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JUNE 1965

AGGREGATE NUCLEAR DAMAGE ASSESSMENT TECHNIQUES APPLIED TO WESTERN EUROPE (U)

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SANTA MONICA • CALIFORNIA

[redacted]

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PREFACE

This RAND Memorandum on nuclear damage assessment techniques applied to Western Europe was undertaken at the request of the Office of the Secretary of Defense (International Security Affairs). The study has three purposes: (1) to present building blocks for making estimates of civil damage to Western Europe in general war, (2) to illustrate the use of these building blocks, and (3) to present summary data on the effects of strategic nuclear weapons used against Western Europe in alternative ways.

Studies of potential mortalities and casualties in general war are often accused of raising issues which should not be discussed, let alone analyzed. But how else can proper weight be given to the civil damage implications of alternative defense programs? Such an analysis also realistically evaluates the usefulness of measures proposed to reduce or alleviate damage.

No specific policy is endorsed here, but the tools are presented with which the reader can determine the mortalities and/or casualties that would result from alternative enemy attacks. The reader must design his own attack and make his own policy decisions.

The Memorandum is designed to be of use to those who have only rudimentary knowledge of targeting and the effects of nuclear weapons but who need a quick means of computing civil damage to Western Europe, given various assumptions about Soviet strategic capabilities and tactics. It is emphasized that the Memorandum presents damage assessment techniques, not campaign analysis. The user must specify the nature of the attacks to be analyzed.

SUMMARY

This RAND Memorandum presents aggregate techniques for computing civil mortalities and casualties from general war in Western Europe. Mortalities and casualties directly inflicted from blast and fallout may be computed for counterforce and/or counterurban attacks for all of Western Europe or on a country-by-country basis. These techniques can be used without recourse to computer calculations. However, they are based on and have been checked by computations made with a detailed damage assessment program. The program is designed for use with high speed electronic computers.

For Soviet counterforce attacks, estimates of civil blast damage can be made by using the techniques in Section II. If these attacks use groundburst weapons, the damage from fallout can be found by using Section III. For Soviet counterurban attacks, Section IV can be used to estimate damage from both blast and fallout. For mixed counterforce and counterurban attacks, Sections II, III, and IV may be used in combination to compute total civil damage to Western Europe.

Only mortalities and casualties directly attributable to the effects of nuclear weapons are incorporated. Admittedly, indirect causes, such as disease and exposure, would also be significant, but no attempt to estimate such damage is made here. To do so would require too many uncertain assumptions about the postattack environment and the behavior of both populations and governments.

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I. INTRODUCTION

Hand and computer techniques both have limitations for assessing damage from nuclear attack. If many cases and many weapons per case are involved, hand techniques are too slow and tedious. Computer techniques are simply not available to many interested groups, and when they are, the study time is lengthy in spite of the high speed. Furthermore, it is often difficult to see why results come out as they do when much of the computation is buried in a machine. Consequently, sensitivity analyses cannot be conducted quickly and effectively.

There are several reasons for providing policy makers and analysts with damage assessment techniques that are simpler and quicker than the usual computer models or the detailed hand computed models. First, aggregate and approximate measures of damage are often sufficient for decisionmaking or study purposes, and rough answers early in the deliberations are more valuable than refined estimates late in the process. Second, it is frequently difficult to make adequate predictions as to which comparisons will be required. Simple techniques may fill a study gap although more detailed damage assessments must still be carried out by computer. Third, simple damage assessment techniques can give policy makers a better grasp of critical relationships. They are then better able to assess the validity of results, to judge the significance of assumptions, and to determine requirements for additional sensitivity analyses. Thus, simple techniques should lead to damage assessments that are timely and relevant to current strategic debate.

NATO's contingent planning for the possibility of general war and its choice of strategic nuclear forces require quantitative comparisons of alternative strategic programs. One important element in such comparisons is damage to Western Europe from different types of Soviet attacks -- first strike, second strike, counterforce, counterurban, restrained, or unrestrained. This Memorandum presents data for the rapid assessment of major components of this damage -- the number of directly inflicted civil mortalities and casualties.[1] All the basic calculations and much of the discussion is in terms of mortalities. However, the results are given parametrically and, as is shown below, casualties can be estimated as well by suitable changes in these parameters.

Section II contains curves and data for computing blast mortalities or casualties in Western Europe by target category, given different weights of attack.[2] Because civil blast damage is often concentrated at points within a target system highly collocated with population, we present data on the collocation of civilian population with important target systems in Western Europe. The curves and data in Section II are based on results derived from the Quick Count model, an electronic computer damage assessment program developed at The RAND Corporation.[3]

If weapons are groundburst, mortalities and casualties due to fallout must be incorporated in the estimate of civil damage. Curves and formulae for doing this are presented in Section III. Fallout deposited by one weapon will often overlap with fallout from other weapons. In such regions the radiation from different weapons must be added. Hence, it is usually impossible to attribute fallout damage to any one target system. Nor is it possible to attribute the fallout damage in any country to the weapons that detonate in that country. However, so long as the general geographic distribution of different

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[1]The term "casualties" includes both dead and injured.

[2]Although the threat of fire, either firestorm or conflagration, is an important element to consider in the design of civil defense programs, most estimates for a population without special shelters lead to a greater vulnerability to blast effects and hence blast damage can be taken as a reasonable approximation to blast and fire damage.

[3]See L. H. Wegner, Quick Count -- A General War Casualty Estimation Model, The RAND Corporation, RM-3811-PR, August 1963 (For Official Use Only). For more detailed information on the mechanics of the program, see N. D. Cohen, The Quick Count System: A User's Manual, The RAND Corporation, RM-4006-PR, April 1964 (For Official Use Only). Quick Count, like most damage assessment models for use with computers, is simply a mechanization of detailed hand damage assessment techniques. Appendix D briefly discusses the model and input assumptions.

attacks is the same, the damage due to fallout is primarily determined by a parameter reflecting the total amount of radioactive material deposited -- the total fission megatons delivered groundburst.[1] Section IV presents results in terms of this parameter for cases where attacks widely cover Western Europe. Appendix B gives the results country by country but again on the assumption that the attacks are on all of Western Europe.[2]

Section IV presents data on attacks against the urban population. Blast damage is given for three levels of aggregation. At the highest level of aggregation, curves are presented that show the maximum damage the Soviets could inflict over all Western Europe for different weights of counterurban attack, with and without countermilitary attacks. However, as the user of this Memorandum may wish to investigate other Soviet allocations of weapons to urban targets, results are also given permitting him to do this country by country or city by city. Some results combining blast and fallout are also given for those who wish to appraise the total damage inflicting potential of Soviet counterurban attacks without additional calculations.

Section V uses the building blocks of the previous sections to generate results for hypothetical Soviet attacks. These cases and others have been compared with Quick Count runs of the same cases to check that the approximate methods of combining the damage from different parts of an attack agree with the Quick Count model, which looks at combined effects population point by population point. The examples illustrate how the reader can make his own attack assumptions and arrive at an assessment of the resulting civil damage.

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[1] Thermonuclear weapons derive part of their energy from fission of nuclei -- the fission yield -- and part from fusion of nuclei -- the fusion yield. The fraction of the total yield due to fission is the <u>fraction fission</u>. The preponderance of fallout radioactivity is from fission products that are captured by vaporized solids as they congeal and return to earth. Hence the importance of <u>megatons fission products groundburst</u> in fallout.

[2] Because of limitations of the computer, in some cases it has been necessary to combine countries into country groups.

The building blocks presented here can be used as either a step toward more detailed analysis or as a quick way to vary the assumptions in more detailed analysis. Section VI summarizes the techniques and cautions against their misuse. All the techniques used here provide only approximate, aggregate results. Any requirement for greater precision necessitates the use of detailed computer models. However, even computer models are limited in their accuracy by the quality of information available on weapons effects and population location.

It should be emphasized that this Memorandum provides only a civil damage assessment model. There are a number of readily available manuals for computing the effects of nuclear weapons on military targets.[1]

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[1]Especially the Physical Vulnerability Handbook -- Nuclear Weapons (U), Prepared by Defense Intelligence Agency Production Center, PC 550/1-2-63, September 1, 1963 (Confidential). This publication supersedes AFM 200-8, Nuclear Weapons Employment Handbook, September 1, 1961.

II. BLAST DAMAGE FROM MILITARY ATTACKS

This section presents data for the reader's computation of blast mortalities or casualties by target category in Western Europe.[1] These data will also allow the reader to judge opportunities for the reduction of civil damage by selective restraint or by changes in deployment or dispersion to minimize the collocation of civilians with military targets. Hence, data are presented separately for targets with 50,000 or more people within 4 n.mi., labeled "collocated," and targets with less than 50,000 people within 4 n.mi., labeled "noncollocated." As all major ports could be classed as collocated according to this criterion, they have been separated into ports with 200,000 or more people within 4 n.mi., labeled "very collocated," and ports with less than 200,000 people within 4 n.mi., labeled "partially collocated." A breakdown of the targets by category, country, and collocation is given in Table 1.

Blast mortalities from uniform attacks against each target system were computed using the blast damage assessment portion of the Quick Count program for one and two weapons per target airburst and for yields from 40 kilotons to 5 megatons. The results are presented graphically in Figures 1 to 9.[2] The results for the collocated and noncollocated portions of the target categories are presented in Figures 10 to 15. Note that, in order to fit curves on the graph paper, <u>different figures have different vertical scales</u>. The results for attacks against several target systems can be approximated simply by adding the results at each target system.

Although the curves are designed to be read directly in terms of mortalities for airburst attacks of a specified yield they can also be used to find casualties for airburst attacks or mortalities or casualties for groundburst attacks as explained below.

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[1]The results are presented in tabular form by country in Appendix B. Because of computer limitations it has been necessary to combine some countries into country groups.

[2]All text figures will be found on pp. 35-67.

Table 1

NUMBER OF TARGETS BY CATEGORY, COUNTRY, AND DEGREE OF COLLOCATION WITH CIVIL POPULATION

Target Category	Population Within 4 n.mi. (thousands)	Scandinavia: Denmark	Scandinavia: Norway	Benelux: Belgium	Benelux: Netherlands	Benelux: Luxembourg	Iberia: Portugal	Iberia: Spain	France	Germany	Greece	Italy	Turkey	United Kingdom	Total	
Primary offensive airfields	≥ 50				5			1	4	2			2		14	102
	< 50	5	5	9	6		3	6	14	21	6		6	7	88	
Secondary offensive and defensive airfields	≥ 50			1	1	1	1		6	5		5	2	6	28	181
	< 50	3	9		2		4	7	41	33		14	13	27	153	
Reserve airfields	≥ 50		1	1					3			3		2	10	81
	< 50		1	1				3	20		2	11	6	27	71	
Nuclear submarine ports[a]	≥ 50							1	2			1			4	7
	< 50		1		1								1		3	
Major ports[b]	≥ 200	1		3	2		1	4	6	3		5	2	12	39	98
	50-200	5	6	1	5		1	8	8	3	2	8	2	10	59	
Army materiel depots	≥ 50		3	2		1		6	10	22	1	2	6		53	163
	< 50	3	15	4			1	5	9	43	6		24		110	
Major command centers									2	7					9	9
Nike sites										40					40	40
Hawk belt[c]										46					46	
Totals		17	41	22	22	2	11	41	125	225	17	49	64	91	727	

Notes:

[a]Including ports used by submarine tenders.

[b]These exclude the nuclear submarine ports. All the major ports have 50,000 or more civilians within 4 n.mi. Therefore, for this target class we have listed those ports where the collocated population is 200,000 or more.

[c]Only a portion of the Hawk belt sufficient to permit aircraft penetration was used.

A CEP (Circular Error Probable[1]) of 0.5 n.mi. and delivery probability[2] of 0.7 were used. Mortalities are not sensitive to the CEP of the attacking weapons, and hence these curves can be used for 0 to 1 n.mi. CEP.[3] They can also be used for different delivery probabilities and number of weapons per target by means discussed below.

As an example of the use of the figures, consider an attack in which all weapons are 3 MT airburst with 0.7 delivery probability. Two weapons per target are sent to primary offensive airfields (Figure 1) and one weapon per target to secondary offensive and defensive airfields. Reading the n = 2 curve of Figure 1 and the n = 1 curve of Figure 2 at 3 MT one has:

Target Category	Weapons per Target	Yield	Blast Mortalities (millions)
Primary airfields (102)	2	3 MT	4.7
Secondary airfields (181)	1	3 MT	11.5
Total blast mortalities			16.2

A total of 2 (102) + 181 = 385 weapons were assigned and blast mortalities were 16.2 million. Since no groundburst weapons were used, additional mortalities from fallout would be negligible.

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[1]The CEP is a measure of weapon accuracy -- it is the radius of the smallest circle in which 50 per cent of a large number of shots would be expected to fall.

[2]Throughout this Memorandum the delivery probability includes the overall probability that a weapon assigned to a target actually detonates at or near it. Incorporated in the delivery probability are factors of reliability, probability of surviving a prior attack, and, for aircraft, probability of surviving defenses. The 0.7 figure would be representative of surface-to-surface missiles launched prior to any United States Allied Command Europe (referred to hereafter as U.S.-ACE) attack or submarine-launched missiles under first or second strike conditions.

[3]However, the CEP would enter into the enemy's calculation of kill probability at the military targets under attack and thus would affect his decision as to what yield and number of weapons was satisfactory from his point of view.

Suppose that now the attack is varied so that the yield at all these targets is reduced to 40 KT. Then the total mortalities would be 0.3 + 0.6 = 0.9 million.

As a more complicated example using the breakdown into collocated and noncollocated targets, assume that 40 KT weapons are used but now the collocated airfields (14 primary and 28 secondary) are not hit. Then using Figures 10 and 11, one has:

Target Category	Weapons per Target	Yield	Blast Mortalities (thousands)
Noncollocated primary airfields (88)	2	40 KT	190
Noncollocated secondary airfields (153)	1	40 KT	430
	Total blast mortalities		620

Thus removing 42 targets (15 per cent) has reduced mortalities from 900 thousand to 620 thousand.

VARIANTS -- GROUNDBURST, CASUALTIES, DIFFERENT VULNERABILITY ASSUMPTIONS

Weapons effects handbooks and damage assessment models (including Quick Count) compute blast damage by means of the weapon radius parameter.[1] Vulnerability assumptions, height of burst, and yield all enter into the calculation of expected blast damage by means of the weapon radius.

If results of blast damage calculations are plotted against the weapon radius they may then be used for any yield and height of burst and vulnerability assumptions by computation of the appropriate weapon radius. If mortality vulnerability assumptions are used to determine the weapon radius, the results will be estimated mortalities; if casualty vulnerability assumptions are used the results will be estimated casualties.

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[1]The weapon radius is approximately the distance from the point on the ground directly under the weapon (ground zero) to the point at which there is a 50 per cent chance of receiving the given level of damage. See Physical Vulnerability Handbook -- Nuclear Weapons (U), I, p. 35 for a precise definition.

At the top of Figures 1-15 there is a weapon radius scale showing the radii used in the Quick Count calculations. These radii correspond to the assumption of 50 per cent probability of death at 7 pounds per square inch (psi) overpressure[1] and a height of burst of $500 \cdot (y)^{\frac{1}{3}}$ feet where y is the yield of the weapon in megatons.[2]

Figure 16 serves as an aid in the use of Figures 1-15 for computations of other than blast mortalities from airburst attacks. It is a plot of weapon radius versus yield for computing casualties from air-burst attacks, and mortalities and casualties from groundburst attacks. The casualty radii are based on a criterion of 4 psi for 50 per cent probability of casualties. This is intended to encompass both severely and moderately injured, that is, those requiring and not requiring hospitalization. Undoubtedly, many of the injured would in fact die and the casualty results might better approximate blast mortalities under many circumstances.

For example, assume that two weapons of 3 MT each are assigned to the primary airfields, all groundburst. Then from Figure 16 the groundburst weapon radius is 3.1 n.mi. At this weapon radius Figure 1 gives (n = 2 curve) 2.6 million blast mortalities instead of the 4.7 million previously arrived at for the airburst case.[3] Although groundbursting lowers blast mortalities it introduces fallout and, under present fallout shelter conditions, would lead to a net increase in total (blast and fallout) mortalities.

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[1]A human being can withstand pressures well in excess of 7 psi. This number is a measure of the blast resistance of sheltering readily available to a properly instructed populace provided it receives and acts to take cover on warning -- an assumption consistent with an attack following a period of intense crisis.

[2]In the terminology of Weapon Effects this is a "scaled height of burst" of 500 ft. This scaled height of burst approximately maximizes weapons effects against soft targets, for examples, aircraft and ordinary construction.

[3]See p. 7.

DELIVERY PROBABILITIES OTHER THAN 0.7

The above examples have used only the delivery probability of 0.7. We will now present formulae that can be used to determine mortalities and casualties for other delivery probabilities. The formulae below are derived in Appendix A.

Let p be the delivery probability to be used. Let m(1) and m(2) be the mortalities as read from the graphs for one and two weapons per target, respectively. They are exact for one and two weapons per target. For more than two weapons per target approximations are given.

The mortalities for one weapon per target of delivery probability p can be stated

$$\left(\frac{p}{0.7}\right)m(1).$$

For two weapons per target with delivery probability p the expected mortalities are

$$2\left(\frac{p}{0.7}\right)\left(1 - \frac{p}{0.7}\right)m(1) + \left(\frac{p}{0.7}\right)^2 m(2)$$

Notice that the first term will be negative if $p > 0.7$.

As an example, suppose two 3 MT weapons per target are assigned airburst to primary airfields with a reliability of 0.8 but that prior U.S.-ACE strikes leave only a 0.2 chance that the attacking system has survived. Then the overall delivery probability is $p = 0.2(0.8) = 0.16$ and $p/0.7 \simeq 0.23$. Figure 1 at 3 MT for one and two weapons per target, respectively, gives m(1) = 2.8 million and m(2) = 4.7 million. With the above formula, expected blast mortalities at this target class are $2(0.23)(1 - 0.23)2.8 + (0.23)^2 4.7 = 2(0.23)(.77)2.8 + 0.05(4.7 = 0.99 + .24 = 1.23$ million.

For more than two weapons per target, let n be the number of weapons per target. The simplest approximation is to use the formula above for two weapons per target but replace p by np/2. This will be a good approximation, provided np is less than or equal to 2 and n is not too large (see Appendix A). This should handle most cases, because usually a value of $np > 2$ will lead to an overkill of the military target. A better but more complicated approximation that should give good results for larger values of n and np is

$$\frac{m(1)}{K}\left[1 - \left(1 - K\frac{p}{0.7}\right)^n\right] ,$$

where

$$K = 2 - \frac{m(2)}{m(1)} .$$

This formula reduces to the formulae for one and two weapons given above when n is 1 or 2.

HETEROGENEOUS COUNTERFORCE ATTACKS

Different systems will usually attack a given target class. If they all have about the same yield, one approximation to the total damage would be to use the formula for two weapons per target with p replaced by one-half the expected number of weapons delivered.[1]

If weapons of substantially different yield are assigned and the expected number of the larger yield weapons delivered is greater than the expected number of smaller yield weapons, then the smaller weapons can probably be ignored. If, however, more of the smaller yield weapons are expected than the larger ones, the result may be quite different. A more accurate approximation for the case of two yield types can then be used. Take the mortalities to be

m(small only) · prob (no large) + m(large only)

where prob (no large) is the probability that no large weapons are delivered to an individual target[2] and m(small only) and m(large only) are expected mortalities due to each type, assuming the other is not used, computed as above.

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[1]The expected number of weapons delivered is the sum of the delivery probabilities of all weapons allocated to the target. Thus if two weapons of 0.3 delivery probability each and one weapon of 0.2 delivery probability are assigned, the expected number delivered is 0.3 + 0.3 + 0.2 = 2(0.3) + 0.2 = 0.8 weapons.

[2]The probability that a single weapon will not be delivered to a target, the "nondelivery probability," is one minus the delivery probability. If several weapons are assigned to a target the probability that none of them arrives is the product of the nondelivery probabilities of the individual weapons.

III. FALLOUT AND COMBINED BLAST AND FALLOUT COMPUTATIONS

Fallout damage is both variable and uncertain. Even if we assume that all aspects of an attack are known and remain fixed, potential fallout mortalities would vary from day to day because of wind directions. This variability is particularly large when the population is relatively unprotected, as is the case in Western Europe. For this reason, thorough damage assessment studies examine fallout damage for a spectrum of wind maps. Results are given in terms of averages or averages and ranges.

Computations of fallout mortalities are uncertain for several other reasons. First, we know little about enemy targeting, for example, whether weapons would be airburst or groundburst at different target systems. Second, there are uncertainties about enemy weapon characteristics, particularly the total yield and the fraction fission yield. Third, there are uncertainties in population reaction. Would the population be able to find fallout protection? How long would the population remain in shelters? Finally there is inadequate knowledge of parameters basic to fallout damage computations, for example, the mid-lethal dose (the radiation that would be fatal to 50 per cent of the populace exposed to it) and the residual radiation level (the total radiation deposited by a 100 per cent fission weapon).

The labor of computing fallout damage for a full sized attack by laying out fallout patterns by hand is so great that electronic computer techniques are mandatory if a sufficient number of cases are to be run to be useful in analysis or planning. Nevertheless, for attacks over roughly the same area and with fixed civil defense assumptions, the dominant factor is the total weight of attack expressed in the number of megatons fission products from groundburst weapons. Figure 17 plots mortalities due to fallout only versus weight of attack for widespread military attacks against airfields, ports, and a few command and control points in Western Europe. Also plotted are the fallout only mortalities resulting from attacks against urban areas. Figure 17 can be used to make a crude estimate of the range of mortalities to be expected from fallout. A breakdown of mortalities by country can be found in Appendix B for attacks covering Western Europe.

For the military attacks four winds were run. The numbers 1 through 4 on the graph refer to these winds, as tabulated below:

Wind Maps	
Number	Date
1	12-15-51
2	5-15-52
3	5- 5-52
4	9- 5-52

Wind 2 was used for the counterurban attacks. Figure 17 should not be used if an attack is concentrated on just a few countries or in other ways deviates strongly from a distribution of targets covering Western Europe. In any case, it is good only for rough estimates.

Appendix C discusses the Random Bomb Drops method of computing fallout damage and compares results using that method with the results in Figure 17. Appendix C also summarizes the shielding and other fallout assumptions used in the computations.

CASUALTIES

A commonly used mid-lethal dose for computing casualties due to radiation sickness is 200 roentgens. As a rough approximation of the combination of fatalities and casualties, Figure 17 can be read at a level corresponding to 2.25 (450/200) times the megatons fission of the actual attack.

EFFECTS OF FALLOUT SHELTERING

The fallout calculations of Figure 17 are based on the assumption that 70 per cent of the population is in sheltering such as that found in houses (a mean shielding factor of 0.5), 25 per cent is in sheltering such as basements of houses (a mean shielding factor of 0.1) and the remaining 5 per cent is in sheltering like that found in the basements of large buildings or the middle floors of large undamaged buildings (a mean shielding factor of .02). These assumptions are consistent with the present lack of civil defense instruction and storing of food in shelter areas.

The results of Figure 17 would be changed significantly if different levels of preparedness were assumed. To give some idea of the sensitivity of results to the degree of protection assumed, the tabulation below shows the mortalities due to fallout only for three different attacks if all the population were in houses, basements, or special shelters. The results were obtained by the Quick Count model and, of course, are illustrative only, since in any civil defense posture there would be a distribution of people in different types of shelters. Mortalities are in millions.

Mortalities for basic shelter assumptions (mixture of shelter types)	Mortalities if all the population is assumed to be in sheltering equivalent in protection to		
	Houses	Basements	Special Shelters
38	47	18	0.2
48	60	24	0.5
112	130	82	1.0

Note that if all the populace had special shelters, mortalities due to fallout only would be reduced from 112 million to 1 million (the last attack shown). This result should be taken as indicative of the value of fallout shelters to those occupying them. It should not be interpreted as meaning that a fallout shelter program could keep fallout mortalities as low as 1 million in such an attack because the entire populace does not have these shelters. The experience of the United States civil defense program indicates that it is relatively inexpensive to provide shelters to a sizable fraction of the population by taking advantage of existing structures, but that to attempt to provide shelter spaces for all is very difficult and costly.

COMBINED BLAST AND FALLOUT DAMAGE

Quick Count runs computed mortalities due to blast alone and fallout alone, and total mortalities. The sum of mortalities due to blast alone and fallout alone are greater than total mortalities because of double counting but this can be corrected by using the following equation (developed by least squares fitting).[1]

$$T \doteq B + F - BF/237$$

where T is total mortalities, B the mortalities due to blast only, and F the mortalities due to fallout only, all expressed in millions. Similar equations are derived for each country or country group in Appendix B. Figure 18 presents the equation in graphical form. Along the horizontal axis we have plotted fallout only mortalities and on the vertical axis, blast only mortalities. Combined mortalities are given where the fallout only line intersects the blast only curve. For example, if blast only mortalities are 60 million and fallout only mortalities are 60 million, then combined blast and fallout mortalities are not 120 million, but (with double counting eliminated) approximately 105 million.

[1]The equation gives total mortalities to within 5 per cent for all cases tested but is probably not valid much beyond 200 million, a range in which damage assessment is not too meaningful in any case.

IV. COUNTERURBAN ATTACKS

BLAST AND FALLOUT MORTALITIES BY COUNTRY OR COUNTRY GROUP

Figures 19-27 present mortalities by country or country group as a function of "standard" 5 MT weapons launched and groundburst against urban targets on the assumption that such a Soviet attack attempts to maximize total mortalities.[1] The standard weapon has a delivery probability of 0.7, an assumed fraction fission of 0.3, and a CEP of 1 n.mi.[2]

The calculations are based on an undamaged Western European population, that is, the population has suffered no prior damage from counterforce attacks. If the population has suffered prior damage from countermilitary attacks, then mortalities from the counterurban attack would be lower because less of the population would be left. However, total mortalities would be greater.[3] These curves and the city-by-city data presented below were constructed using a subroutine of the Quick Count model -- the Urban Ground Zero Selector. This routine selects aim points for urban weapons and presents more detailed output but at the expense of using a more restricted population data base than that used for full Quick Count runs. It omits population in outlaying areas of cities. Hence, the results are somewhat lower than they would be if the more complete data base had been used. Figures 31 and 32, discussed below, use the more complete data base.

The curves presented in Figures 19-27 represent the outcome to Western Europe if all Soviet weapons are allocated to cities in a first

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[1]The numbers on the curves refer to the attacks on all of Western Europe and will be explained later. Figure 33 presents curves for converting airburst weapons into groundburst blast equivalents and may be used in conjunction with Figures 19-27 to compute blast mortalities from airburst weapons. Thus 100 weapons airburst are equivalent to 150 groundburst. Reading Figures 19-21 at 150 weapons, blast mortalities for the United Kingdom, West Germany, and France would be 26, 13, and 14 million, respectively.

[2]If a delivery probability (p) other than 0.7 is used, then multiply the curve data by p/0.7 times the number of weapons assigned. This formula is reasonably accurate for p between 0.5 and 1.

[3]See Figure 31.

strike, before ACE retaliation has reduced Soviet strategic capabilities. The curves can also represent the Soviet damage inflicting capability -- the maximum damage the Soviets could inflict with a given number of residual weapons -- after a NATO first strike in response to a substantial Soviet attack on Western Europe.[1] Thus we see from Figure 19 that if the Soviets allocated 100 weapons to the United Kingdom, blast mortalities would be 24 million. One hundred allocated to West Germany (Figure 20) could cause 11 million blast mortalities; 100 weapons allocated to France (Figure 21) would cause 13 million mortalities.

The blast plus fallout curves in Figures 19-27 are more complex. If weapons are groundburst, then fallout occurs over all of Western Europe. It is not correct to compute fallout mortalities in a country from weapons groundburst only in that country. (Blast mortalities are independent from country to country.) Consequently, the upper curves of Figures 19-27 were computed on the following basis. Weapon allocation was designed to maximize blast mortalities for the total population of Western Europe.[2] The number of 5 MT weapons launched were 50, 100, 250, 500, 750, 1000, 2000. The numbers 1 through 7 on each curve correspond to these weights of attack. Thus, if a total of 100 weapons were allotted for an urban attack on all of Western Europe, the number that would be groundburst in each country can be determined by drawing a vertical line from the figure 2 on the upper curve (corresponding to a weight of attack of 100 weapons) to the bottom scale and reading the number of weapons assumed to be allotted to that country. Thus, 28 weapons would be groundburst against the United Kingdom, 16 against West Germany, 13 against France, and so on. This same sort of computation can be performed using the solid curves to determine the number

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[1]See below for a discussion of their use in Soviet second strikes.

[2]It is important to remember that the distribution of fallout is very sensitive to wind patterns and fallout shelter protection. The fallout computations are based on a wind map providing average results for attacks on Western Europe. The same wind would not necessarily provide average results for attacks on the United States or the Soviet Union. The curves are based on 75 per cent of the population in houses, 20 per cent in basements and only 5 per cent with good fallout shelter protection. This assumption reflects lack of a fallout shelter program in Western Europe.

of weapons that would be airburst against a country. The blast plus fallout curve for each country represents the blast and fallout effects of weapons groundburst in the country plus the fallout mortalities attributed to weapons groundburst in other countries. This accounts for the rather large differences in some of the countries, especially West Germany and Turkey, between blast only mortalities and blast plus fallout mortalities.

Figures 28-30 present the enemy's allocation of standard 5 MT weapons to each country as a function of total weapons launched in the range 50 to 200 for attacks maximizing total mortalities in Western Europe. Because the distribution of urban population varies substantially from country to country, linear relationships, such as that for the United Kingdom, are not expected as a rule.

BLAST AND FALLOUT MORTALITIES -- WESTERN EUROPE

Figure 31 aggregates the data in the previous figures to provide Soviet damage inflicting capability from blast and fallout against Western Europe as a function of 5 MT weapons launched. To illustrate the differences in damage inflicting capability against a damaged population compared with an undamaged one, Figure 31 also shows corresponding curves when Western Europe suffers 46 and 63 million mortalities in Soviet counterforce strikes. The strikes include major targets such as airfields, command and control centers, major ports, and so on. The difference in realized damage is due to the inclusion of Soviet bombers in the counterforce role as well as missiles for the higher level curves. For a damaged population, the residual Soviet damage inflicting capability is the difference between the ordinate of the (say) 63 million curve and the realized damage of 63 million. For example, if Western Europe had suffered 46 million mortalities in a counterforce attack, and the Soviets had 100 weapons to allocate against cities, the Soviet residual damage inflicting capability would be 39 million (85 million less 46 million). This compares with 58 million for a previously undamaged population subject to 100 weapons. As the damage potential curves will have the same shape for other levels of realized damage, the reader can, through interpolation, construct other curves between the zero counterforce damage curve and the 63 million curve. These curves would give approximate residual damage inflicting capability for given levels of realized damage in the 0 to 63 million range.

Similar curves but for blast only are given in Figure 32. See Section V for examples of the use of this figure.

Since the reader may be interested in yields other than 5 MT against urban areas, Figure 33 presents a curve for translating different yields into 5 MT equivalents and a curve for converting airburst weapons into groundburst equivalents for blast damage calculations. The reader may use these curves in conjunction with the blast damage curves in Figures 19-33 to account for a variation in the type of urban attack. The curve applies only to counterurban attacks and should not be used to compute mortalities from counterforce attacks.

BLAST MORTALITIES BY CITY

Because there may be interest in weapon allocations by city as well as by country, Table 2 presents mortalities in the 24 largest cities of Western Europe when 120 5 MT equivalents are allocated to them. Columns for incremental mortalities per weapon and cumulative mortalities are shown. In addition, column (5) shows the Soviet weapon allocation order that would maximize total damage summed over these 24 cities.[1] For example, the first weapon allocated to Brussels would cause 380,000 mortalities, but it would come thirty-first in the list of weapons allocated, because the incremental mortalities from sending any of the 30 previous weapons to other cities would be greater than sending a weapon to Brussels. Total mortalities for five weapons allocated to Brussels would be 857,000 mortalities.

[1] Some weapons would be allocated early to cities not in the top 24 because the incremental mortalities from hitting these cities would be greater than mortalities from the larger cities as they are hit again and again.

Table 2

BLAST MORTALITIES BY CITY FROM URBAN ATTACKS, ASSUMING 5 MT WEAPONS GROUNDBURST, 0.7 DELIVERY PROBABILITY (thousands)

City	Country	Quick Count Population[a]	Incremental Mortalities	Weapon Order	Cumulative Mortalities
(1)	(2)	(3)	(4)	(5)	(6)
London	United Kingdom	8413.1	1029.3	3	1029.3
			623.6	11	1652.9
			608.0	12	2260.9
			499.8	19	2760.7
			491.4	21	3252.1
Paris	France	6861.1	1148.3	1	1148.3
			670.0	8	1818.3
			493.4	20	2311.7
			486.0	22	2797.7
			398.3	29	3196.0
Lancashire	United Kingdom	2421.7	518.1	17	518.1
			292.2	40	810.3
			192.7	52	1003.0
			189.2	55	1192.2
			153.8	63	1346.0
West Midland	United Kingdom	2355.3	628.0	10	628.0
			338.0	34	966.0
			213.0	47	1179.5
			155.6	62	1335.1
			153.6	64	1488.7
Madrid	Spain	2214.4	1143.3	2	1143.3
			460.1	24	1603.4
			209.1	48	1812.5
			110.8	78	1923.3
			68.2	98	1991.5
Rome	Italy	1919.2	660.0	9	660.0
			327.2	35	977.2
			190.6	54	1167.8
			183.3	56	1351.1
			126.9	70	1478.0
Hamburg	West Germany	1818.9	546.5	15	546.5
			375.8	32	922.3
			131.1	69	1053.4
			113.9	75	1167.3
			74.0	92	1241.3

Table 2 (continued)

City	Country	Quick Count Population[a]	Incremental Mortalities	Weapon Order	Cumulative Mortalities
(1)	(2)	(3)	(4)	(5)	(6)
Clydeside	United Kingdom	1785.9	568.5	14	568.5
			290.2	41	858.7
			173.9	58	1032.6
			118.2	74	1150.8
			90.3	83	1241.1
West Yorkshire	United Kingdom	1698.5	726.0	7	726.0
			325.9	37	1051.9
			170.8	59	1222.7
			104.3	80	1327.0
			71.4	94	1398.4
Athens	Greece	1626.4	769.2	6	769.2
			326.1	36	1095.3
			159.2	61	1254.5
			91.6	82	1345.3
			59.5	103	1405.0
Barcelona	Spain	1465.2	810.2	5	810.2
			312.6	38	1122.8
			133.1	68	1255.9
			65.2	100	1321.1
			37.4	113	1358.5
Milan	Italy	1403.5	571.9	13	571.9
			263.4	42	835.3
			142.2	66	977.5
			89.1	84	1066.6
			62.1	101	1128.7
Merseyside	United Kingdom	1392.7	457.4	23	457.4
			230.9	44	688.3
			136.9	67	825.2
			92.3	81	917.5
			69.1	97	986.6
Istanbul	Turkey	1322.7	837.2	4	837.2
			296.0	39	1133.2
			107.4	79	1240.6
			41.0	112	1281.6
			17.1	119	1298.7
Brussels	Belgium	1306.6	380.1	31	380.1
			199.9	50	580.0
			123.1	73	703.0
			85.3	86	788.3
			69.1	96	857.4

Table 2 (continued)

City	Country	Quick Count Population[a]	Incremental Mortalities	Weapon Order	Cumulative Mortalities
(1)	(2)	(3)	(4)	(5)	(6)
Copenhagen	Denmark	1263.7	434.7	27	434.7
			215.5	46	650.2
			125.5	71	775.7
			83.6	87	859.3
			60.7	102	920.0
Naples	Italy	1131.9	500.0	18	500.0
			220.4	45	720.4
			113.0	76	833.4
			67.7	99	901.1
			45.7	109	946.8
München	West Germany	1090.7	433.8	28	433.8
			202.5	49	636.3
			110.9	77	747.2
			70.3	95	817.5
			49.4	105	866.9
Turin	Italy	925.8	469.1	23	469.1
			191.0	53	660.1
			88.1	85	748.2
			47.5	107	795.7
			29.7	117	825.4
Amsterdam	Netherlands	871.7	534.8	16	534.8
			193.0	51	727.8
			73.0	93	800.8
			30.0	116	830.8
			14.0	120	844.8
Lisbon	Portugal	862.6	445.4	26	445.4
			179.2	57	624.6
			81.4	89	706.0
			43.2	110	749.2
			26.5	118	775.7
Tyneside	United Kingdom	840.7	390.8	30	390.8
			167.3	60	558.1
			82.6	88	640.9
			47.9	106	688.8
			31.6	115	720.4
Stockholm	Sweden	804.4	237.6	43	237.6
			124.4	72	362.0
			76.3	91	438.3
			52.7	104	491.0
			42.3	111	533.3

Table 2 (continued)

City	Country	Quick Count Population[a]	Incremental Mortalities	Weapon Order	Cumulative Mortalities
(1)	(2)	(3)	(4)	(5)	(6)
Köln	West Germany	786.9	345.9	33	345.9
			152.8	65	498.7
			78.6	90	577.3
			47.2	108	624.5
			32.0	114	656.5

Note:

[a] The criterion for inclusion of population in a Quick Count urban area is relevance to blast damage, not political subdivision. Thus the total population per urban area in Quick Count may not correspond to census data or other sources.

If the Soviets were to attempt to maximize total blast mortalities in cities across Western Europe, then the first weapon would be allocated to Paris, which provides the greatest number of incremental mortalities. The second weapon would be allocated to Madrid, which gives the second greatest number of incremental mortalities, and so on. The calculation is carried out for up to 120 weapons. For comparative purposes the total Quick Count populations of the 24 largest cities in Europe are shown.

Assume that the Soviets wish to allocate 50 weapons so as to cause the largest possible mortalities in Western Europe. Their allocation would be given by those weapons ordered 1 to 50 in Table 2. Thus Brussels would receive two weapons, Copenhagen 2, Paris 5, and so forth through München, 2. The resulting total mortalities would not be much lower if reasonable deviations from this allocation were used. Thus, simply allocating two weapons to each city in the list (48 weapons) yields 21 million blast mortalities against 23 million for the maximum allocation of 50 weapons.

SOVIET COUNTERCITY SECOND STRIKES

The data of this section can also be used to estimate the damage inflicting capability of residual Soviet forces under the assumption that the Soviets can target these residual forces efficiently, that is, sufficient Soviet command and control survives to order such an attack and the Soviet war plans include such options for the surviving forces. Examples will be found in Section V.

V. EXAMPLES OF COMPLETE ATTACKS

In this section we illustrate the use of the building blocks contained in Sections II, III, and IV. Three cases are analyzed. Outcomes, using the aggregate method, are compared with Quick Count runs of identical attacks to check the validity of the aggregation procedures used.

In the first case the Soviet Union engages in an airburst campaign against major targets in Western Europe. Targeting neither attempts nor avoids inflicting civil damage, but the attacker airbursts all weapons to minimize the chance that fallout will spread into Eastern Europe and the Soviet Union and to permit free movement of his ground forces.

The second case is an "unconstrained" countermilitary campaign where all weapons are groundburst. The mortalities from these countermilitary attacks, labeled "realized mortalities," are computed below. Then the additional mortalities that could be inflicted by a counterurban attack of 150 weapons -- the residual damage inflicting capability -- are computed by finding the total mortalities of the combined counterforce and counterurban attack and subtracting the realized mortalities.

The third case consists of a very constrained counterforce attack. The Soviets are assumed to reduce the yield of their weapons to 100 KT. Weapons are airburst only.

REALIZED BLAST MORTALITIES

The first four columns of Table 3 summarize the counterforce allocation used. It is assumed that Western Europe is attacked by 4 MT weapons with a fraction fission of 0.3 and a reliability of 0.7. The allocation of Table 3 represents one reasonable allocation given the relative importance of various targets and weapon kill probabilities. Alternative countermilitary allocations would be handled in a similar manner.

Table 3

HYPOTHETICAL COUNTERFORCE ALLOCATION AND RESULTING MORTALITIES
ASSUMING 4 MT WEAPONS, 0.3 FRACTION FISSION, 0.7 RELIABILITY

Target Category	Number of Aim Points	Weapons Per Aim Point	Total Weapons Assigned	Blast Mortalities (millions)	
				Airburst	Groundburst[a]
	(1)	(2)	(3)	(4)	(5)
Primary offensive airfields	102	2	204	5.6	3.2
Secondary offensive and defensive airfields	181	1	181	13.5	7.4
Nuclear submarine ports	7	2	14	.6	.5
Major ports	98	2	186	29.0	24.0
Major command centers[b]	9	3	27	1.4	1.0
TOTALS			612	50.1	36.2[b]

Notes:

[a]Fallout must be included to get total mortalities -- see text and Table 4.

[b]In this exercise, major command centers were assumed to be so important that 3 weapons would be aimed at them. Mortalities for 3 weapons can be computed using the information from Figure 7 and from the text, pp. 10-11.

To arrive at the blast mortalities for the groundburst attack it is necessary first to find the weapon radius corresponding to a 4 MT groundburst weapon from Figure 16 -- 3.4 miles. Using the weapon radius scale at the top of Figures 1, 2, 4, 5, and 7, the curves on those figures can then be read to give the blast mortalities in column (5) of Table 3, a total of 36 million blast mortalities for the groundburst attack. For the two cases shown in Table 3, Quick Count gives 46 and 33 million respectively, indicating that at these weapon radii there is some overlapping of effects at the different target classes leading to some double counting of mortalities by the aggregate technique.

REALIZED BLAST AND FALLOUT MORTALITIES

Because of fallout, the groundburst attack will cause additional mortalities. The computation of this amount is summarized in Table 4. First the total megatons of fission delivered is computed, using the information in Table 3. This is the total number of weapons assigned, times the delivery probability, times the yield, times the fraction fission; or, 612 x 0.7 x 4 x 0.3 = 514. Then the mortalities due to fallout only are read from Figure 17, a range of 66 to 99 million. However, we cannot get total mortalities, T, simply by adding fallout only mortalities, F, to blast only mortalities, B, because that would involve double counting. Instead, the formula given in Section III is used: $T = B + F - BF/237$ giving the final result of 92 to 120 million blast and fallout realized mortalities from the groundburst attack. The Quick Count result for this case varies from 90 to 114 million.

BLAST MORTALITIES FROM MIXED COUNTERMILITARY AND COUNTERURBAN ATTACKS

Now suppose that the Soviets still retain 150 4 MT weapons as a withheld retaliatory threat. Table 5 summarizes the blast mortality calculations if these are launched against urban areas in addition to the countermilitary attacks. To illustrate the computational methods, it is assumed that these attacks are all airburst when used as a follow-on to the airburst strike, and all are groundburst when there is a follow-on to the counterforce attack using groundburst weapons.

Table 4

SUMMARY OF REALIZED BLAST PLUS FALLOUT
MORTALITIES, GROUNDBURST ATTACK
(millions)

Delivered MT fission	= 514
Mortalities due to fallout only, F (Figure 17)	= 66 to 99
Mortalities due to blast only, B (Table 3)	= 36
Total Mortalities, $T = B + F - \frac{BF}{237}$	= 92 to 120

Table 5

SUMMARY OF COMPUTATION OF COUNTERFORCE PLUS COUNTERURBAN MORTALITIES (millions)

Blast	All Airburst	All Groundburst
Number weapons allocated counterurban	150	150
Number blast equivalent 5 MT groundburst weapons[a]	150 x 1.4 = 210	150 x .88 = 132
Total blast mortalities[b]	87	72

<u>Fallout (For all groundburst attack)</u>

Total MT fission delivered = (612 + 150)(0.7)(4)(0.3) = 640

Fallout only mortalities[c] (F) = 78 to 110

Blast only mortalities (B) = 72

Total mortalities $(B + F - \frac{BF}{237})$

72 + 78 - [(72)(78)/237] = 126
72 + 110 - [(72)(110)/237] = 148

<u>Notes</u>:

[a] See Figure 33 and discussion on page 30.

[b] See Figure 32, Table 3, and discussion on page 30.

[c] See Figure 17.

First the 5 MT groundburst equivalents for a 4 MT airburst and a 4 MT groundburst must be computed from Figure 33. For a 4 MT airburst the equivalent is 1.4 and for a 4 MT groundburst .88. Thus for urban blast mortality calculations, 150 4 MT weapons airburst are equivalent to 150 x 1.4 = 210 5 MT groundburst weapons; 150 4 MT weapons groundburst are equivalent to 150 x .88 = 132 5 MT groundburst weapons.

Total blast mortalities can now be read from Figure 32. For the all airburst case the prior (realized) damage (Table 3) is 50 million. The 50 million prior damage curve at 210 5 MT equivalents gives total mortalities of 87 million. After the 50 million realized damage is subtracted, the residual damage inflicting capability of the 150 weapons airburst is 37 million.

The groundburst blast computation is similar, although in this case the curve corresponding to 36 million prior blast damage should be used. Total blast mortalities in this case are then 72 million, an increment of 36 million over the countermilitary blast mortalities.

COMBINED BLAST AND FALLOUT MORTALITIES FROM MIXED ATTACKS

In the groundburst case, Table 5 summarizes the fallout mortality computation. The fission yield delivered groundburst is now 640 MT because of the additional 150 weapons. From Figure 17 we see that fallout only mortalities from 640 MT groundburst range from 78 to 110 million. Table 5 shows that by combining fallout mortalities and the 72 million total blast mortalities by the formula B + F - BF/237, total mortalities range from 126 to 148 million. After the realized damage of 92 to 120 million (Table 4) is subtracted, the residual damage inflicting capability in this case is 28 to 34 million.[1]

Table 6 presents the results of a constrained counterforce attack on the target system in Table 3. The 100 KT yield is chosen as illustrative, to show the flexibility of the techniques presented here.

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[1]If the countermilitary strike is an airburst attack and the follow-on counterurban strike is groundburst, total blast plus fallout mortalities are found to be 89 to 101 million. A Quick Count run for this case using a single wind (15 February 1951) indicated 98 million mortalities.

Table 6

RESTRAINED COUNTERFORCE ALLOCATION AND RESULTING MORTALITIES, 100 KT, 0.7 RELIABILITY

Target Category	Number of Aim Points	Weapons per Aim Point	Total Weapons Assigned	Blast Mortalities (millions)
Primary offensive airfields	102	2	204	.58
Secondary offensive and defensive airfields	181	1	181	1.1
Nuclear submarine ports	7	2	14	.28
Major ports	98	2	186	9.0
Major command centers	9	2	27	.18
TOTAL				11.1

VI. POSSIBLE EXTENSIONS AND FINAL COMMENTS

The techniques in Sections II through IV permit rapid calculation of mortalities and casualties in Western Europe during general war. It is possible to compute the effects of blast and fallout from both counterforce and counterurban attacks. Outcomes for Western Europe as a whole are most easily calculated. However, with some additional work, aggregate calculations can be broken down by country, or, for urban attacks, by city.

The building block analysis used here makes evident the relative importance of attacking alternative target systems as measured by differential mortalities, and it helps to indicate those variations of an attack that would lead to substantial changes in outcomes. However, the building block techniques presented here are not suitable for the analysis of civil casualties from a tactical nuclear land battle conducted without general war, because civil damage in that case would depend strongly on the location of mobile targets. These locations are, in turn, dependent on the course of battle. When tactical nuclear warfare is conducted as part of a general war, civil damage from tactical targets would be relatively small compared with the immense possible damage at the strategic targets analyzed here.

Blast mortalities in Section II are summarized by target categories. Appendix B presents blast mortalities by target category and country. Rearrangement of targets by category or categorical subdivisions could be made for special purposes or to permit more detailed allocations. The limit of this process would be a target-by-target compendium of blast mortalities. This would be done by hand if machine techniques were not available (see Appendix A).

The lowest yield used in Section II is 40 KT. Although the calculations could be extended below this range, the level of aggregation in the Quick Count population base is such that the results probably would be no more meaningful than a simple extrapolation of the graphs of Section II.

The fallout calculations in Section III are based on a particular set of assumptions with respect to the distribution of population to shelters. Further calculations varying these assumptions could be made, in particular, an analysis showing outcomes for alternative civil defense programs.

Mortalities and casualties are dependent on the enemy's attack doctrine. For example, a strategic attack might or might not include attacks on cities, be groundburst, or include ports. For the moderate weight attacks of Section V, mortalities could vary from well over 100 million down to 20 million if ports, say, were excluded from the target list. And if the Soviet Union exercised restraint in its choice of yield the latter number could be reduced even more.

Great uncertainty about general war outcomes arises from the many possible interactions between the force structure and doctrines of NATO and the Soviet Union. Therefore, the sensitivity of damage assessment techniques to type of attack cannot be considered as a limit of the techniques. How well do damage assessment techniques estimate damage once the nature of an attack is specified? There are uncertainties in the physical data on which all damage assessment techniques are based. Estimates of parameters such as the overpressure, used in estimating blast effects, or mid-lethal dose, used in calculating fallout effects, are subject to variation. And there are very large uncertainties about the degree of protection the population would have, the population's reaction to an attack, and postattack conditions. (Postattack conditions would undoubtedly lead to the death of substantial numbers of injured.) Nevertheless, rational force planning requires some estimates of the range of damage that could occur.

The comparisons in Section V show that the results of using the aggregate techniques agree adequately with Quick Count runs. But for the reasons discussed above, we still do not know how accurately Quick Count or any damage estimation routine computes the civil damage of general war attacks.

For many questions, it is the relative outcome for different types of attacks that is important, not absolute magnitudes. And damage assessment techniques do provide ways to measure relative outcomes. Used properly, and with full sensitivity to the uncertainties, damage assessment techniques are helpful in assessing alternative force structures and doctrines.

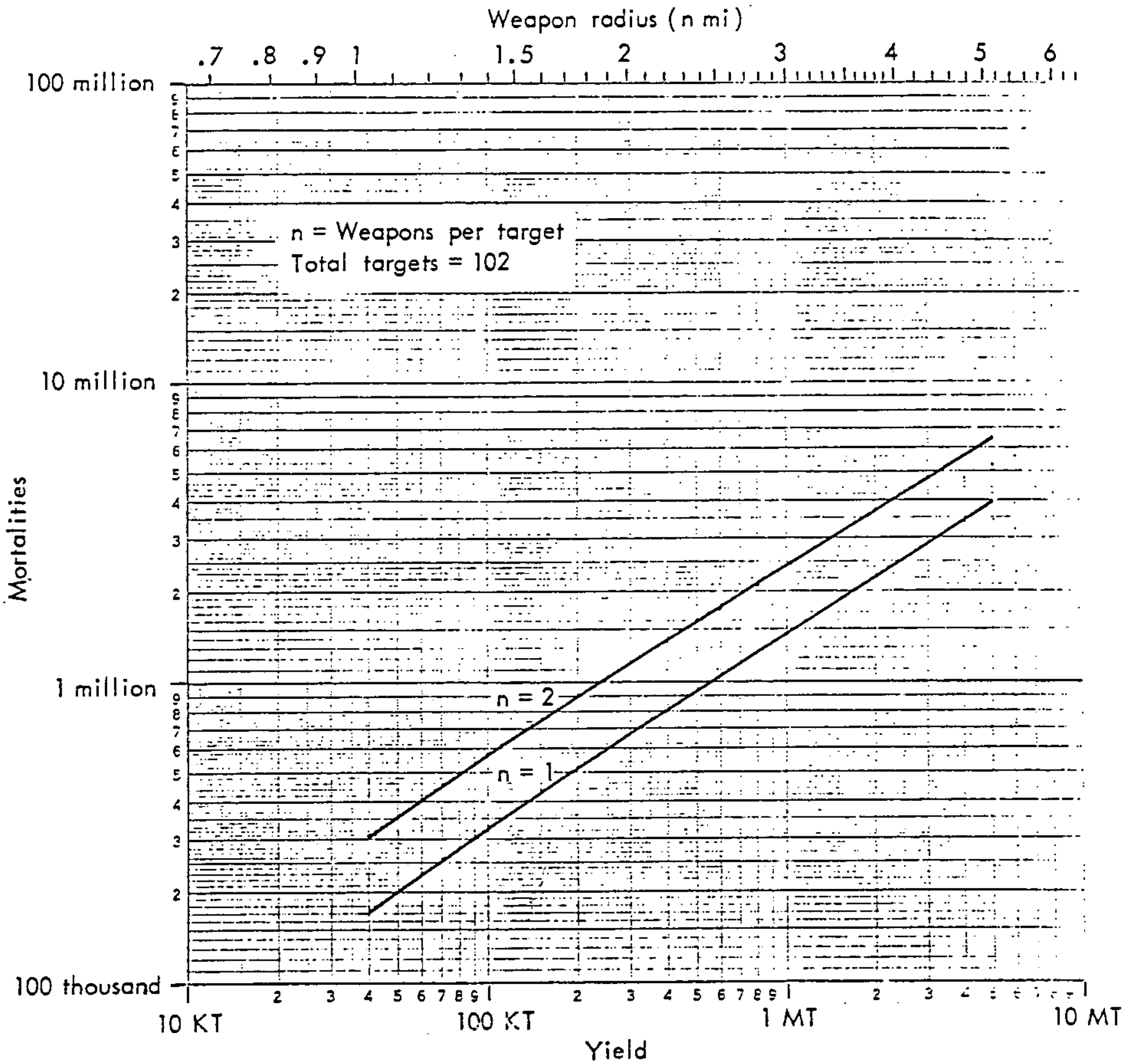

Figure 1—Primary offensive airfields—blast mortalities by weight of attack

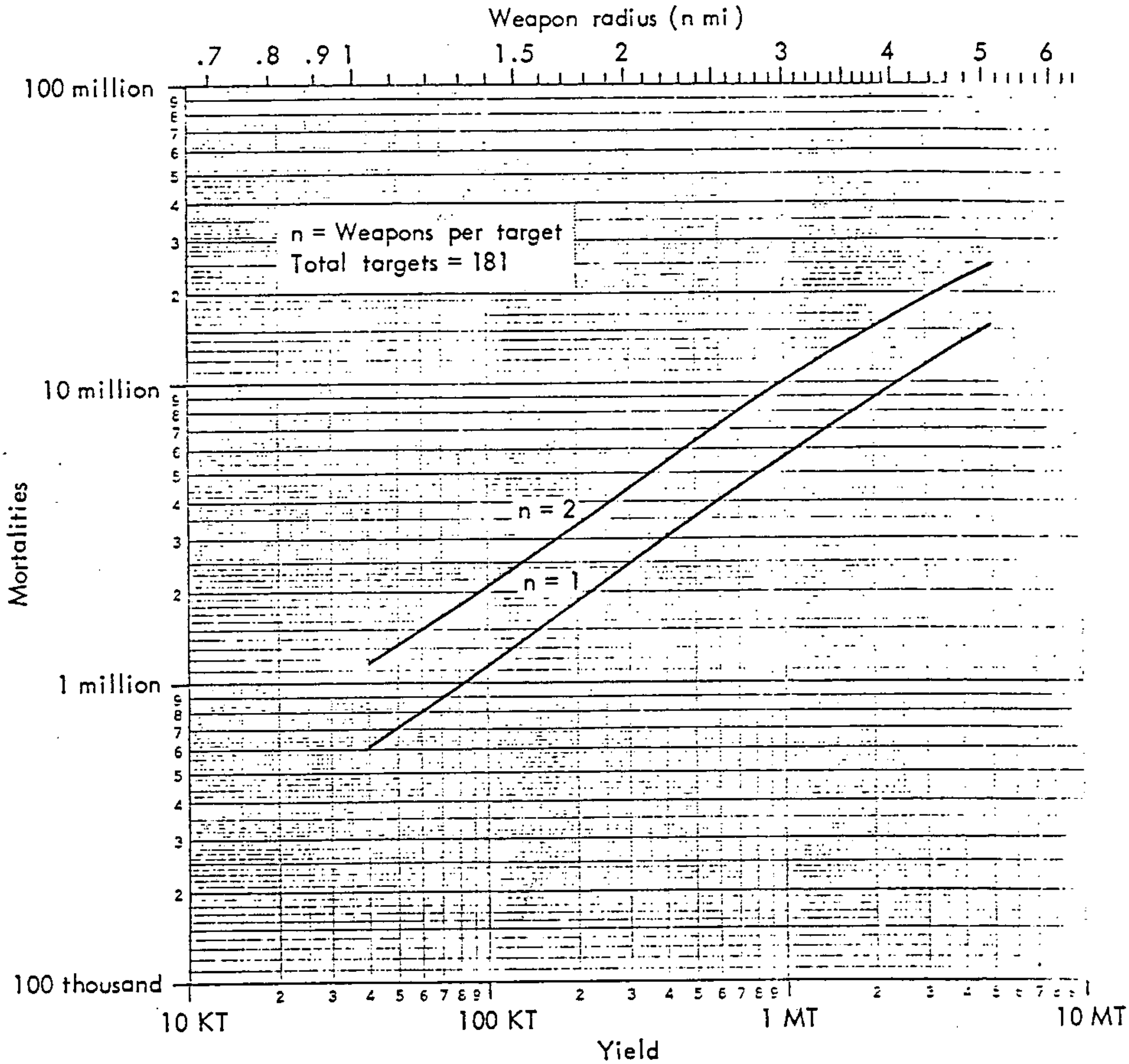

Figure 2—Secondary offensive and defensive airfields—blast mortalities by weight of attack

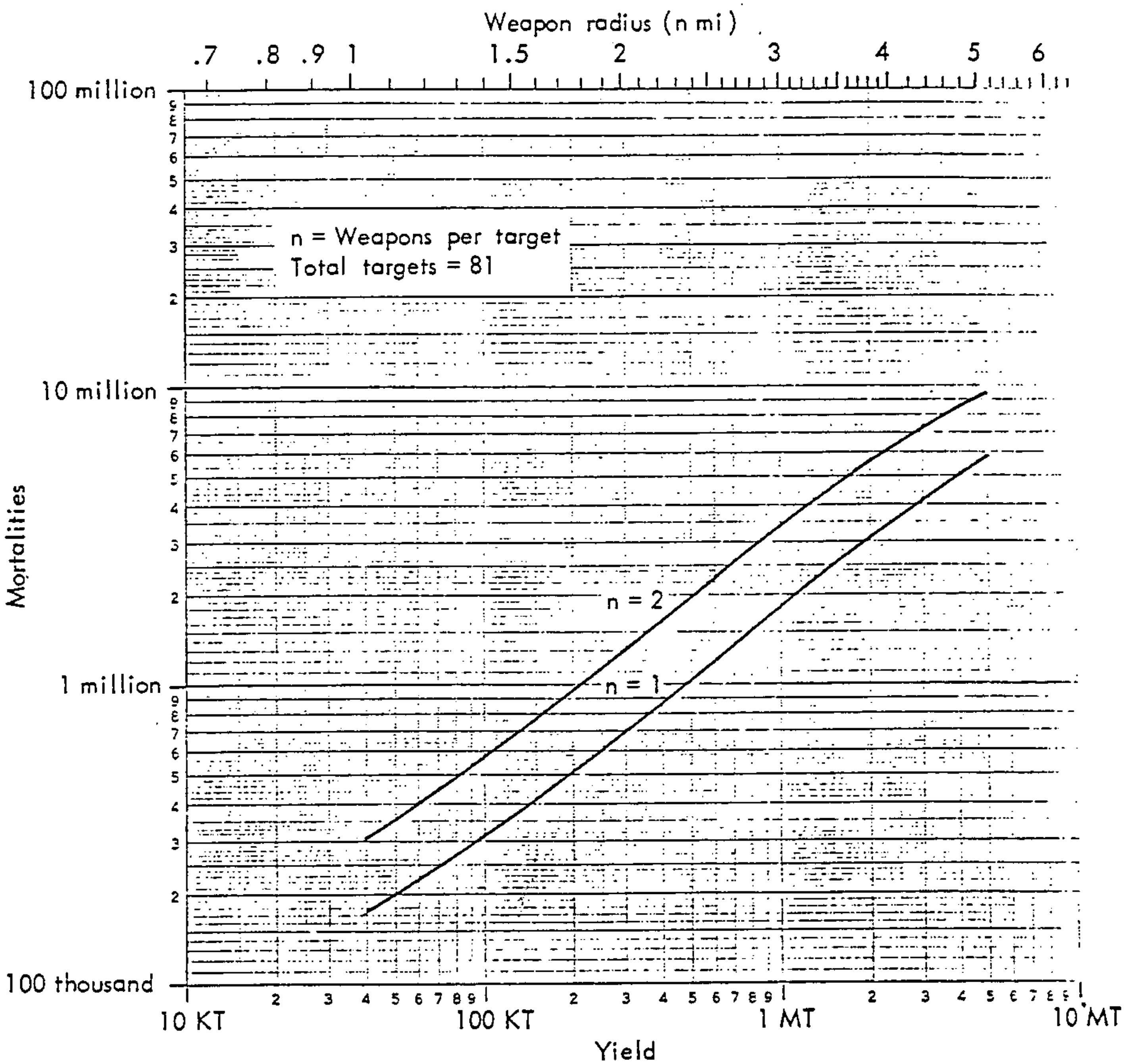

Figure 3—Reserve airfields—blast mortalities by weight of attack

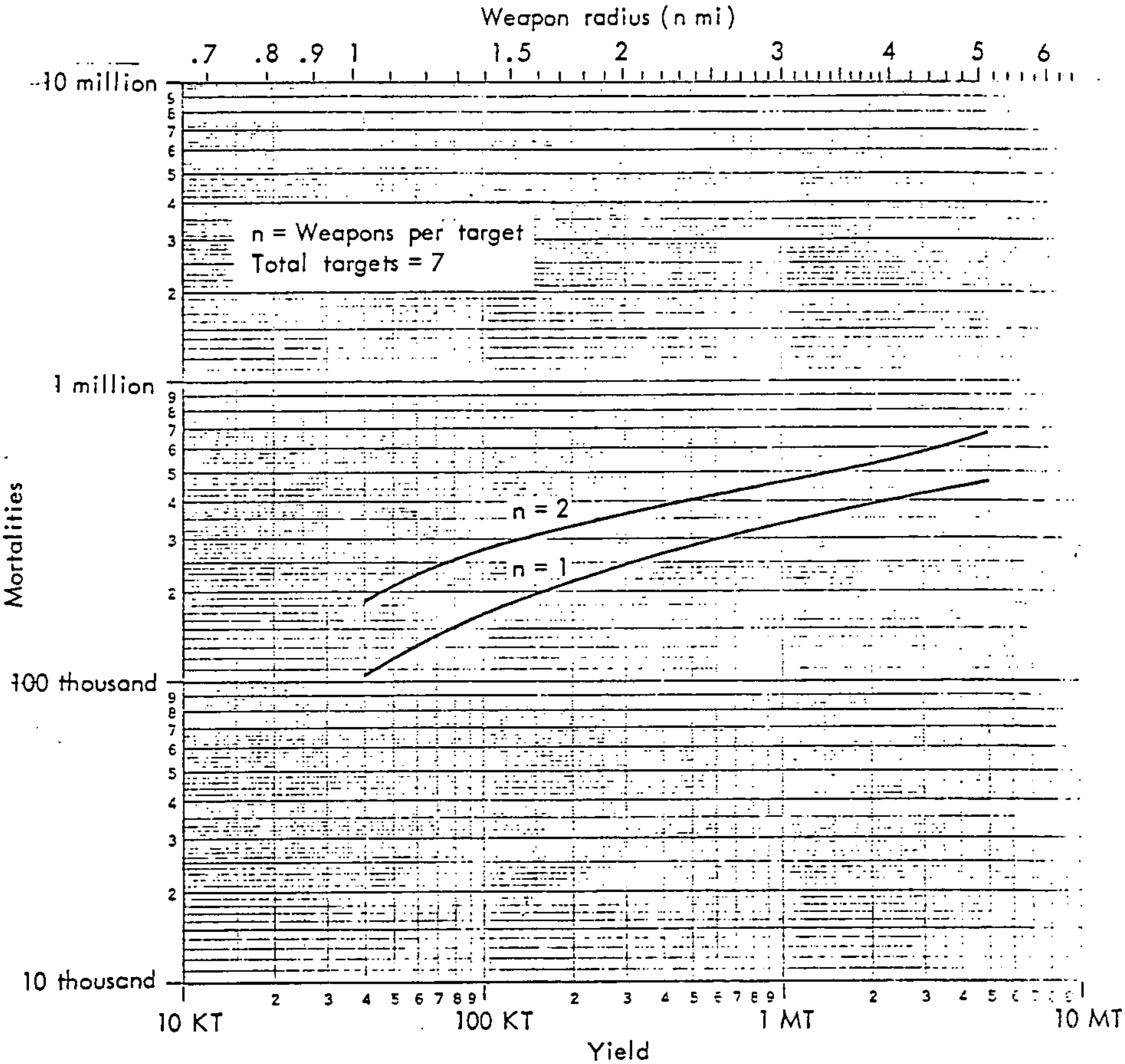

Figure 4—Nuclear submarine ports—blast mortalities by weight of attack

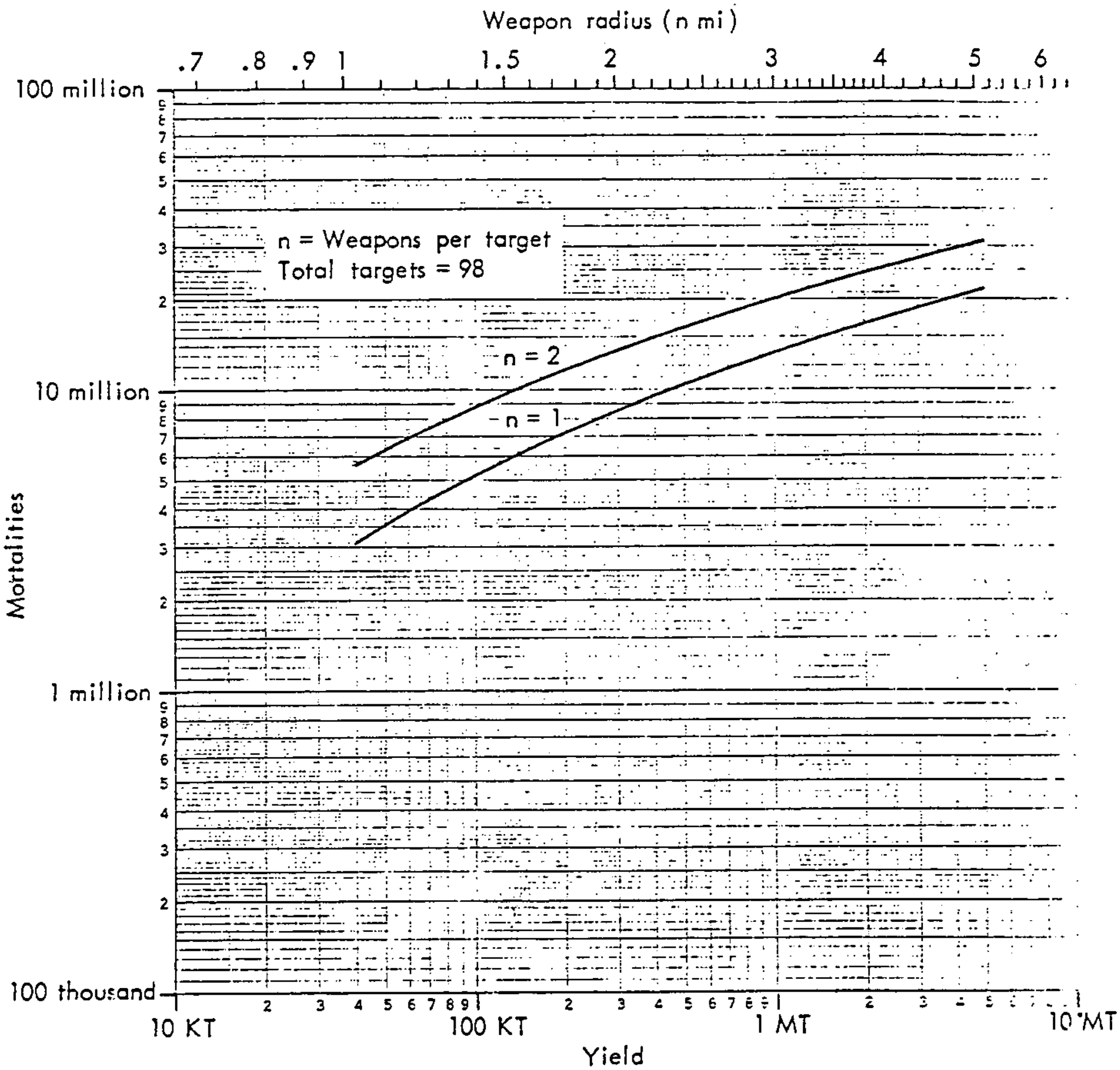

Figure 5—Major ports—blast mortalities by weight of attack

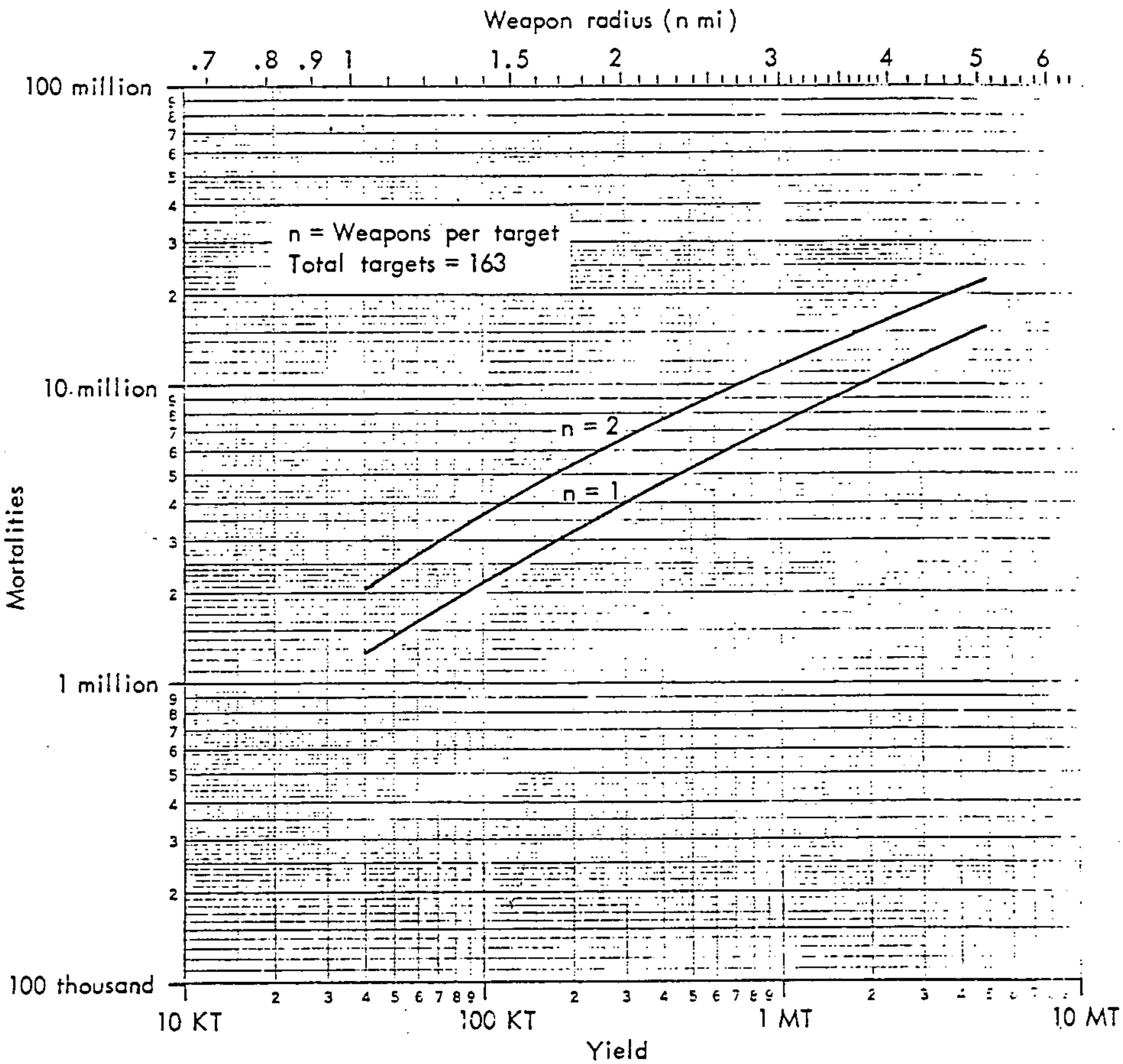

Figure 6—Army materiel depots—blast mortalities by weight of attack

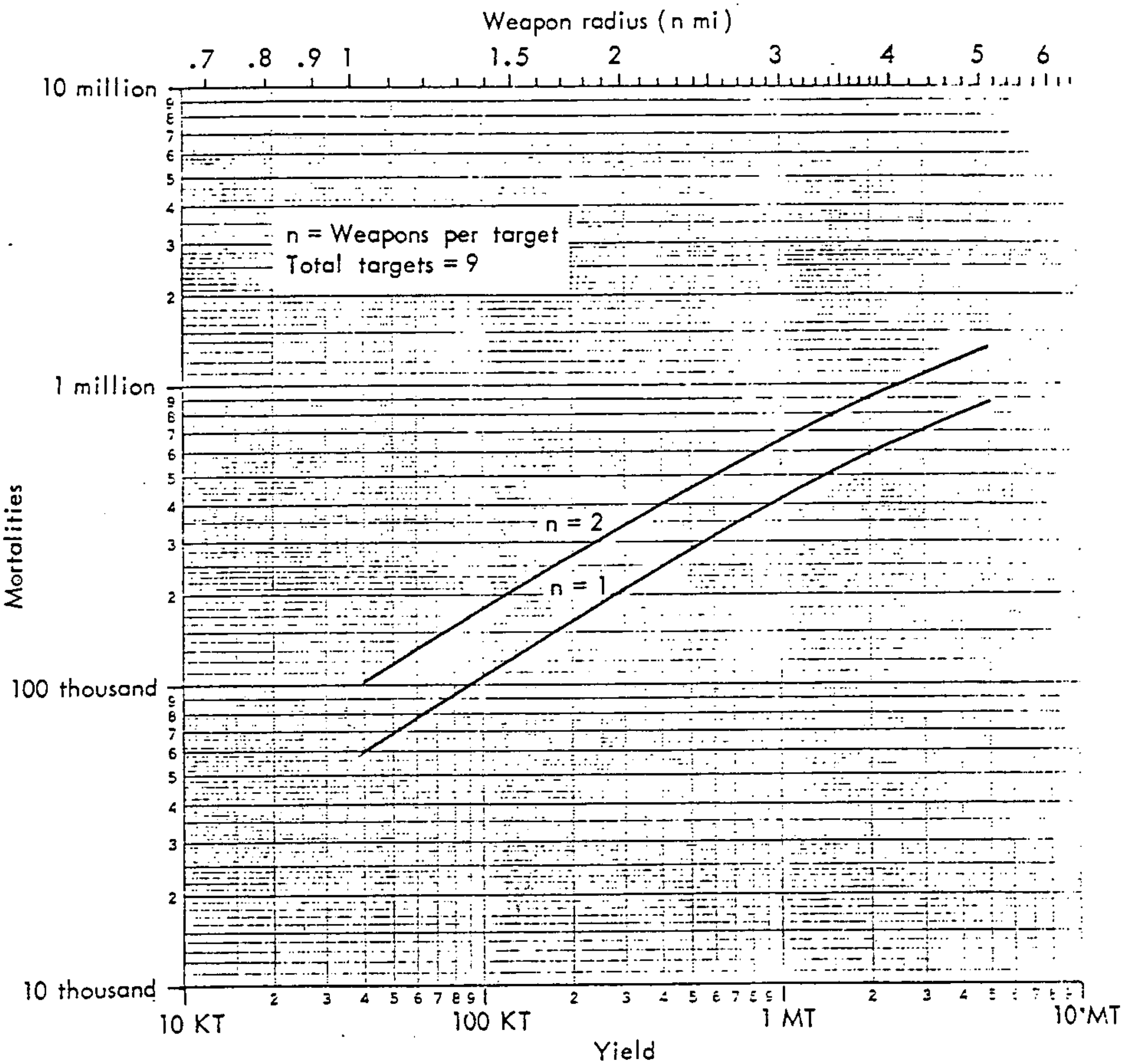

Figure 7—Major command centers—blast mortalities by weight of attack

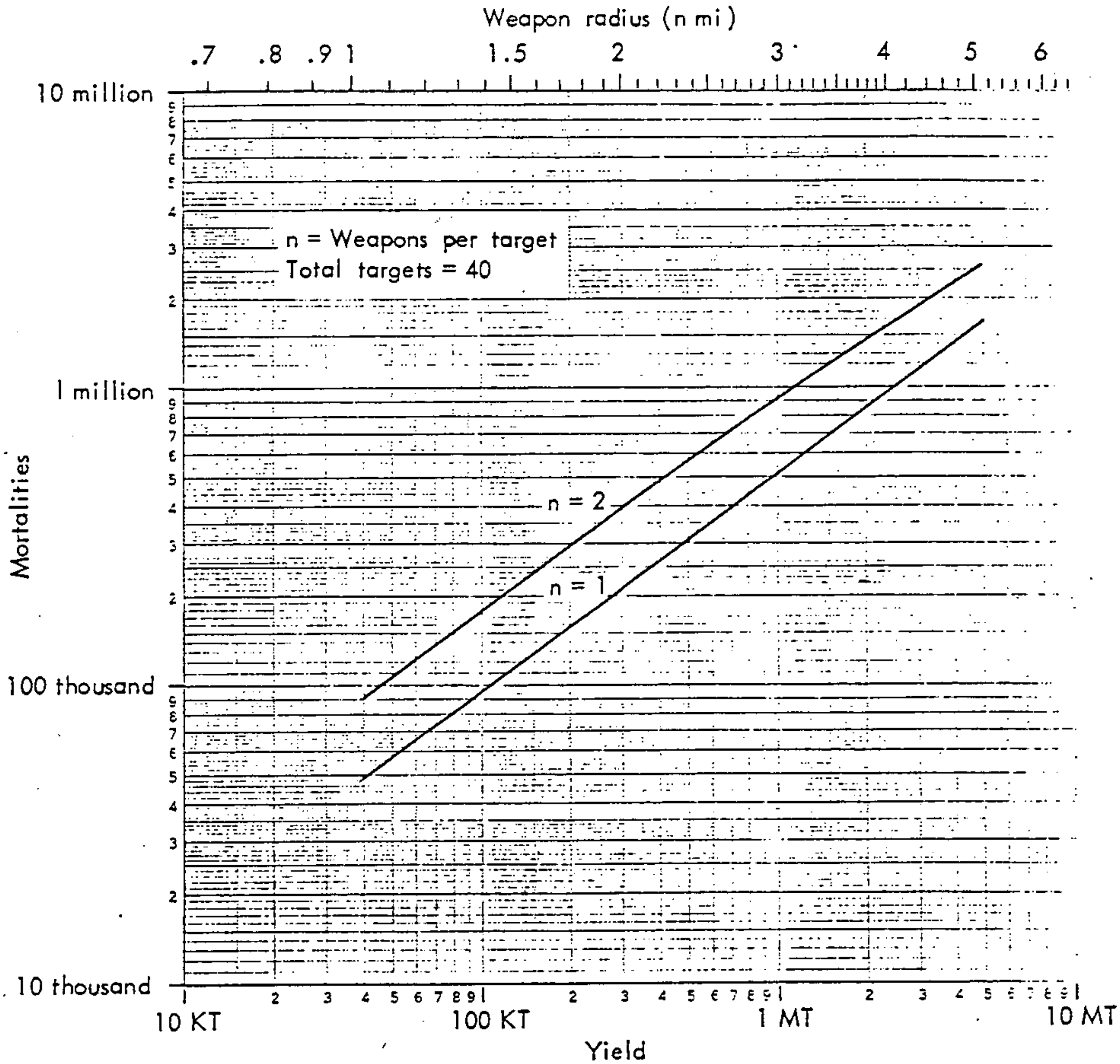

Figure 8—Nike sites—blast mortalities by weight of attack

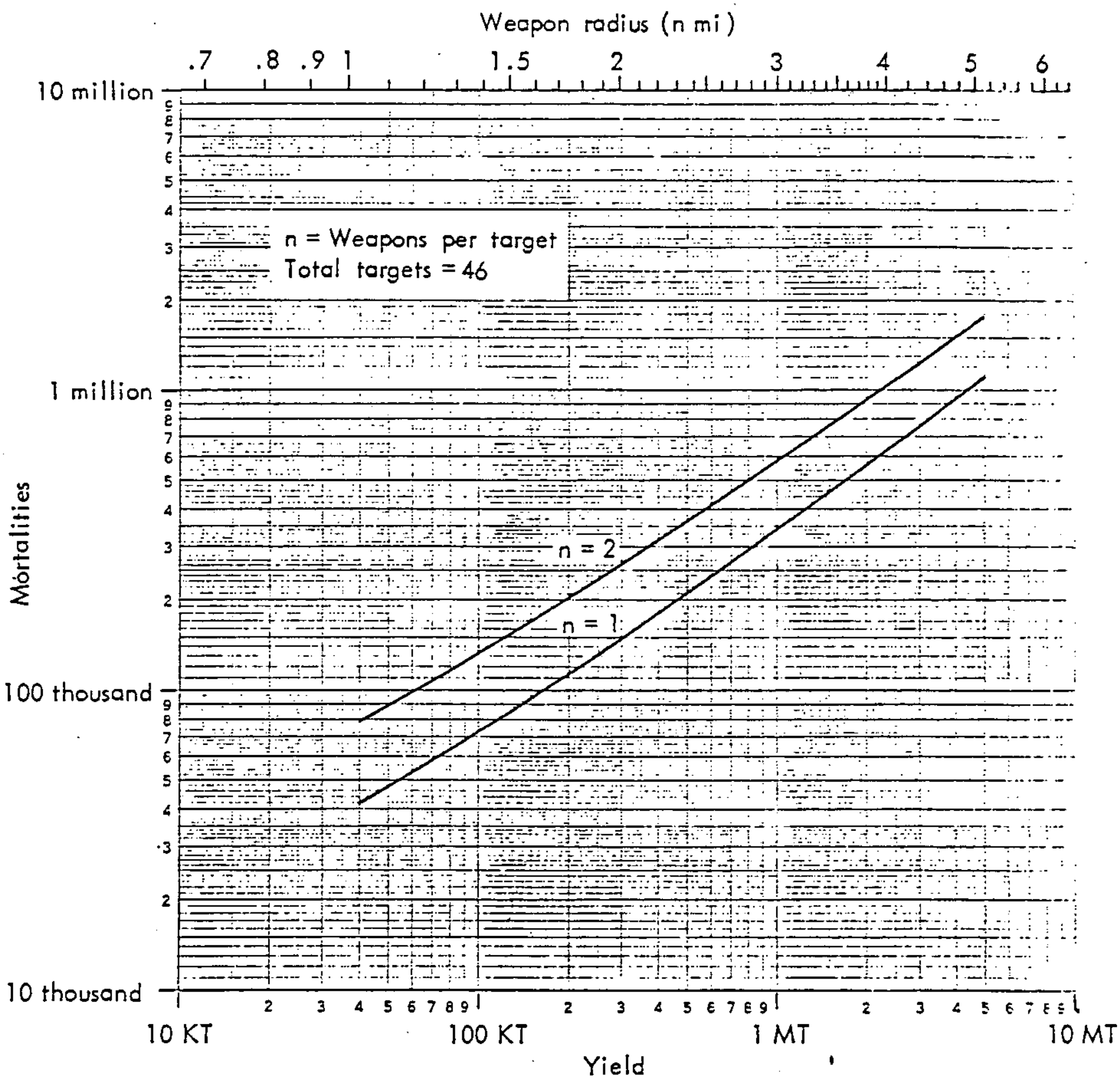

Figure 9—Hawk belt—blast mortalities by weight of attack

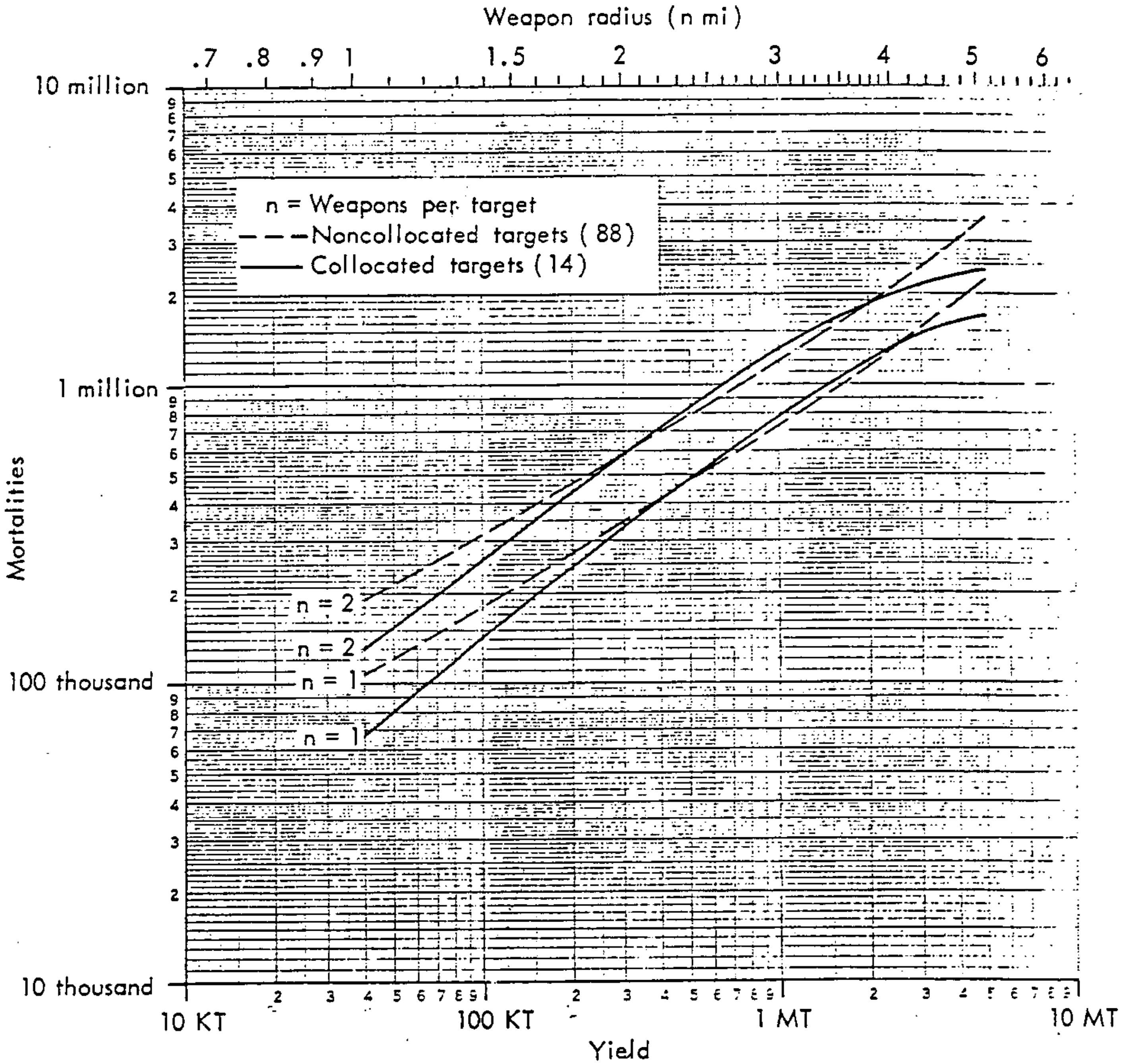

Figure 10—Primary offensive airfields—blast mortalities by weight of attack (collocated and noncollocated targets)

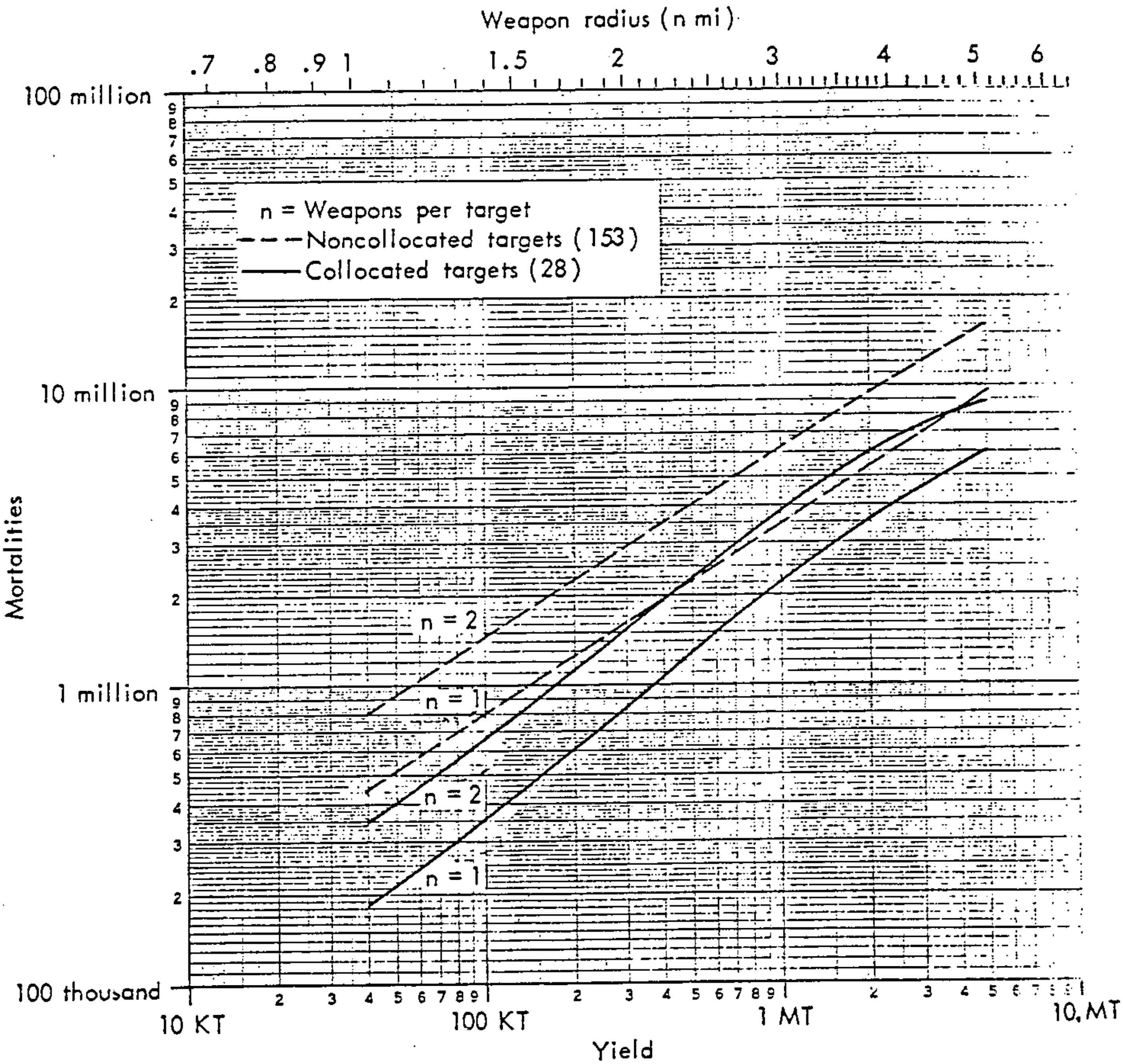

Figure 11—Secondary offensive and defensive airfields—blast mortalities by weight of attack (collocated and noncollocated targets)

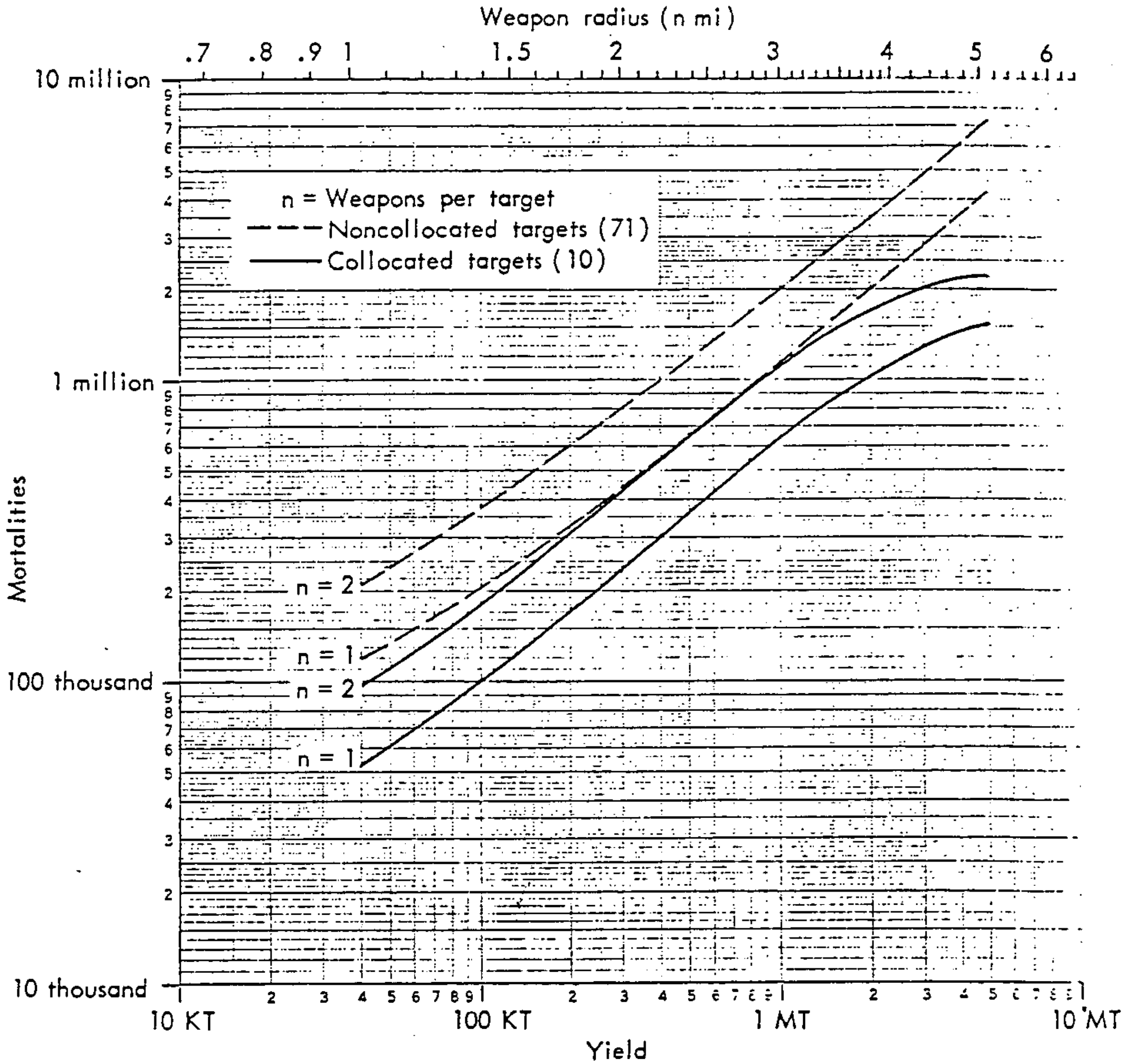

Figure 12—Reserve airfields—blast mortalities by weight of attack (collocated and noncollocated targets)

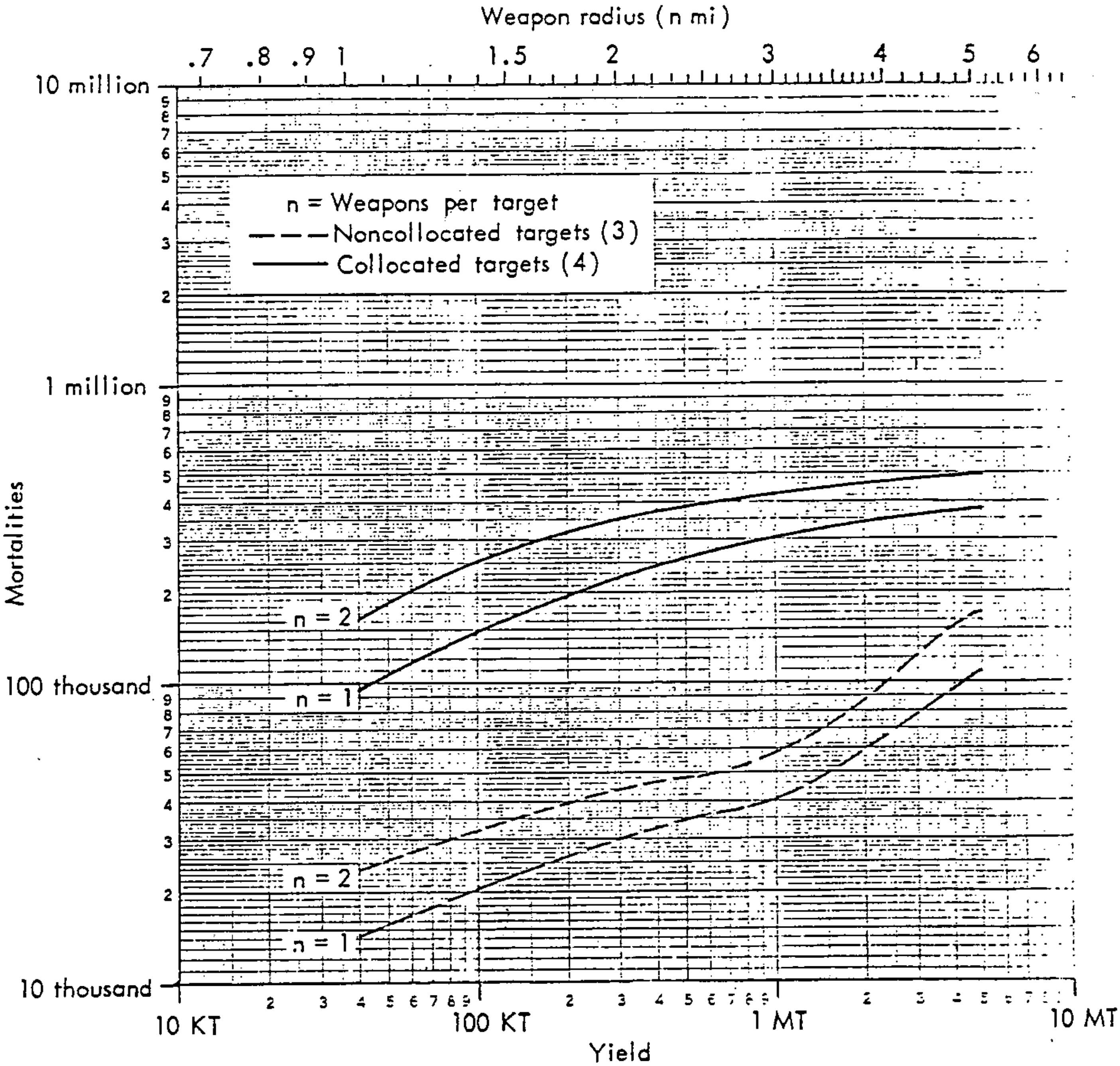

Figure 13—Nuclear submarine ports—blast mortalities by weight of attack (collocated and noncollocated targets)

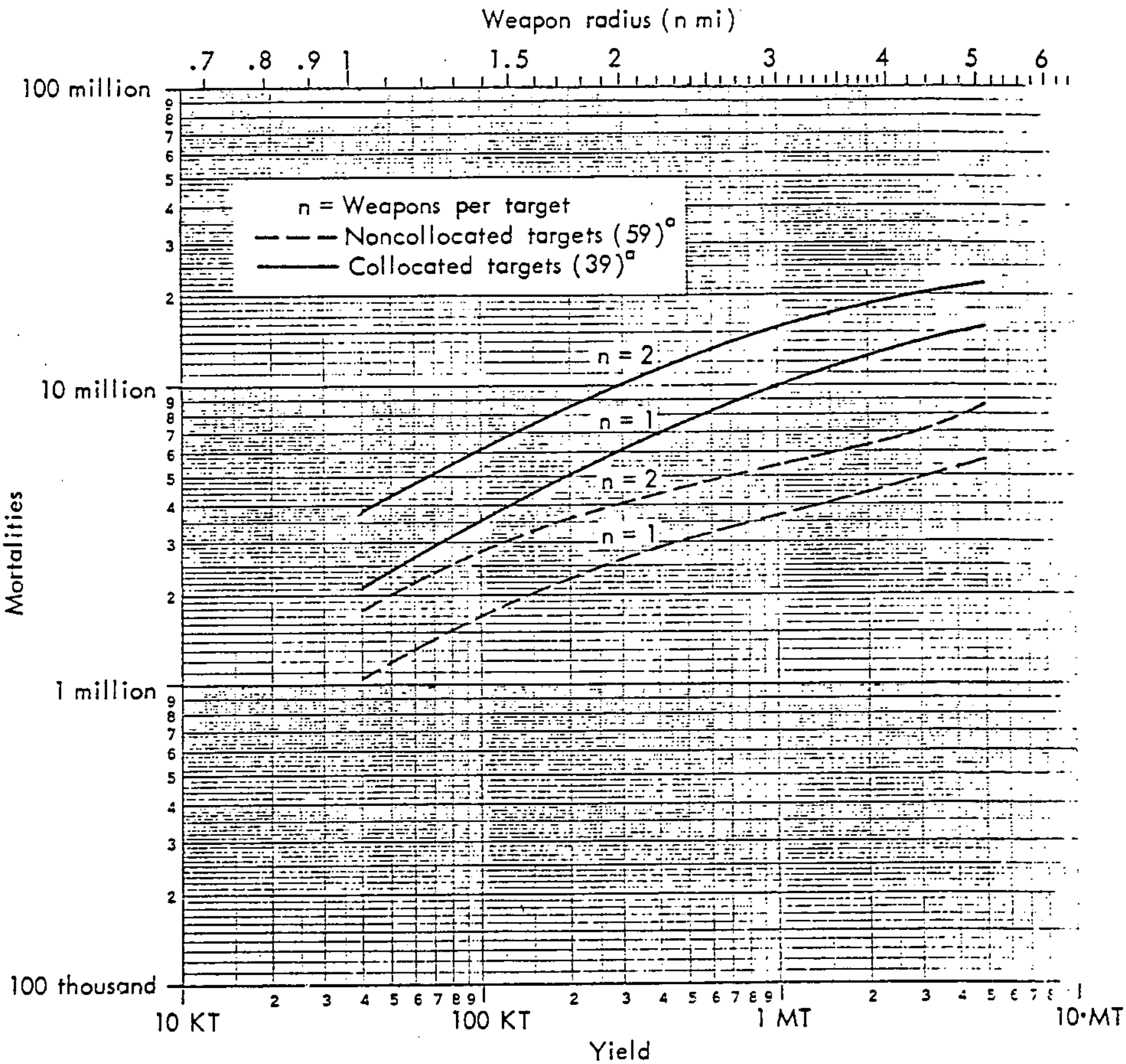

Figure 14—Major ports—blast mortalities by weight of attack (collocated and noncollocated targets)

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[a] The collocation criterion for this category is different from other categories. See p. 5.

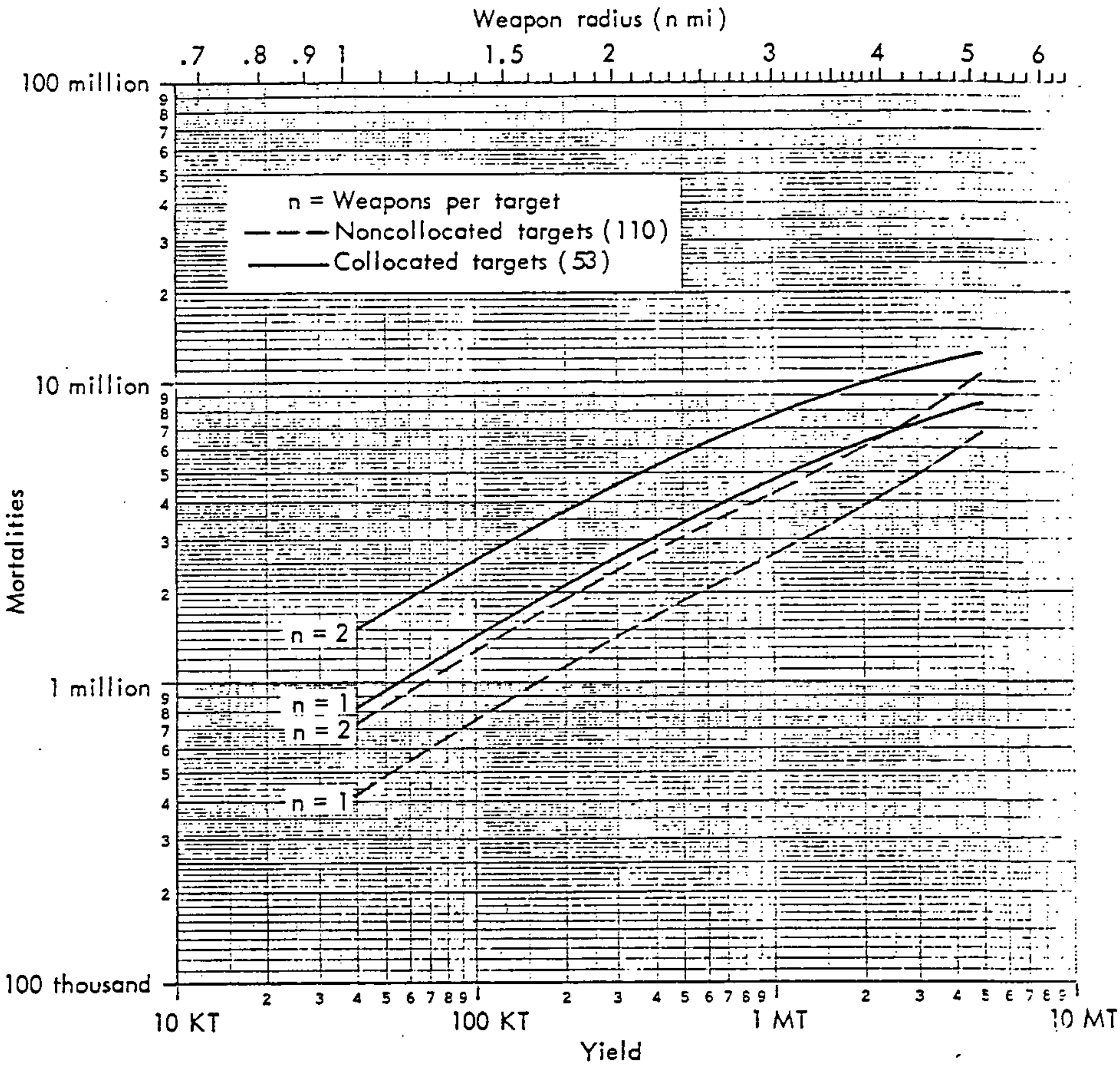

Figure 15—Army materiel depots—blast mortalities by weight of attack (collocated and noncollocated targets)

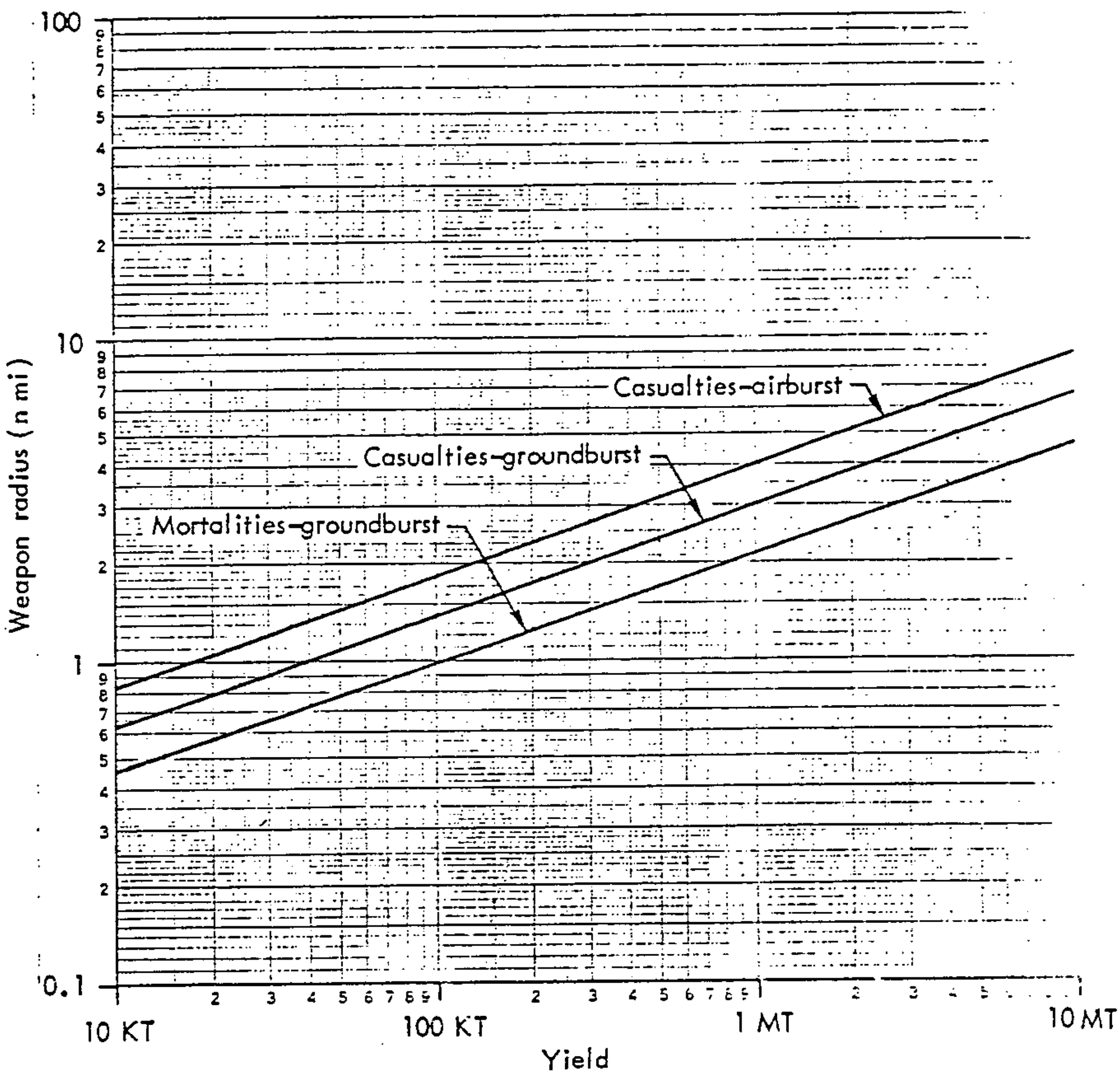

Figure 16—Weapon radii for casualties from airburst and groundburst weapons and for mortalities from groundburst weapons

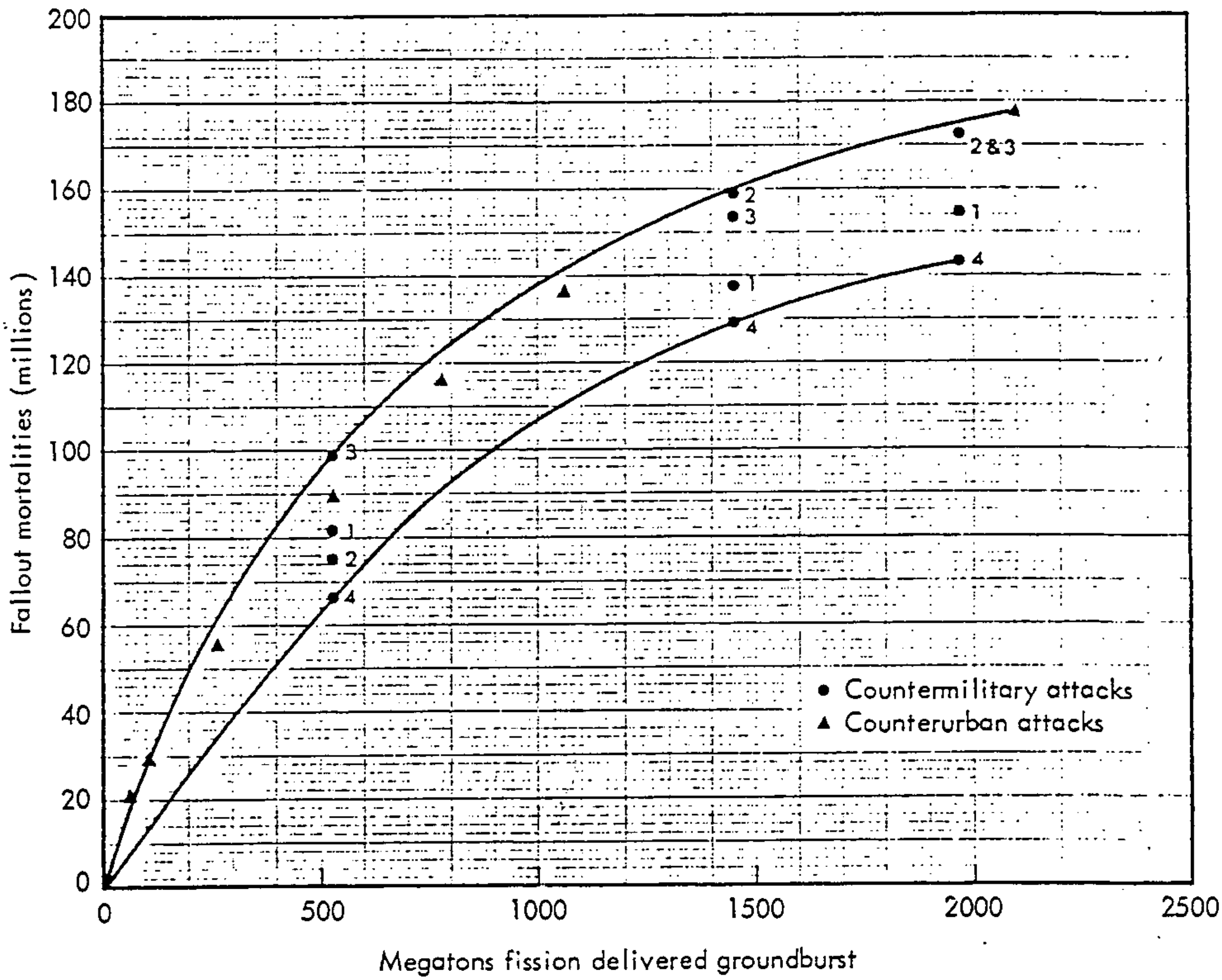

Figure 17—Fallout mortalities

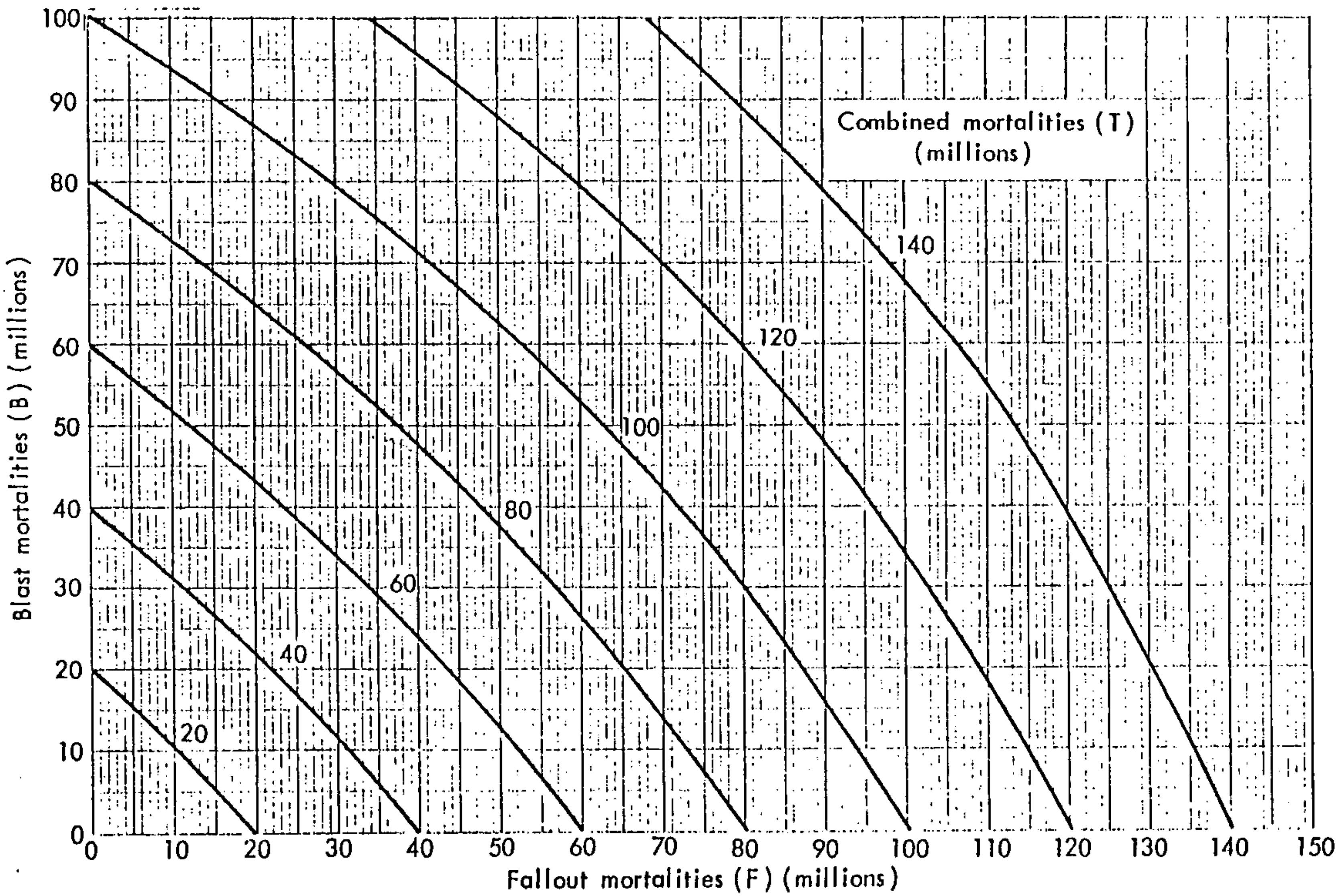

Figure 18—Combined blast and fallout mortalities in Western Europe

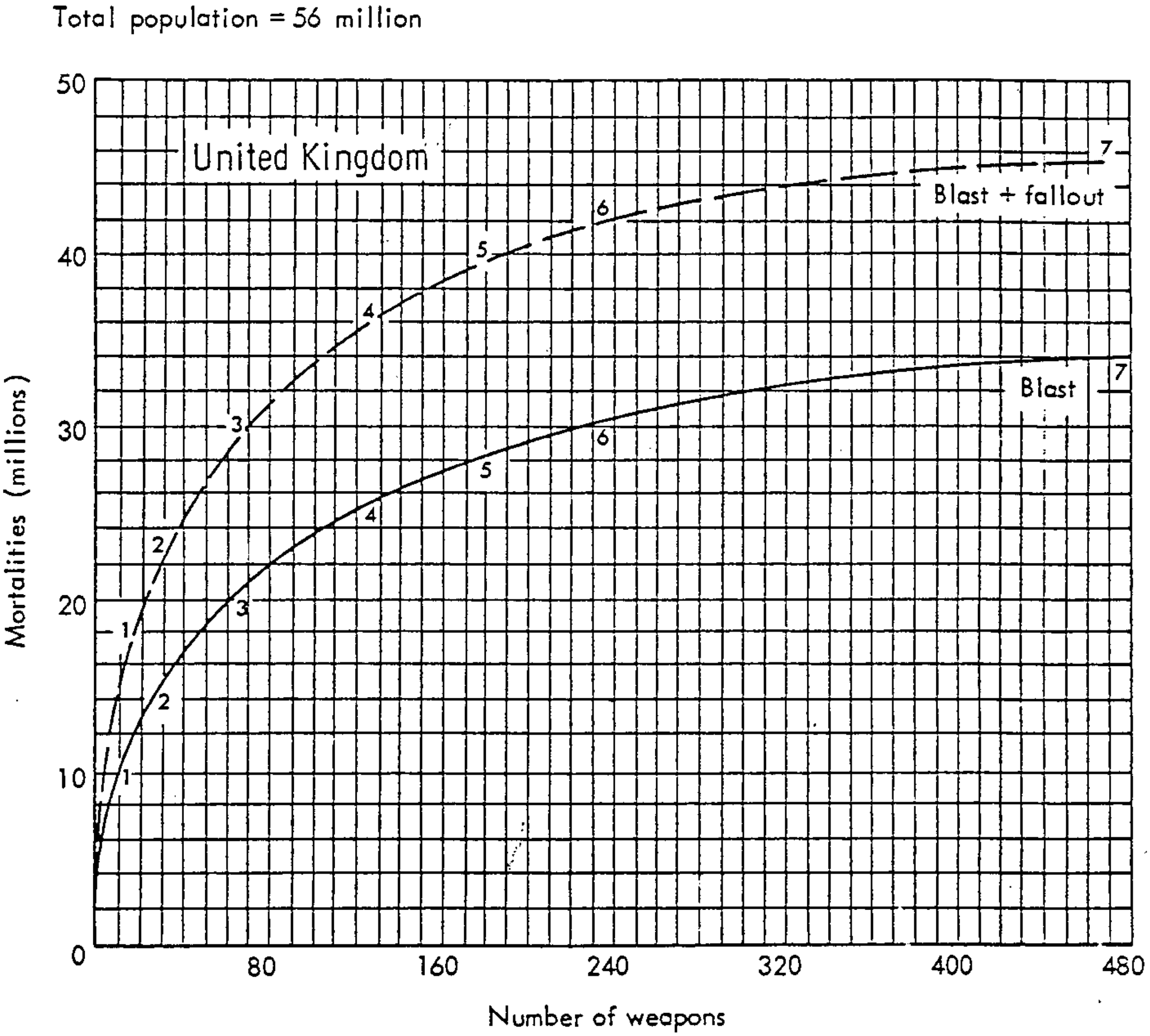

Figure 19—Mortalities from urban attacks—United Kingdom

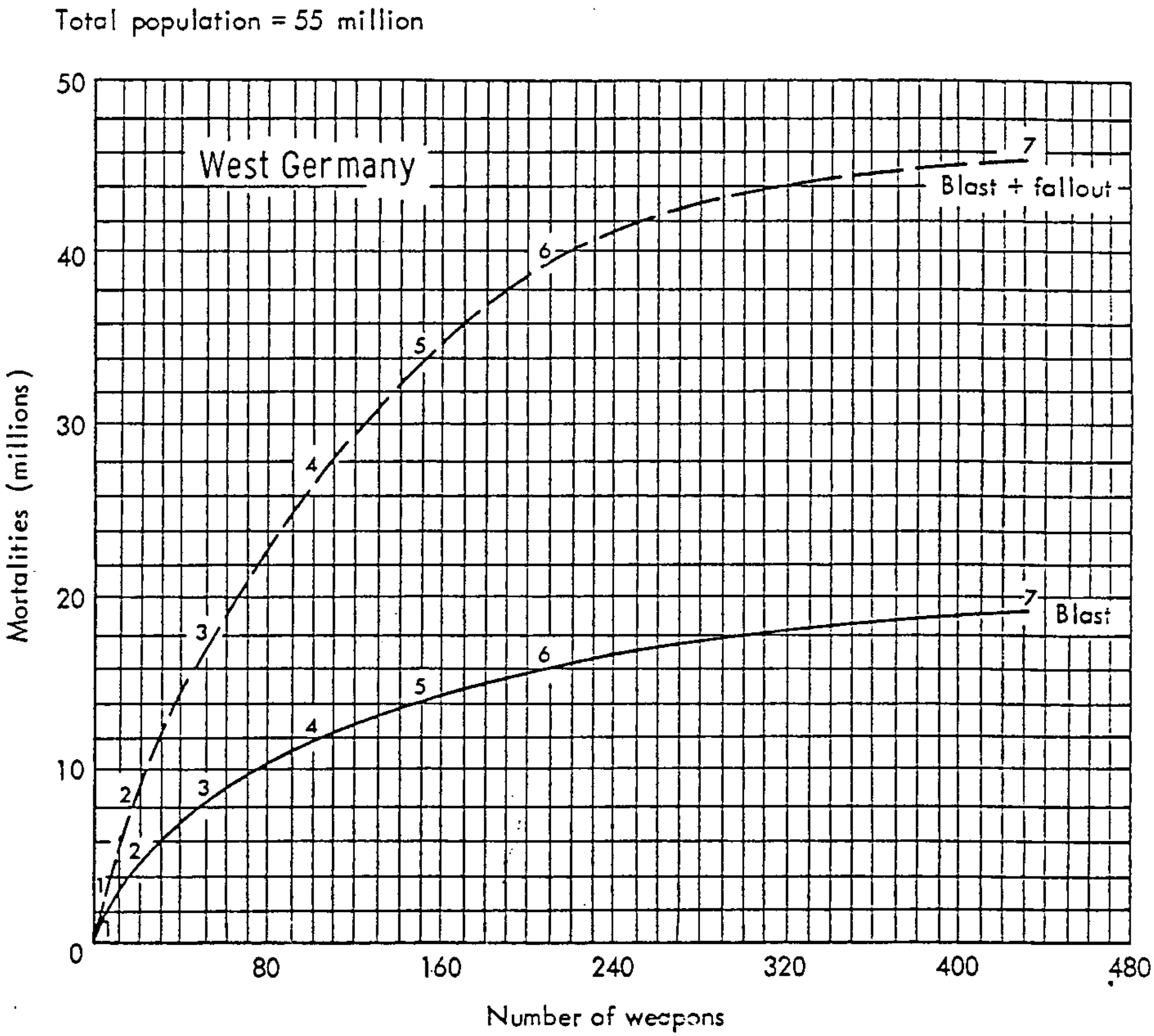

Figure 20—Mortalities from urban attacks—West Germany

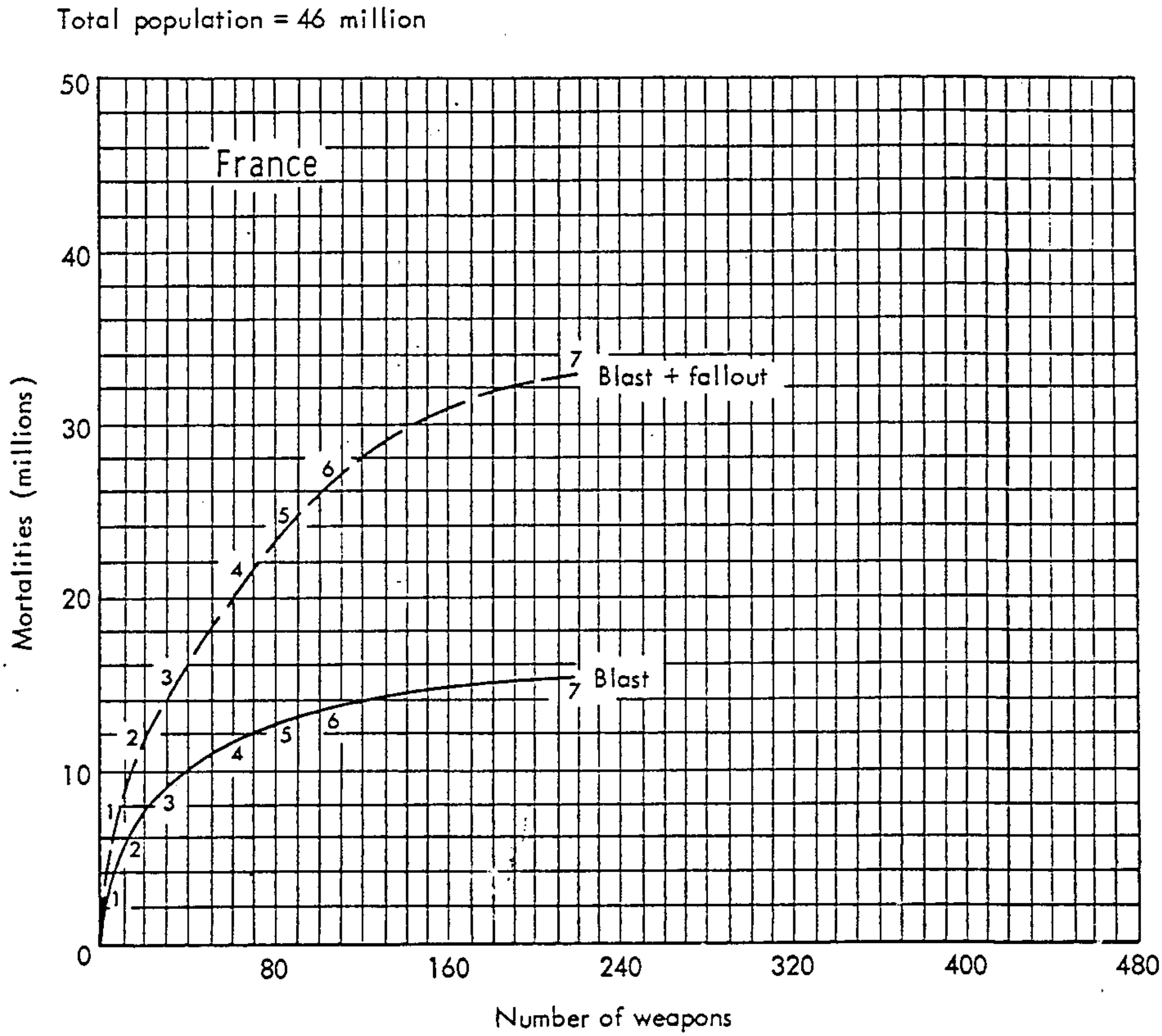

Figure 21—Mortalities from urban attacks—France

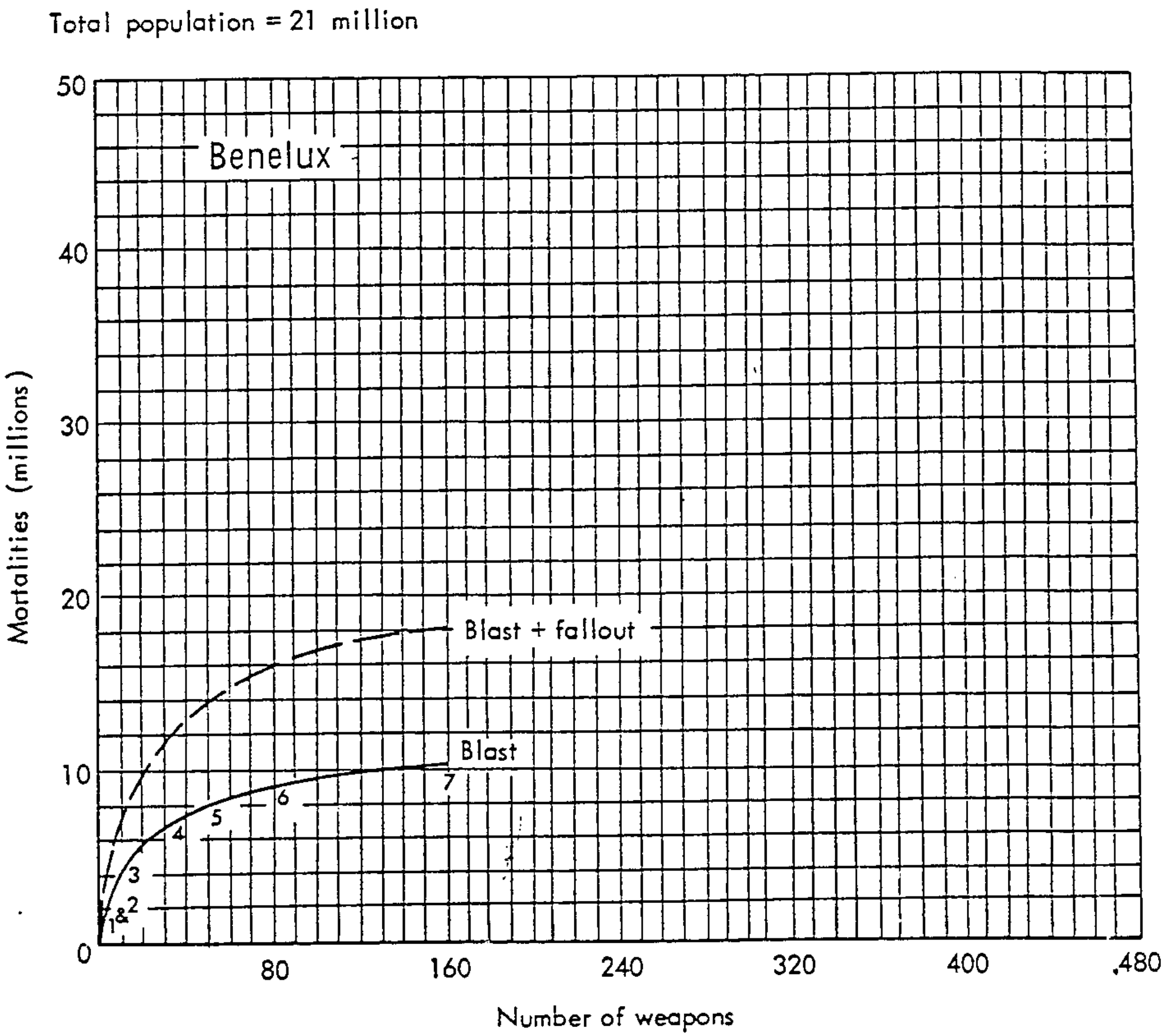

Figure 22—Mortalities from urban attacks—Benelux

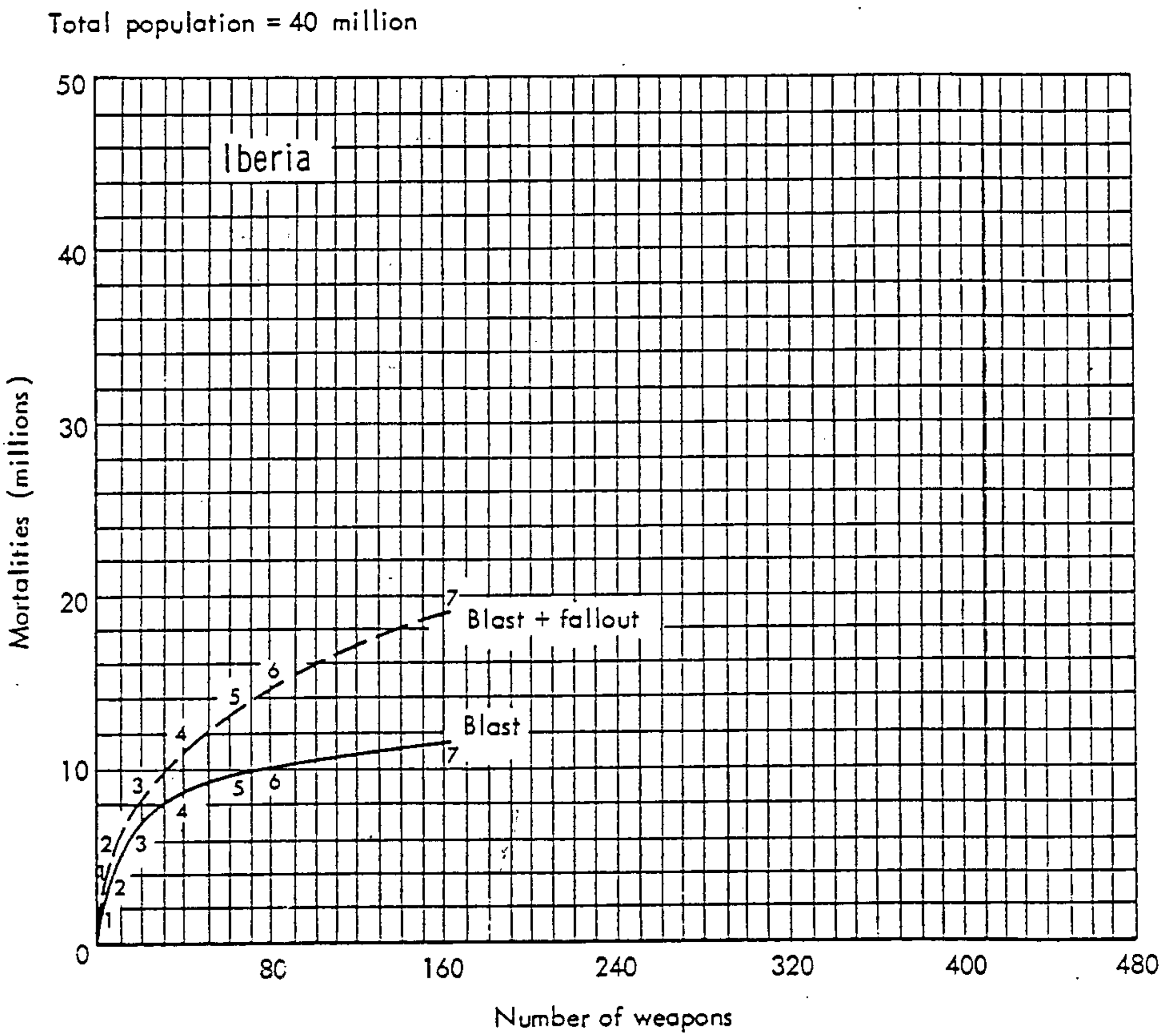

Figure 23—Mortalities from urban attacks—Iberia

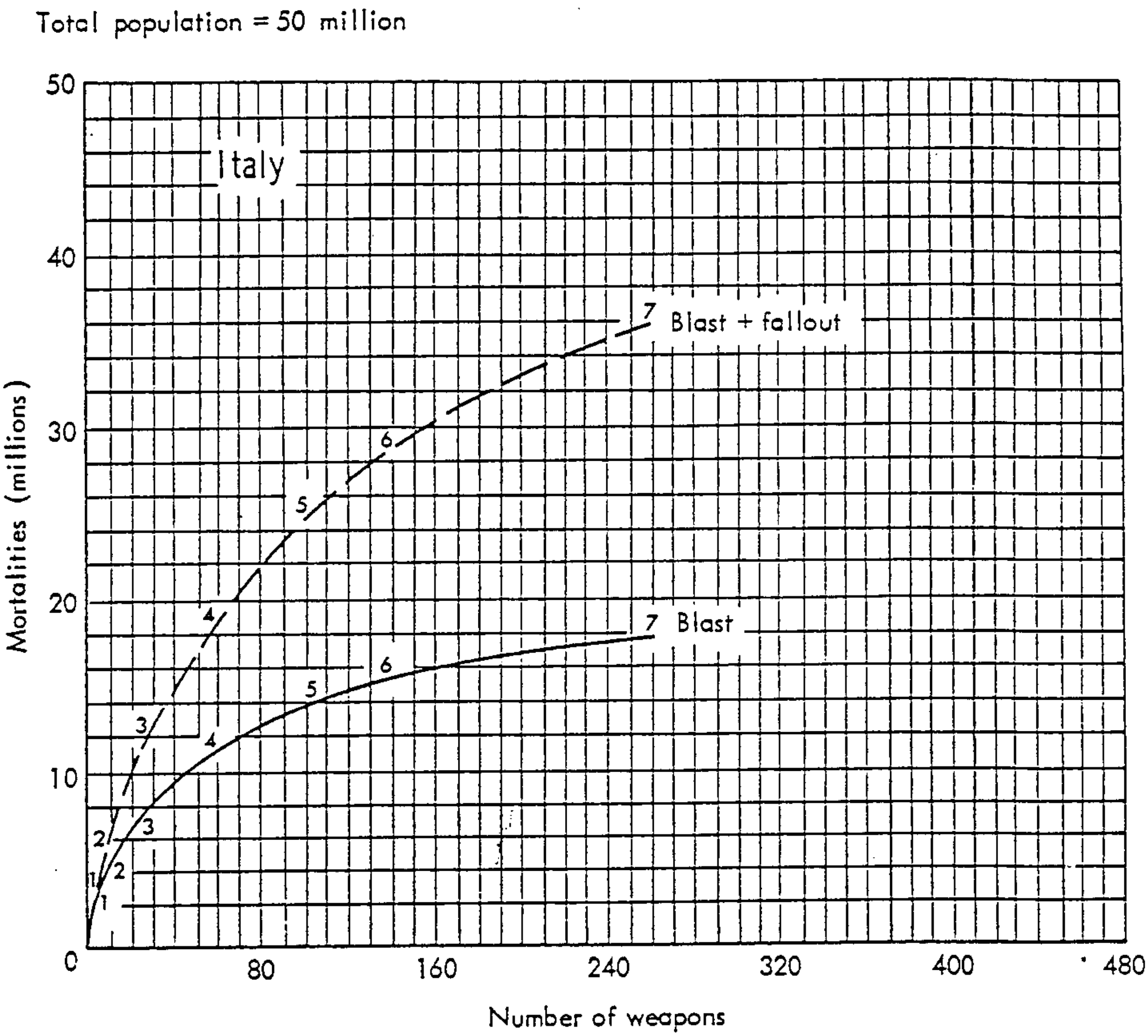

Figure 24—Mortalities from urban attacks—Italy

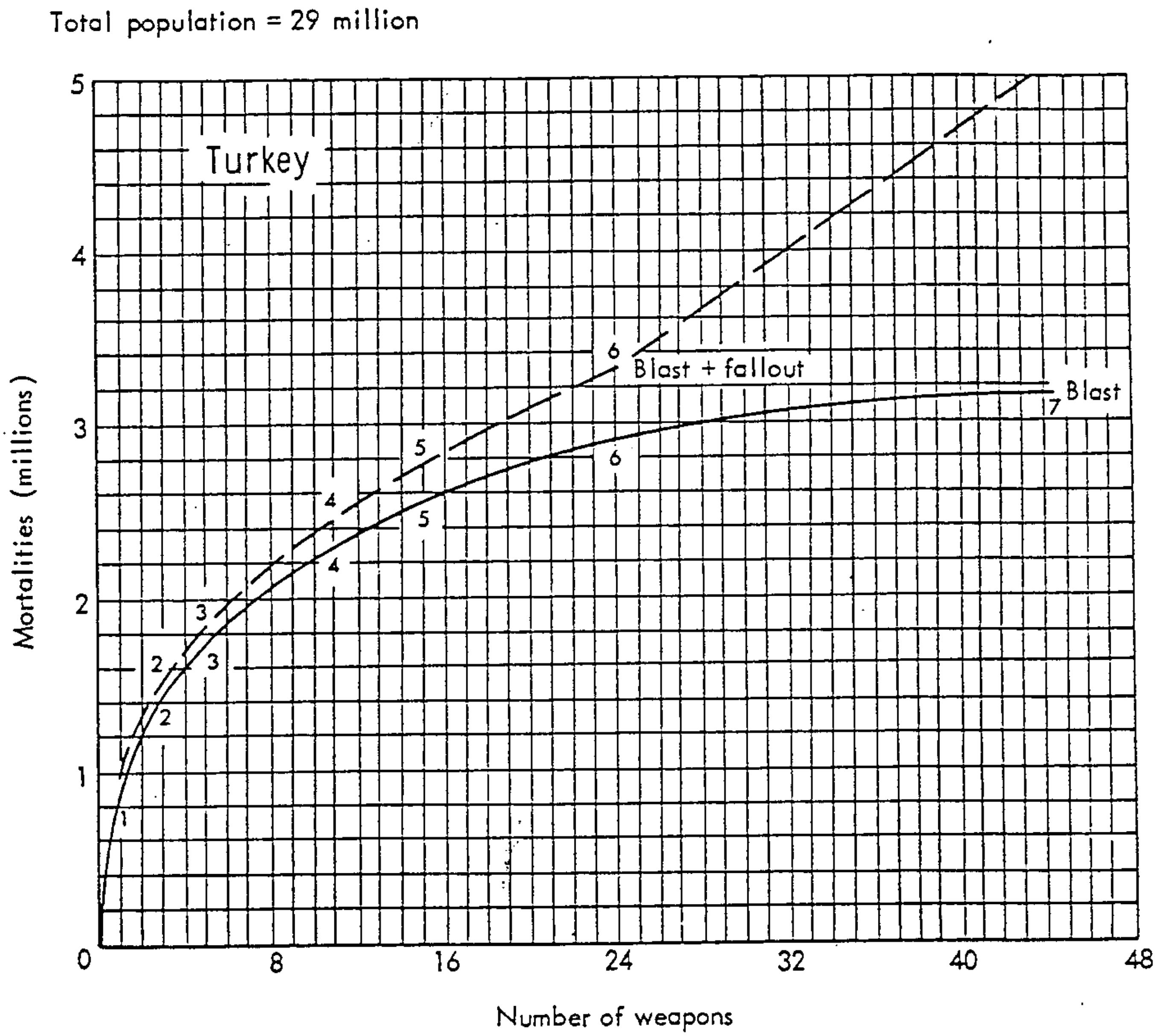

Figure 25—Mortalities from urban attacks—Turkey

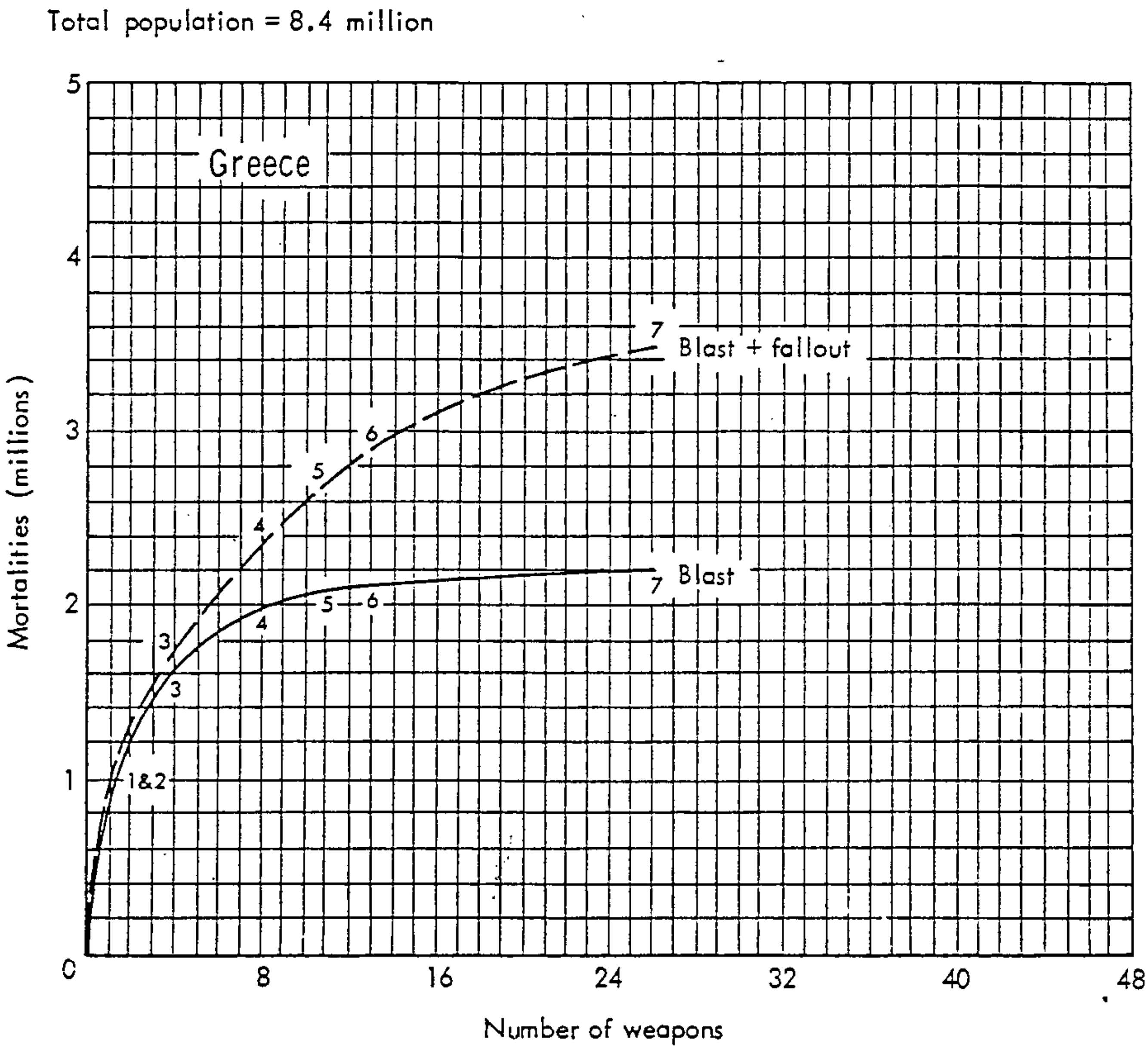

Figure 26—Mortalities from urban attacks—Greece

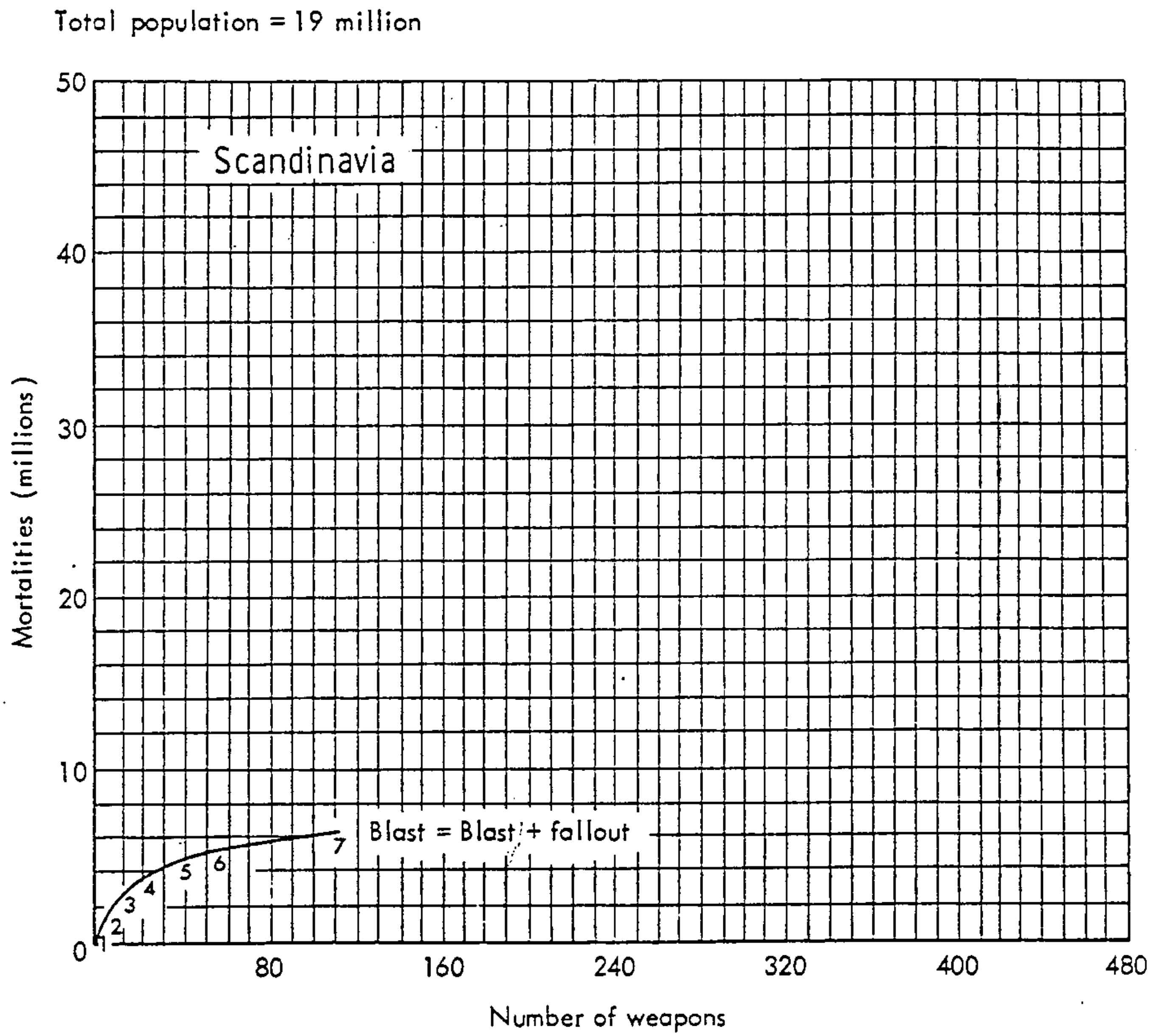

Figure 27—Mortalities from urban attacks—Scandinavia

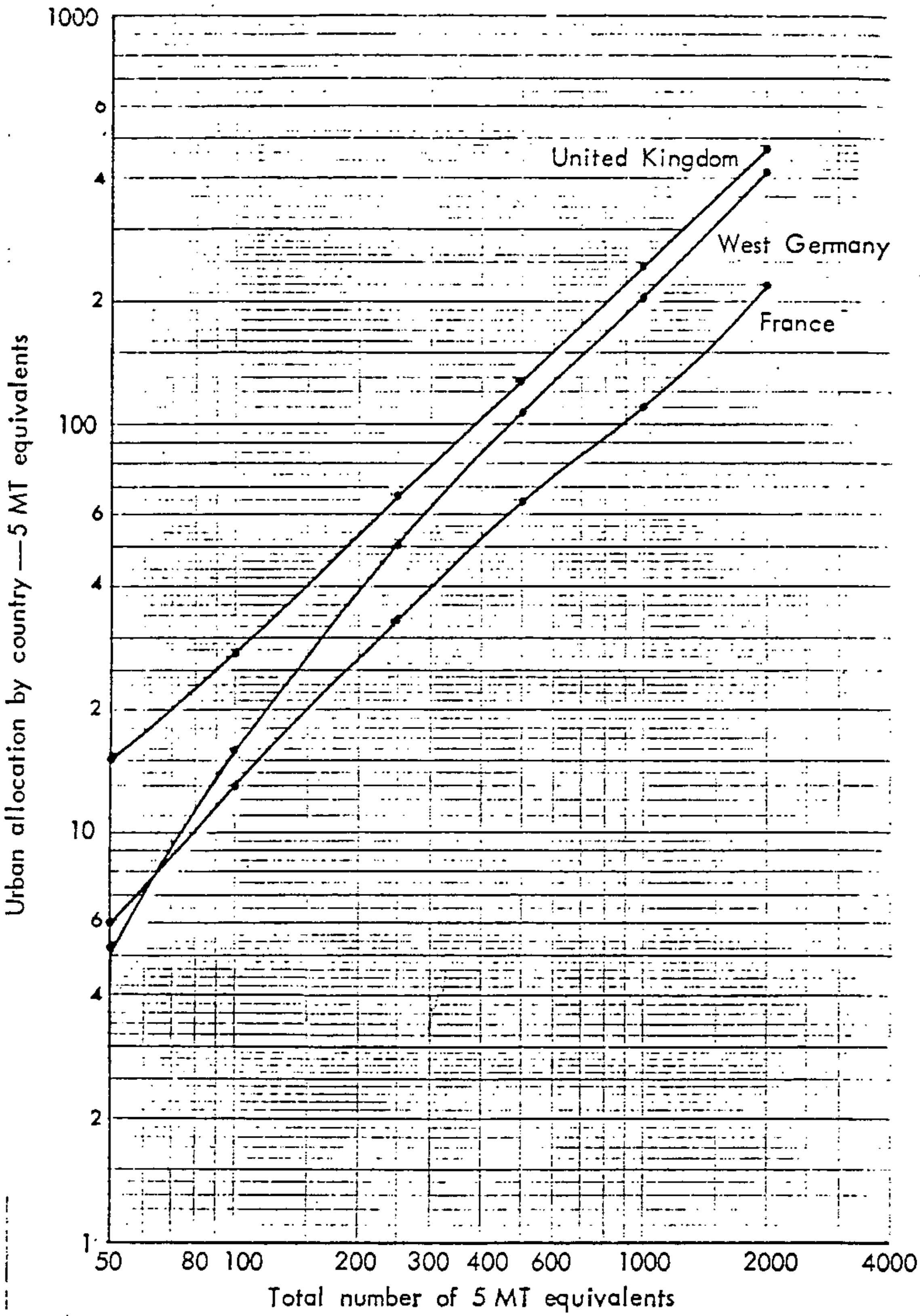

Figure 28—Soviet damage maximizing allocation by country—France, United Kingdom, West Germany

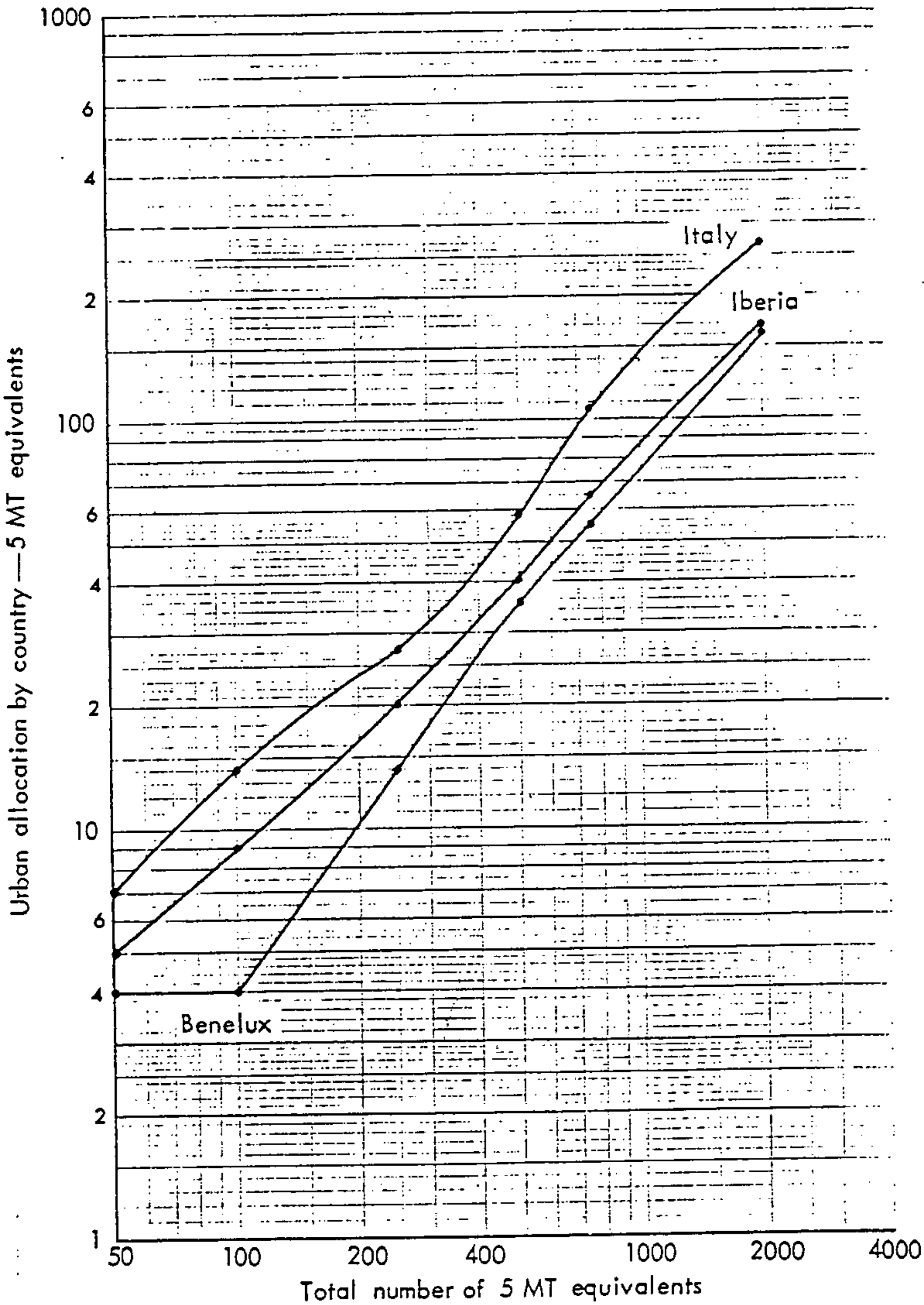

Figure 29—Soviet damage maximizing allocation by country—Benelux, Iberia, Italy

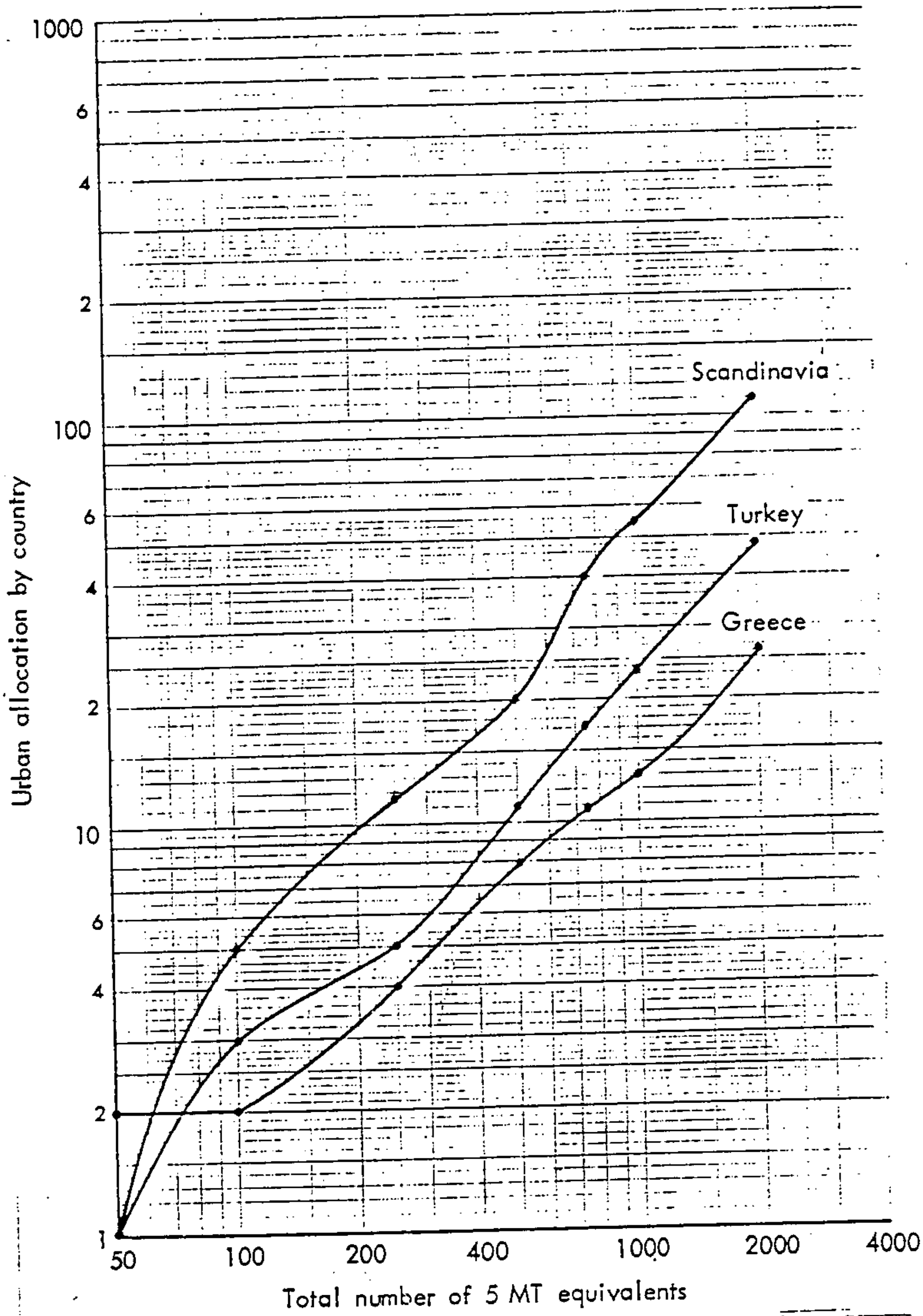

Figure 30—Soviet damage maximizing allocation by country—Greece, Scandinavia, Turkey

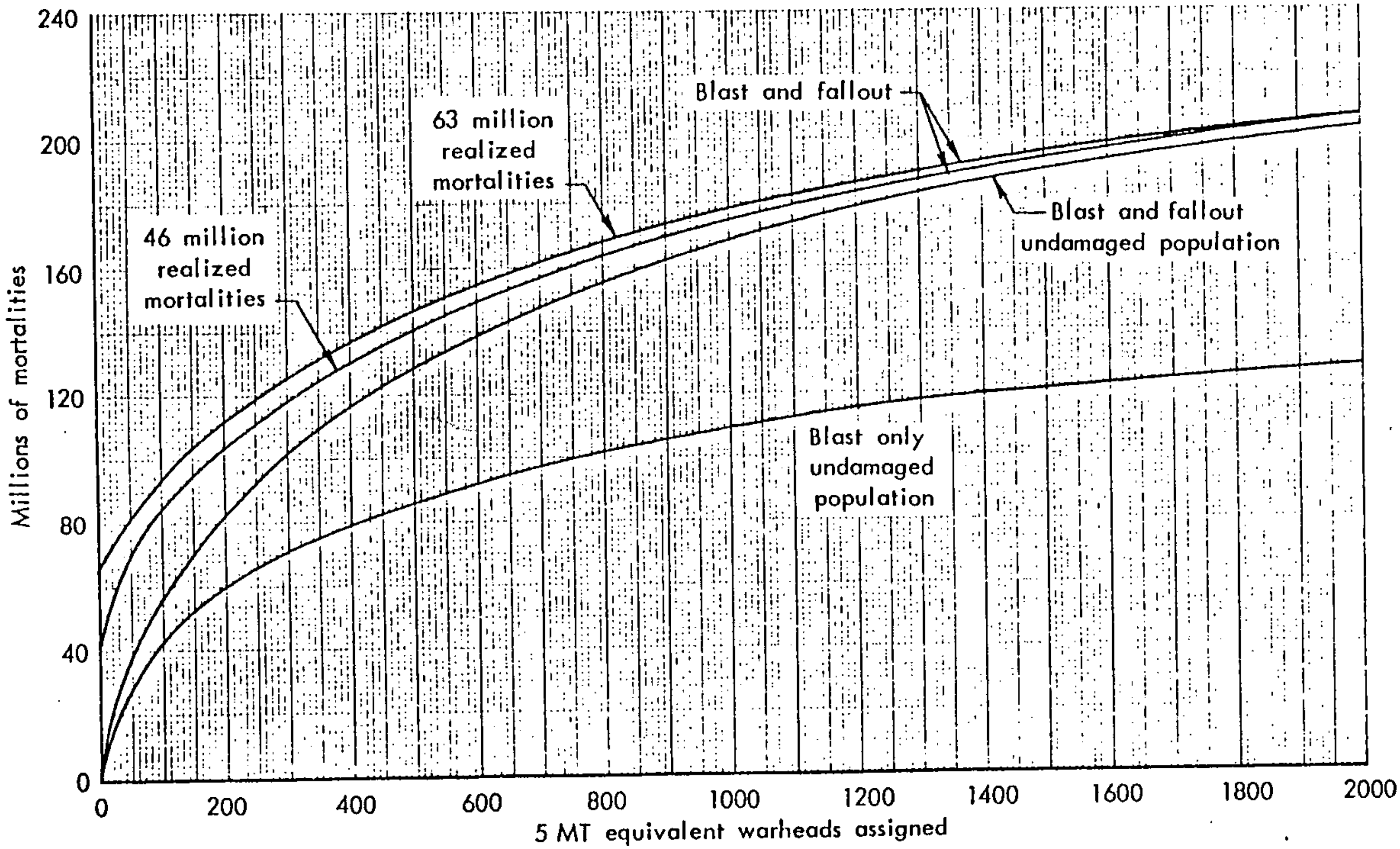

Figure 31—Soviet residual damage inflicting capability against West Europe—blast and fallout

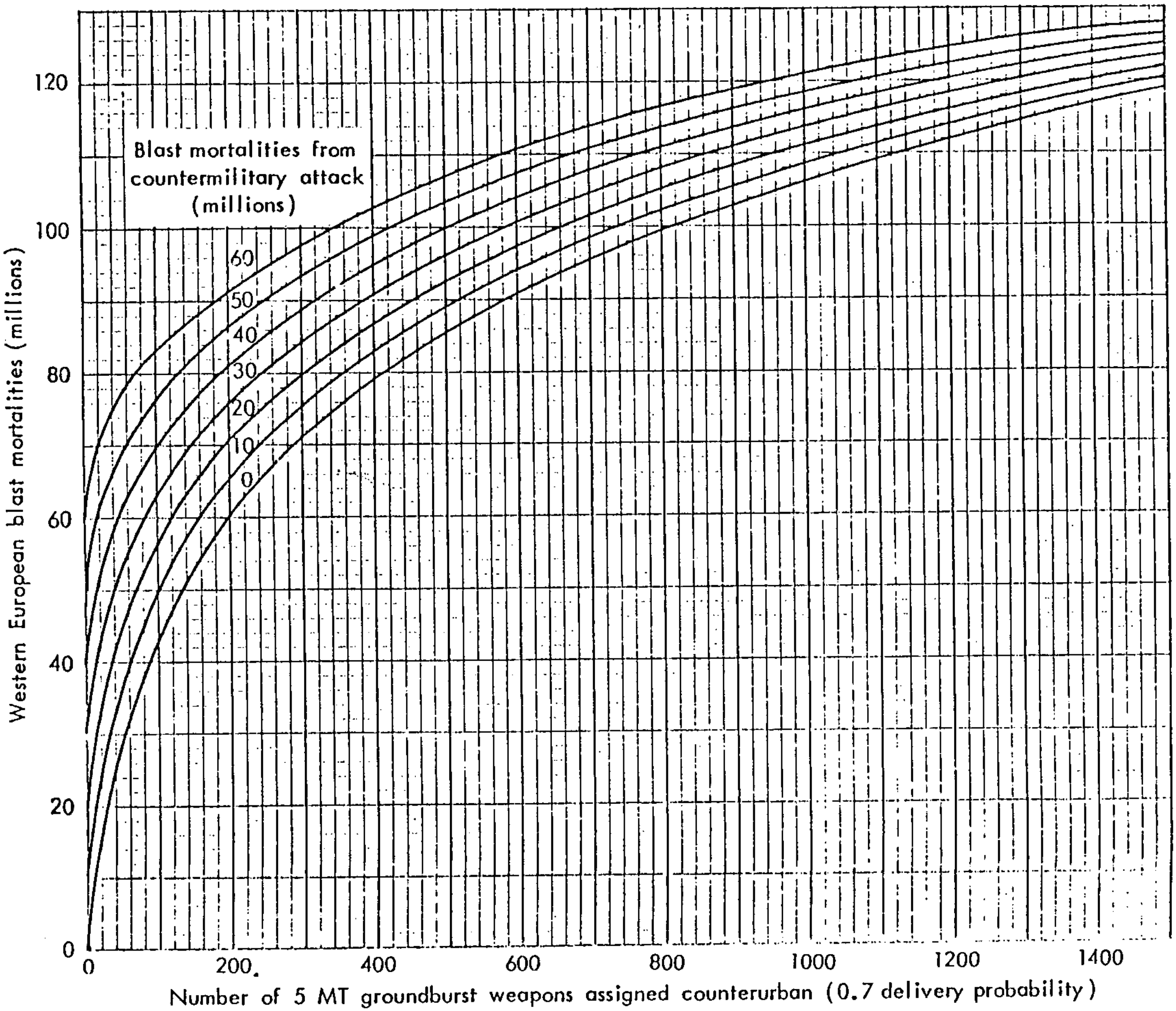

Figure 32—Blast mortalities from combined countermilitary and counterurban attacks

Appendix A

MATHEMATICAL DERIVATIONS

FORMULAE FOR ADJUSTING BLAST MORTALITIES TO DELIVERY PROBABILITIES OTHER THAN 0.7

As in the text, let m(1) and m(2) denote the expected mortalities if one or two weapons are assigned to a target with delivery probability 0.7. These are the quantities graphed in Section II.

Let t(1) and t(2) denote the expected mortalities if one or two weapons are assigned with delivery probability 1. Then

$$m(1) = 0.7t(1)$$

$$m(2) = 2(0.7)(1 - 0.7)t(1) + (0.7)^2 t(2).$$

These equations can be solved for t(1) and t(2) giving

$$t(1) = m(1)/(0.7)$$

$$t(2) = \frac{m(2) - 2(1 - 0.7)m(1)}{(0.7)^2}$$

Suppose now the delivery probability is taken to be p. Let n(1) and n(2) denote the expected mortalities with one or two weapons. Then

$$n(1) = pt(1)$$

$$n(2) = 2p(1 - p)t(1) + p^2 t(2).$$

Substituting the values for t(1) and t(2) found above and simplifying,

$$n(1) = \left(\frac{p}{0.7}\right)m(1)$$

$$n(2) = 2\left(\frac{p}{0.7}\right)\left(1 - \frac{p}{0.7}\right)m(1) + \left(\frac{p}{0.7}\right)^2 m(2).$$

For more than two weapons per target, approximation methods are needed. The simplest, and quite satisfactory for most purposes, is to assume that the mortalities are primarily a function of the expected number of weapons delivered, E, and to use the two weapons per target formula above to approximate this function. Let n be the number of weapons assigned per target, so that E = np. If we let n = 2, E = 2p or p = E/2. Writing the formula for two weapons in terms of E yields

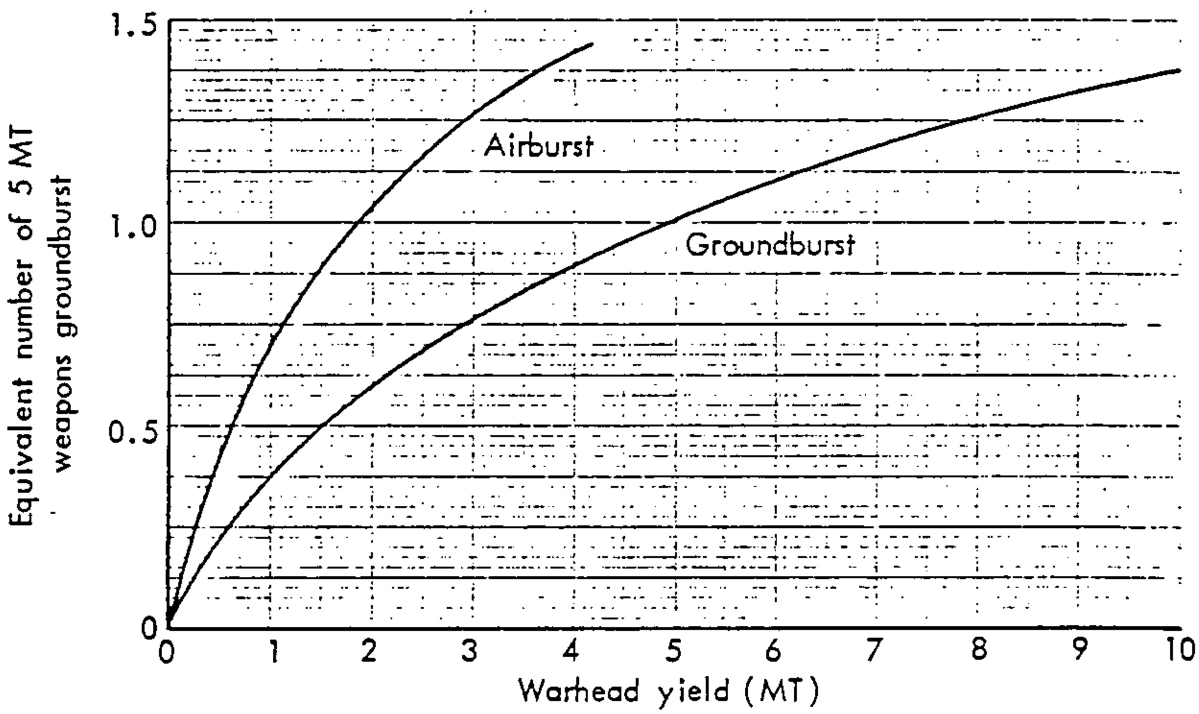

Figure 33—Number of blast equivalent 5 MT groundburst weapons

$$2\left(\frac{E/2}{0.7}\right)\left(1 - \frac{E/2}{0.7}\right)m(1) + \left(\frac{E/2}{0.7}\right)^2 M(2).$$

Using this formula for all n, we get the approximation:

$$2\frac{np}{1.4}\left(1 - \frac{np}{1.4}\right) \times m(1) + \left(\frac{np}{1.4}\right)^2 M(2). \qquad (1)$$

A more satisfactory approximation that is found by assuming the function $t(n)$ gives the mortalities expected if n weapons are delivered with certainty is of the form

$$t(n) = T(1 - r^n)$$

for some T and r. This formula would be exactly correct if all the population affected was at the same distance from the target.

If n weapons are assigned with probability p, the expected mortalities, M, are

$$M = \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} t(k)$$

$$= \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} T(1 - r^k)$$

$$= T \sum_{k=0}^{n} \binom{n}{k} p^k (1 - p)^{n-k} - T \sum_{k=0}^{n} \binom{n}{k} (pr)^k (1 - p)^{n-k}$$

$$= T[1 - (rp + 1 - p)^n]$$

$$M = T\{1 - [1 - (1 - r)p]^n\} . \qquad (2)$$

To use this we need to express T and $(1 - r)$ in terms of $M(1)$ and $M(2)$, the expecced mortalities for one and two weapons of delivery probability $p = 0.7$. Using equation (2) with $p = 0.7$ and $n = 1$ and 2:

$$m(1) = T\{1 - [1 - (1 - r)0.7]\}$$

$$m(2) = T\{1 - [1 - (1 - r)0.7]^2\}.$$

Solving this pair for $(1 - r)$ and T and substituting in (2) yields for general p,

$$M = \frac{m(1)}{K} [1 - (1 - K\ p/0.7)^n], \quad (3)$$

where $K = 2 - m(2)/m(1)$. If $K = 0$, use

$$M = m(1)n\ p/0.7.$$

Table A-1 shows the largest n for which the two approximations differ by less than 10 per cent. For larger n formula (3) is recommended, although the degree of extrapolation involved if np is much greater than 2 makes neither reliable.

FORMULAE FOR ELIMINATING DOUBLE COUNTING IN COMBINING BLAST AND FALLOUT EFFECTS

Let B be the expected mortalities (or casualties) due to blast alone, either in a country, group of countries, or all of Western Europe; let F be the expected mortalities (or casualties) due to fallout only in the same region; and let T be the total mortalities from both blast and fallout. In general, $T < B + F$, the difference being the number of people who are both blast and fallout mortalities (or casualties). If either B or F is small, relative to the total population involved, the difference between T and B + F will tend to be small. However, when both B and F are large relative to the total population at risk, the sum B + F can be considerably larger than T.

Although no formula can give T simply in terms of B and F, because it is possible for two cases to give the same B and F but different T, there are considerations that suggest a formula of the form $T = B + F - BF/K$ will give a reasonable approximation for a suitable choice of K. It has, first of all, the aforementioned properties of leading to a small correction if either B or F is small relative to K, and a large correction when both are large relative to K.

Such a formula would be exactly correct if there were no correlation, in a probability sense, between fallout only and blast only mortalities (or casualties). In this case K would be the total population "at risk." However, there is no a priori of specifying exactly how many are at risk or of ruling out either positive or negative

Table A-1

TABLE OF n_{max}, THE LARGEST VALUE OF n FOR WHICH FORMULA (1) SHOULD BE USED

K	p	n_{max}	K	p	n_{max}	K	p	n_{max}	K	p	n_{max}
.1	.05	> 15	.3	.05	> 15	.5	.05	14	.7	.05	10
.1	.10	> 15	.3	.10	12	.5	.10	8	.7	.10	6
.1	.30	12	.3	.30	5	.5	.30	4	.7	.30	3
.1	.50	8	.3	.50	4	.5	.50	3	.7	.50	5
.1	.70	6	.3	.70	3	.5	.70	5	.7	.70	3
.1	.90	5	.3	.90	3	.5	.90	4	.7	.90	2
.1	1.00	5	.3	1.00	6	.5	1.00	3	.7	1.00	2

correlations. Hence, we take the approach of formula fitting; that is, we find the value of K that "best" fits the available Quick Count runs and measure how well the formula fits the runs with this choice of K. We take as the measure of fit the root mean square error.

Let us suppose one has n calculations of B, F, and T, denoted by B_i, F_i, T_i for $1 \le i \le n$. We wish to fit this data by a formula of the form $T = B + F - BF/K$ where K is chosen so as to minimize the mean square error defined as

$$E = \frac{1}{n} \sum_{i=1}^{n} [T_i - (B_i + F_i - B_i F_i/K)]^2$$

(The root mean square error is the square root of E.)

Differentiating with respect to K:

$$\frac{\partial E}{\partial K} = - \frac{2}{K^2 n} \sum_{i=1}^{n} B_i F_i (T_i - B_i - F_i + B_i F_i/K).$$

The quantity $\partial E/\partial K$ is zero for the K which minimizes E, hence K is the solution to the equation

$$\sum_{i=1}^{n} B_i F_i (T_i - B_i - F_i + B_i F_i/K) = 0,$$

that is,

$$K = \frac{\Sigma_i (B_i F_i)^2}{\Sigma_i B_i F_i (B_i + F_i - T_i)} .$$

This formula is used in Appendix B to derive values of K for each country and for all of Western Europe using the data of Table B-10. Table B-11 shows the resulting values of K, the root mean square error of the difference between Quick Count and formula-computed totals and the root mean square per cent error of these differences.

The root mean square per cent error varies greatly from country to country, from a low of 1.6 per cent for France to a high of 9 per cent for Turkey.

CALCULATING CIVIL BLAST DAMAGE FROM COUNTERMILITARY ATTACKS

The calculations of Section II were done using the Quick Count model. It is possible that some readers will find that the target categories in Section II do not suit their purposes. They may wish to use a different list or a different categorization of targets in the list, or they may wish to have blast damage results on individual targets. Although Quick Count could be rerun for these purposes, this would be inefficient. Furthermore, Quick Count or other large scale models may not be readily available. Hence, the following paragraphs discuss a means whereby such calculations can be done by hand or partly or completely programmed for automatic processing equipment of moderate capabilities.

The basic data requirement is for population by geographic location so that a tabulation of population versus distance to aim point may be constructed for each target. It is assumed that this is expressed in terms of population in concentric annuli of radii r_1, r_2, ..., r_n with $0 < r_1 < r_2 \ldots < r_n$. For convenience in notation we let $r_o = 0$. Let p_i, $1 \le i \le n$ be the total population inside the annulus with inner radius r_{i-1} and outer radius r_i. (For $i = 1$ this is just the total population inside the circle of radius r_1.) The spacing of the r_is and how far out one should go both depend on the range of weapon radii to be considered. For small weapon radii a finer spacing is required although it is not necessary to go out as far. However, if both large and small radii are to be considered, it is necessary both to have a fine spacing and go out a large distance.

The Physical Vulnerability Handbook -- Nuclear Weapons (U),[1] presents graphs of the average destruction in a circle whose center is at the aim point. Once the characteristics of a weapon system and population vulnerability are specified this quantity can be expressed as a function of the radius of the circle, r. Let D(r) be this function,

[1]Physical Vulnerability Handbook -- Nuclear Weapons (U), Prepared by Defense Intelligence Agency Production Center, PC 550/1-2-63, September 1, 1963 (Confidential), pp. V-11 to V-13. This publication supersedes AFM 200-8, Nuclear Weapons Employment Handbook, September 1, 1961.

that is, D(r) is the average fraction of a circle of radius r destroyed by a system with a given weapon radius and CEP. Then it can be shown that the average fraction of the i^{th} annulus (with inner radius r_{i-1} and outer radius r_i) destroyed, d_i, is

$$d_i = \frac{D(r_i)r_i^2 - D(r_{i-1})r_{i-1}^2}{r_i^2 - r_{i-1}^2}$$

and the expected population damage from one weapon delivered with certainty is

$$m(1) = \sum_{i=1}^{n} p_i d_i .$$

For n weapons delivered with certainty the expected damage can be approximated by

$$m(n) = \sum_{i=1}^{n} p_i d_i (1 - d_i)^{n-1}.$$

In n independent weapons are assigned with delivery probability r the expected mortalities would be

$$\sum_{j=1}^{n} \binom{n}{j} r^j (1 - r)^{n-j} m(j),$$

where

$$\binom{n}{j} = n!/(n - j)!j! \quad .$$

If more than one type of weapon is assigned to the target, expected mortalities can be determined by computing the expected mortalities from the first weapon type in each annulus, subtracting this number from the population in the annulus to get expected survivors in that annulus, and then applying the second weapon type to get expected additional mortalities in each annulus, and so on.

Aggregating by Target Groups

If the same targeting is to be made against each target in a group, such as all noncollocated primary airfields, then considerable work can be saved if one takes advantage of the fact that the total expected mortalities over the target group can be found by applying the above techniques to a single hypothetical target for which the total population in each annulus is the sum over all targets in the group of the total population in the corresponding annuli. Thus, once this aggregated population versus distance has been found for a target class it can be treated as only one target for the civil blast damage assessment calculation.

Errors Introduced by Ignoring Correlation Between Targets

The above techniques introduce no error provided no population point is close enough to two targets to be affected when both are attacked. One can get bounds on the error introduced by ignoring this effect by making

a. Lower bound damage estimate -- include each population point only once, associated with the closest target.

b. Upper bound damage estimate -- include each population point with every target it is near at its distance to that target.

Appendix B

COUNTRY-BY-COUNTRY RESULTS

Tables B-1 through B-9 contain blast mortalities by country for the cases used to construct the curves in Section II. Because of computer limitations it has been necessary to combine some countries into country groups. Table B-10 contains mortalities caused by blast only, fallout only, and blast plus fallout. These were used to construct the curves in the figures of Section III.

The targeting used to generate Table B-10 is essentially that used in the hypothetical attack of Section V. In addition to the 4 MT attack discussed in Section V, the yield was raised to 11 MT.[1] A feature of the Quick Count program permits the results of two attacks to be combined. Thus Table B-10 contains results for a 4 MT counterforce attack, an 11 MT attack, and a combined 4 MT and 11 MT attack.

The data of Table B-10 was used to compute values of K for use in the formula $T = B + F - BF/K$ for estimating total mortalities (T) in terms of blast only mortalities (B) and fallout only mortalities (F). These values of K are given in Table B-11 as well as the standard deviation of the differences between the totals arrived at by Quick Count and the formula. In using the formula and the values of K it is necessary to express mortalities or casualties in millions.

For reference, Table B-12 gives total population and area in square statute miles for the countries treated.

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[1] An 11 MT attack was used to (1) provide a range of attack and (2) establish equal weapon radii for different weapon yields. The weapon radius of an 11 MT weapon groundburst is equal to that of a 4 MT weapon airburst. Using the Quick Count routine, a check on the "building block" calculations of Section V could be run simultaneously with the fallout computation.

Table B-1

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- BENELUX
(Population: 21 million)

Target Category	Number of Targets	One Weapon Per Target .04 MT	.2 MT	1 MT	5 MT	Two Weapons Per Target .04 MT	.2 MT	1 MT	5 MT
		Blast Mortalities (thousands)							
Primary Airfields									
collocated	5	41.6	144	483	1070	78.2	259	790	1540
noncollocated	15	36.5	82.4	212	699	63.9	140	371	1170
Secondary Airfields									
collocated	3	17.9	53.8	229	935	30.3	103	424	1530
noncollocated	2	3.3	7.9	32.1	102	5.0	14.9	56.9	174
Reserve Airfields									
collocated	1	13.4	36.6	92.7	201	23.3	57.5	142	288
noncollocated	1	.6	1.1	3.9	30.3	.8	2.1	7.0	53.8
Nuclear Submarine Ports									
collocated	0								
noncollocated	1	13.2	25.2	32.1	33.1	22.8	36.9	42.3	43.2
Other Major Ports									
very collocated	5	430	1070	2180	3200	792	1820	3280	4440
partially collocated	6	89.4	201	434	1210	155	320	682	1860
Army Materiel Depots									
collocated	3	37.5	90.7	232	574	65.7	147	358	832
noncollocated	4	5.8	15.9	64.5	230	10.3	29.9	116	368

Table B-2

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- FRANCE
(Population: 46 million)

Target Category	Number of Targets	Blast Mortalities (thousands): One Weapon Per Target: .04 MT	.2 MT	1 MT	5 MT	Two Weapons Per Target: .04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	4	5.1	21.7	109	252	9.9	42.2	188	365
noncollocated	14	17.6	49.5	109	278	32.2	83.1	178	450
Secondary Airfields									
collocated	6	26.1	94.7	367	913	50.5	183	641	1330
noncollocated	41	141	395	1140	3170	264	757	2110	5240
Reserve Airfields									
collocated	3	2.4	10.6	54.7	121	4.0	19.6	88.8	173
noncollocated	20	17.4	56.5	215	719	31.6	102	367	1160
Nuclear Submarine Ports									
collocated	2	46.2	101	164	202	82.4	159	230	275
noncollocated	0								
Other Major Ports									
very collocated	6	173	400	715	1000	318	660	1040	1360
partially collocated	8	101	216	356	458	177	337	503	633
Army Materiel Depots									
collocated	10	117	266	475	675	212	434	695	960
noncollocated	9	78.7	189	500	1390	136	353	923	2480
Major Command Centers	2	19.2	42.4	97.3	324	23.7	64.9	180	624

Table B-3

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- GREECE
(Population: 8.4 million)

Target Category	One Number of Targets	Blast Mortalities (thousands) One Weapon Per Target .04 MT	.2 MT	1 MT	5 MT	Two Weapons Per Target .04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	0								
noncollocated	6	9.5	26.7	53.3	132	17.3	43.7	80.6	222
Secondary Airfields									
collocated	0								
noncollocated	0								
Reserve Airfields									
collocated	0								
noncollocated	2	6.4	25.4	118	550	12.7	44.5	223	913
Nuclear Submarine Ports									
collocated	0								
noncollocated	0								
Other Major Ports									
very collocated	0								
partially collocated	2	50.3	92.8	116	123	85.9	136	156	163
Army Materiel Depots									
collocated	1	51.2	150	424	912	96.0	284	739	1320
noncollocated	6	8.8	30.4	78.2	286	16.2	49.1	124	498

Table B-4

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- IBERIA
(Population: 40 million)

Target Category	Number of Targets	Blast Mortalities (thousands): One Weapon Per Target .04 MT	.2 MT	1 MT	5 MT	Two Weapons Per Target .04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	1	1.8	8.5	35.3	57.9	3.4	15.9	55.9	79.7
noncollocated	9	6.3	14.3	53.0	322	9.6	23.1	94.9	556
Secondary Airfields									
collocated	1	13.9	46.6	173	475	26.1	89.6	313	702
noncollocated	11	6.0	16.9	55.2	369	10.7	29.2	98.3	610
Reserve Airfields									
collocated	0								
noncollocated	3	2.4	12.5	41.1	337.1	4.1	18.4	68.0	606
Nuclear Submarine Ports									
collocated	0								
noncollocated	0								
Other Major Ports									
very collocated	5	302	612	869	973	524	923	1180	1290
partially collocated	9	117	252	410	605	206	394	578	869
Army Materiel Depots									
collocated	6	67.3	150	280	645	119	241	416	1010
noncollocated	6	18.8	51.6	166	629	32.8	91.4	291	1010

Table B-5

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- ITALY
(Population: 50 million)

Target Category	Number of Targets	Blast Mortalities (thousands)							
		One Weapon Per Target				Two Weapons Per Target			
		.04 MT	.2 MT	1 MT	5 MT	.04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	0								
noncollocated	0								
Secondary Airfields									
collocated	5	61.7	179	546	1290	115	320	913	1890
noncollocated	14	19.4	49.3	135	500	33.5	85.8	230	847
Reserve Airfields									
collocated	3	29.3	98.9	309	586	56.9	184	508	825
noncollocated	11	38.4	110	372	1170	68.9	212	678	1930
Nuclear Submarine Ports									
collocated	1	46.3	92.8	136	161	81.5	144	190	222
noncollocated	0								
Other Major Ports									
very collocated	5	305	712	1320	1940	559	1180	1910	2500
partially collocated	8	152	332	531	665	269	519	730	896
Army Materiel Depots									
collocated	2	103	263	574	984	196	476	933	1410
noncollocated	0								

Table B-6

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- SCANDINAVIA
(Population: 19 million)

		Blast Mortalities (thousands)							
		One Weapon Per Target				Two Weapons Per Target			
Target Category	Number of Targets	.04 MT	.2 MT	1 MT	5 MT	.04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	0								
noncollocated	10	7.8	18.0	59.2	230.1	12.0	32.4	104	397
Secondary Airfields									
collocated	0								
noncollocated	12	4.2	15.9	65.4	323	7.9	29.1	124	563
Reserve Airfields									
collocated	1	1.3	3.9	69.7	336	1.4	6.4	131	488
noncollocated	1	.1	.3	.9	8.6	.2	.6	1.7	15.5
Nuclear Submarine Ports									
collocated	0								
noncollocated	1	.3	.3	5.0	60.1	.3	.9	10.0	99.9
Other Major Ports									
very collocated	1	49.4	133.3	326	640	93.8	249	568	956
partially collocated	11	201.0	421.4	655	781	355	655	908	1040
Army Materiel Depots									
collocated	3	19.0	39.2	110	378	32.7	61.2	180	548
noncollocated	18	12.9	30.7	53.2	85.6	23.4	48.7	76	133

Table B-7

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- TURKEY
(Population: 29 million)

		Blast Mortalities (thousands)							
		One Weapon Per Target				Two Weapons Per Target			
Target Category	Number of Targets	.04 MT	.2 MT	1 MT	5 MT	.04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	2	3.7	16.5	61.2	107	7.3	30.8	97.1	152
noncollocated	6	5.9	13.9	21.7	35.5	10.5	21.3	32.2	57.6
Secondary Airfields									
collocated	2	20.9	59.0	131	173	39.0	102	192	232
noncollocated	13	5.5	19.0	54.2	424	9.8	33.6	89.0	754
Reserve Airfields									
collocated	0								
noncollocated	6	1.5	3.5	10.4	48.5	2.6	6.6	19.7	86.1
Nuclear Submarine Ports									
collocated	0								
noncollocated	1	.4	1.0	2.6	15.0	.7	1.7	5.0	27.8
Other Major Ports									
very collocated	2	24.6	117	540	1050	49.0	224	902	1440
partially collocated	2	13.9	33.0	64.5	85.2	24.9	52.7	93.4	118
Army Materiel Depots									
collocated	6	213	542	1010	1200	395	900	1420	1590
noncollocated	24	39.5	88.9	162	432	68.4	140	2490	696

Table B-8

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- UNITED KINGDOM
(Population: 56 million)

Target Category	Number of Targets	Blast Mortalities (thousands) One Weapon Per Target .04 MT	.2 MT	1 MT	5 MT	Two Weapons Per Target .04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	0								
noncollocated	7	2.9	6.9	20.1	97.4	5.0	13.2	37.8	174
Secondary Airfields									
collocated	6	12.6	48.8	201	611	23.0	91.0	346	921
noncollocated	27	38.3	106	336	672	69.6	205	629	1830
Reserve Airfields									
collocated	2	1.1	2.7	18.1	124	1.8	5.0	34.2	187
noncollocated	27	52.5	121	381	1340	89.1	234	718	2330
Nuclear Submarine Ports									
collocated	0								
noncollocated	0								
Other Major Ports[a]									
very collocated	12	630	1550	3320	5930	1180	2760	5420	9060
partially collocated	10	276	590	1040	1760	492	960	1600	2810
Army Materiel Depots									
collocated	0								
noncollocated	0								

Note:

[a]Holyloch nuclear submarine port included as a major port.

Table B-9

BLAST MORTALITIES BY TARGET CATEGORY AND WEIGHT OF ATTACK -- WEST GERMANY
(Population: 55 million)

Target Category	Number of Targets	Blast Mortalities (thousands) One Weapon Per Target .04 MT	.2 MT	1 MT	5 MT	Two Weapons Per Target .04 MT	.2 MT	1 MT	5 MT
Primary Airfields									
collocated	2	16.1	44.8	100	166	30.7	77.3	152	233
noncollocated	21	19.2	60.0	174	461	36.3	108	294	726
Secondary Airfields									
collocated	5	32.6	126	499	1420	60.4	226	832	2090
noncollocated	33	216	609	1670	3900	397	1080	2680	5480
Reserve Airfields									
collocated	0								
noncollocated	0								
Nuclear Submarine Ports									
collocated	C								
noncollocated	0								
Other Major Ports									
very collocated	3	60.3	139	269	423	108	218	367	533
partially collocated	3	48.2	95.7	141	180	83.6	146	195	247
Army Materiel Depots									
collocated	22	213	580	1460	3080	391	1010	2340	4560
noncollocated	43	240	713	1610	3700	434	1180	2500	5410
Major Command Centers	7	39.4	115	286	504	75.8	204	428	672
Nike Sites	40	48.5	151	521	1550	89.2	276	879	2420
Hawk Belt	46	41.4	118	349	1100	76.0	209	591	1730

Table B-10

QUICK COUNT RESULTS -- BLAST AND FALLOUT MORTALITIES FROM COUNTERMILITARY ATTACKS

Country Wind Map	Population	4 MT Attack (523 MT Fission) Blast Only	Fallout Only	Blast and Fallout	11 MT Attack (1437 MT Fission) Blast Only	Fallout Only	Blast and Fallout	Combined Attack (1959 MT Fission) Blast Only	Fallout Only	Blast and Fallout
Benelux	21									
12-15-51		5.8	12.0	14.2	7.8	16.4	18.1	8.8	18.9	19.6
5-15-52		↓	11.5	13.9	↓	15.9	17.5	↓	17.3	18.3
7-5-52		↓	15.1	15.7	↓	18.2	18.7	↓	19.6	19.7
9-5-52		↓	12.7	14.7	↓	17.2	18.5	↓	19.3	19.8
France	46									
12-15-15		4.5	10.3	13.5	6.9	19.0	22.0	8.6	21.8	24.7
5-15-52		↓	19.0	21.0	↓	30.0	31.5	↓	32.6	33.7
7-5-52		↓	17.9	19.8	↓	26.2	27.6	↓	29.1	30.2
9-5-52		↓	5.1	8.9	↓	15.9	18.9	↓	17.4	20.8
Greece	8.4									
12-15-51		0.3	.6	.7	0.3	2.0	2.3	0.4	2.2	2.5
5-15-52		↓	.4	.7	↓	1.8	2.0	↓	2.0	2.3
7-5-52		↓	.7	.9	↓	3.0	3.1	↓	3.2	3.3
9-5-52		↓	1.4	1.5	↓	2.8	2.9	↓	3.2	3.4
Iberia	40									
12-15-51		2.3	6.9	7.9	3.0	9.0	10.2	3.4	11.4	12.0
5-15-52		↓	4.1	6.1	↓	12.0	13.7	↓	13.4	15.0
7-5-52		↓	7.0	8.3	↓	12.2	13.2	↓	14.1	14.8
9-5-52		↓	2.4	4.7	↓	9.6	12.0	↓	10.6	13.3
Italy	50									
12-15-51		3.5	12.5	15.3	4.3	25.5	27.6	4.8	29.0	31.0
5-15-52		↓	5.8	8.1	↓	21.4	23.0	↓	22.9	24.4
7-5-52		↓	8.1	9.7	↓	15.2	16.7	↓	17.8	18.9
9-5-52		↓	4.4	7.5	↓	10.9	13.9	↓	12.3	15.4

(continued)

Table B-10 (continued)

Country Wind Map	Population	4 MT Attack (523 MT Fission)			11 MT Attack (1437 MT Fission)			Combined Attack (1959 MT Fission)		
		Blast Only	Fallout Only	Blast and Fallout	Blast Only	Fallout Only	Blast and Fallout	Blast Only	Fallout Only	Blast and Fallout
Scandinavia	19									
12-15-51		1.8	.3	2.1	2.3	1.5	3.6	2.6	1.6	3.9
5-15-52		↓	1.3	2.7	↓	2.4	3.8	↓	2.9	4.3
7-5-52		↓	2.4	3.5	↓	4.5	5.6	↓	5.2	6.1
9-5-52		↓	.8	2.5	↓	3.0	4.9	↓	3.4	5.5
Turkey	29									
12-15-51		1.6	1.7	3.2	2.1	4.7	6.6	2.4	5.3	7.4
5-15-52		↓	..8	2.3	↓	5.5	7.1	↓	5.7	7.6
7-5-52		↓	2.3	3.5	↓	5.2	6.2	↓	6.0	7.0
9-5-52		↓	3.5	3.9	↓	5.5	6.1	↓	6.5	6.7
United Kingdom	56									
12-15-51		8.5	3.8	11.6	12.0	10.2	18.9	14.7	11.4	21.3
5-15-52		↓	18.7	23.8	↓	31.5	35.9	↓	35.4	39.3
7-5-52		↓	23.1	28.2	↓	32.8	37.2	↓	38.2	41.7
9-5-52		↓	4.8	12.7	↓	20.0	27.2	↓	21.4	29.7
West Germany	55									
12-15-51		4.3	32.0	34.8	6.8	44.4	46.4	8.1	48.0	50.0
5-15-52		↓	13.5	16.1	↓	37.1	39.3	↓	39.8	41.6
7-5-52		↓	21.6	24.0	↓	35.5	37.6	↓	39.7	41.4
9-5-52		↓	30.4	32.9	↓	42.3	44.5	↓	46.6	48.5
Totals	237									
12-15-51		32.6	81.4	104.6	45.6	137.1	160.0	53.7	153.9	176.9
5-15-52		↓	75.3	95.1	↓	159.2	175.4	↓	173.7	188.3
7-5-52		↓	98.7	114.0	↓	153.3	166.3	↓	173.3	183.5
9-5-52		↓	65.7	89.5	↓	128.0	149.7	↓	141.6	163.9

Table B-11

VALUES OF K, ROOT MEAN SQUARE ERROR, AND ROOT MEAN SQUARE PER CENT ERROR, FOR THE APPROXIMATION T = B + F - BF/K

Country	K (millions)	Root Mean Square Error (millions)	Root Mean Square Per Cent Error (per cent)
Benelux	20	.29	1.8
France	34	.39	1.6
Greece	4.7	.052	4.1
Iberia	21	.56	5.1
Italy	36	.74	5.1
Scandinavia	8.9	.25	5.7
Turkey	12	.53	9.0
United Kingdom	49	.52	2.4
West Germany	58	.57	1.9
Western Europe	237	2.6	1.9

Source:

See text for discussion of use. See Appendix A for derivation of formulae to compute K.

Table B-12

TOTAL POPULATION OF WESTERN EUROPE IN QUICK COUNT MORTALITY MODEL AND COUNTRY AREAS

Country	Population (millions)	Area (thousands of square statute miles)
United Kingdom	56	94
Benelux	21	26
Scandinavia	19	342
West Germany	55	96
France	46	213
Iberia	40	230
Italy	50	116
Greece	8	51
Turkey	29	301
TOTAL	324	1469

Appendix C

THE RANDOM BOMB DROPS METHOD OF COMPUTING FALLOUT DAMAGE

A technique that achieves easily used aggregate results at the expense of abstracting the geographic distribution of aim points is the Random Bomb Drops fallout model.[1] This model is based on the following assumptions for the attack:

- All bombs have the same yield, the same number are sent to each aim point, and all are detonated simultaneously.
- The fallout patterns of the bombs are identical with respect to the areas contained within isodose contours.
- The area into which the bombs are dropped is large relative to the area of dangerous doses of a single weapon.
- The aim points are distributed uniformly at random within the selected area.

The last two assumptions most severely limit the applicability of the model to Western Europe. In order to subdivide Western Europe into regions small enough for the assumption on uniform distribution of aim points to be valid it is necessary to violate the assumption that most of the fallout is deposited in the region. Insular and peninsular areas are particularly troublesome in this respect. It may, however, be applicable for Central Europe.

Wegner carries through the random drops calculations most completely for a 10 MT yield weapon and a 20 knot mean wind. It is this case that is presented here. However, there are sufficient data in the Wegner work that curves for any weapon yield and mean wind speed can readily be constructed by hand.

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[1] S. M. Greenfield, Radioactive Contamination from a Multibomb Campaign, The RAND Corporation, RM-1969, January 1956; and L. H. Wegner, Some Extension of the "Random Bomb Drops" Local Fallout Model of RM-1969, The RAND Corporation, RM-2973-PR, March 1962.

Figure 34 presents average mortalities as a function of two variables, a and ρ.[1] If we let Y be the total blast yield delivered in megatons, A the area of the region in thousands of square nautical miles, and w/pt the number of weapons per aim point, the ρ is defined as

$$\rho = \frac{Y}{A(w/pt)} ,$$

while a is the product of the following six quantities:

- Weapons per aim point (w/pt)
- Fraction fission (fission yield/blast yield) (f)
- Residual radiation level in roentgens per hour per kiloton per square statute mile divided by 2500 (r/2500)
- Terrain shielding factor (t)
- Shelter shielding factor (s)
- Mid-lethal dose divided by 435 (LD-50/435).[2]

Thus

$$a = (w/pt) \cdot f \cdot (r/2500) \cdot t \cdot s \cdot (LD\text{-}50/435).$$

If casualties instead of mortalities are to be computed the dose is assumed to give 50 per cent probability of casualties in place of the mid-lethal dose.[3] Notice in Figure 34 that a variation in a by a factor of two can drastically change the fraction mortalities. Because of the many uncertainties in the factors incorporated in a, there

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[1]The parameter ρ reflects the number of independent patterns laid down (if two weapons are aimed at the same target, their patterns are not independent) and a reflects the relative lethality of a single pattern.

[2]In Wegner, RM-2973-PR, these curves were drawn on the assumptions that r = 2500 and LD-50 = 435 and that one weapon was delivered per aim point. The above definitions of a and ρ allow these parameters to be varied. A commonly used mid-lethal dose is 450. Empirical evidence is limited; in fact, the LD-50 may be as low as 350 or as high as 900.

[3]A commonly used mid-casualty dose is 200. This figure also is uncertain, but there is more empirical evidence for it than for LD-50.

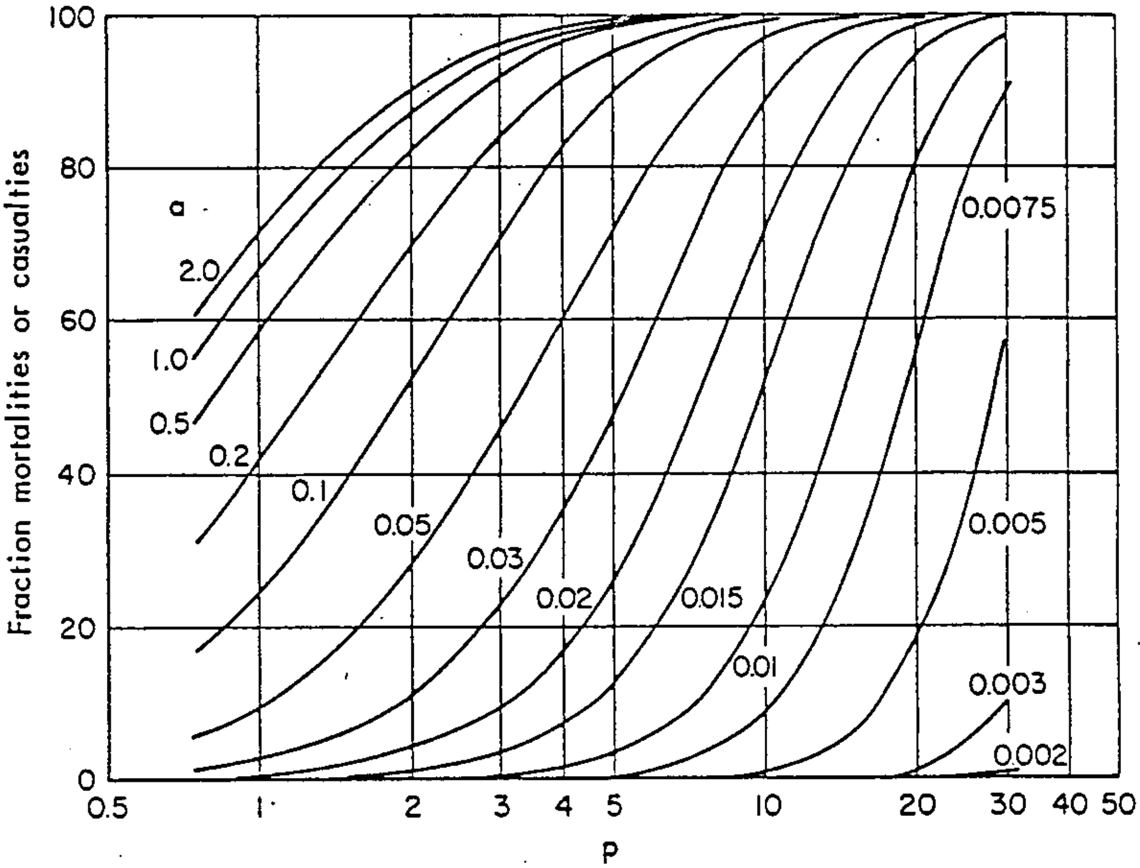

Figure 34—Average mortalities or casualties due to whole-body radiation from fallout—10 MT yield, 20 KT mean wind

is composite uncertainty of well over a factor of two. These uncertainties and the sensitivity of results to them are not removed by more sophisticated machine computation techniques.

In the machine and random drop calculations of fallout mortalities in this Memorandum the parameter values used are

$$f = 0.3$$
$$r = 2500$$
$$t = 0.7$$
$$\text{LD-50} = 450.$$

Thus for these assumptions

$$a = (w/pt) \cdot (0.3) \cdot (2500/2500) \cdot (0.7) \cdot s \cdot (450/435)$$
$$= .22 \cdot (w/pt) \cdot s.$$

For the calculations of this study the population has been divided into three shelter categories. Values of a for one and two weapons per target are shown in the following table:

Shelter Category (2 weeks occupancy)	Fraction Population	Shelter Shielding Factor (s)	Values of a: One Weapon Per Aim Point	Values of a: Two Weapons Per Aim Point
1 (Houses)	.75	.5	.11	.22
2 (Basements of houses)	.20	.1	.022	.043
3 (Good protection)	.05	.02	.0043	.0086

Notice that as the weight of an attack is increased the weapons per aim point may increase. This is reflected in both ρ and a.

If the number of weapons per aim point and the area of the region is specified, then mortalities can be expressed as a function of the total fission yield of the attack. This is done in Figure 35 assuming two weapons per aim point, and taking the weighted sum of the curves for each of the three shelter categories. Two areas were used, the smallest is 960,000 square nautical miles and represents the total area of all Western European countries, with only one-half

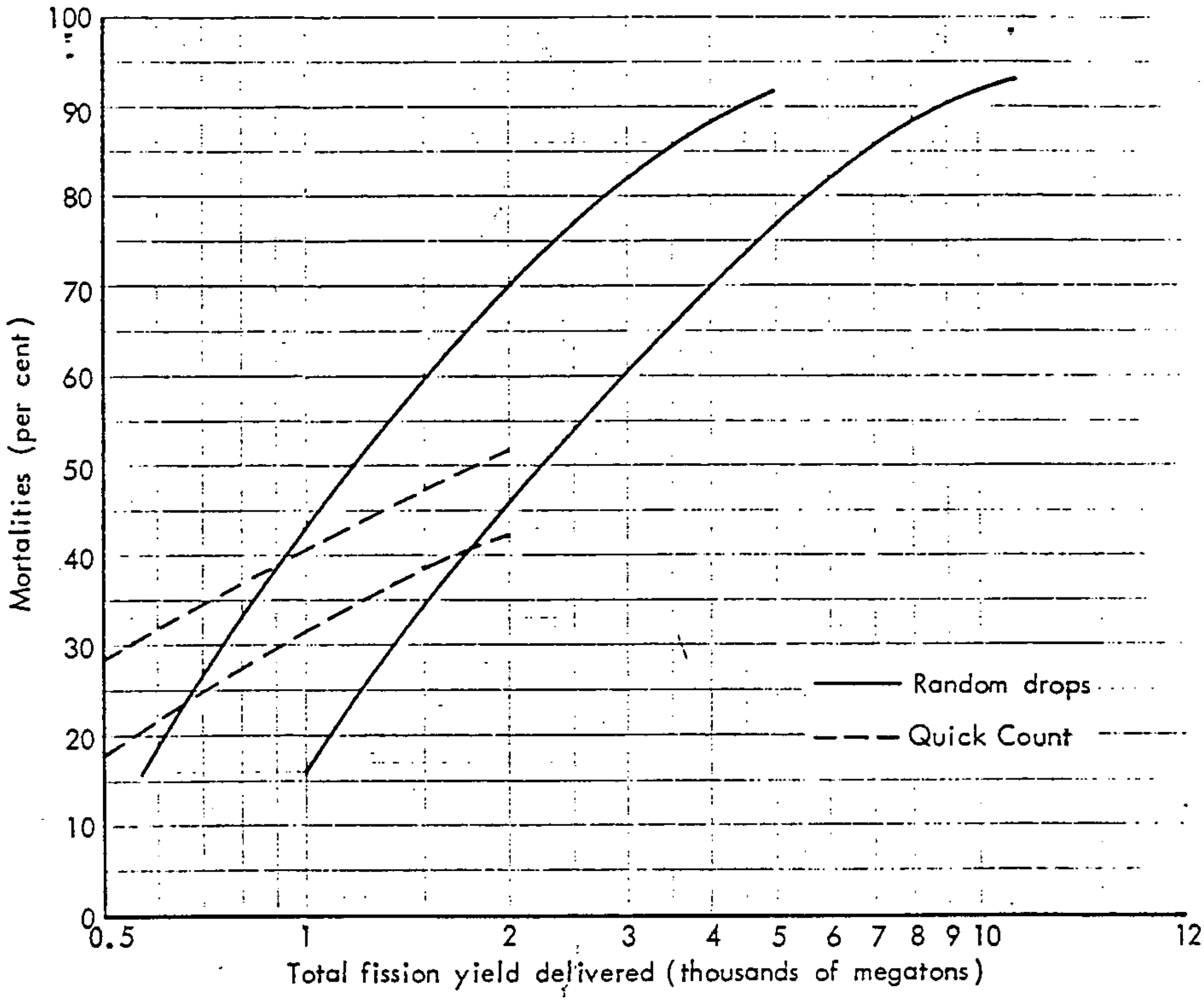

Figure 35—Average mortalities due to fallout for Western Europe wide attack[a]

[a]See text for discussion of attack and vulnerability assumptions.

Appendix D

MORTALITY MODEL AND CIVIL VULNERABILITY ASSUMPTIONS

Mortality computations were made using the Quick Count model developed at The RAND Corporation. Quick Count is a digital computer program using as its basic inputs a distribution of population to monitoring points, an aim-point by aim-point weapon allocation, a wind map or maps, a fallout shielding table, and other parameters related to the vulnerability of people to prompt and local fallout effects of nuclear weapons.

The vulnerability assumptions used are found in Table D-1.[1] The most critical of these are the blast mid-lethal radius, 7 psi; the fallout mid-lethal dose, 450 roentgens maximum biological dose; and the residual radiation level (including terrain shielding), 1750 roentgens per hour per kiloton per square mile. For blast this corresponds to a 50 per cent mortality rate from a 1 MT weapon airburst at about 3 n.mi.; for a 5 MT weapon this radius is about 5 n.mi.

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[1]The blast effects terminology and definitions are those of Physical Vulnerability Handbook -- Nuclear Weapons (U).

Table D-1

MORTALITIES MODEL INPUT PARAMETERS AND SHIELDING TABLES

Blast[a]

1 MT groundburst weapon radius = 2.15 n.mi.

1 MT airburst weapon radius = 3.00 n.mi.

σ = 20

Cube root scaling used for other yields

Fallout

50 per cent lethal dose = 450 roentgens maximum biological dose[b]

Standard deviation = 100

Residual radiation level[c] = $1750 \frac{\text{roentgens/hour}}{\text{kiloton/square mile}}$

Shelter Categories

Category	Mean Shielding Factor[d]	Standard Deviation	Population Distribution (per cent)
1 (Houses)	0.5	0.1	70
2 (Basements)	0.1	0.025	25
3 (Special shelters)	0.02	0.005	5

Notes:

[a]These values correspond to a VN-T-K of 10-P-0 and a scaled height of burst for airburst weapons of 500 ft at 1 KT. For this vulnerability number and σ = 20, 4 per cent probability of death occurs at 4 psi, 50 per cent at 7 psi, and 90 per cent at 10 psi. See Physical Vulnerability Handbook -- Nuclear Weapons (U), prepared by Defense Intelligence Agency Production Center, PC 550/1-2-63, September 1, 1963, pp. I-40, 41, and 52 (Confidential).

[b]The maximum biological dose is computed by assuming a $t^{-1.2}$ decay law, a 10 per cent "irreparable" factor, and a recovery rate of 2.4 per cent per day.

[c]The residual radiation level is the product of the gamma activity factor and the terrain shielding factor.

[d]Includes degradation due to assumed necessity to conduct limited activities outside shelters after two weeks.

Appendix E

TEXT OF A BRIEFING GIVEN TO NATO STANDING GROUP, APRIL 14-16, 1965

The choice between alternative strategic nuclear forces and planning for general war requires quantitative comparisons of war outcomes. Evaluating war outcomes is, of course, an extremely complex task. It involves the military effectiveness of different types of attack and the civil damage that could occur in different kinds of general war.

Today, we are going to discuss the measurement of civil damage. We shall discuss one type of damage assessment technique that we call the "aggregate" or "building block" technique of damage assessment. We can contrast this with both hand techniques and high-speed computer models. Our discussion will be in terms of the civilian damage in Western Europe. We are, of course, aware that civil damage is more complex than the number of mortalities and casualties that would occur; for instance, the loss of economic resources must be considered. However, there is a correlation between the civil losses in general war and the damage to economic resources. And so in this discussion, we will deal only in mortalities and casualties. We emphasize also that we are discussing damage assessment, not war gaming or campaign analysis, of which damage assessment is only a part.

Any damage assessment model, whether it is a hand or a computer model or whether it is the aggregated or building block model that we will discuss today, should be flexible. As shown on Chart 1, it should be able to account for countermilitary attacks that are constrained and attacks that are unconstrained. A constrained attack we might define as one where weapons are all airburst and yields used are relatively low. In addition, there may be some selective avoidance of targets because of collocation with population. In contrast, an unconstrained case would be one where weapons are all groundburst and the yields used are high.

In addition to accounting for collateral civil damage from the countermilitary attacks, a damage assessment model should be able to incorporate the damage from counterurban attacks if any should occur. And of course, the model should be able to incorporate and combine the damage from countermilitary attacks and counterurban attacks without double counting.

On Chart 2 we show data base requirements for damage assessment models. These requirements apply to hand or computer techniques as well as the building block techniques that we are discussing today. These requirements include weapons effects, the geographic distribution of the population, and the geographic distribution of the target system. For fallout calculations, a set of wind patterns is necessary and the shielding of the population must be specified.

All damage assessments are built up from two basic weapon effects which we illustrate on Charts 3 and 4. First, we show the blast effects of a nuclear weapon.[1] We have shown schematically the fraction of mortalities that would occur at different distances from a given ground zero. For computational purposes, the weapon radius is used -- distance from ground zero at which 50 per cent mortalities occur. The weapon radius depends on the yield of the weapons, the height of burst and the vulnerability of the populace.

In addition to the blast effects, a damage assessment model accounts for fallout patterns (Chart 4). These take on an elliptical shape around the ground zero. To compute fallout mortalities, we need a wind pattern or a set of wind patterns, and we must specify the shielding of the population. All damage assessment models, hand, or computer, or aggregated type, combine these two effects to arrive at estimates of the total mortalities that could occur in a general war.

The structure of our discussion today is such that Dr. McGarvey will discuss the basic building blocks we use to compute civil damage. After that I will present a series of examples to illustrate the use of the model. However, two things must be said before we begin. First, the results that you will see, the building blocks, are <u>based</u> on and <u>checked by</u> a high-speed computer model called Quick Count.

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[1]Blast effects tend to dominate thermal effects as a damage-producing agent.

Quick Count was developed at The RAND Corporation and has been used by us, the Strategic Air Command, and the Air Battle Analysis Center in the Department of Defense. Second, the examples that you will see are primarily illustrative. They are meant to demonstrate the application of the damage assessment model. You will notice that we do not present a war game or a campaign analysis but simply some examples of the use of the model. And I will now turn the discussion over to Dr. McGarvey.

THE MODEL

The discussion to follow is a technical one. We are going to explain step by step how one would use the materials in the report in order to arrive at an assessment of the civil damage to Western Europe in a general war. One reason for doing this is to clarify the factors which are most important in determining the level of damage which would be inflicted.

It is important to realize that the damage that Western Europe would suffer is dependent upon the nature of the war that is fought. Categorical statements of the level of damage are not very helpful unless they are related to specific types of attack and unless the user of these results has some understanding of the major sensitivities involved.

Damage assessment is only a part of campaign analysis. The user of any damage assessment model must describe the nature of the attacks. In constructing the model discussed here we have tried to give the user as much freedom of choice as possible in describing the nature of the Soviet attack and the effects of NATO attacks on the Soviet forces.

As is shown on Chart 5, the user of the model must select the targets to be attacked by the enemy. He does this by allocating weapons by target categories. Within a target category, targets can be included or excluded on a country-by-country basis.

Furthermore, the user of the model must decide what type of attack is to be employed against these targets. He must specify, by target category, the yield, the number of weapons per target, whether these are airburst or groundburst, and the overall delivery probability of these weapons.

This last parameter, the overall delivery probability, is a composite of many things which must be computed as a part of campaign analysis. In particular, if a NATO strike is assumed to occur before the enemy weapon carriers are launched, it incorporates the probability the weapons have survived this strike. It also includes the reliability of the weapon systems and, in the case of bombers, includes the probability of surviving defenses.

The user must also decide the weight and character of the counter-urban attack, if any, that is to be incorporated in the analysis.

In addition to those things which the user is obliged to decide before he can make a damage assessment we have also made it possible for the user to make variations in our assumptions on the vulnerability of the populace to blast affects and the degree of fallout sheltering available to the population.

For simplicity our discussion will emphasize mortalities. However, the model can be used to compute casualties, i.e., combined mortalities and injured, as well by changing the input parameters used. We will for the most part talk in terms of total mortalities throughout Western Europe. The user can also find mortalities country by country or, in some cases, aggregated by country group. The reason that, in some cases, results can be reported only by country group has to do with limitations on the storage or "memory" capacities of the computers used. Because of these, it was necessary to combine some countries into country groups.

Any damage assessment model must incorporate mortalities from both blast and fallout.[1] Chart 6 summarizes the steps involved in

[1]Unless one is studying a situation where there are special blast shelters or a situation involving very high yield (100 MT or over) warheads detonated at high altitudes, the effects of blast are more dangerous to the populace than those of fire, either through firestorm or conflagration.

making a damage assessment once the nature of the attack has been specified. In our model the first step is to compute the blast mortalities from attacks against military targets. Then if there are any counterurban attacks the blast mortalities from these counterurban attacks are combined with blast mortalities from the countermilitary attack in step two. If all weapons are airburst, calculations are complete at this point. However, if some of the weapons have been groundburst it is necessary to incorporate fallout effects. This is done in two steps. The first step gives us a number which has only mathematical meaning -- we compute the mortalities from fallout only, that is the mortalities due to fallout *if* there were no blast mortalities. Since, in fact, there will be blast mortalities, to obtain the total mortalities we must combine those from blast and fallout, and this is the last step. However, as you will see, this is not done by simple addition of blast to fallout as this would involve errors due to double counting.

We have taken each major target category in Western Europe and computed the blast mortalities if each target in this target system is attacked with one or two weapons per target. Yields range from 40 kilotons to 5 megatons. These calculations were done using the blast damage assessment portion of the Quick Count model. The results were then plotted as a function of the yield of the attacking weapons obtaining graphs such as that shown on Chart 7. This chart shows the results for 102 Primary Offensive Airfields. The results in the chart are based on the assumption that the weapons were airburst and that each had an overall delivery probability of 0.7. Techniques are presented in the report for using different delivery probabilities. If the user chose to allocate two weapons per target to this target category this would involve 204 weapons. If these were of 1 megaton yield the chart indicates that the mortalities from this part of the attack would be about 2.4 million mortalities. If the weapons were 40 kilotons each, the mortalities attributed to this part of the attack would be about 300,000.

We have constructed similar charts for other target categories, such as secondary and reserve airfields, nuclear sub ports, other major ports, army materiel depots, the most important command and control targets and various defensive installations.

There is sufficient detail in the report so that the mortalities can be found country group by country group. Thus, the effects of excluding particular countries can be incorporated if desired. If the countermilitary aspects of the attack involve several target categories, the results at each target category are computed using charts of this form and the results are simply summed.

Summing over target categories involves a certain possibility of error because of double counting of mortalities where targets of two different types are located near to each other. We have checked the validity of summing blast mortalities over different target categories by checking the results through Quick Count runs against several target categories. In the cases where double counting would be most severe the effect of this approximation leads to no more than a 10 per cent error. A more typical result is 5 per cent or lower error. This double counting problem does <u>not</u> occur <u>within</u> a target category because the target category calculations were done by Quick Count. It only arises when one sums the results from different target categories.

We have found that within a target category there is a great deal of variation of collocation of targets with civil population, and consequently, in the degree of civil blast damage from attacks against those targets. In order to permit the user of the model to study cases of selective restraint where the Soviet Union uses a different type of attack against collocated targets than it uses against relatively noncollocated targets, we have divided each target category into two subcategories called "collocated" and "noncollocated" targets. The criterion for deciding whether a target was collocated or not was the total population within 4 nautical miles of the target. If this population exceeded 50,000 the target was labeled "collocated;" if it was less then it was labeled "noncollocated." Chart 2 shows the effect of distinguishing between collocated and noncollocated targets for primary airfields. For this target category, 14 of the 102 targets are collocated. In a uniform attack against the whole target category, these 14 targets account for roughly half the blast mortalities.

If the assumed Soviet attack is all airburst and is only against military targets that is all there is to the damage assessment. But there is the possibility that some of the Soviet weapons are allocated against urban targets. Chart 9 shows the simplest case, a case in which there are no countermilitary attacks. Chart 9 shows the blast mortalities that could result if the Soviets allocated different numbers of 5 megaton weapons against cities designing their attack so as to achieve the largest possible number of mortalities in Western Europe. The results are plotted as a function of the number of 5 MT warheads assigned to this counterurban mission. The curve begins at zero, which, of course, is the case of no countermilitary attack and no counterurban attack; in other words, no attack at all, and the result is zero mortalities. The curve rises steeply at first and then levels off because the first weapons are allocated to large undamaged cities whereas as one moves farther to the right on the chart, one finds that it is necessary to allocate weapons to smaller cities or to allocate weapons to cities which have already suffered prior damage. As an example of the use of the chart, if the Soviets allocated 100 weapons against urban targets so as to maximize total West European mortalities the blast mortalities resulting would be on the order of 40 million. The user may not wish to assume the Soviets are interested in maximizing mortalities across all of Western Europe and hence the report includes charts such as this one for each country (or in some cases, country groups) and includes tables of data on a city-by-city basis. This gives the user some latitude in his interpretation of Soviet objectives.

Of course the situation described by this chart is not a realistic one, since it is the one in which the Soviets allocate no weapons against military targets but only attack cities. To combine the effects of countermilitary and counterurban attacks we have arrived at some empirical results based on detailed calculations using the Quick Count model. These are summarized in Chart 10. Take the uppermost curve on Chart 10 as an example. This curve was computed using a countermilitary attack of such a weight and character that the countermilitary attack alone led to some 50 million blast mortalities. To this countermilitary attack various levels of counterurban attack were added, again designed to maximize total mortalities, and the results of the combined attacks were computed with the Quick Count model. Reading this uppermost curve at the left we have the case again of no counterurban attack at all and thus total mortalities are 50 million. If to this countermilitary attack a counterurban attack of 100 weapons is added total blast mortalities from the combined attack will be on the order of 75 million. This chart shows curves for only three levels of counterforce attack; zero, one leading to 36 million in mortalities, and one leading to 50 million mortalities. The report presents a greater number of similar curves.

Curves such as these provide step two in the damage assessment calculation and give us total blast mortalities. However, the curves as they stand can be very misleading since fallout would add substantially to the mortalities in groundburst attacks. To show the significance of the fallout to these numbers, Chart 11 shows combined blast and fallout mortalities for the same conditions recorded on Chart 10.

We turn now to the incorporation of fallout in the mortality estimation. The damage assessment model is somewhat more limited in its flexibility for incorporating fallout than it is for blast for we have only included fallout results for European-wide attacks whereas the blast results can be used for attacks against any grouping of countries. This is because blast mortalities in a country can be attributed directly to the weapons allocated to a country. Therefore, it is easy to include or exclude a particular country from an attack. However, fallout mortalities in a country depend not only on the attack on that country but also the attacks against countries upwind. Thus, although data in the report permits computation of fallout mortalities on a country-by-country basis, this can be done only for attacks against all of West Europe. Fallout mortality computation from attacks which have a very different geographic distribution of targets require use of high-speed computer models.

Once the general geographic distribution of an attack is specified, (in our case we are talking about this being distributed over all of West Europe) and once the details of distribution of people to various types of structures is specified, the mortalities due to fallout are then predominantly a function of the wind conditions on the day of the attack and the total amount of radioactive materials deposited in the fallout. On Chart 12 we have recorded the results from several Quick Count runs, showing fallout-only mortalities from West European-wide attacks of varying weights. We have plotted these mortalities against, on the horizontal axis, the total countermilitary plus counter-urban megatons fission delivered groundburst in the attack. The results are presented as a band rather than a single line to represent the variations resulting from the use of four different winds. The winds used were those found from wind maps of December 15, 1951; May 15, 1952; July 5, 1952; and September 5, 1952. As one can see the variation due to wind is substantial and it can be even more substantial on a country-by-country basis as can be seen by looking at the tabular results in Appendix B of the report.

The parameter along the horizontal axis requires some explanation. It is, again, a measure of the total radioactive materials deposited in the fallout process and hence it includes both counterurban and countermilitary weapons. The fallout problem arises when weapons are groundburst, for they vaporize materials of the soil which then cool and solidify and rain back down to earth carrying with them the radioactive products of the bomb. Thus, only weapons actually delivered and groundburst are included in the fallout computation. Finally, the yield of thermonuclear weapons, the blast yield, arises from two mechanisms. One is fusion of nuclei and the other is fission of nuclei, and it is the fission process which leads to most of the radioactive material. Therefore, the parameter along the horizontal axis is total counterurban plus countermilitary megatons fission delivered groundburst.

As an example of the use of this chart, if one thousand megatons fission were delivered groundburst in an attack, total mortalities due to fallout alone would range from about 110 to 140 million.

At this point in the damage assessment we have computed two numbers -- the mortalities due to blast, ignoring fallout, and the mortalities due to fallout ignoring blast. Of course, what is of interest is the total mortalities. To repeat, these cannot be found simply by adding the blast only and fallout only mortalities because of the possibility of double counting. The Quick Count model computes in each monitoring rectangle the expected mortalities due to blast only, fallout only, and the combined effects. It then adds these results over all monitoring rectangles and in this way avoids the problem of double counting.

Chart 13 shows the results of some statistical curve fitting which we have done using numerous Quick Count results. We find that it can be used to eliminate the double counting and arrive at combined blast and fallout mortalities to an accuracy of 3 per cent or better. Along the vertical axis we have plotted the fallout only mortalities and along the horizontal axis the blast only mortalities. By reading the chart at the intersection of blast only and fallout only mortalities, one can arrive at combined mortalities. As an example, if blast only mortalities are 60 million and fallout only mortalities are 60 million, then combined blast and fallout mortalities are not 120 million, but because of the double counting the combined mortalities are approximately 105 million.

The remainder of the discussion will consist of some sample calculations using the model which will serve to illustrate how these techniques are applied and which will give some understanding of the range of outcomes that it is possible to have and some of the major factors that lead to this range of outcomes.

ILLUSTRATIVE EXAMPLES

The first example that we present (Chart 14) consists of a Soviet attack with 100 kiloton weapons with a 0.7 delivery probability. These weapons are all airburst on a subset of the target systems in our report. The number of aim points are listed in the first column. The number of weapons programmed against each target are listed in the second column. These represent one reasonable allocation, given the vulnerability and relative importance of the targets. The results are read in the last column. These are found by reading the blast effect charts for each target category. For example, in the case of primary airfields, one reads Chart 7 at 100 KT. Two weapons per target are assumed, and so the two-weapon curve is read, giving mortalities of .58 million. Blast mortalities are computed for each target system under consideration. Total mortalities are then found by simple addition, in this case, 10.89 million. As you will notice, most of the damage comes from the attack against ports. If the attack were extremely constrained and the Soviets did not attack ports, mortalities could be on the order of 2 million. It should be emphasized that these numbers represent the damage from only a fraction of the estimated Soviet capabilities. This is not a campaign analysis because there would be many more strikes than we have shown in this example. Using the same set of targets, we present on Chart 15 a selective destruction example. The weapons used are 4 megatons. The 4 megaton yield is an interesting case to consider because this is the estimated yield of Soviet MRBMs. The number of aim points in this example are the same and the number of weapons per aim point are the same as on the preceding chart. Mortalities are derived in the same way as in the previous example. In the case of primary airfields, mortalities now rise to 5.6 million. Total mortalities become about 50 million. Mortalities from the port attack are 29 million. If ports were not targeted, mortalities would be on the order of 20 million. Again, this represents only the mortalities from a Soviet first strike, possibly only from their MRBMs, and in a campaign analysis, one would want to consider realized damage and the potential damage at each phase of the war.

Chart 16 shows the results of Chart 15 country by country. On Chart 17 we look at the same attack except it is assumed the Soviets strike second. This is reflected in the reduction of the delivery probability to 0.3. Again these are only sample calculations. In a full campaign analysis it would be necessary to account for the fact that different Soviet systems would have different survival probabilities.

Thus, soft MRBMs would have a low delivery probability, hard ones a somewhat higher delivery probability, and sub-launched missiles would have a high delivery probability. Methods are included in the report for dealing with these more complicated situations.

To show the flexibility of the model, we next treat an all groundburst case, using the same target systems (Charts 18 and 19). The weapons are again 4 MT, and they have a 0.7 reliability. Since the weapons are groundburst, the fraction fission is required. This is assumed to be 0.3. Because the weapon radius of groundburst weapons with respect to blast mortalities is lower than that for airburst weapons, the total number of blast mortalities in this case is 36 million compared with 50 million when the weapons are airburst. Most of the blast mortalities again come from the ports. These are the blast mortalities only from 612 groundburst weapons allocated to military targets. (The total mortalities [blast and fallout] from this attack would be on the order of 95 to 115 million.)

Now, I said at the beginning of the discussion that a damage assessment model must be able to incorporate the results of counterurban strikes, should any occur. As an illustration, we assume that the Soviets have 150 4 megaton weapons which could be used on cities. Now, since the counterurban calculations are based on 5 MT standard weapons, it is necessary to convert the 150 4 MT weapons to 5 MT equivalents. In this case, 150 groundburst 4 MT weapons are the equivalent of 132 5 MT weapons. Reading the 36 million curve (because there have been 36 million mortalities from the counterforces attack) on Chart 10 at 132, the total blast mortalities are 67 million, an increment of 31 million over the countermilitary blast mortalities.

On Chart 19 we include the mortalities due to fallout. This requires a calculation of the total megatons fission delivered. In this example there are 641 megatons fission delivered, both countermilitary and counterurban. Reading the fallout only curve at 641, the range of fallout only mortalities is 80 to 110 million.

We combine the blast only and fallout only mortalities using Chart 13 by reading the blast only axis at 67 million and the fallout only axis at 80 and 110 respectively and finding total mortalities of 125 to 146 million.

On our final chart we list some of the advantages that we see in the aggregated building block approach. First, approximate measures are often sufficient to answer many questions and the 5 per cent difference that we find between the computer results and the building block technique that we have discussed today are not significant, particularly when the limited accuracy of the most detailed techniques are taken into account. Second, in many forums, high-speed computer techniques may not be available or where available, study cycle time may be lengthy. Consequently, these techniques can provide some quick answers while more detailed analyses are made. The last two items on our list are perhaps more important. The user can employ the aggregated techniques to obtain a better feeling for critical variables in civil damage -- for example, the relationship between dispersal and civil damage. Because the building blocks present a detailed breakdown of damage, they can aid in sensitivity analysis -- they suggest variations in assumptions that should be explored and indicate how these will affect results. For all of these reasons we believe that aggregated techniques are valuable. They are not, we also believe, in any way substitutes for the computer techniques on which they are based.

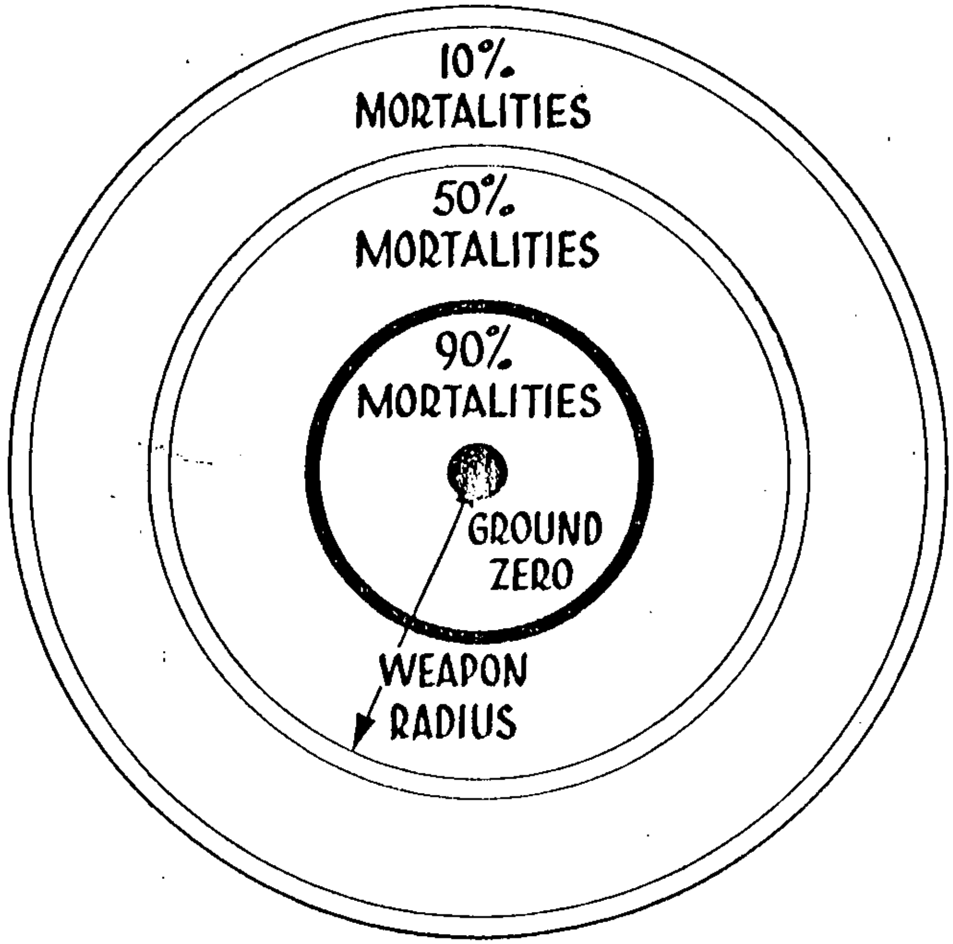
AGGREGATED DAMAGE ASSESSMENT TECHNIQUES (U)

DAMAGE ASSESSMENT MODEL
SHOULD BE ABLE TO INCORPORATE

- COUNTER-MILITARY STRIKES
  - CONSTRAINED
  - UNCONSTRAINED
- COUNTER-URBAN STRIKES
- COMBINED ATTACKS

CHART 1

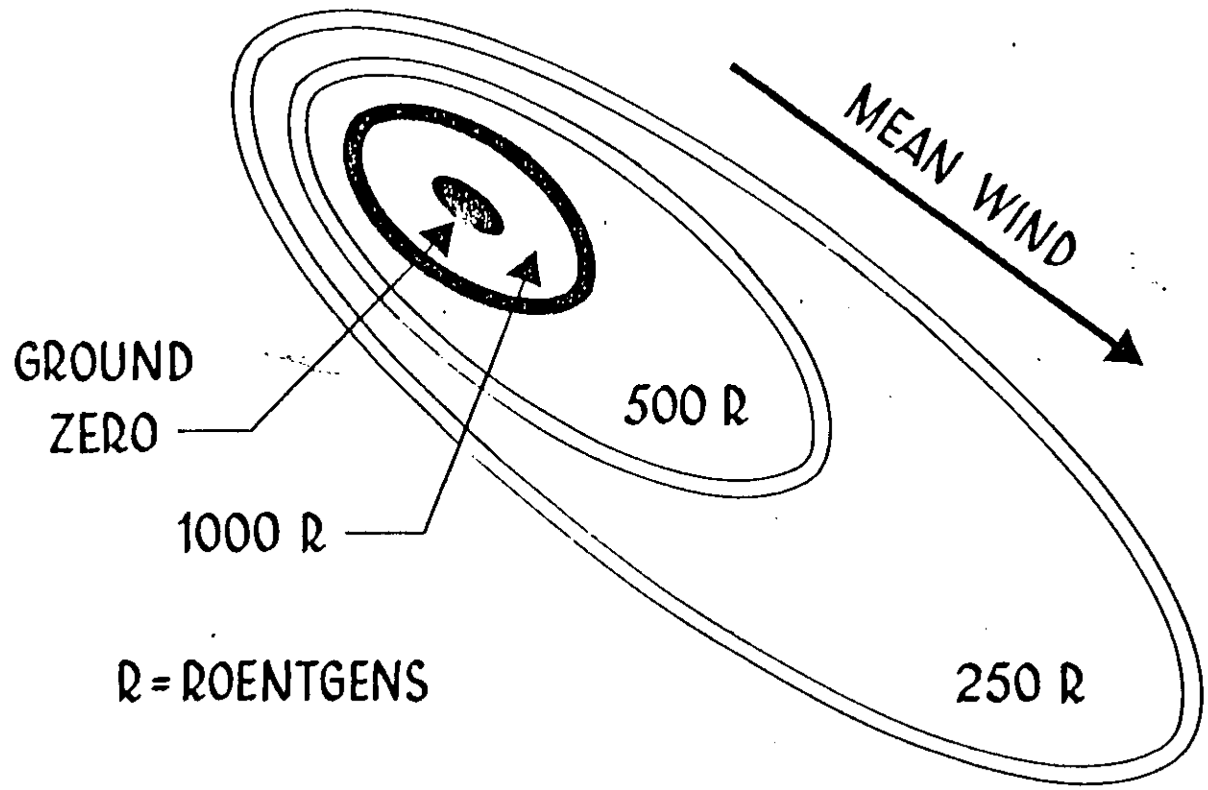
MORTALITIES FROM BLAST



WEAPON RADIUS, DETERMINED BY YIELD,
HEIGHT OF BURST AND VULNERABILITY OF POPULATION

CHART 2

MORTALITIES FROM FALLOUT



DAMAGE ASSESSMENT MODEL MUST ALSO INCORPORATE SHIELDING OF POPULATION

CHART 3

DATA BASE REQUIREMENTS FOR DAMAGE ASSESSMENT (HAND OR MACHINE)

- WEAPONS EFFECTS
- GEOGRAPHIC DISTRIBUTION OF POPULATION
- GEOGRAPHIC DISTRIBUTION OF TARGETS
- WIND MAPS
- SHIELDING OF POPULATION

CHART 4

USER MUST SELECT

- TARGETS ATTACKED
- PARAMETERS OF THE ATTACK
- CHARACTER OF COUNTERURBAN ATTACK, IF ANY

USER MAY VARY

- VULNERABILITY ASSUMPTIONS
- FALLOUT SHELTER ASSUMPTIONS

CHART 5

STEPS IN DAMAGE ASSESSMENT

COMPUTE BLAST MORTALITIES FROM COUNTERMILITARY ATTACKS

INCORPORATE BLAST MORTALITIES FROM COUNTERURBAN ATTACKS, IF ANY

COMPUTE FALLOUT MORTALITIES

COMPUTE COMBINED BLAST AND FALLOUT MORTALITIES

CHART 6

PRIMARY AIRFIELDS — BLAST MORTALITIES

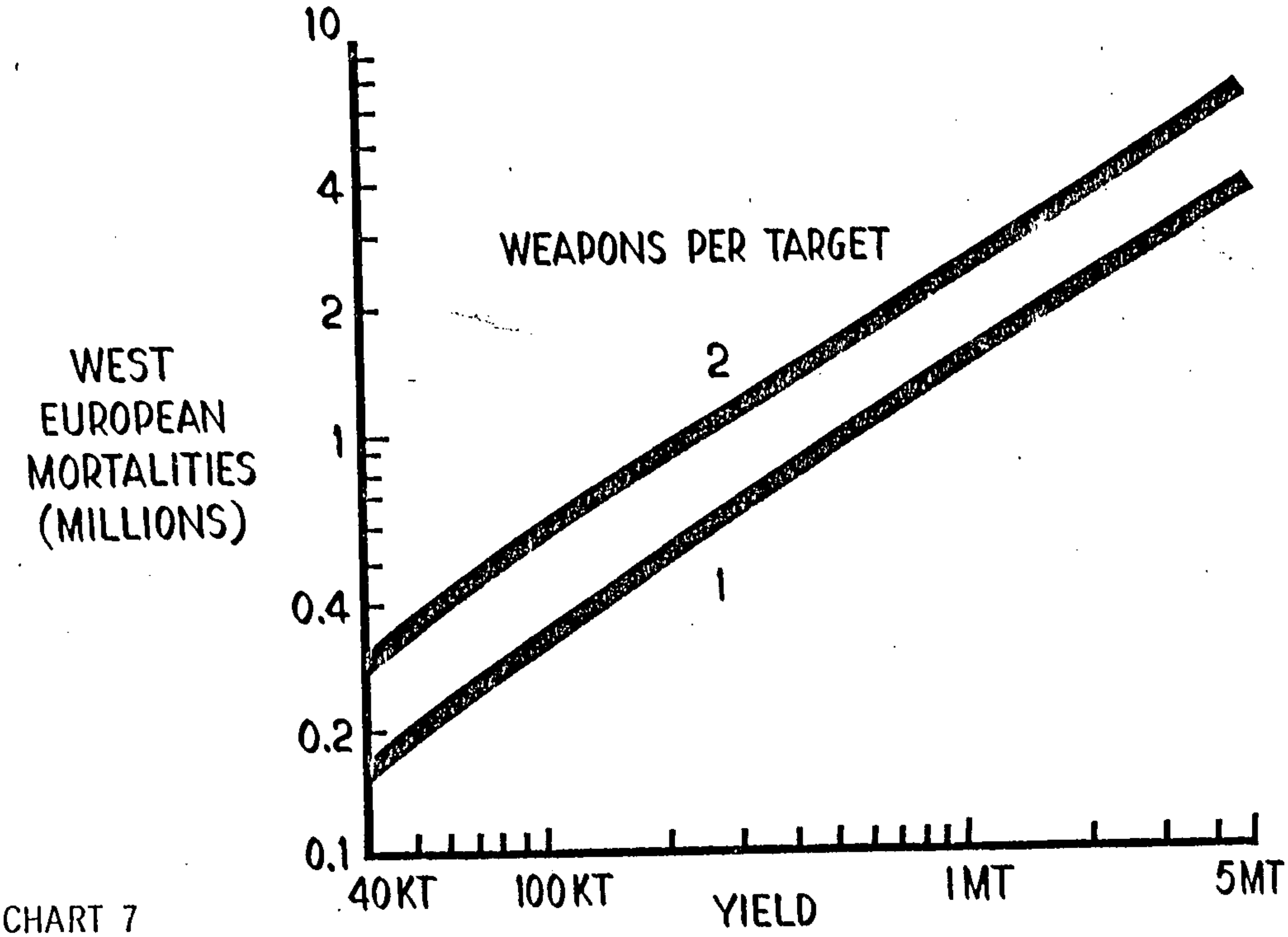


CHART 7

PRIMARY AIRFIELDS — BLAST MORTALITIES BY WEIGHT OF ATTACK

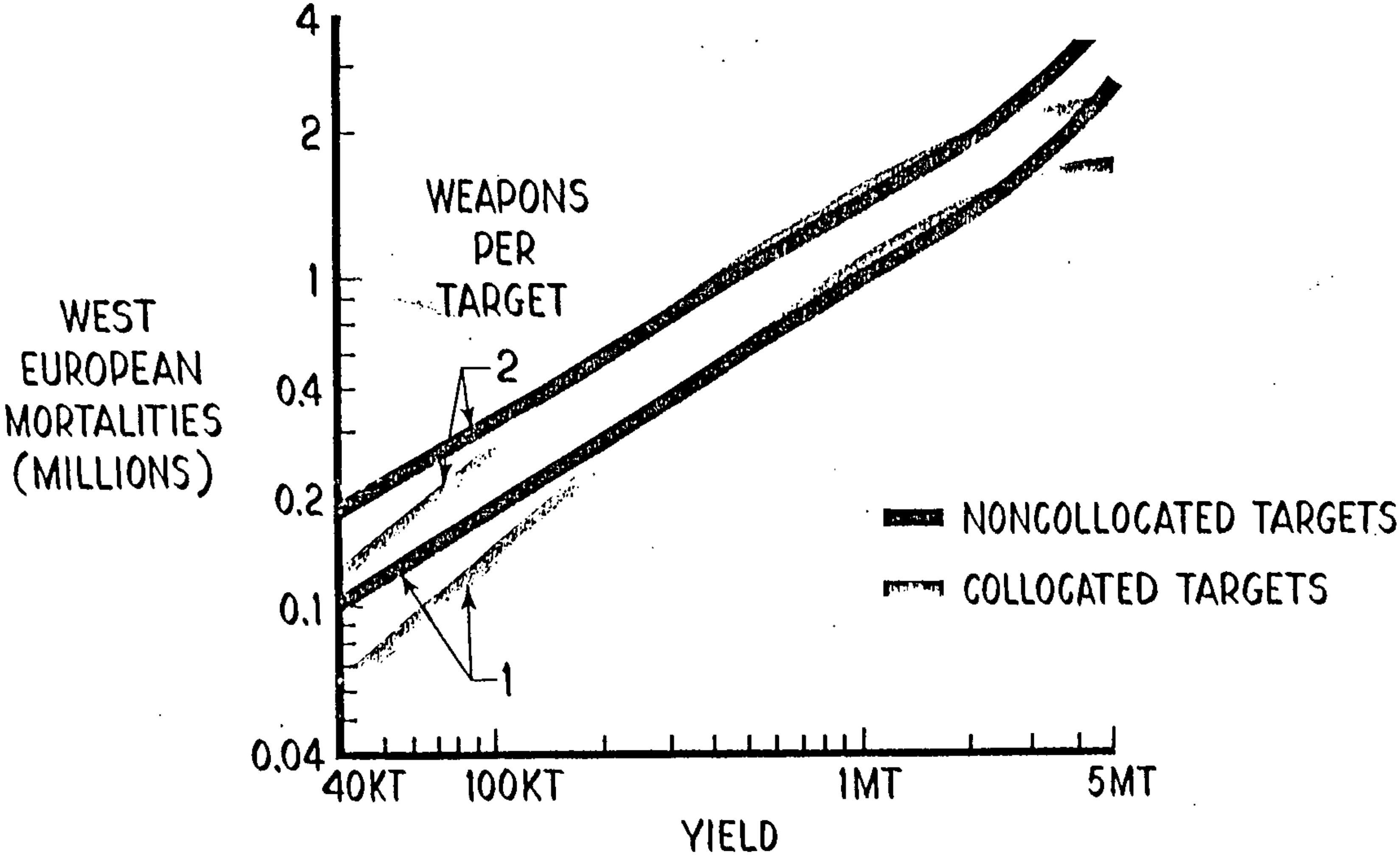


CHART 8

BLAST MORTALITIES FROM COUNTERURBAN ATTACK

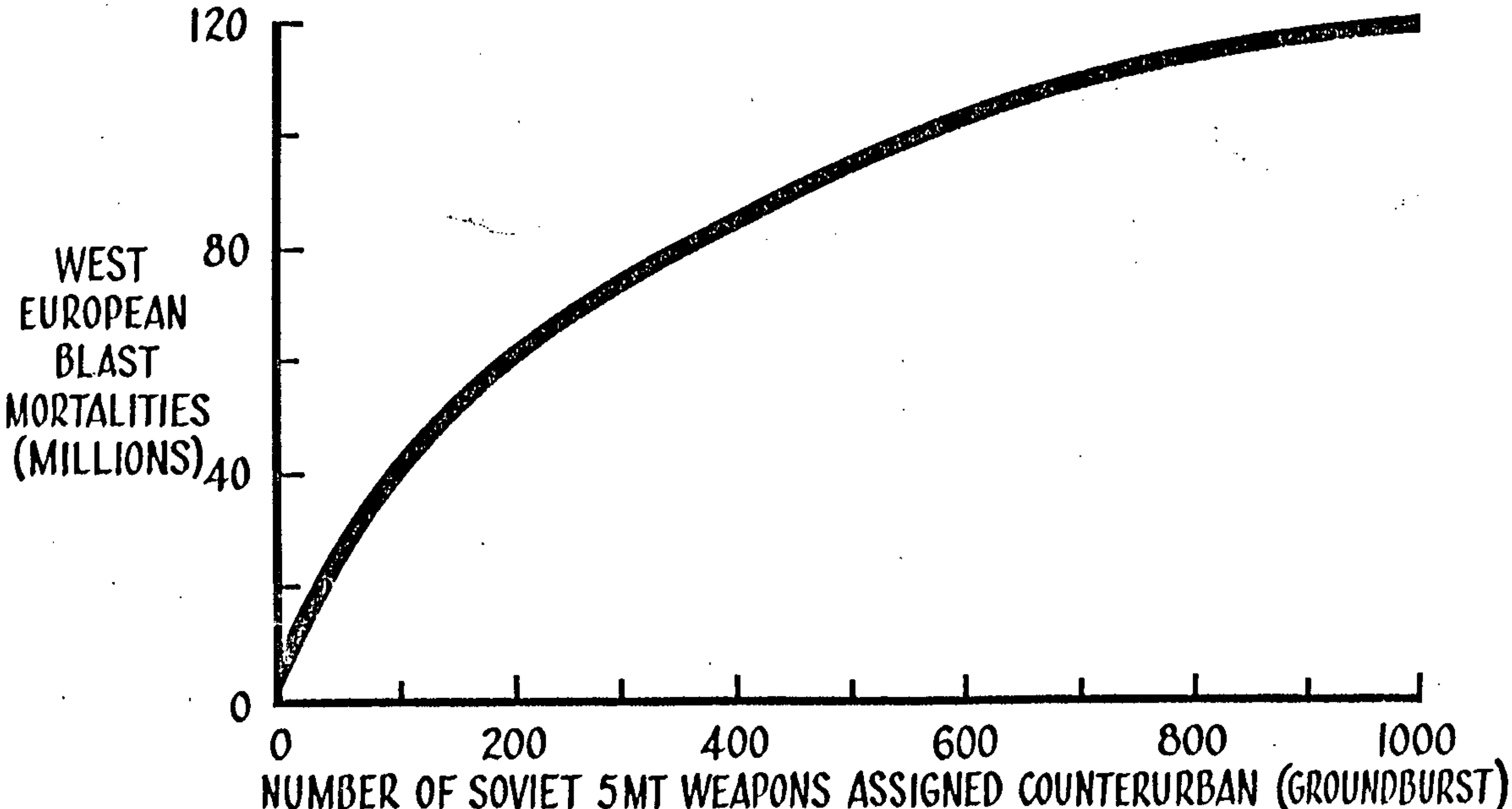


CHART 9

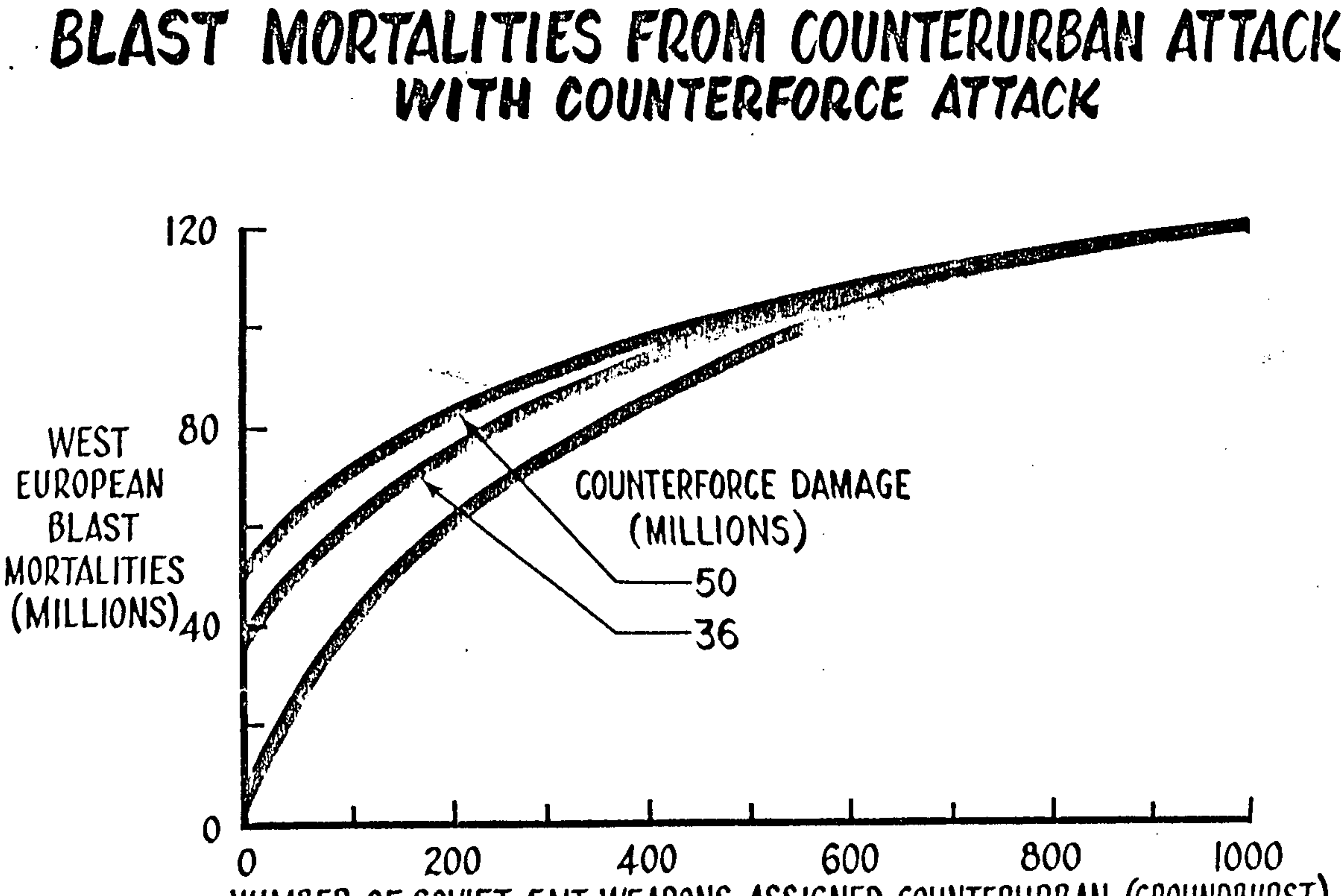

BLAST MORTALITIES FROM COUNTERURBAN ATTACK
WITH COUNTERFORCE ATTACK
WEST EUROPEAN BLAST MORTALITIES (MILLIONS)
120
80
40
0
COUNTERFORCE DAMAGE (MILLIONS)
50
36
0
200
400
600
800
1000
NUMBER OF SOVIET 5MT WEAPONS ASSIGNED COUNTERURBAN (GROUNDBURST)

CHART 10

BLAST MORTALITIES FROM COUNTERURBAN ATTACK WITH COUNTERFORCE ATTACK

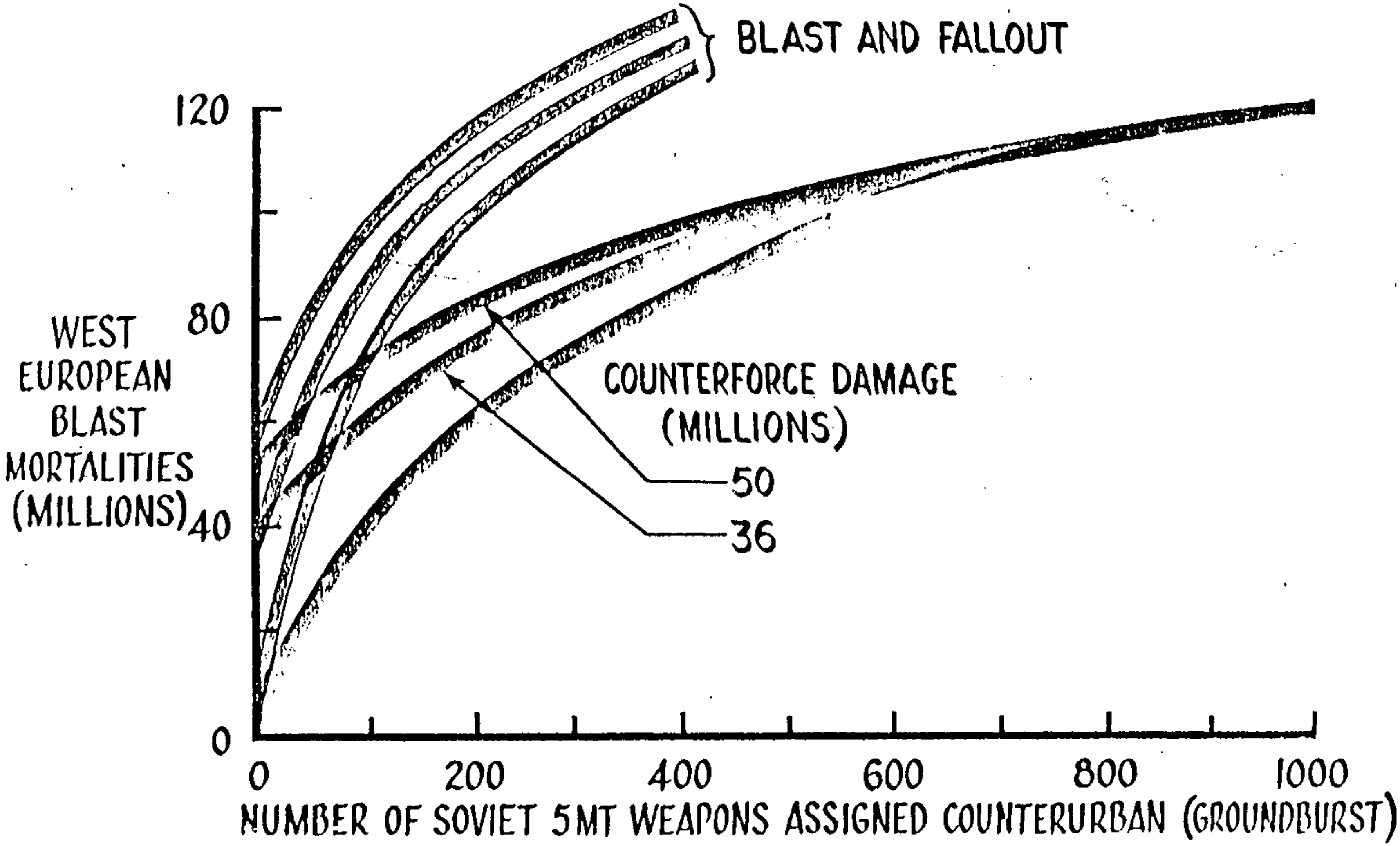


CHART 11

FALLOUT MORTALITIES

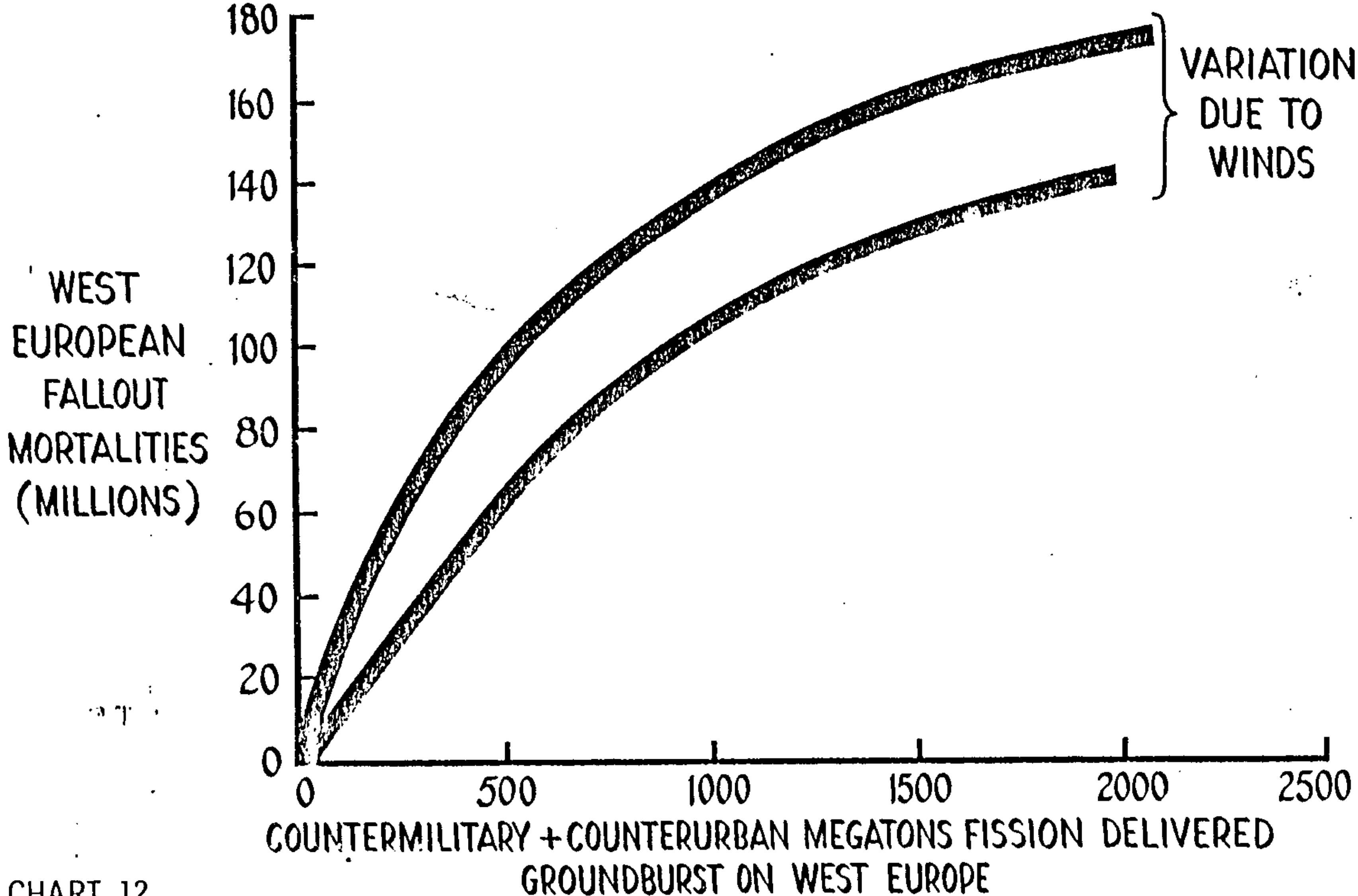


CHART 12

COMBINED BLAST AND FALLOUT MORTALITIES IN WESTERN EUROPE

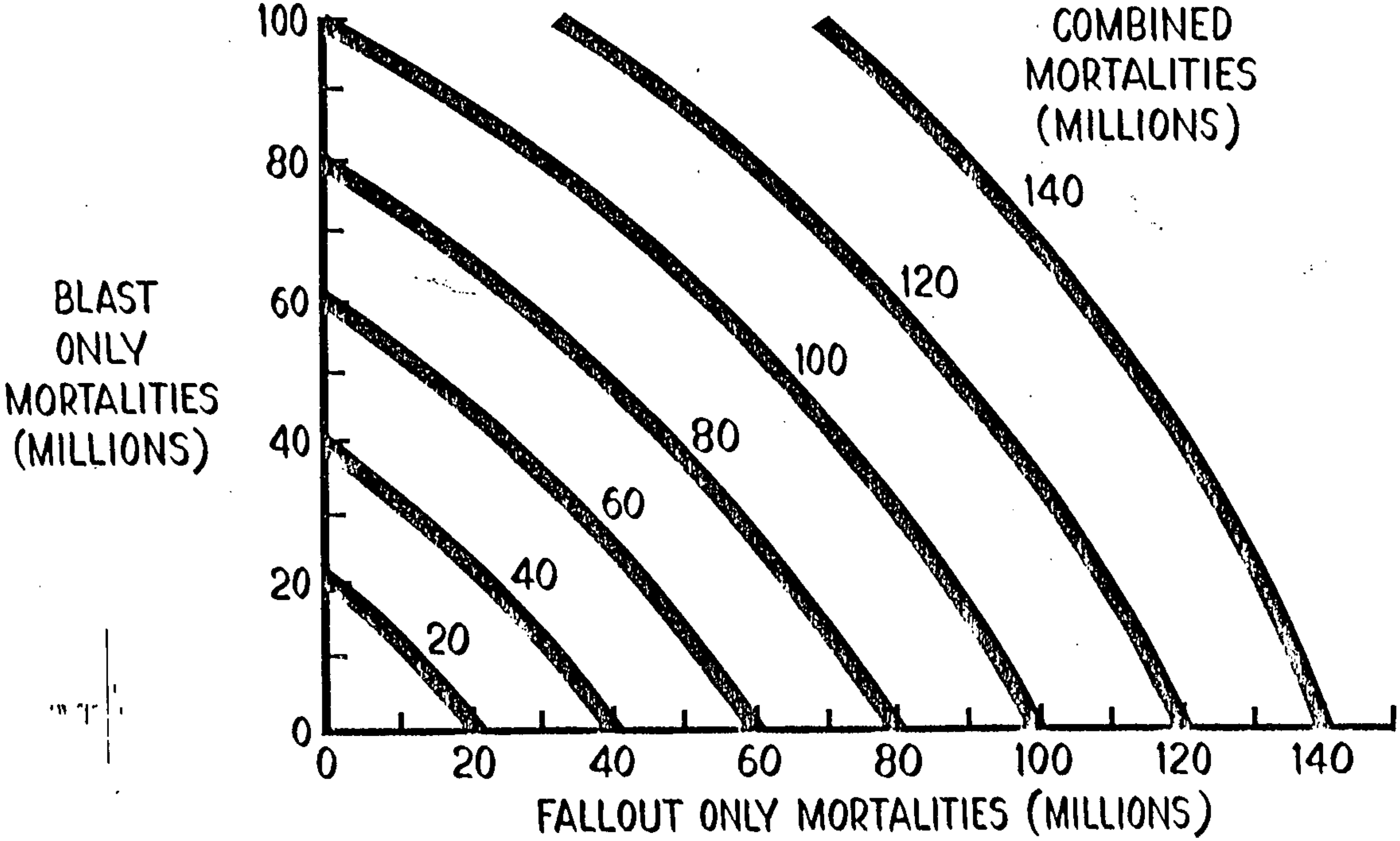


CHART 13

HYPOTHETICAL COUNTERFORCE ATTACK

ALL WEAPONS: 100 KT; 0.7 DELIVERY PROBABILITY; AIRBURST

TARGET CATEGORY	NUMBER OF AIM POINTS	WEAPONS PER AIM POINT	TOTAL WEAPONS ASSIGNED	BLAST MORTALITIES (MILLIONS)
PRIMARY AIRFIELDS	102	2	204	.58
SECONDARY AIRFIELDS	181	1	181	1.13
MAJOR PORTS	105	2	210	9.00
MAJOR C^3	9	2	18	.18
TOTALS			613	10.89

CHART 14

A "SELECTIVE DESTRUCTION" EXAMPLE

ALL WEAPONS: 4 MT, 0.7 RELIABILITY, AIRBURST ONLY

COUNTERMILITARY ATTACK

	NUMBER OF AIM POINTS	WEAPONS PER AIM POINT	TOTAL WEAPONS ASSIGNED	BLAST MORTALITIES (MILLIONS)
PRIMARY AIRFIELDS	102	2	204	5.6
SECONDARY AIRFIELDS	181	1	181	13.5
MAJOR PORTS	105	2	210	29.6
MAJOR C^3	9	2	18	1.4
			613	50.1

CHART 15

SELECTIVE DESTRUCTION—BY COUNTRY

	BLAST MORTALITIES (MILLIONS)
UNITED KINGDOM	12.9
BENELUX	8.9
SCANDINAVIA	2.3
WEST GERMANY	8.6
FRANCE	7.8
SPAIN AND PORTUGAL	3.0
ITALY	4.3
GREECE	.4
TURKEY	2.1
	50.1

CHART 16

HYPOTHETICAL SOVIET SECOND STRIKE
(SELECTIVE DESTRUCTION)

ALL WEAPONS: 4 MT, 0.3 DELIVERY PROBABILITY, AIRBURST

TARGET CATEGORY	NUMBER OF AIM POINTS	WEAPONS PER AIM POINT	TOTAL WEAPONS ASSIGNED	BLAST MORTALITIES (MILLIONS)
PRIMARY AIRFIELDS	102	2	204	2.4
SECONDARY AIRFIELDS	181	1	181	6.0
MAJOR PORTS	105	2	210	15.3
MAJOR C^3	9	2	18	0.6
TOTAL			613	24.3

CHART 17

HYPOTHETICAL MIXED COUNTERFORCE & COUNTERURBAN ATTACK
BLAST MORTALITY CALCULATION

ALL WEAPONS: 4 MT; 0.7 RELIABILITY; GROUND BURST; FRACTION FISSION = 0.3

- COUNTERMILITARY ATTACK

TARGET CATEGORY	NUMBER OF AIM POINTS	WEAPONS PER AIM POINTS	TOTAL WEAPONS ASSIGNED	BLAST MORTALITIES (MILLIONS)
PRIMARY AIRFIELDS	102	2	204	3.2
SECONDARY AIRFIELDS	181	1	181	7.4
MAJOR PORTS	105	2	210	24.6
MAJOR C^3	9	2	18	1.0
			613	36.2

- COUNTERURBAN ATTACK

150 WEAPONS @ 4 MT = 132 WEAPONS @ 5 MT

(150 x .88 = 132)

TOTAL BLAST MORTALITIES–MIXED ATTACK 67

CHART 18

HYPOTHETICAL MIXED ATTACK

FALLOUT AND COMBINED MORTALITIES CALCULATIONS

	MORTALITIES (MILLIONS)
● FALLOUT	
MT FISSION DELIVERED	
$(613 + 150)(0.7)(4)(0.3) = 641$	
FALLOUT MORTALITIES	80 TO 110
● COMBINED BLAST AND FALLOUT MORTALITIES	
BLAST (B)	67
FALLOUT ONLY (F)	80 TO 110
TOTAL	125 TO 146

CHART 19

ADVANTAGES OF AGGREGATE TECHNIQUES

- APPROXIMATE MEASURES OFTEN SUFFICIENT
- FILL STUDY GAPS
- REVEAL CRITICAL RELATIONSHIPS
- AIDS SENSITIVITY ANALYSIS

CHART 20

WEAPON RADIUS FOR GROUNDBURST WEAPONS

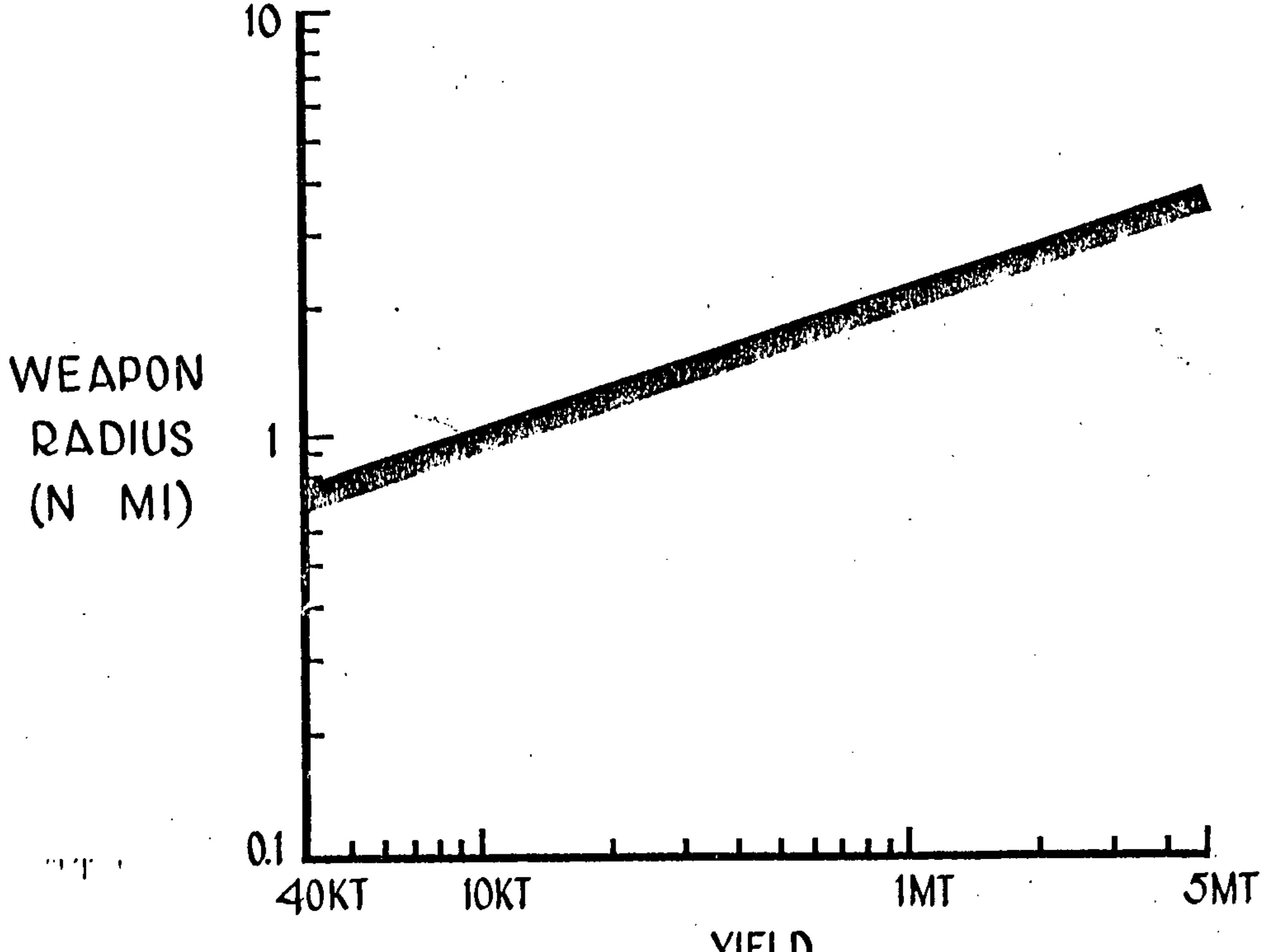


CHART 21

NUMBER OF BLAST EQUIVALENT 5 MT GROUNDBURST WEAPONS

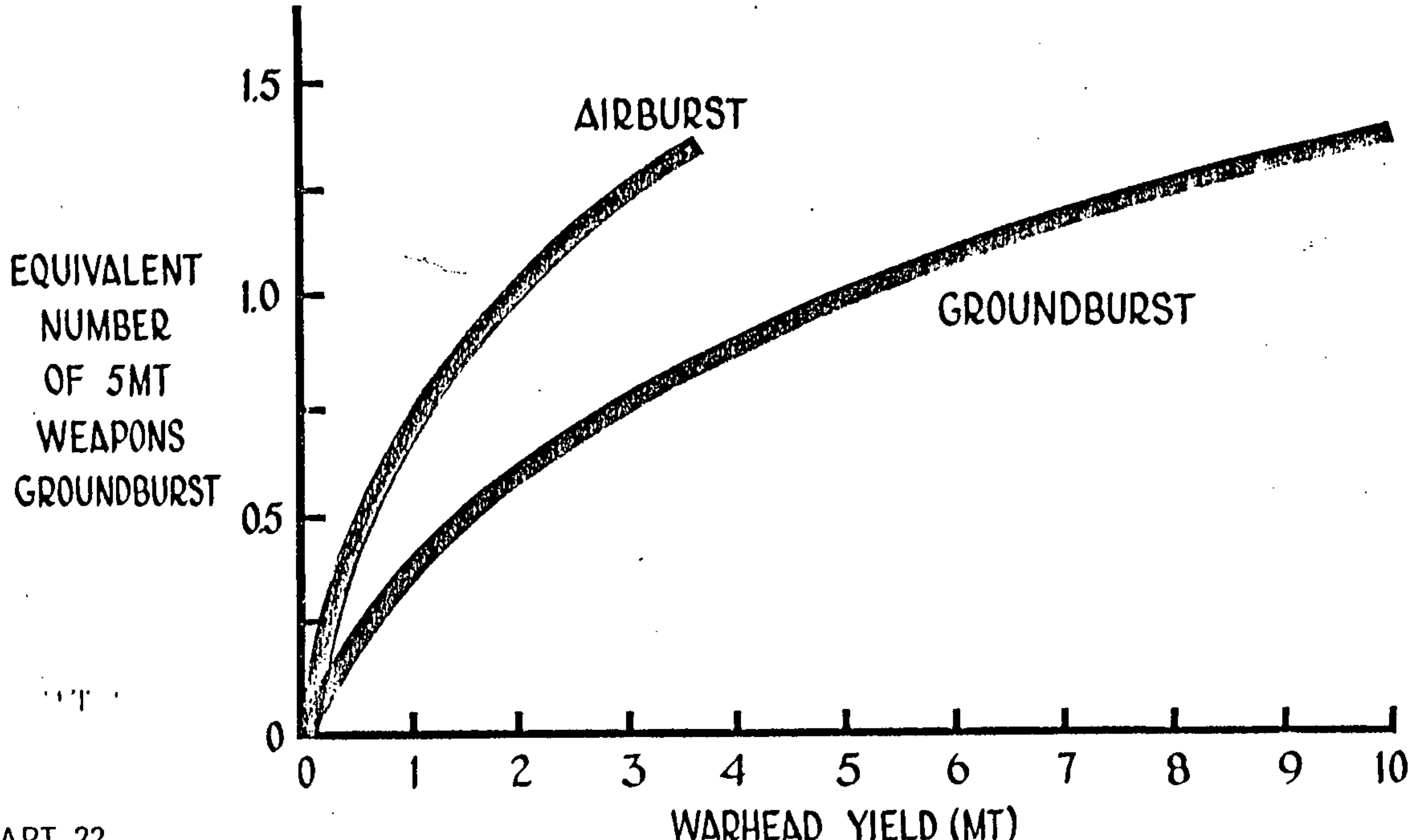


CHART 22