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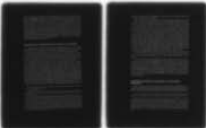
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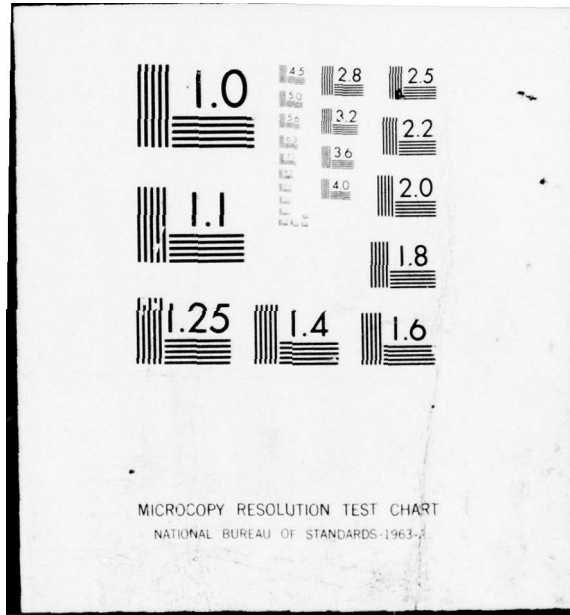
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November 1977

Fatality Uncertainties in Limited Nuclear War

Bruce Bennett

A Project AIR FORCE report
prepared for the
United States Air Force

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PREFACE

Rand has recently been developing new models to apply to strategic nuclear exchange and nuclear damage assessment. This effort has produced a family of models, called SNAPPER (for Strategic Nuclear Attack Program for Planning and Evaluation of Results), which use the latest damage assessment techniques to deal explicitly with both strategic system parameters and their uncertainties. The working model is now essentially complete, and documentation will soon be available.

The present report illustrates the usefulness of the SNAPPER analytic techniques by analyzing possible fatality levels that a Soviet nuclear attack on U.S. strategic forces might inflict. When he was Secretary of Defense, James R. Schlesinger renewed the concern over this contingency in his "Counterforce Briefing" to Congress.¹ The Congressional Office of Technology Assessment subsequently critiqued his arguments, and that critique in turn was summarized by Sidney D. Drell and Frank von Hippel in their article "Limited Nuclear War," which appeared in the November 1976 issue of *Scientific American*. That article is used here as a basis for discussing the pitfalls of what have apparently become accepted methods for analyzing the effects of strategic attacks, as well as for studying particular implications of the limited counterforce contingency.

Indeed, it was Rand's perception of the importance of uncertainties in attack outcomes that led to the development of SNAPPER as a model specifically designed to handle uncertainties in strategic analysis and to provide simple statistical statements of damage uncertainties. This report illustrates one of the most important potential uses of SNAPPER by showing the distribution of possible outcomes of such attacks. It should be of interest to those in the Air Force and elsewhere in the defense community who are concerned with counterforce attack and limited nuclear option issues.

The work was performed as part of the Project AIR FORCE (formerly Project RAND) research project entitled "Future Strategic Aerospace Force Requirements."

¹ In *Analyses of Effects of Limited Nuclear Warfare*, prepared for the Subcommittee on Arms Control, International Organizations, and Security Agreements of the Committee on Foreign Relations, U.S. Senate, September 1975.

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SUMMARY

The November 1976 issue of *Scientific American* carried an article by Sidney D. Drell and Frank von Hippel entitled "Limited Nuclear War." The article critiques the concept of a limited Soviet counterforce attack on the basis of an analysis which concludes that any such attack, if it were to be strategically effective, would cause high fatality levels, and that even a large-scale limited attack that caused the death of 20 million Americans would leave the United States with an overwhelming retaliatory force.

Arguing that the USSR is not currently pondering such attacks and is not actively training its population in civil defense against nuclear war, the authors contend that the United States should not inflame the situation by building up our own flexible counterforce capabilities as recommended by James R. Schlesinger in a briefing he presented in 1974 to a Senate committee when he was Secretary of Defense.

The present report does not attempt to deal with the very serious politico-strategic matter of probable Soviet and U.S. responses and counterresponses to actions taken on either side. Rather, it attempts to refute a major portion of Drell and von Hippel's argument by presenting evidence that potentially effective counterforce attacks actually can be carried out with relatively low collateral fatalities, in which case such attacks merit our concern and lend some justification, at least, to Schlesinger's recommendation.

The conclusions of the report heavily depend on two crucial issues to which, it is argued, Drell and von Hippel do not devote sufficient attention: the importance of the assumptions underlying the various attack scenarios, and the wide-ranging effects of uncertainty on fatality calculations.

A technique for dealing with these issues is Rand's new SNAPPER damage assessment model, which provides more realistic fatality distributions for the basic scenario assumptions. It is also used to test the assertion that any limited counterforce attack will necessarily cause high fatality levels if it is to be strategically successful.

Drell and von Hippel's fatality estimates are shown to be of essentially two types: median levels and "worst-case" outcomes. Their cases rely on narrow and rigid adherence to point estimates published by the Department of Defense. The consequence is that their calculations ignore most of the major uncertainties, and thus yield estimates that can prove to be very misleading. When the effects of only the most basic uncertainties are taken into account, fatality outcomes can vary over an order of magnitude. These fatality distributions, produced by SNAPPER, are useful in that they both give the general level of fatalities to be expected and indicate the potential risk for any given attack.

Most analyses of limited counterforce attacks assume that the Soviets would be concerned with minimizing U.S. fatality levels, an assumption that may or may not be true. If it is true, it is hard to believe that Soviet targeting would be based solely on military effectiveness criteria. Limited counterforce attacks *could* cause 20 million fatalities or more, but there are three ways by which an attacker can reduce fatalities below that figure: by avoiding attacks on bases collocated with

large population centers, by electing to use airbursts instead of ground bursts, and by decreasing weapon yield. If the Soviets employed such strategies, the fatalities from a limited "comprehensive" counterforce attack would be about one to three million people, and the attack would still be about 90 percent as militarily effective as an attack that did not attempt to minimize fatalities. It therefore meets Schlesinger's fatality criterion for an effective limited counterforce attack.

By no means is this meant to suggest that we should regard the possibility of such an attack with equanimity. On the contrary, a figure of one to three million deaths would certainly constitute a disaster unprecedented in our nation's military history. Nevertheless, it is one or two orders of magnitude less than the number of deaths that could result from a massive nuclear exchange involving attacks on cities, and it would be unwise for us to dismiss it from the realm of possibility.

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The author is grateful for the helpful suggestions and corrections provided by Tom Brown, Carl Builder, Jim Foster, and Dennis Smallwood. Carl Builder also suggested the topic of this report and directed its development. The author is indebted to Bruce Whetstone for aiding in the development of the computer data bases used. Full responsibility for the results and information presented remains, of course, with the author.

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I. INTRODUCTION

In 1974, then Secretary of Defense James R. Schlesinger presented a "counterforce briefing" to a Senate committee that renewed the debate over counterforce war.¹ His testimony centered on the potential effectiveness of a limited Soviet counterforce attack against U.S. land-based forces. His argument was that the substantial growth in numbers of Soviet weapons and in the USSR's ability to mount discriminating attacks suggested that a Soviet counterforce attack could be militarily effective while limiting collateral damage to such an extent that it would be clearly distinguishable from the damage an unlimited attack would inflict. Because the bulk of the U.S. population would still remain vulnerable to a subsequent massive Soviet attack, our lack of correspondingly limited response options might well deter the United States from taking any action at all. To prevent such a situation, Schlesinger contended that the United States must develop a flexible deterrence posture that includes limited strategic options as well as massive responses.

In November 1976, Sidney Drell and Frank von Hippel published a critique of Schlesinger's analysis and of the limited counterforce concept in general.² Their analysis is derived from Schlesinger's testimony, from the subsequent critique thereof by the Congressional Office of Technology Assessment (OTA),³ and from the Department of Defense analysis responding to the OTA critique.⁴ The DOD analysis considered attacks with destruction of up to 80 percent of the missile force, 60 percent of the bomber force, and 90 percent of the in-port SSBN force. In assessing *the requirements for and consequences of such attacks*, Drell and von Hippel argue that Schlesinger's assumptions regarding Soviet attack strategy were unjustifiable and that the methods for assessing collateral damage were inappropriate. The authors' own analysis concludes that (1) the casualties from *any* militarily significant limited attack would inflict devastatingly high casualties; (2) even a massive attack that included the death of 20 million Americans would still leave an overwhelming U.S. retaliatory force;⁵ and (3) "It is therefore at least misleading to suggest that a successful and strategically effective counterforce attack could be carried out with low civilian casualties."⁶

Drell and von Hippel raise some important considerations, but their analysis is open to question because it fails to address explicitly the substantial uncertainties in assessing strategic attack options. When these are considered, one realizes that both force destruction and fatality levels can differ widely from those cited by Drell

¹ The briefing is reproduced in *Analyses of Effects of Limited Nuclear Warfare*, prepared by the Department of Defense for the Subcommittee on Arms Control, International Organizations, and Security Agreements of the Committee on Foreign Relations, U.S. Senate, September 1975, pp. 101-156 (hereinafter cited as *Analyses of Effects*).

² Sidney D. Drell and Frank von Hippel, "Limited Nuclear War," *Scientific American*, November 1976, pp. 27-37.

³ Separately and at different times, Drell and von Hippel contributed to the OTA critiques in 1975.

⁴ *Analyses of Effects*, pp. 4-24.

⁵ This ignores the relative force changes. In their "comprehensive" attack the Soviet Union would destroy about 60 percent of the total U.S. forces at the cost of about 20 to 30 percent of their own. Such an exchange could be significant if we assume any role for the U.S. forces beyond "assured destruction."

⁶ Drell and von Hippel, p. 35.

and von Hippel. This report will treat, in particular, the issues related to estimation of probable fatality levels. In so doing, it will address the following questions:

- Are the scenario assumptions consistent and justifiable, and how sensitive are the outcomes to those assumptions?
- How uncertain are the calculations and what are the implications of explicitly accounting for uncertainty?
- How can analytic methods be improved to treat these uncertainties and to demonstrate the tradeoffs between limited attack strategies given uncertainty?
- Does a limited counterforce attack necessarily cause enormous devastation (20 million fatalities)?

II. FATALITY LEVELS FOR LIMITED COUNTERFORCE ATTACKS

Two major uncertainties in the scenario conditions for a Soviet counterforce attack make predictions of fatality levels subject to substantial variability. First, and most important, is uncertainty about the nature of the attack. The second is uncertainty about the scope and effectiveness of measures taken to protect the U.S. population against nuclear weapons effects, both prompt and fallout. To allow for some of these uncertainties, Drell and von Hippel reproduce the DOD's estimated fatality levels resulting from five postulated attacks. This section describes and evaluates these fatality levels and the assumptions that appear to underlie them. It then discusses the other uncertainties involved in fatality calculations. Finally, the same five cases will be evaluated by use of Rand's SNAPPER damage assessment model to show explicitly how some of the uncertainties affect the estimation of fatalities.

THE DOD FATALITY LEVELS AS USED BY DRELL AND VON HIPPEL

Drell and von Hippel¹ reproduce and use the five DOD fatality point estimates given in Fig. 1 but confine their attention almost exclusively to cases C, D, and E. It is important to note that Schlesinger used cases A and B to show that the Soviets might well decide that such attacks are feasible because of the relatively low fatality levels, whereas Drell and von Hippel use cases C, D, and E to confirm their argument not only that *all* Soviet counterforce attacks, if militarily effective, would produce unacceptably high fatality levels, but also that even the most massive attacks would still leave the United States with "an overwhelming retaliatory force," both factors meaning that counterforce attacks would be acts of such folly that it is difficult to imagine the Soviets would consider them. The approximate order-of-magnitude difference between the two sets of results is striking, and suggests significant differences in their underlying assumptions, as Fig. 1 confirms.

EXAMINING THE ATTACK ASSUMPTIONS

In these five cases, five parameters are allowed to vary: weapon yield, attack size, height of burst, shelter posture, and wind. DOD's treatment of these param-

¹ P. 35. Although Fig. 1 includes all of the DOD information presented by Drell and von Hippel, their article omits a great deal of data on other important parameters. To fill the gaps, data from *Analyses of Effects* was used here when available; otherwise, some approximations were made by this author. Most of this information is summarized in Table 1. The pattern attack on SAC bases is assumed to include four weapons directed at each base with one ground burst on the base and three airbursts at 5.0 nautical miles (n mi) from the base in an equilateral triangular pattern rotated to minimize fatalities. These airbursts are at a height of 7250 feet. The SSBN port airbursts are assumed to be at 88 scaled feet. Finally, this report assumes that only one weapon is used against each SSBN port attacked.

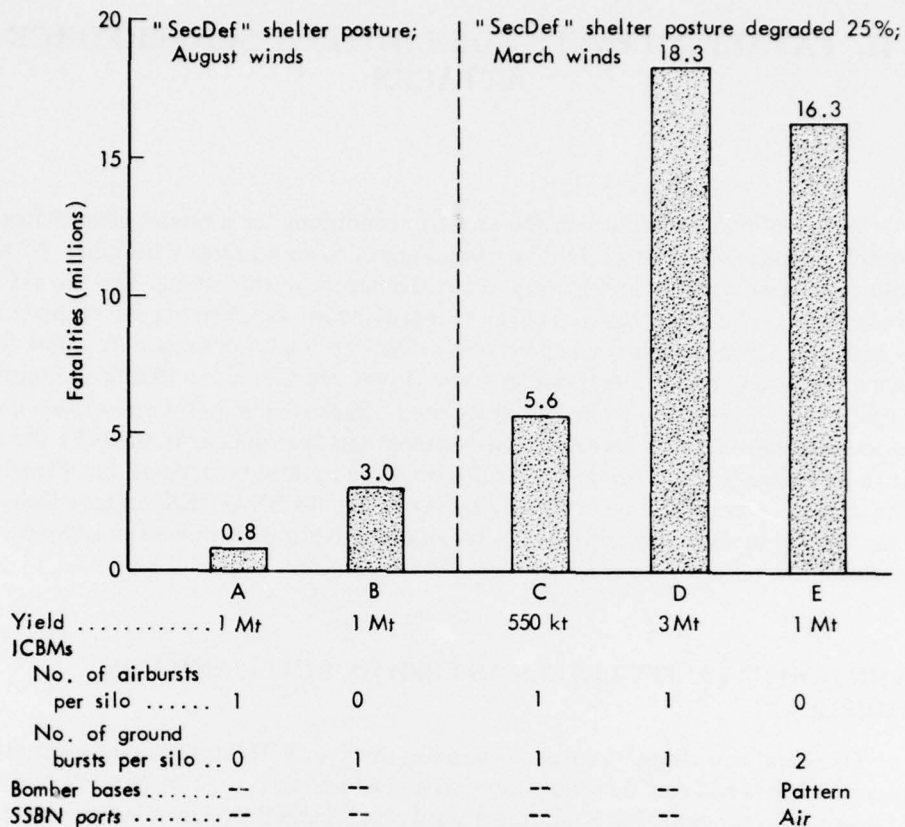


Fig. 1—DOD fatality levels for five postulated Soviet Counterforce attacks (after Drell and von Hippel, p. 35)

ters as uncertain was implicit in its analysis, as clearly indicated in the "Background" section of their report:

In response to a request from Senator Sparkman, DOD has undertaken a sensitivity analysis of collateral damage to assist the Senate Foreign Relations Committee and others to better understand the uncertainties associated with DOD estimates of expected casualties (fatalities and non-fatal injuries) and damage resulting from postulated Soviet nuclear attacks on selected military targets in the U.S. The intent of this analysis was to provide to the committee, to the extent possible, an indication of the sensitivity of results to input assumptions and attack scenarios. . . . The analysis included:

- Pattern attacks around U.S. bomber bases;
- 2-RV attacks against ICBM silos;
- Use of various weapon yields and fission fractions consistent with current intelligence estimates;

Use of both favorable and adverse weather conditions (from the point of view of civil effects);
 Civil Defense assumptions which both maximize and minimize civil effects;
 An assessment of the military effectiveness of the various attacks.²

By examining these parameters and how they were used by both Schlesinger and his critics, much can be learned about the two sides' different expectations and the variation being accounted for.

In cases A and B, Schlesinger chose the standard "best estimate" for the yield for the new Soviet MIRVed systems like the SS-18 MOD 2; presumably, then, use of this value should lead to "most likely" outcomes. Cases C, D, and E use values at or around this "best estimate," and thus cover the range of possible outcomes with respect to yield.

With respect to attack size, cases A to D deal exclusively with countersilo attacks. That focus is fairly reasonable, because even in the "comprehensive attack," over 90 percent of the warheads are directed against ICBMs. Schlesinger's cases A and B involve only one warhead per silo, however, a rather extreme assumption with respect to the effectiveness of the attack unless it is assumed that the Soviets have both excellent accuracy and a reprogramming capability to cover unreliable systems, as Schlesinger does assume by using a 100 percent arrival probability. Since the Soviets do not seem to have such capabilities yet, he was apparently talking about a future threat. In contrast, cases C, D, and E assume a two-warhead-per-silo attack, as is more conventional in analyses of the short-term threat. For some reason, however, those cases retain the 100 percent arrival-probability assumption, which overestimates the expected number of warheads detonated (and thus fatalities) in terms of the short-term threat.

As for the choice between ground bursts and airbursts: Normally, airbursts cause fewer fatalities because they produce relatively low amounts of close-in fallout, but the fuzing must be very accurate to make airbursts militarily effective. Because many analysts doubt the accuracy of Soviet fuzing for countersilo use, they usually base fatality calculations on ground bursts against silos (cases B and E). Optimistic estimates of fuzing accuracy make airbursts preferable to ground bursts for military effectiveness, and also provide lower fatality estimates (case A). A mixture of ground and airbursts (cases C and D) provides a compromise estimate.

The assumptions on shelter posture³ and winds at the top of Fig. 1, however, are largely responsible for the magnitude of the difference between the estimated fatalities. In general, August winds tend toward an average number of fatalities, whereas March winds will cause the highest fatality levels for *most* attacks. The "SecDef" posture is a fairly median posture when compared with many postures suggested in various defense publications,⁴ while degrading it by 25 percent places it in the lower range of widely used shelter postures. With regard to two of the four

² *Analyses of Effects*, p. 12.

³ A "shelter posture" is a distribution of people among varying degrees of fallout shelter measured by protection factors. A protection factor is a number used to divide the fallout dosage outdoors to obtain the effective dosage to which people in the shelter are exposed. The "SecDef" shelter posture received its name because then Secretary of Defense Schlesinger used it in his calculations. It employs four protection factors of 3, 14, 50, and 100, with 45, 20, 10, and 25 percent of the people in each, respectively.

⁴ See the discussion of this issue in *Analyses of Effects*, pp. 13-15.

major determinants of fallout,⁵ then, Schlesinger's cases A and B will tend to produce expected fatalities; cases C, D, and E approximate worst-case results. This is verified by DOD's "Background" statement, where it is indicated that the "comprehensive attack", case E, would result in 6.7 million expected fatalities,⁶ much less than half the "worst-case" value of 16.3 million given by Drell and von Hippel. Drell's projection of these worst-case conditions as being the only ones of interest is clearly shown in his Congressional testimony when he stated that, "In place of the 800,000 fatality figure quoted in Secretary Schlesinger's estimate cited above, the Defense Department now finds that fatalities will necessarily be in the range of 10 to 20 million, due to prompt effects and fallout alone, if the attack is designed to destroy the majority of the attacked ICBM force."⁷ This statement clearly contradicts DOD's expected fatality level.

THE EFFECT OF UNCERTAINTY ON FATALITY CALCULATIONS

It seems almost inevitable that, with counterforce attacks, there will be large uncertainties in various parameters. Drell and von Hippel deal with some of them, but many other important sources of uncertainty affect fatality calculations.

Starting with *weapon system parameters*, there are uncertainties about the yield, accuracy, burst height, reliability, and availability of all systems. The uncertainty deepens when we begin to talk about Soviet systems, and is complicated by further uncertainties such as the warhead mix for a given missile system.

On the vulnerability side of the equation, we again find a number of uncertainties, including human vulnerability to various prompt weapons effects (notably, blast and prompt radiation). We know little about these effects beyond what we learned at Hiroshima and Nagasaki, and those data are related to weapons much smaller than the ones postulated here for a counterforce attack.⁸ Vulnerability is also a function of any form of shielding between the explosion and the people, which may be highly variable. Further, human vulnerability may be greatly influenced by the amount of medical care, shelter, and nutrition that affected people receive after the attack, all of which are similarly uncertain. Most calculations assume that blast and radiation effects are independent (to simplify calculation), whereas they are really additive. And then we should note that although populations are more mobile than most targets, the implications of warning time (for evacuation and civil

⁵ These four are winds, shelter posture, the amount of fissionable material used (which is a function of yield), and population distribution.

⁶ *Analyses of Effects*, p. 12.

⁷ *Effects of Limited Nuclear Warfare*, hearing before the Subcommittee on Arms Control, International Organizations, and Security Agreements of the Committee on Foreign Relations, U.S. Senate, September 1975, p. 30.

⁸ Historically, casualty projections based on limited data have been extremely poor, with order-of-magnitude errors not uncommon. One of the best examples occurred after World War I. Based on the German bombings of 1917 and 1918, "Calculations were made of the weight of German bombs delivered on London itself, and of the casualties inflicted. A ratio was derived of 50 casualties per ton of bombs (of which one-third would be killed and the remainder wounded), and this ratio was in fact to be retained for RAF planning purposes until 1940." See George H. Quester, *Deterrence Before Hiroshima*. John Wiley & Sons, Inc., New York, 1966, p. 61. When war brought heavy bombings after 1940, the actual ratio was empirically shown to be more like 1 to 3 casualties per ton of bombs (pp. 122, 157-158, 171). We therefore should always be aware that our calculations may prove wrong. This point is reinforced by the magnitude of changes that the Defense Intelligence Agency (DIA) has made in its nuclear damage assessment methodology within the last few years.

defense, and for panic) are so difficult to evaluate that they are seldom taken into account in models of nuclear attack.

The limited amount of test data available has led to another type of uncertainty, perhaps not as widely recognized as the physical effects described above: the uncertainty in *modeling* nuclear effects. Fallout is the most difficult to quantify, but blast and prompt radiation effects are also uncertain, and most models ignore other prompt effects that are hard to calculate, such as conflagrations and fire storms. With fallout, variations in wind and other climatic conditions can cause casualty levels to range over several orders of magnitude. Also, the unit amount of radioactivity produced (the K-factor or "Magic Number") varies by at least a factor of two between theory and empirical observations;⁹ and since most models use the theoretical value, they probably overestimate the radioactivity produced. These problems are common to most fallout models; however, one of the greatest uncertainties is reflected by the large differences between models, as shown by the three dissimilar patterns in Fig. 2. The patterns drawn by Drell and von Hippel suggest that they may have used the Weapons Systems Evaluation Group (WSEG) model (see Fig. 2) or some simpler geometric representation.¹⁰ And for airbursts, the height of burst adjustment is another source of variation across models.

Finally, it is impossible to foretell the conditions that would prevail in a nuclear war. It could come at various alert levels, with varying attack intensities and timing, and with different objectives, all of which would produce different outcomes.

To treat these kinds of uncertainties in damage assessments, Rand has developed a new family of models (SNAPPER) that use simulation to evaluate the effects of uncertainty ranges. The SNAPPER nuclear damage assessment model, briefly described in the appendix, is designed to capture the distribution of fatality levels caused by variations in many of the parameters mentioned above. In its simplest format SNAPPER can cover, with distributions or ranges, all the parameters varied in the fatality levels reported by Drell and von Hippel. Therefore, we will employ this version to indicate how SNAPPER can enrich our understanding of fatality estimates.

COMPARING SNAPPER AND THE DRELL AND VON HIPPEL ESTIMATES

Table 1 summarizes the input parameters and uncertainties considered in each type of analysis. The attacks postulated by the DOD and repeated by Drell and von Hippel will be used exactly as defined in each case. This includes retaining the

⁹ *Response to DCPA Questions on Fallout*, DCPA Research Report No. 20, prepared by Subcommittee on Fallout, Advisory Committee on Civil Defense, National Academy of Sciences, November 1973, pp. 2-6.

¹⁰ Drell and von Hippel, pp. 32-33. Their patterns look *fairly* similar to the WSEG pattern in Fig. 2. The WSEG model is used in this report because of this similarity and because it is the most widely accepted fallout model for damage assessment work. The WSEG model's popularity is due to both its fast run time and relatively rigorous derivation, though it is not the most "accurate" model available because of the way it handles the fallout process. For more information on fallout models, see W. W. Kellogg, *Atmospheric Transport and Close-in Fallout of Radioactive Debris from Atomic Explosions*, The Rand Corporation, P-1091, May 1957; and C. J. Seery and M. Polan, *An Analysis of Fallout Prediction Models*, Vol. 2, U.S. Naval Radiological Defense Laboratory, NRDL-TRC-68-59, August 28, 1968.

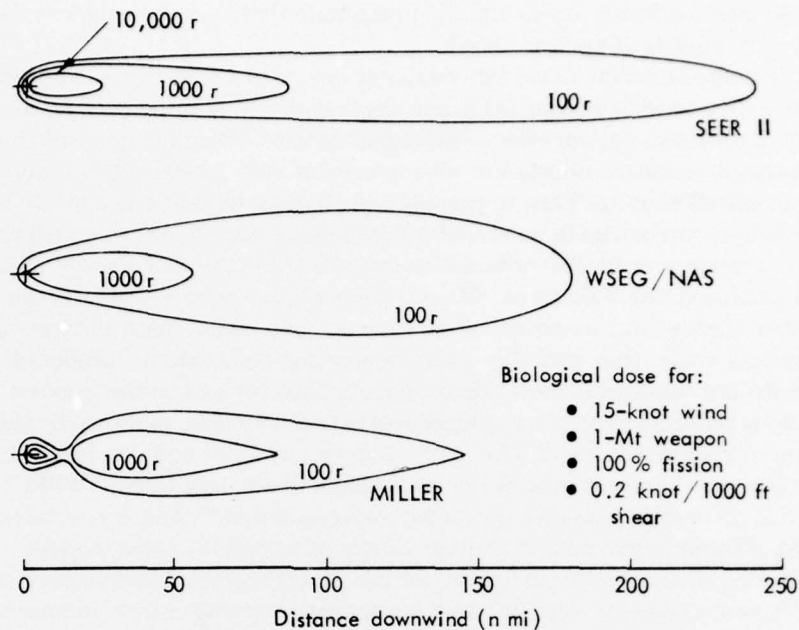


Fig. 2—Comparison of three fallout models for doses over 100 r

unreasonable 100 percent reliability figure for cases C, D, and E. Case C differs somewhat from the other attacks in several aspects, including a somewhat higher fission fraction and a somewhat lower-scaled burst height.¹¹ For the attack analyzed in each case, only the actual ground zero was allowed to vary, based upon the circular error probable (CEP) of the weapon system. The other uncertainties implicitly evaluated were the shelter posture and winds. A fairly wide range of uncertainty on shelter posture was used in order to include some of the possible variance in the "K-Factor" or radiation level, which impacts fatality levels as the inverse of shelter posture.

In handling uncertainties in inputs, SNAPPER uses distributions of inputs to develop distributions of outputs by Monte Carlo sampling. In this analysis, the actual ground zero was determined by choosing a set of random numbers from the circular normal distribution based upon the CEP for each arriving weapon. The winds used were "mean-effective" winds chosen at random five-day intervals from 1972 (five-day intervals being sufficient to generally insure independence). The variance in shelter posture was captured by measuring the impact of increasing or decreasing it 33-1/3 percent around the basic value for each wind and attack. The three points (+ 33-1/3 percent, 0 percent, -33-1/3 percent) serve as mid-interval

¹¹ See Frank L. Adelman, Joseph C. Krupp, and C. Tucker Battle, *Intermediate- and Long-term Effects of Limited Nuclear Attacks*, System Planning Corporation, Report 277, September 1976, p. 10. A scaled height of burst of 80 to 90 feet is "optimum" against targets in the 2000 pounds per square inch (psi) range according to DIA's *Physical Vulnerability Handbook*.

Table 1
COMPARISON OF DOD AND SNAPPER INPUT PARAMETERS

Parameter	Schlesinger's Cases				Other Cases					
	Case A		Case B		Case C		Case D		Case E	
	DOD	SNAPPER	DOD	SNAPPER	DOD	SNAPPER	DOD	SNAPPER	DOD	SNAPPER
Yield	1 Mt	1 Mt	1 Mt	1 Mt	550 kt	550 kt	3 Mt	3 Mt	1 Mt	1 Mt
CEP, ft	?	1500	?	1500	?	1500	?	1500	?	1500
Actual ground zero	DGZ ^a	Simulated	DGZ	Simulated	DGZ	Simulated	DGZ	Simulated	DGZ	Simulated
Reliability	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Height of burst over silos (scaled feet)	?	84	0	0	60	60	?	84	0	0
Fission fraction	50%	50%	50%	50%	65%	65%	?	50%	50%	50%
Shelter posture	SecDef	SecDef ± 50%	SecDef	SecDef ± 50%	SecDef	SecDef ± 50%	SecDef	SecDef ± 50%	SecDef - 25%	SecDef ± 50%
Winds	August	20 synoptic	August	20 synoptic	March	20 synoptic	March	20 synoptic	March	20 synoptic
K-factor	?	2000	?	2000	?	2000	?	2000	?	2000
Terrain-shielding factor	?	75%	?	75%	?	75%	?	75%	?	75%

SOURCES: Drell and von Hippel; *Analysis of Effects of Limited Nuclear Warfare*; author's approximations.

^aDesired ground zero.

estimates of a uniform distribution extending plus or minus 50 percent around the SecDef shelter posture.

The results of these comparative SNAPPER runs are shown in Figs. 3 to 7. Figure 3 uses two methods of presentation to compare the Schlesinger results quoted by Drell and von Hippel with the SNAPPER estimates for case A, the one-megaton airburst case. On the left, a standard bar graph is employed, showing that fatalities have a 1.5 percent probability of being over 2,800,000, and a 39 percent probability of being between 600,000 and 1,000,000, the basic interval that includes Schlesinger's result. The right half of Fig. 3 plots fatalities against the cumulative probability that they will be less than any given level, the normal SNAPPER output. Thus, case A fatalities should not be below 300,000 or above 3.3 million (with about 95 percent confidence); the median level is about 820,000, and fatalities should be below 1.0 million with 64 percent probability. The Schlesinger fatality level is close to the median, but it exceeds the lower limit by a factor of three and is only one-fourth of the upper limit. It is therefore specious precision to say that a one-megaton airburst on each ICBM silo would kill 800,000 people, even though that figure lies close to the median.

Figure 4 displays similar results for case B, the one-megaton ground burst on each ICBM silo. The 3.0-million level cited by Drell and von Hippel is again about the median value, which is interesting considering its origin as a rough estimate: Schlesinger, who had done calculations for case A, stated with regard to case B, "If the Soviets chose to surface-burst their weapons rather than airburst their wea-

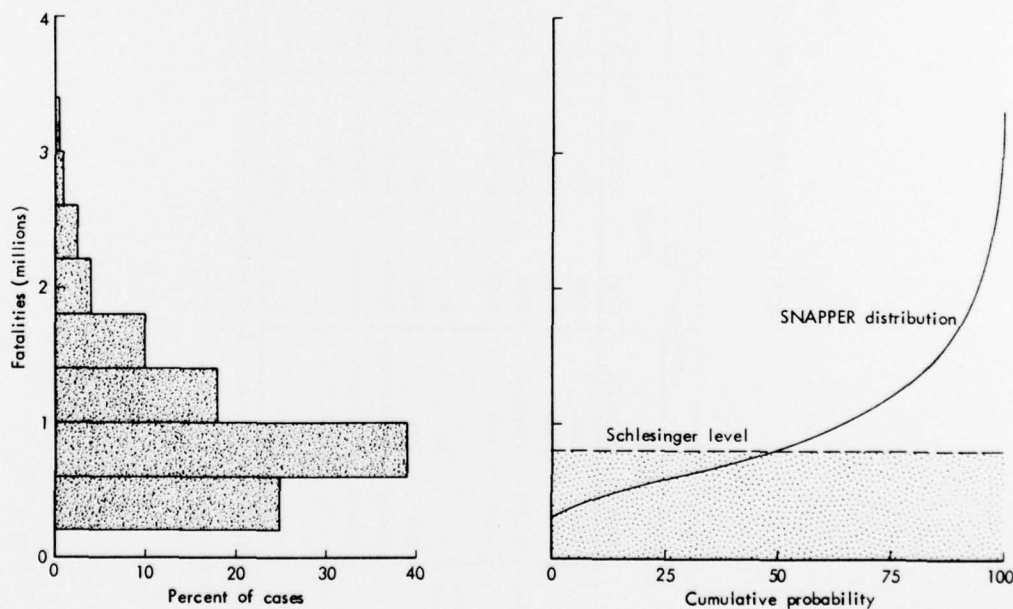


Fig. 3—SNAPPER comparison of possible fatality levels from a Soviet Counterforce attack with a one-megaton airburst on all U.S. ICBM silos (case A)

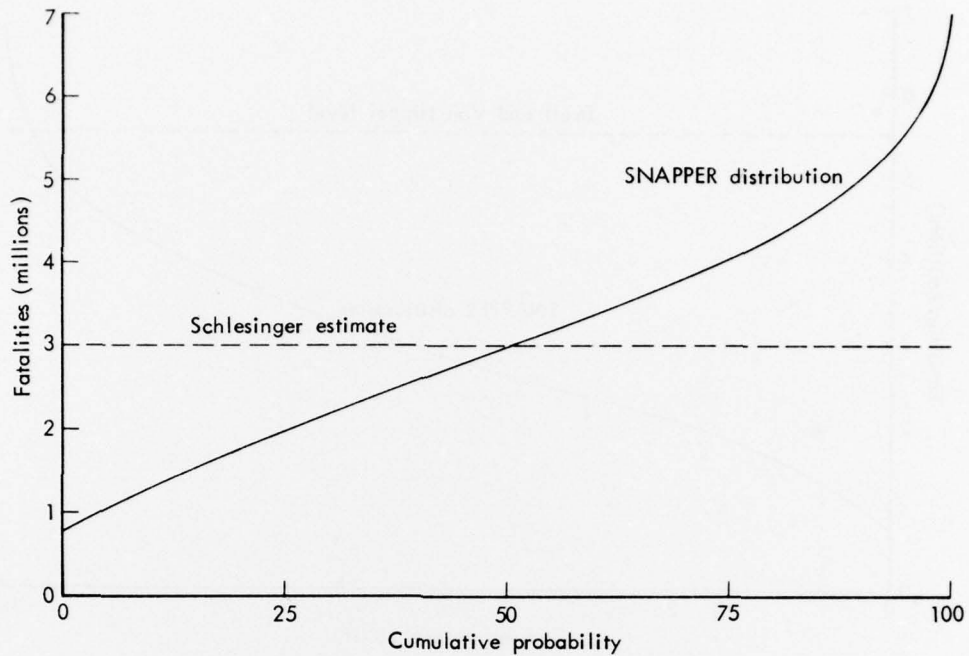


Fig. 4—SNAPPER comparison of possible fatality levels from a Soviet counterforce attack with a one-megaton ground burst on all U.S. ICBM silos (case B)

pons, it would drive the number of fatalities or casualties to a significantly higher level, something on the order of three million.”

Figure 5 depicts a sharply different comparison for case C, the 550 kt air and ground burst attack, which is the first of the cases that Drell and von Hippel use to show the “impracticality” of a limited Soviet counterforce attack. The point estimate of 5.6 million fatalities hits at about the 97th percentile of the SNAPPER distribution, showing it to be very close to a “worst-case” result over the uncertainties in wind, shelter posture, and actual ground zero. Note that the distribution for case C is strikingly similar to that of case B, as would be expected from the roughly equivalent effective fission yield of these two attacks, since fallout is the dominant fatality mechanism. The fact that case B is reported as having a point estimate of 3.0 million fatalities versus the nearly double point estimate for case C indicates the extent to which the counterforce critics are distorting attack outcomes.

Figure 6 shows that the case D fatality level also appears to be a worst case for the same reasons as in case C, falling at roughly the 98th percentile of the SNAPPER distribution. The relatively wide downwind fallout patterns of a 3-megaton attack carry the potential risk of floating over several major urban areas, so that we see a fairly large tail on the distribution. Thus the point estimate of 18.3 million fatalities could be too low if such conditions occur, but is otherwise too high by as much as a factor of 6.

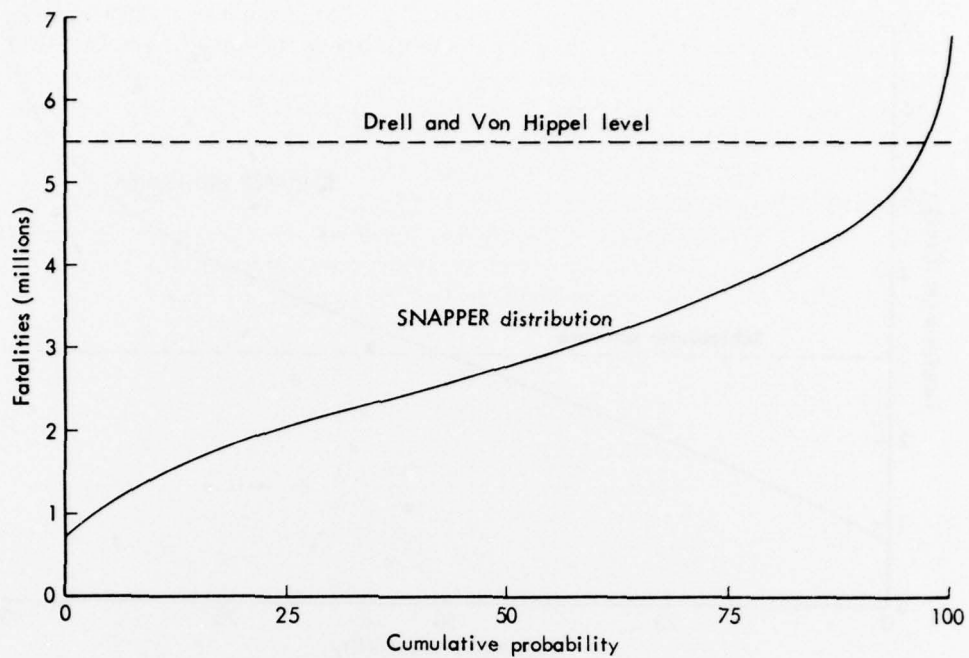


Fig. 5—SNAPPER comparison of possible fatality levels from a Soviet counterforce attack with a 550-kiloton air and ground burst on all U.S. ICBM silos (case C)

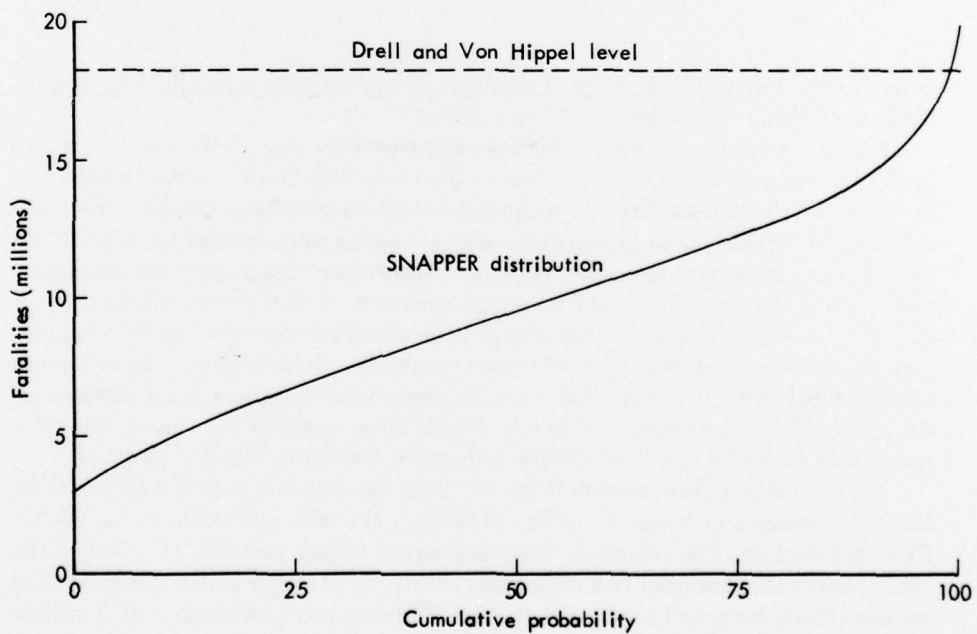


Fig. 6—SNAPPER comparison of possible fatality levels from a Soviet counterforce attack consisting of a 3-megaton air and ground burst on all U.S. ICBM silos (case D)

Finally, Fig. 7 presents fatality estimates for a "comprehensive" attack, case E. In this figure, the fatality level given is slightly above the top of the SNAPPER distribution. This may well be due to differences in bomber-base or SSBN port attacks, which were not well documented by Drell and von Hippel. Other possible causes include differences in the population representation employed, the wind patterns used, the fallout model, or the terrain shielding factor. While each of these latter factors would also affect cases C and D, the effects could be somewhat different, given the broader nature of this attack. Whatever the reason, case E is also clearly a worst-case outcome for the given attack parameters, and is *more than twice* the SNAPPER level about 60 percent of the time.

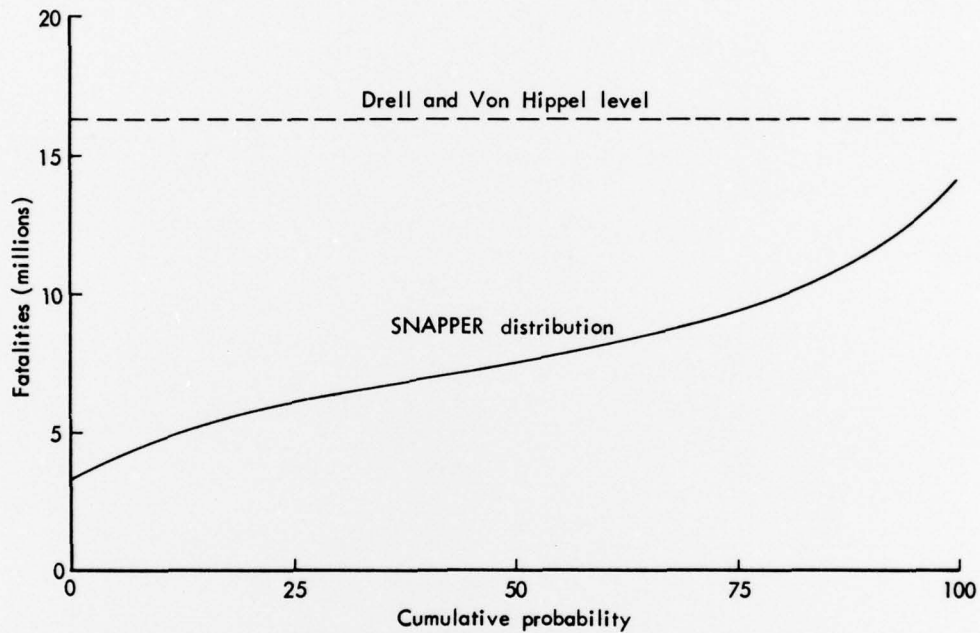
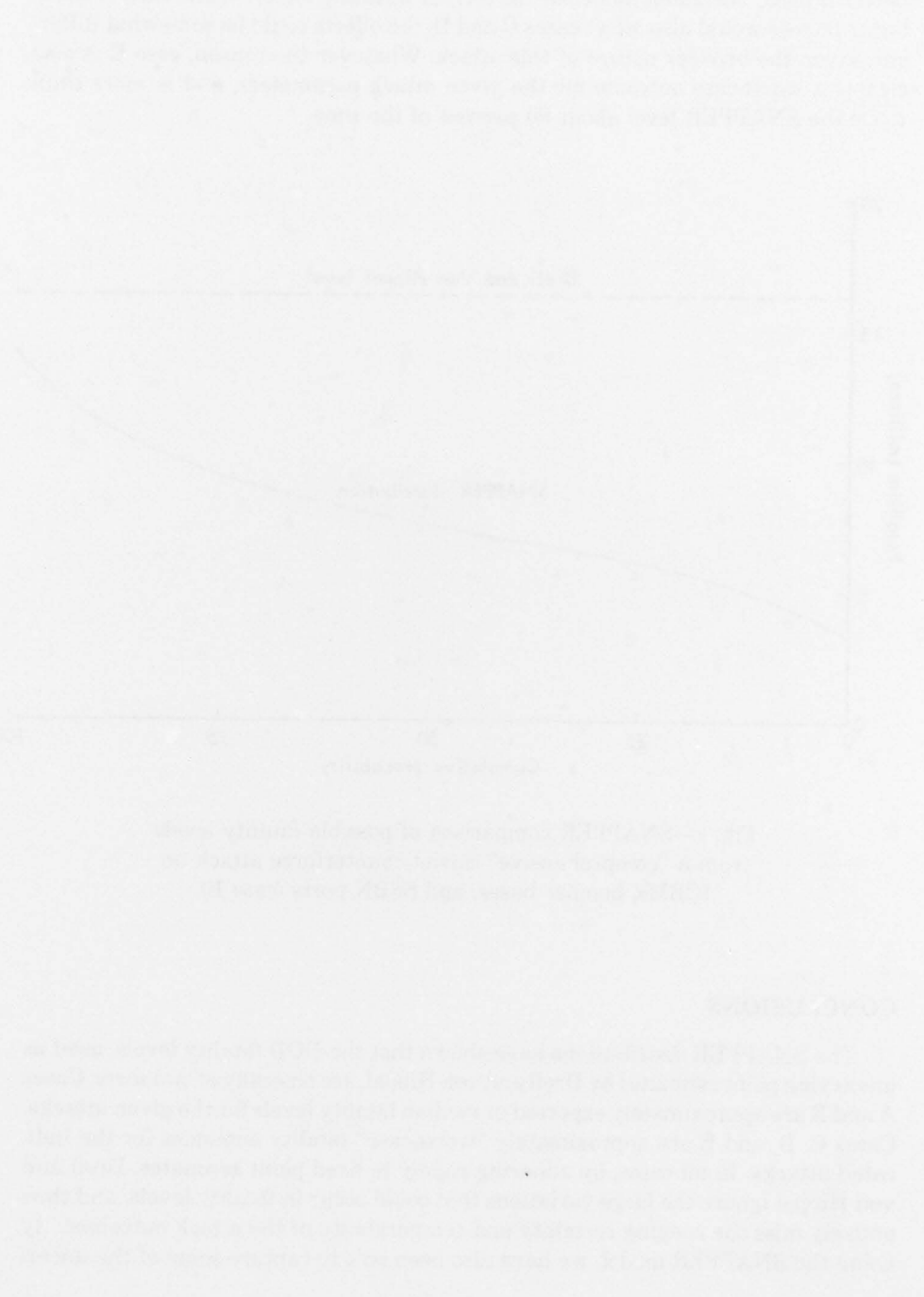


Fig. 7—SNAPPER comparison of possible fatality levels from a "comprehensive" Soviet counterforce attack on ICBMs, bomber bases, and SSBN ports (case E)

CONCLUSIONS

The SNAPPER distributions have shown that the DOD fatality levels, used as unvarying point estimates by Drell and von Hippel, are basically of two sorts. Cases A and B are approximately expected or median fatality levels for the given attacks. Cases C, D, and E are approximately "worst-case" fatality outcomes for the indicated attacks. In all cases, by adhering rigidly to fixed point estimates, Drell and von Hippel ignore the large variations that could occur in fatality levels, and thus entirely miss the ranging certainty and comparability of the attack outcomes. By using the SNAPPER model, we have also been able to capture some of the uncer-

tainties inherent in models of nuclear warfare and use them to calculate possible fatality distributions. This approach is preferable to using point estimates, which tend to make us forget that even a limited recourse to nuclear weapons would be fairly unpredictable in its immediate effects, quite aside from the imperfectly understood indirect effects and the dangers of escalation.



III. EFFECT OF POSSIBLE SOVIET ATTEMPTS TO MINIMIZE FATALITIES

Most analyses of counterforce attacks assume that the Soviets would be concerned with trying to minimize collateral fatalities. This may or may not be true. If it is not true, calculations of collateral fatalities may prove to have little relevance to the larger questions involved in counterforce attacks. If it is true, then it seems unreasonable to postulate Soviet attacks without taking into account their desire to minimize fatality levels. Few analyses make the effort to deal simultaneously with both military effectiveness and collateral fatalities, apparently because it is difficult to do so. If one is willing to make some simplifications, however, the tradeoffs are calculable.

With apparent reference to the "comprehensive" attack, Drell and von Hippel state:

In any case it is clear that even with a massive attack resulting in enormous devastation, including the direct death of 20 million Americans, the U.S.S.R. would have accomplished little of strategic military value. . . . It is therefore at least misleading to suggest that a successful and strategically effective counterforce attack could be carried out with low civilian casualties.

While it is not within the scope of this report to deal with questions of "strategic military value," it is easy to show that, if the Soviets so desired, they could carry out an attack comparable to the "comprehensive" attack postulated but with fatality levels an order of magnitude less than 20 million. Because such levels would be "low" by Schlesinger's standards, there appears to be good reason for questioning Drell and von Hippel's conclusions.

MODIFYING THE SOVIET ATTACK TO REDUCE FATALITIES

A careful examination of the fatality data indicates at least three ways in which fatality levels can be lowered. The first is widely recognized: avoiding attacks on bases that would cause high fatality levels (such as the Whiteman AFB Minuteman force). The second is fuzing for airbursts instead of ground bursts. (This is practicable if airburst fuzing does not seriously degrade weapon delivery accuracy, as indicated earlier.) Although airbursts increase prompt fatalities, they decrease fallout fatalities, and the latter effect *normally* predominates. A third way to reduce fatalities is to decrease the yield of weapons used and thus decrease both prompt and fallout fatalities. Doing so also lowers target kill-probability, but slightly increased accuracy can often compensate for that degradation.

Starting with the "comprehensive" attack data (case E), Fig. 8 shows the progressive impact of these three efforts to minimize fatalities. The curve labeled "Avoid high fatality bases" reflects the same attack on all but the Whiteman Minuteman forces and eight bomber bases.¹ This lowers fatalities to the range of

¹ Carswell, Fairchild, MacDill, March, Mather, McGuire, Westover, and Wright-Patterson AFBs.

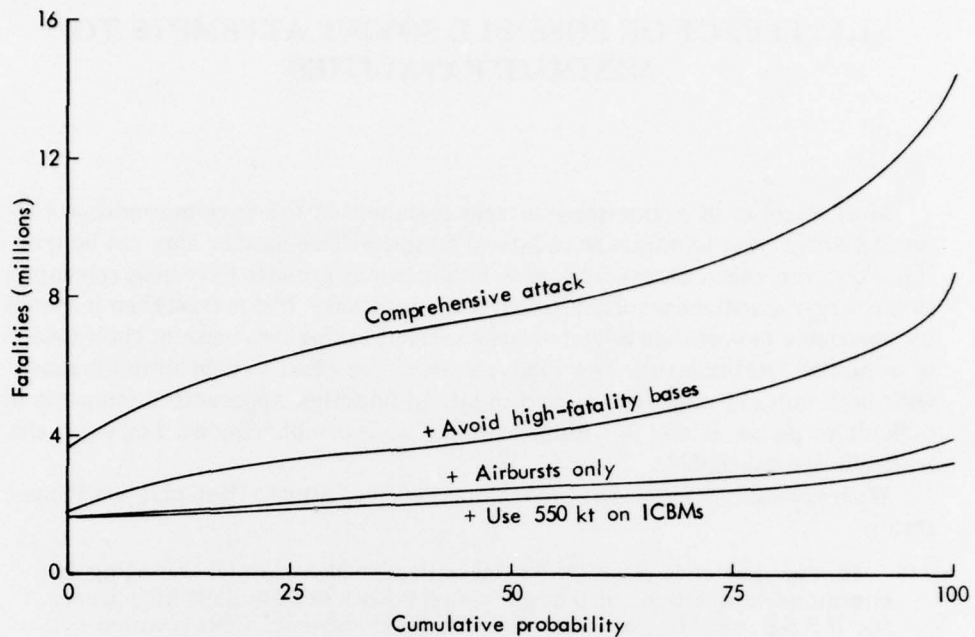


Fig. 8—Fatality distributions produced by increasing levels of Soviet effort to limit collateral damage

1.8 million to 8.8 million, with a 4-million median, about one-half the "comprehensive" attack level. By then descending to "airbursts only," the range falls to 1.7 to 3.9 million, with a 2.4-million median. Finally, by using only 550-kt warheads on the ICBMs (but one megaton on bomber bases and SSBN ports), the fatality range is lowered to 1.6 million to 3.4 million, with the median at 2.2 million.² This last median is about one-tenth the 20-million fatality level used by Drell and von Hippel to argue against the credibility of counterforce attacks. Further, these attacks still include Drell and von Hippel's overestimate of 100 percent reliability. If more realistic missile reliabilities are used (85 percent for ICBMs, 80 percent for SLBMs), the latter fatality range becomes 1.2 million to 2.8 million, with a 1.8-million median.

To show that these modifications do not significantly dilute the military effectiveness of the attacks, expected destruction levels of the strategic forces at risk were calculated for each option in Fig. 9, based on the expected damage levels indicated by Drell and von Hippel and their DOD source.³ ICBM, bomber, and SSBN destructions were aggregated for three aggregate measures (deliverable warheads, deliverable Equivalent Megatons (EMT), and effective countermilitary

² In the airburst-only attack, a scaled height of burst of 84 feet was used on ICBMs and a height of burst of 7250 feet was used for all bomber-base weapons. In moving to 550-kt warheads, a fission fraction of 0.65 was assumed, but a scaled height of burst of 84 feet was retained.

³ Forces at risk are defined as all ICBMs and bombers and all SSBNs in port. The data on effectiveness appear on p. 35 of Drell and von Hippel's article, and on p. 23 of *Analyses of Effects*.

potential (ECMP),⁴ with the uncertainty ranges across these measures shown by the question marks in Fig. 9. In sum, the modified attacks are anywhere from 4 percent to 10 percent less "effective" than the comprehensive attack, which is to suggest that to achieve a significant (10-fold) decrease in collateral fatalities, the Soviets need trade only a slight (10-percent) decrease in military effectiveness. This is borne out in Fig. 10, which compares the counterforce attack Drell and von Hippel call unacceptable with the ranges of fatality outcomes generated with SNAPPER and the effectiveness data from Fig. 9.

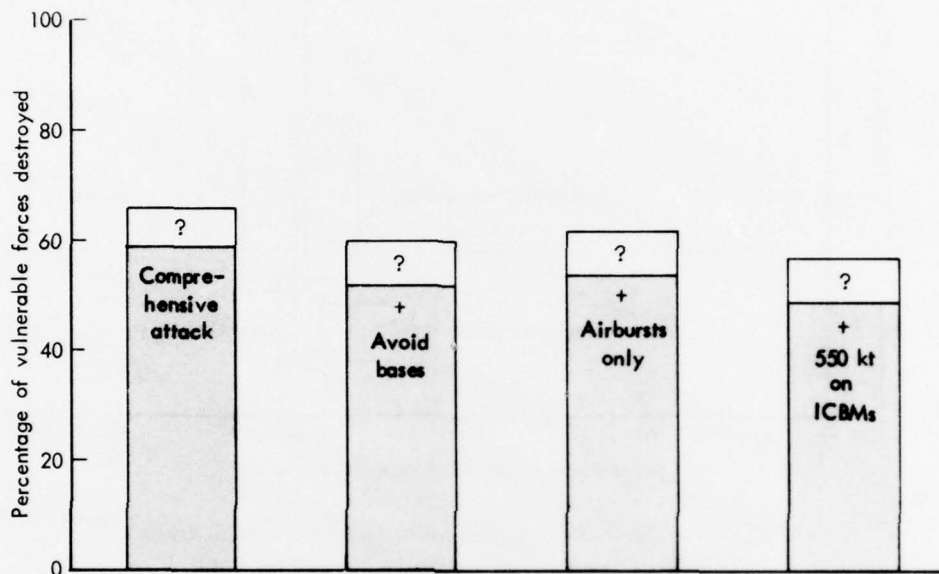


Fig. 9—Expected destruction of vulnerable U.S. forces by "comprehensive" and modified attacks (based on DOD estimates)

CONCLUSIONS

Soviet counterforce attacks nearly as effective as Drell and von Hippel's "comprehensive" attack can be undertaken against the United States at the cost of inflicting about 1 million to 3 million fatalities. This many deaths certainly would constitute a disaster unprecedented in our nation's military history, but it is nevertheless one or two orders of magnitude less than the number of deaths that could result from a massive nuclear exchange involving attacks on cities. It is therefore not at all misleading to state that potentially effective counterforce attacks can be carried out against the United States with relatively low collateral fatalities compared with those we would suffer in a massive, uncontrolled nuclear war.

⁴ CMP has also been referred to as lethality or the Tsipis K. Effective CMP accounts for system reliability in a manner that gives a weapon a CMP maximum corresponding to the value that would give a kill probability equal to the reliability.

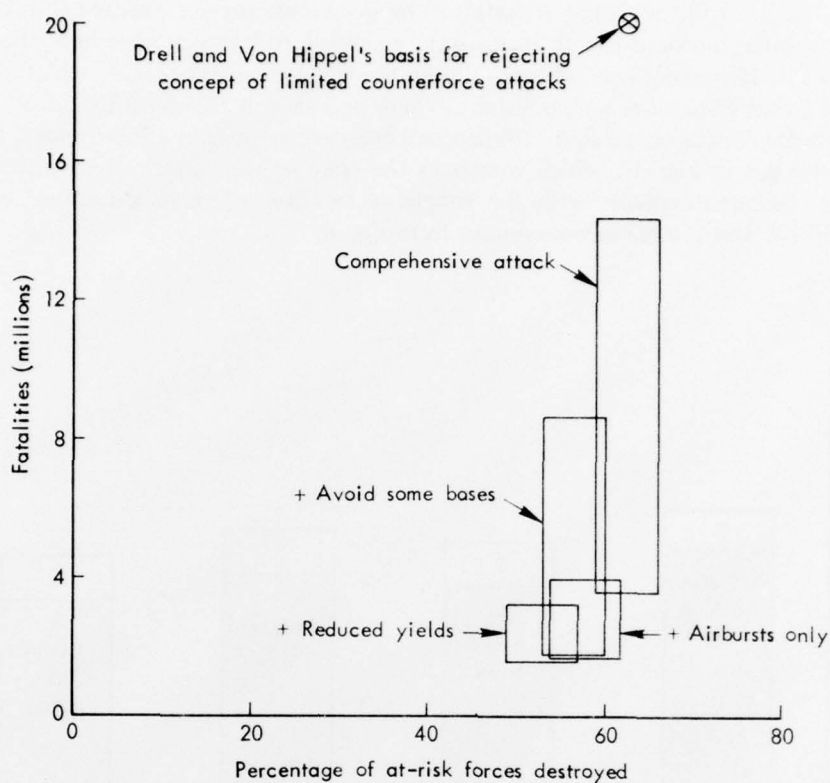


Fig. 10—Tradeoffs between military effectiveness and collateral fatalities as shown by ranges for each (SNAPPER calculations)

APPENDIX ¹

Strategic analysis has for many years employed nuclear damage assessment models in evaluating the effects of nuclear war. Most of the models in use today are only slight modifications of those originally designed in the 1960s. In general, because these models were designed to analyze massive exchanges, they are very large, consume a great deal of computer time, and usually contain numerous options to meet the needs of a wide variety of users. As a result, they have become fairly complex, and their use is prohibitive to all but those analysts who have developed fairly strong programming skills.

Why, then, yet another nuclear damage assessment model? The answer is that the needs of strategic analysis have changed to the point that the models of the 1960s are no longer profitable to use. For one thing, strategic thinking has gone through a number of transformations in recent years, and though the concepts of limited nuclear attacks or pure counterforce attacks are not new, the analytical capabilities required to deal with them are somewhat different from those built into the older massive-exchange models.

We are also becoming more aware that policymakers will want to participate directly in the planning of nuclear operations. They probably will not be well versed in mathematics or computers, but they may want to see and be able to read whatever output the computer generates. There is also a growing number of analysts who want to use damage assessment techniques but who are not well versed in computers. This implies that new models are needed that are easier to use, and whose outputs are easier for the "layman" to understand and interpret.

We have also seen a number of changes in the methodology of damage assessment in the past few years. This is true with respect to both prompt-effects calculations and fallout calculations, as well as with respect to statistical summaries and other basic aspects. Some methodological changes are also the product of third-generation computers with their advantages in speed, storage, peripheral access, and uniformity, which render the computational procedures that were optimal ten or fifteen years ago of dubious importance today.

As methodological and philosophical changes have occurred in the strategic area, some damage assessment procedures have simply been discarded, while others have been patched up time and again until they have become little better than "black boxes." In recognition of this problem and the changing requirements of strategic analysis, Rand performed several studies over the last few years to determine the kinds of tools that have become necessary. We then turned to their design and integration, and produced the SNAPPER model (*Strategic Nuclear Attack Program for Planning and Evaluation of Results*).

In many aspects, SNAPPER differs sharply from the traditional models. It retains the capabilities of many of the older models, but it is designed to work optimally for smaller, more localized attacks, for which it possesses a large competitive advantage. It is smaller and faster than the traditional models, and it empha-

¹ Most of the text of this appendix is taken from the introductory section of the forthcoming SNAPPER manual.

sizes analysis of uncertainties in order to deal adequately with small attacks, which are much more strongly affected by the "laws of small numbers."

SNAPPER's other major distinction is its user interface. Analysts with a limited background in computers can use SNAPPER comfortably and with minimum effort. Users with more computer background can take advantage of several special options that give SNAPPER as much flexibility as they are likely to desire. In general, inputs are relatively simple, and outputs are in simple, easy-to-read tabular and graphic formats.

THE DAMAGE ASSESSMENT MODEL

In performing damage assessment, two basic steps are required. In the first, the geographic area of the attack is determined and used for drawing a sample, from the data bases, of resource points that could experience damage. The second task is to evaluate the damage to each resource point in the sample caused by the specific attack of interest. In SNAPPER, the first step is performed by the "preprocessor," and the second by the "damage assessor."

The preprocessor begins by reading the target and weapon specifications for damage assessment. It uses these to determine the targets and aim points to be used, and also performs an initial weapons allocation to produce temporary desired ground zeros (DGZs). Targets are written in one data set and the temporary DGZs are written in another for processing by the damage assessor. The aim points are used to specify the areas in which population will be affected; these areas are geographically divided into two regions: one for prompt effects and the other for fallout effects. These regions are used to screen the *population data base*, with an approximately equal number of tracts sampled from each type of region and combined to form the population sample, which is also passed to the damage assessor.

The damage assessor is somewhat similar to other damage calculators. It inputs the attack specification and combines it with the temporary DGZs to parameterize the DGZs of the attack. These are first evaluated for prompt population effects using the DIA vulnerability-number/weapon-radius methodology with only minor extensions. Fallout effects can then be calculated against the population by using the SEER III model or any one of three geometric fallout models: WSEG/NAS, MILLER, and CAMEL. Finally, target damage is also calculated by the DIA methodology. "Expected value" calculations of prompt damage are run, followed by as many Monte Carlo simulations as the user desires (up to 50). Statistics are compiled, and the results are then output.

To determine the relative advantages of different weapons or different targeting offsets against any given target, a target evaluation mode is provided. By simply setting two parameters, the entire program is rerun for either targeting offsets and/or differing weapons, the results of which can be directly compared by the analyst.

At present, the damage assessment model is nearly completed and has been fairly extensively tested. Most of the effort on this project is now being expended on documentation and providing data bases (winds, populations, and targets) for the United States, the Soviet Union, and countries in NATO and the Warsaw Pact.

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The report

Presents counterarguments to the article "Limited Nuclear War," by S. D. Drell and F. von Hippel, Scientific American, November 1976. The article concludes that any Soviet limited counterforce attack, if strategically effective, would inflict very high fatality levels; and because the USSR is not pondering such attacks, the U.S. should not inflame the situation by building up flexible counterforce capabilities as recommended by Secretary of Defense Schlesinger in 1974. The report argues that Drell and von Hippel neglect the importance of the assumptions underlying attack scenarios and the wide-ranging effects of uncertainty on fatality calculations. Using Rand's new SNAPPER model for assessing nuclear damage, the report concludes that the USSR could launch potentially effective limited counterforce attacks while causing only a one to three million U.S. fatalities, exactly the range suggested by Schlesinger. It therefore would be unwise to dismiss such attacks from the realm of possibility. (WH) ↑

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