84. The casualty function for parachute mines against people in dwellings is given in Figure 5. These data can be used to approximate a damage matrix which might be expected from a MK84 bomb as is shown in Figure 6 where the cells are in 20 foot increments.

These data are used as inputs to the multiple matrix model, MUMM, to estimate expected casualties. Casualties for this case are fatalities and personnel who require hospitalization for 30 days or more. Data from World War II suggest that about one-half the casualties will be fatalities. Table 3 summarizes the number of casualties associated with different attacks on the three tanks.

*This is consistent with a maximum census density for a population grid of 30 people per hectare and a bunching of civilians in available dwellings under warned conditions.

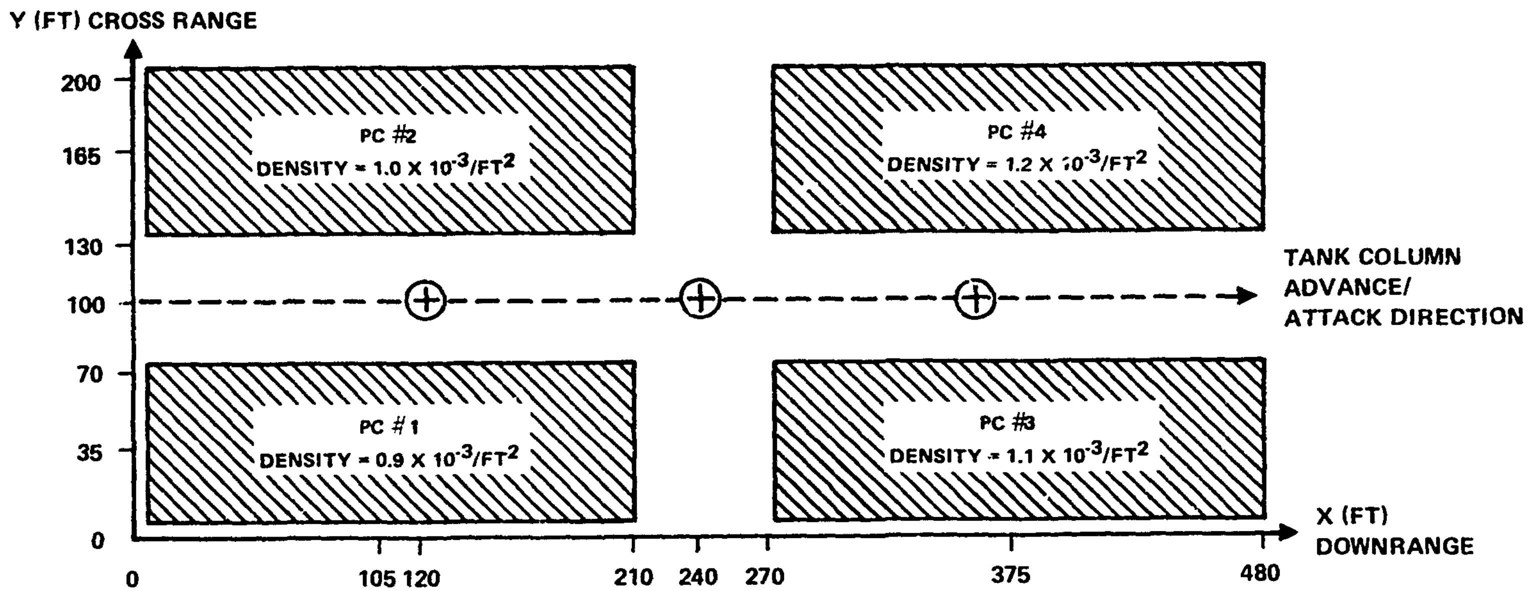

FIGURE 4. ELEMENTS OF AN ASSAULT UNIT

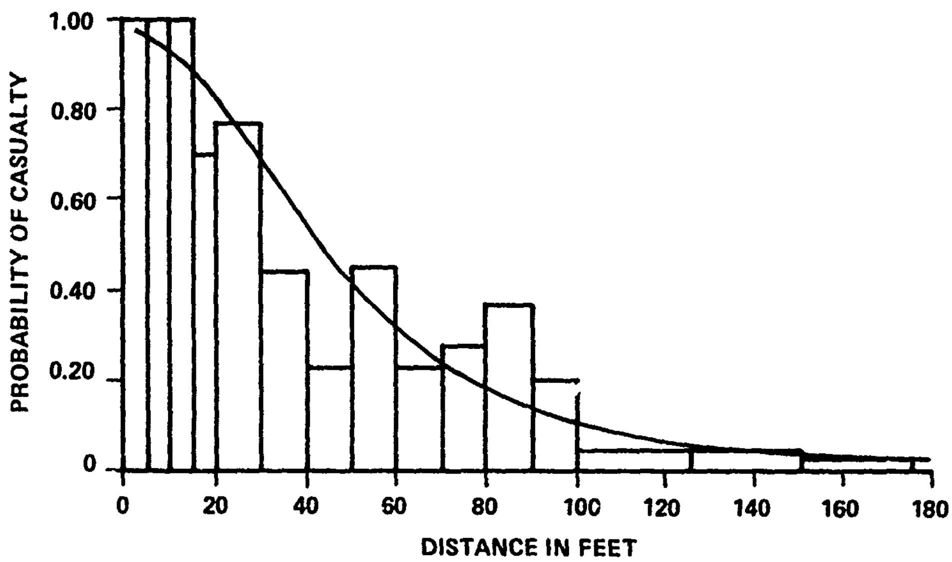

FIGURE 5. PARACHUTE MINES, OBSERVED CASUALTY RISK RATES AND CURVE OF BEST FIT

.02	.02	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.02	.02	.02	.02	.02	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00
.03	.03	.03	.03	.02	.02	.02	.02	.02	.00	.00	.00	.00	.00	.00
.03	.03	.03	.03	.03	.03	.02	.02	.02	.02	.00	.00	.00	.00	.00
.03	.03	.03	.03	.03	.03	.03	.03	.02	.02	.02	.00	.00	.00	.00
.20	.20	.20	.20	.03	.03	.03	.03	.03	.02	.02	.02	.00	.00	.00
.36	.36	.36	.20	.20	.20	.03	.03	.03	.03	.02	.02	.02	.00	.00
.27	.27	.27	.36	.36	.20	.20	.03	.03	.03	.03	.02	.02	.00	.00
.22	.22	.22	.27	.27	.36	.36	.20	.03	.03	.03	.02	.02	.02	.00
.44	.44	.44	.22	.22	.27	.36	.20	.20	.03	.03	.03	.02	.02	.00
.22	.22	.22	.44	.22	.22	.27	.36	.20	.03	.03	.03	.02	.02	.00
.43	.43	.22	.22	.44	.22	.27	.36	.20	.20	.03	.03	.03	.02	.02
.77	.77	.43	.22	.22	.44	.22	.27	.36	.20	.03	.03	.03	.02	.02
.85	.85	.77	.43	.22	.44	.22	.27	.36	.20	.03	.03	.03	.02	.02
1.00	.85	.77	.43	.22	.44	.22	.27	.36	.20	.03	.03	.03	.02	.02

PATTERN CENTER

FIGURE 6 ASSUMED DAMAGE MATRIX FOR A MK 84 – UPPER RIGHT QUADRANT.

Table 3. Casualties at a Hünfeld Intersection

Case	Weapon Laydown Summary (No./DGZ)			Population Center Casualty Summary				
	DGZ #1	DGZ #2	DGZ #3	PC #1	PC #2	PC #3	PC #4	Total
Baseline	1	1	1	3.2	3.6	3.9	4.3	15.0
A	1	2	3	3.8	4.2	8.2	9.0	25.2
B	2	2	2	5.5	6.1	6.7	7.3	25.6
C	4	4	4	8.2	9.1	10.0	11.0	38.3
D	8	8	8	10.7	11.8	13.0	14.2	49.7
X	∞	∞	∞	13.2	14.7	16.2	17.6	61.7

NOTE: For multiple weapons on the same DGZ, no correlation in dispersion errors between weapons has been assumed. This corresponds to multiple passes by one aircraft attacking tanks.

It is unlikely that a nuclear weapon would be used at the intersection for the situation discussed above because conventional weapons are sufficient, nuclear weapons are expensive and would over kill the targets and the collateral damage would be high. If a nuclear weapon was used, it would probably be the minimum yield available. It is informative to determine the expected collateral damage if a 0.1 KT weapon were used. The maximum radius of effect for people in buildings would be 550 m associated with initial nuclear radiation and thus with a maximum density of 30 people per hectare, 907 fatalities could be expected. Fatalities would increase significantly at higher yields.

2.3.4 Assault Units in Hünfeld

Calculations in this section compare collateral casualties due to conventional and nuclear weapons used against assault units located in a section of Hünfeld.

The following definition of Soviet assault units is taken from Reference 6 regarding Soviet assault units of World War II.

"Assault detachments and groups were the basic tactical unit of Soviet forces engaged in assaults on towns and cities. They were formed in the combined-arms as well as the tank units, and their mission was to clear out the individual enemy resistance points in urban combat zones. The detachments ordinarily comprised an infantry battalion, units of combat engineers, and frequently flame thrower troops. These were reinforced by tanks, self-propelled artillery and anti-tank guns. Detachments were subdivided into smaller subunits, called assault groups, which consisted of up to a platoon of infantry and submachine gunners reinforced with 2 to 4 artillery guns, several tanks, and combat engineer and flame thrower troops. Infantry officers were normally in charge of assault detachments because infantry troops were the most numerous elements".

The assumed location of the assault units is shown in Figure 7.

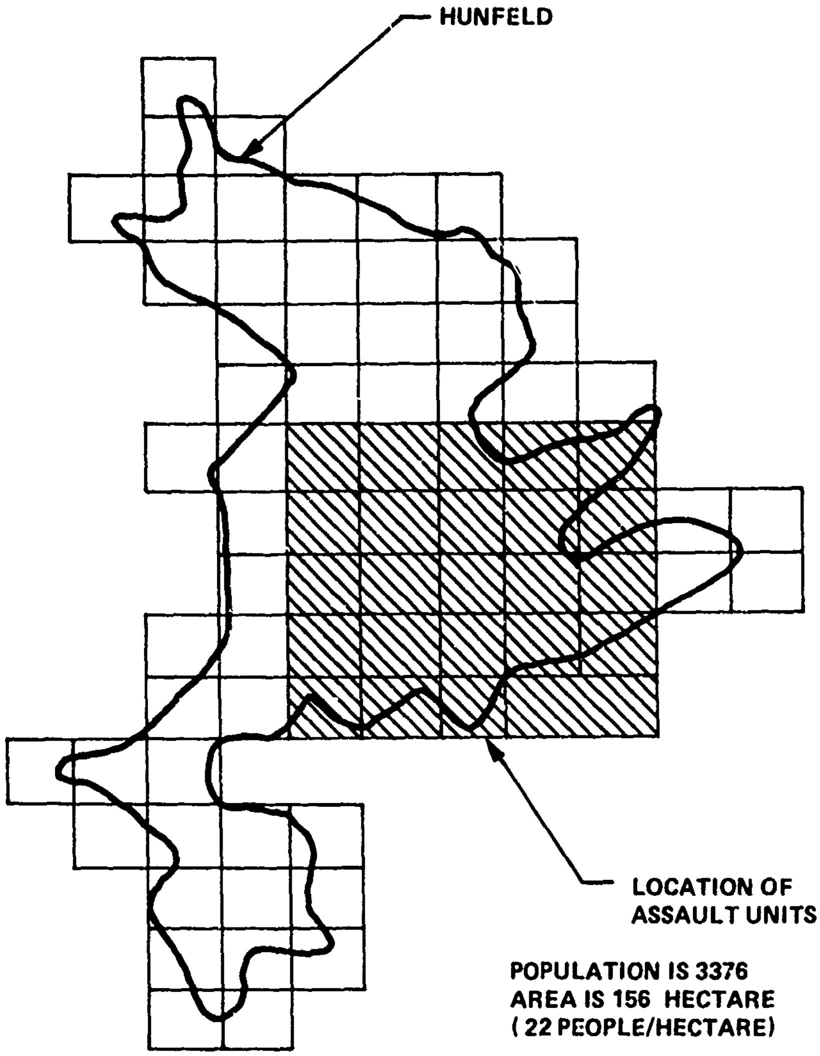

FIGURE 7. ASSAULT UNIT LOCATION

Assault units are assumed to be uniformly dispersed within the cross-hatched area and as noted above are primarily infantry troops and support personnel. If the personnel are not available, tanks and artillery units are essentially ineffective in fighting in built up areas; hence, the military targets can be assumed to be personnel and aircraft attacks with fragmenting bombs are reasonably effective against personnel in areas of this size. The number of bombs required can be computed from Equation 3 if the lethal radius against military personnel can be predicted for each bomb and if the expected fraction associated with unit kill can be determined. Nominally 30 percent incapacitation is considered to nullify unit effectiveness. Using a 30 percent damage level and a lethal radius of 50 feet which is about right for a 750 pound bomb and a prone soldier, 818 bombs of the 750 pound class would be required to disable the assault units. Using these data in Equations (1) through (5) but with civilian lethal radius data it is possible to estimate that there would be 200 prompt fatalities and 172 secondary fatalities for a total of 372 which constitues about 5 percent of the total civilian population of Hünfeld.

On the other hand, the smallest nuclear weapon to achieve 30 percent coverage against this area is 1.0 KT using current technology and perhaps .1 KT using future technology. The area occupied by assault units is 156 hectare and 30 percent of this area corresponds to a radius of about 700 meters. Coverage for a 1.0 KT weapon is shown in Figure 8. The 700 meter distance is exceeded by the mid-lethal radius for initial nuclear radiation for all shelter conditions except basements and sub-basements in multistory buildings.

Also shown are the areas affected by blast, prompt nuclear radiation and fire. These areas are based on a lethal radius which is the radius within which the kill probability is unity and outside of which the kill probability is zero (i.e. "cookie cutter" area). Note that at 1 KT the fire and initial radiation areas are the same.

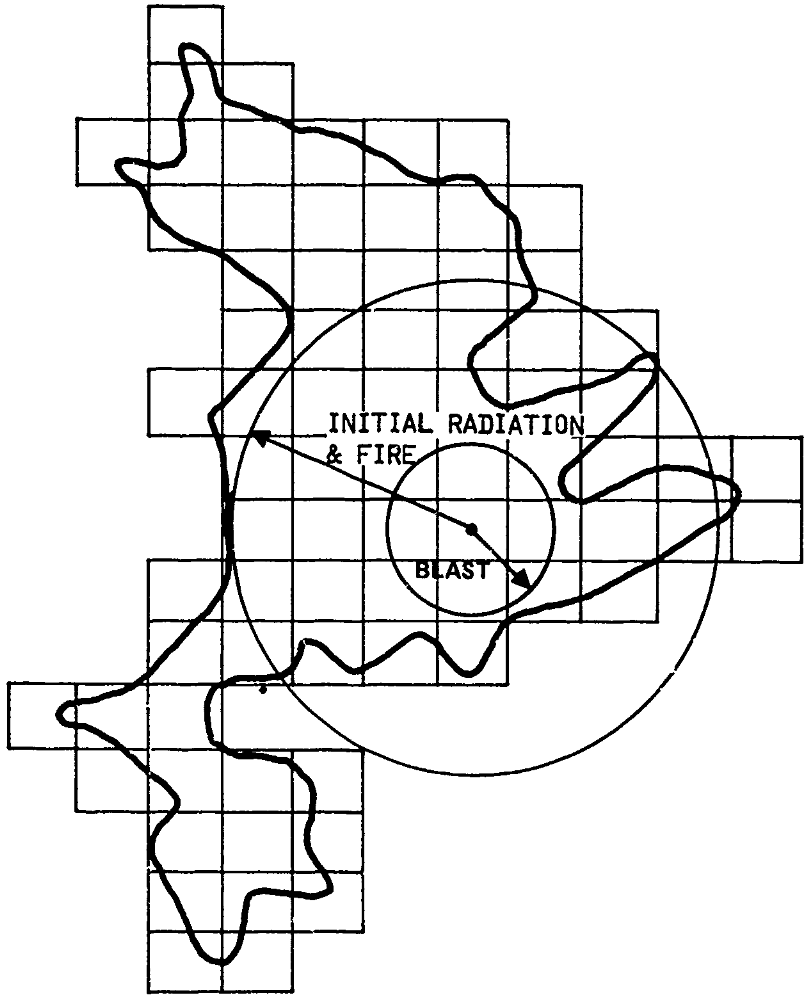

FIGURE 8. NUCLEAR DAMAGE RADII (1 KT)

Table 4 shows the fatalities and percent of Hünfeld population killed as a result of the various nuclear weapon effects of the 1 KT attack on the assault unit.

Table 4. Nuclear attack against assault units

Weapon Effect	Population Killed	% of Total
Blast	902	12
Initial Nuclear Radiation (INR) + Blast	4210	54
Fire + INR + Blast	4210	54

These are in contrast to the 5 percent expected fatalities when a conventional attack is used to accomplish the same objective.

2.3.5 A Tank Battalion Adjacent to Hünfeld

The third microscopic situation of interest involves a Soviet Tank Battalion in column formation along the main highway adjacent to Hünfeld. The location is shown by the crescent shaped solid curve of Figure 9. A conventional attack against the tank battalion is carried out using aircraft-delivered Rockeye weapons. Basic input data are taken from JMEM. The AIDA model is used for various numbers of Rockeyes to determine the number associated with an expected damage to tanks of 30 percent and for this number of conventional weapons the expected civilian fatalities is determined to be 232.

The alternative nuclear attack situation assumes offset aim points where the offset achieves 30 percent fatalities to tank crews at a 3000 rad radiation level but otherwise minimizes civilian collateral damage. The area lethal to civilians is found by determining the offset point for 30 percent radiation incapacitation of tank crews and then drawing the prompt lethal radius for civilians about the offset point.

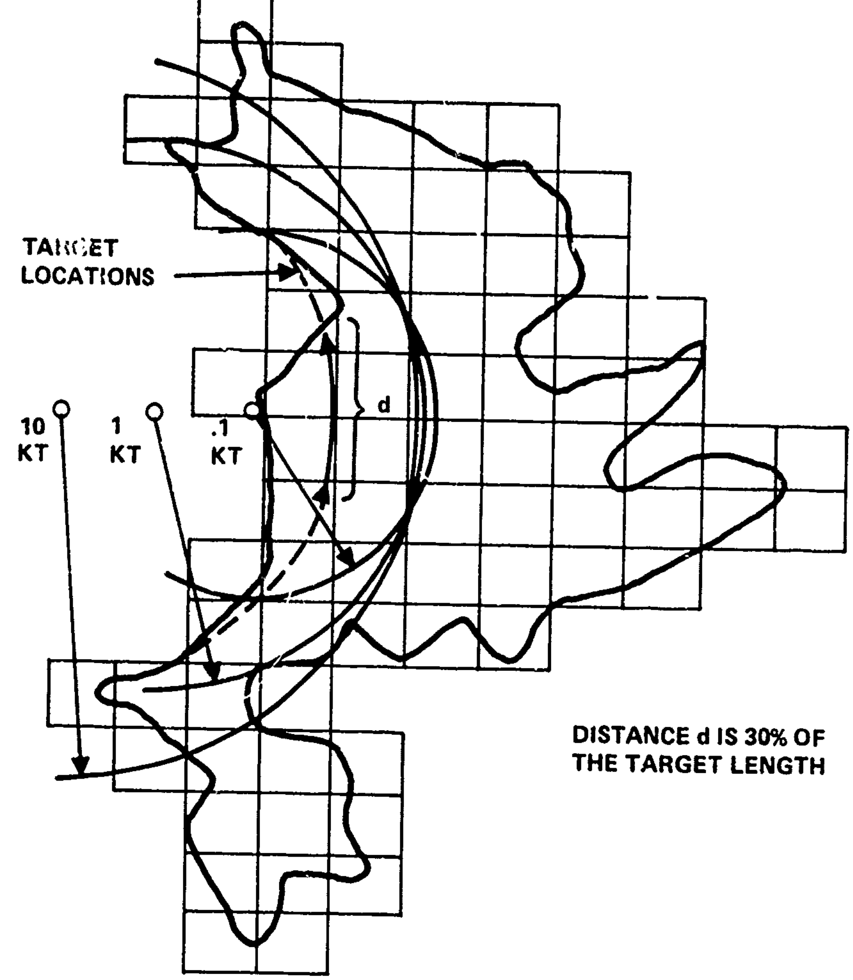

FIGURE 9. NUCLEAR ATTACK AGAINST A TANK BATTALION

Results are shown in Figure 9 for 0.1, 1 and 10 KT nuclear weapons. Clearly, the area lethal to civilians is minimum for the case of 0.1 KT and 1277 fatalities are expected for this case.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 ATTACK ANALYSIS CONCLUSIONS

Fatalities associated with the conventional and nuclear attacks for the five situations are shown in Table 5.

Table 5. Conventional and nuclear attack fatalities.

Situations	Approximate Conventional Fatalities	Approximate Nuclear Fatalities
Hiroshima	55,000	66,000 (12 KT Act)
Hamburg	42,000	70,000 (12 KT Est)
Assault Units in Hünfeld	370	4,200 (1 KT)
Tank Battalion Adjacent to Hünfeld	230	1,300 (0.1 KT)
Intersection at Hünfeld	<30	900 (0.1 KT)

In addition to historical interest, the Hamburg and Hiroshima cases are useful in providing insight into the process of estimating total fatalities from nuclear attacks. In particular, strategic attack analyses of Soviet built up areas should include secondary fatality estimates. This is particularly true for large scale attacks in which random variations in predictive methods will tend to average out. Also as better information becomes available on the impact of blast in extinguishing ignition, the predictive relationships for burned out areas should be adjusted to reflect the changes.

Several aspects of the various attacks on the Hünfeld area are worthy of discussion. First, it is clear from the anlayses that the use of even small nuclear weapons in lieu of conventional weapons probably will cause five to thirty times as many civilian casualties. Second, even when conventional weapons are used with precision against military targets within cities (in lieu of attacking the population directly as in World War II), there will be some unavoidable civilian casualties. Third, the procedures and techniques developed for the analysis of civilian fatalities appear to be useful for a number of purposes. For example, they will permit the evaluation of new weapons and/or attacks doctrines, provide a basis for the education of command personnel who will be responsible for target development and attack doctrines, and provide assistance to civil defense agencies in determining the utility of various forms of protection. Fourth, although the predictive processes have considerable utility for at least the purposes listed above, the use of the tools for operational planning and decisions on microscopic scenarios may be limited because of input data uncertainties and the nature of the decisions to be made. This issue is discussed below.

The number of civilian casualties due to conventional weapons varies directly with the density of the population in close proximity to the target and the density is highly variable for various reasons. The analyses performed for this project have used census information which is the most available (and perhaps the least accurate) description of the spatial distribution of the population. Entirely credible liming cases include: a lower bound in which the population of the city has fled before the MOBA or similar actions have started, and an upper bound where the census population is multiplied by a factor of about three due to an influx of refugees. For the Hünfeld area these bounds imply that the population at the time of the attack could be anywhere from zero to 23,000 and the average number of people per hectare could be from zero to about 50. Experienced command personnel in the field may, under favorable circumstances, be able to reduce this range of uncertainty in the number of people in the city but even if they can the next questions are, where are the people with respect to the target(s), where will they be when the planned attack actually takes place, and what will their sheltering conditions be?

The decision to launch a conventional attack on a military target withi- a small city is likely to be based on a tradeoff between the collateral casualties and the tactical gain achieved by destroying the target. Since no accepted quantitative measure is known to exist that weighs civilian lives against tactical gain, the decision is based on qualitative considerations. A computer code that would predict an expected value of civilian casualties thus has only limited utility. In general, history does not indicate that a field commander will attack only when there is a zero probability of a civilian casualty. The number of such casualties that is acceptable (historically) varies with the circumstances.

Although it has been possible to develop a code for predicting civilian casualties associated with microscopic scenarios, the arguments above indicate that the conversion of the code to a form usable by the armed services in an operational sense does not appear to be necessary. Such a conversion is therefore not recommended at this time.

The need for conversion of a code for determining civilian casualties associated with macroscopic scenarios to a form useful to the armed services is also questionable. It does not appear likely that a conventional weapon attack on Hamburg (or a similar city) would be carried out today in the way that it was in World War II. If collateral damage were the attack objective as it was in World War II then nuclear weapons can be used with devastating effect. If specific targets within the city are to be destroyed and the collateral damage is to be minimized then conventional weapons can be used. If the combination of individual target size and total number of targets is small, the collateral casualties can be determined by analyzing each target in the city with the SIMM or MUMM codes. The arguments against developing an operational code for microscopic scenarios apply here. If the number and size of targets in a city become large then the Random Bombing Methodology can be used to determine collateral fatalities. The equations that make up the methodology are few in number and readily evaluated manually. A computer program should not be needed for such an evaluation and again, the development of a code is not recommended.

In summary, development specifically tailored for use by the armed services does not appear to be necessary at this time. Should the rationale for this conclusion prove to be incomplete or should it become desirable to develop the codes for reasons not currently foreseen the SIMM, MUMM and AIDA codes could be appropriately modified and documented for use by the services in a project that would require six to eight manmonths of effort.

3.2 CODE DEVELOPMENT RECOMMENDATIONS

The models and methods developed in this program which can be used to estimate civilian collateral damage resulting from conventional weapon attacks currently exist as separate entities. Each model can be used as it exists; however, modifications or extensions have been identified that would enhance the utility of each model. Also it may be desirable to combine some of the models into a single higher level computer program for estimating collateral damage. This section recommends extensions to each model and also discusses the development of a higher level model.

3.2.1 Single Matrix Model, SIMM

First consider the single weapon model. As it currently stands this model will provide a damage matrix, a lethal area and a lethal readius for a specified target when a single conventional weapon is detonated nearby. It can be used to determine casualty functions for soldiers, material targets and/or civilians in various sheltering modes such as standing or prone and its output can be used as an input to the multiple weapon model (MUMM), the airfield damage assessment model (AIDA) and/or the random bombing methodology (RBM) and thus is useful in its present form. However, several modifications would make the model more useful in estimating civilian casualties.

One recommendation is that SIMM be modified to calculate and print out the casualty function. For many cases where alternate conventional weapons are being compared, the casualty function can be the means for comparison. Thus a weapon whose casualty function had the greatest range in effect against a military target might be preferred. SIMM currently prints out matrix data which can be used to determine a casualty function, but direct print out of the casualty function is not accomplished.

The second suggested modification to SIMM is to increase the number of civilian shelter categories which can be treated and to include the shielding effects of intervening walls. It is believed that the material target part of SIMM could be used to simulate different civilian sheltering situations where subelements of differing wall material are assigned threshold data relating to fragment mass and velocity.

3.2.2 Multiple Matrix Model, MUMM

The multiple weapon model is currently capable of estimating casualties based on output data from SIMM, accuracy data on the conventional weapon and area/value data on the targets for multiple weapons of the point detonating kind. It is suggested that MUMM be modified to handle advanced area weapons. Alternative approaches should be implemented to insure that computer costs and running times would be acceptable when area weapons are simulated.

MUMM currently uses weapon impact points, population descriptions and a single weapon damage function specified by the user. Thus it is possible to use MUMM to compute damage to material targets as well as civilian populations. At this time the computations would have to be performed sequentially and it is suggested that they be done in parallel.

An option for alternate population center shapes should be incorporated. This would add to the versatility of the code since only rectangular uniform and circular Gaussian distributions are available at this time.

3.2.3 Airfield Damage Assessment Model, AIDA

As it currently stands AIDA can handle area weapons and point detonating weapons, however, it only accepts rectangular patterns of area weapons. Since many of the advanced area munitions that are currently under development or being studied involve elliptical patterns, it is recommended that AIDA be modified to accommodate such patterns.

3.2.4 Random Bombing Methodology, RBM

The random bombing methodology when used to compare high level conventional attacks with nuclear attacks against cities is based on equal building burn out areas for the two situations. As such, a primary uncertainty involves the functions which are used to estimate building burn out areas for nuclear attacks. The degree to which the blast wave can be expected to extinguish ignitions is controversial and directly contributes to uncertainty in predicting the burned out area. It is likely that laboratory tests and simulations will be carried out to resolve these blast ignition-related uncertainties. As the results become available, computer programs which predict fire start and spread as a result of nuclear attack should be exercised and predictive algorithms should be developed sc that more accurate predictions of secondary damage from nuclear attack can be made. As these prediction uncertainties are reduced appropriate changes should be made in the equations associated with the nuclear part of the random bombing methodology.

3.2.5 Future Development

The recommended procedure for using the models and methods which have been developed or modified under this contract is to use SIMM to obtain a damage matrix which is; (1) input to MUMM along with accuracy data on the weapons and area data on the target density or value; or (2) converted to a lethal radius and used in AIDA: or (3) converted to a lethal radius and used in the RBM relationships. Some of these procedures could be combined in a higher level computer program where each of the current models become subroutines to the larger program. This would result in a rather cumbersome program if AIDA is included and therefore it is recommended that AIDA be kept separate. However, combining SIMM, MUMM and RBM could result in a useful tool for evaluating civilian collateral damage for situations of interest. Thus, if the area of the engagement, military target locations and characteristics, civilian locations and sheltering conditions and weapon characteristics could be specified, the program could calculate casualty functions, estimate target damage and estimate civilian casualty data based on whichever mode -- MUMM or RBM -- was considered appropriate.

The primary reason for combining these models into a single program would be to improve the speed and efficiency with which the required results would be obtained. The need for this improved efficiency is dependent upon the frequency of use and until it is demonstrated that the models will be used often it is suggested that thev remain separate.

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