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ROBERT D GLASSER

Nuclear Pre-emption and Crisis Stability, 1985–1990

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'Crisis instability' suggests the existence of incentives to strike first in a crisis. However, more than one 'type' of incentive can be identified. The author describes the various and often conflicting views of incentives to pre-empt advanced by analysts of strategic studies. An attempt is made to measure the degree of crisis stability existing in the period 1985-90 through modelling the effects of nuclear exchanges between the United States and the Soviet Union. Some recommendations are presented concerning how best to improve crisis stability. The calculations indicate that crisis instability will increase between 1985 and 1990, but the author cautions that any conclusions concerning the existence or absence of stability must be tempered by an appreciation of the tremendous uncertainty involved in estimating war outcomes.

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R.D.G.
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TABLE OF CONTENTS

FIGURES

I observe that you are watching our moves as though we were enemies, and we, noticing this, are watching yours, too. On looking into things, I am unable to find evidence that you are trying to do us any harm, and I am perfectly sure that, as far as we are concerned, we do not even contemplate such a thing; and so I decided to discuss matters with you to see if we could put an end to this mutual mistrust. I know, too, of cases that have occurred in the past when people, sometimes as the result of slanderous information and sometimes merely on the strength of suspicion, have become frightened of each other and then, in their anxiety to strike first before anything is done to them, have done irreparable harm to those who neither intended nor even wanted to do them any harm at all.

Xenophon to a Persian leader as reported
2400 years ago by Xenophon in his
chronicles of the Persian Expedition[1]

INTRODUCTION

A major nuclear war could begin 'accidentally' or as the result of deliberate strokes of a nuclear warfighting strategy. While accidental use of nuclear weapons today seems highly unlikely, given the elaborate warning and control systems in place in the United States and the Soviet Union, it is still possible (and highly popular) to imagine a nuclear apocalypse triggered by an unprecedented breakdown in the technology or by the limited use of nuclear weapons by a group of individuals acting without government authority. Such a war would be particularly tragic because it might happen in spite of the fact that before the 'accident' neither superpower had any intention of using nuclear weapons against the other.

A major nuclear war might also arise from the purposeful escalation of a crisis, say from conventional battle, to tactical, and then strategic nuclear exchanges. Current NATO policy is to reserve the option of using nuclear weapons should conventional forces be unable to stem a Soviet conventional attack on the West. Once NATO has exercised its nuclear option in Europe, it is not difficult to imagine the Soviets also employing nuclear weapons, perhaps limitedly at first. Each side might slowly and deliberately increase the scope and intensity of the conflict to demonstrate resolve, or for whatever other reason, until eventually all evidence of restraint had vanished.

When the nuclear forces of both sides are configured in a certain way, the risk of triggering a major nuclear war may be greater than in either of the cases above. The force configuration in question gives rise to a condition described as nuclear crisis instability. This refers to the existence of significant incentives for each side to strike first in a tense situation. Unlike in the 'accidental' war scenario, the decision to strike first with nuclear weapons is firmly in the hands of official representatives of government. In that sense, a war that begins for reasons of crisis instability is a deliberate act of policy. However, it is also potentially an 'accidental' war, because the decision to strike first may be based upon a false assessment that the other side is about to strike first. As with accidental war, neither side may have had any intention to attack the other with nuclear weapons, but the costs of waiting to see if the enemy might just refrain from a first strike are simply too high and this can create pressures on both to get in the first blow. Since the goal is to catch as many of the enemy's forces on the ground as possible, this type of nuclear war is likely to be swift and massive at its inception.

This monograph is about strategic nuclear crisis stability: how it is defined, measured and maintained. The first chapter describes and critiques the two main and potentially conflicting views of crisis stability advanced by strategic analysts. The incompatibility of these two approaches was demonstrated most recently in the debate over the crisis instability implications of the 'window of vulnerability' (which will also be discussed in Chapter 1). The Scowcroft Commission Report, a highly political document, effectively ended the public discussion of the 'window of vulnerability', but it did not bring the proponents of the two basic approaches to crisis stability any closer together.

In addition to highlighting the differences between these approaches, the goal of this Canberra Paper is to ascertain the degree of crisis stability which exists today and how it is likely to be affected by the force improvements projected for the Soviet Union and United States between now and 1990. Measuring crisis stability requires modelling the effects of nuclear exchanges. Chapter 2 describes the numerous assumptions and uncertainties involved with such modelling. Chapter 3 presents the results of the modelling in the form of answers to four main questions:

(1) Does either side have a substantial incentive to pre-empt in a crisis?
(2) How significant was the 'window of vulnerability' to crisis stability?
(3) Is it possible that the Soviets perceive their own 'window of vulnerability'?
(4) How will the answers to (1)-(3) change between 1985 and 1990?

Finally, Chapter 4 offers some tentative suggestions on how best to improve crisis stability.

CHAPTER 1
APPROACHES TO CRISIS STABILITY

Nearly everyone agrees that crisis stability is desirable, in the same sense that peace is considered preferable to war. Stability implies calm, order, and manageability in a world in which all too often we have seen the opposite. Each US Secretary of Defense since Melvin Laird has agreed with Secretary Brown's prescription that the United States must ensure that neither the US nor the Soviet Union would feel itself under any pressure to initiate an exchange in a crisis.[2] Yet this consensus is only superficial. When one moves from discussing the virtues of stability to designing policies for its maintenance, one finds widespread disagreement. And the disagreement is fundamental: it concerns how best to define, measure and maintain crisis stability. The crisis stability debate is in many ways a microcosm of the larger deterrence debate. Both are based on judgements concerning war: its shape, probability, and controllability. It follows that those who share a common belief regarding the requirements for deterrence are also likely to share similar views of crisis stability.

On a very basic level consensus holds. There is agreement that crisis instability implies the condition in which a substantial incentive exists for each side to strike first in a crisis. The incentive can be defined in terms of gaining an 'advantage', which is the way some describe Europe in 1914, where the ability to mobilise rapidly for attack was considered vital for success; or it can be defined in terms of 'cutting losses'. Richard Rosecrance, for example, has examined situations in which the risks of not striking precipitated many conventional wars.[3] But in the nuclear age, with potential levels of damage so high, it seems difficult to see how one side could achieve an 'advantage' or significantly 'cut losses' by striking first. This is the essence of nuclear deterrence today: Country A could not possibly contemplate political goals that would justify a first strike against Country B, if the result would be the complete devastation of Country A in a retaliation. Both the US and the Soviet Union are considered to have this capability for the 'assured destruction' of their opponent in a retaliation. The US publicly expresses this capability in terms of the percentage of the Soviet population and industry that could be destroyed in a retaliation. For example, Secretary Brown described a US ability to destroy at least 200 major Soviet cities, or about 33 percent of the population and 65 percent of the industry.[4] The Soviets are less specific in describing the damage they could inflict, but it is certainly consistent with assured destruction levels.[5]

It would seem then that the existence of significant incentives to strike first in a crisis would also mean that the two sides no longer had the capability for assured destruction. But this is not necessarily correct. Incentives to pre-empt might exist even if both had forces for assured destruction. The confusion stems from not appreciating that assured destruction forces may become less relevant as the probability of war increases. If one believes that nuclear war is imminent and that striking first could result in 30 or 50 million less casualties, then the impulse to cut one's losses could become strong. Albeit, 'unacceptable damage' would still be absorbed in the retaliation, but this is in terms of pre-crisis thinking, before the probability of war approaches unity. If war is a virtual certainty, then deterrence has already essentially failed, and questions of war-waging increasingly press upon decision-makers.

The relationship between the US and Soviet strategic forces in the mid to late 1950s is probably the most generally accepted example of crisis instability cited by analysts, although, at that time, the incentives to pre-empt were exacerbated by the <u>absence</u> of assured destruction capabilities. Both countries' strategic forces were concentrated in vulnerable strategic bombers, based at only a few locations.[6] A 1954 study by Albert Wohlstetter for the RAND Corporation,[7] for example, showed that the Soviet Union would be able to destroy 85 percent of the Strategic Air Command (SAC) bomber force in a first strike. And a few years later an exercise, which involved staging a spontaneous alert of the entire SAC force to see if the planes would be able to survive a Soviet surprise attack, resulted in not a single aircraft becoming airborne in time.[8]

There is an additional aspect to crisis instability which is also generally accepted by analysts. Thomas Schelling has described how the existence of even a modest temptation to sneak in the first blow might become compounded through mutual suspicion:

> If I go downstairs to investigate a noise at night, with a gun in my hand, and find myself face to face with a burglar who has a gun in his hand, there is a danger of an outcome that neither of us desires. Even if he prefers just to leave quietly, and I wish him to, there is a danger that he may think I want to shoot him and shoot first. Worse, there is the danger that he may think that I think he thinks I want to shoot. And so on...This is the problem of surprise attack. If surprise carries an advantage, it is worthwhile to avert it by striking first. Fear that the other may be about to strike gives us a motive for striking, and so justifies the other's motive.[9]

Schelling is describing how our fear of an enemy attack can actually alter our own probability of striking.

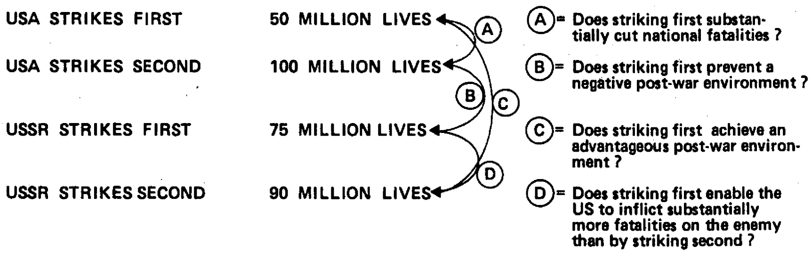
One can easily imagine how actions taken by the superpowers in a crisis might lead to this state of affairs. Countries can demonstrate resolve by their willingness to approach the brink - through steps which raise the risks of continued competition in a crisis. However, this willingness to approach the brink is especially perilous if either side sees a substantial advantage in striking first. Country A, for example, may wish to signal its resolve to Country B by placing its nuclear forces on a low-level alert, as the United States did during the 1973 Arab-Israeli War. Country B may follow suit by placing its forces on an even higher alert level. Country A may decide to disperse its bombers or mobilise conventional forces in critical areas. The closer both countries come to full readiness, the greater their assessments must be of the probability of war and, as Schelling has described, the greater perceived advantages in striking first are likely to affect that probability. Thus, crisis instability can be distinguished from crisis stability by the existence of this added dynamic in the escalation process. Instead of continuing slowly, step by step down into the nuclear abyss, a point may be reached (when the probability of war is sufficiently great to trigger the phenomena described by Schelling) at which the next step sparks a sequence of events which rapidly and compellingly moves the two towards war. In fact, because of the tight coupling of US with Soviet warning and control systems, this process of increasing alert levels could occur almost automatically, rather than as deliberately thought-out acts of escalation.[10] In times of tension this coupling could cause both sides to rely upon preprogrammed computer and organisational responses which reinforced each other in near real-time. This means that in a crisis the point at which both sides begin considering the advantages of striking first is likely to be reached much more rapidly.

It is more difficult to predict precisely what effect first-strike advantages are likely to have in a crisis, than it is to agree that they should be minimised as much as possible. But this leads to a problem. Exactly what constitutes a 'substantial incentive' to pre-empt? It is in answering this question that consensus breaks down and two main, and potentially conflicting, views of strategic nuclear crisis stability emerge. The first approaches deterrence from an assured destruction background, the second from a countervailing or warfighting strategy background. The assured destruction school believes that a side might pre-empt in a crisis only if pre-emption enabled it to significantly cut its national fatalities at war's end. As such, this school measures crisis stability by analysing the potential outcomes of total war. The countervailing strategy proponents also believe crisis stability can be measured by examining potential war outcomes, but this school focuses on a different aspect of war outcome. To differentiate between the two schools it is useful to examine the concept of 'war outcome' more closely.

There are essentially three ways in which a decision-maker can choose to define 'war outcome', and these determine the parameters of four distinct incentives to pre-empt. War outcome can be defined as the post-war damage level in the home country, in the home country relative to the enemy country, or exclusively in terms of the post-war damage level in the enemy country. The example below should help to clarify the distinctions. The chart represents the results of hypothetical nuclear exchanges between the United States and the Soviet Union.

In a US first strike and Soviet retaliation, the United States is left with 50 million fatalities and the USSR with 90 million fatalities. In a Soviet first strike and US retaliation, the US fatalities increase to 100 million and the Soviets' decrease to 75 million. The arrows on the chart identify the four potential incentives to pre-empt. Incentive 'A' is based upon the first conception of 'war outcome' 'B' and 'C' upon the second, and 'D' upon the third.

Figure 1
Hypothetical Exchange US, USSR (No.1)



As the arrow designated 'A' indicates, this incentive is based on a conception of war outcome which focuses exclusively on national damage levels. If a side can significantly cut its national fatalities by striking first, then it has an incentive to strike first. In the example above a US first strike positively changes the war outcome for the US by 50 million American lives (a US first strike results in 50 million American fatalities, while a US second strike results in 100 million American fatalities).

War outcome might also be defined in terms of the relative position of the two countries after the war. How many fatalities has the United States absorbed relative to the USSR? If the United States can significantly improve its relative standing by pre-empting, then this might also create an incentive to strike. In fact, defining 'war outcome' with regard to the relative position of the countries, suggests two potential types of incentives are possible ('B' and 'C' in Figure 1). The first involves striking to prevent a negative relative position. As the arrow designated 'B' indicates, this requires examining the results in both the US and the USSR if the United States struck second. In this case the result is that the Soviet Union ends up with 25 million less fatalities than the United States. The second incentive suggested by this conception of war outcome involves striking first to achieve an advantageous relative position. As arrow 'C' indicates, this requires examining whether a US first strike would result in a sufficiently advantageous post-war relative position to encourage the US to actually strike. In this case the United States ends up with 40 million fewer fatalities than the Soviet Union by pre-empting.

Finally, 'war outcome' can be described not in terms of national fatalities or relative fatalities, but simply with regard to damage in the enemy country. Arrow 'D' points only at the two potential results in the USSR to determine if the US has an incentive to pre-empt. In the example, the US can cause 15 million 'extra' Soviet fatalities by striking first. Figure 2 reviews the different ways of defining 'war outcome' and their corresponding potential incentives.

Clearly, these four potential incentives are not equally compelling. The last incentive, 'D', for example, can easily be dismissed as the least compelling of the four because, unlike the other three, it says nothing about how the pre-empting side fares (either nationally or relative to the opponent). Of the remaining three incentives, one, 'C', is concerned with exploiting advantage rather than avoiding disadvantage, and therefore can be considered the third most compelling. The final two incentives are 'striking first substantially cuts national fatalities', and 'striking first prevents a negative post-war relative environment'. It is likely that a decision-maker would be concerned with saving lives in his own country before considering options involving the relative positions of the two countries (although, some policy-makers have suggested that the primary concern of a Soviet leader would be the survival and, if

Figure 2
War Outcome Definitions and the Incentives They Suggest

War outcome definitions	Incentives they suggest
No.1 Damage to the state	A. The state has an incentive to pre-empt if pre-emption enables it to substantially cut its national fatalities.
No.2 Damage to the state relative to damage to the enemy state	B. The state has an incentive to pre-empt if pre-emption avoids a negative post-war relative environment.
	C. The state has an incentive to pre-empt if pre-emption achieves an advantageous post-war relative environment.
No.3 Damage to the enemy state	D. The state has an incentive to pre-empt if pre-emption enables it to inflict significantly greater damage on the enemy.

possible, domination of the communist system rather than the Soviet people per se). Thus, the incentive which concerns an ability to substantially cut national fatalities ('A') can be considered the most compelling of the four.

Assured Destruction and Countervailing Strategy Approaches: Where Do They Fit In?

The assured destruction school believes that nuclear weapons have fundamentally changed military strategy. As long as the population centres of the two sides remain vulnerable, supporters contend, military victory is a meaningless concept. They believe that deterring war is relatively easy as long as this mutual vulnerability exists. They are less concerned if either country develops an 'advantage' in numbers of weapons (warheads, megatonnage, etc.) because the side with the 'advantage' could not use it to prevent the homeland from being destroyed by the enemy.

The proponents of the countervailing strategy, in contrast, believe that it is precisely because of the mutual vulnerability of the societies that traditional military concepts of advantage are important. They argue that because both sides are 'self-deterred' from waging all-out nuclear war, each side is able to conduct military activity at lower levels of violence. Thus, they contend, numerical military advantages at these lower levels are as meaningful as they have ever been.

The two schools approach crisis stability as differently as they do general deterrence. The assured destruction school concedes to the countervailing school that in some limited situations the mutual vulnerability of the societies will not be sufficient to deter war. These situations are what the school means by 'crisis instability'. Proponents of this approach argue that if the two states develop the capability to substantially cut their national fatalities by striking first, in tense situations they each will think the other is about to strike and therefore that war is imminent. With the probability of war sufficiently high, this school continues, the sides will begin to concentrate less on preventing the disaster than on cutting their losses. As Glenn Snyder has written:

> The primary object of getting in the first blow is to reduce the damage to oneself, as compared with what it would be if the opponent were allowed to strike first ... neither side would contemplate pre-emption unless it believed that the probability of a first strike by the other (p), times the population-economic costs which this strike would cause (c), was greater than the retaliatory damage (d) which would follow its own pre-emptive strike. Thus, the minimum condition for the 'incentive to pre-empt' can be expressed by the formula: $pc>d$.[11]

And, more recently Warner Schilling has said while criticising the debate over the 'window of vulnerability':

> The public discussion of this issue, however, has taken place without any factual information ... about the kinds of gains the Soviets could achieve in terms of damage limitation from such a strike... Would a Soviet first strike serve only to reduce their fatalities from 45 percent to 40 percent or the destruction of the industrial installations from 75 percent to 71 percent? What incentive would differences of this order give Soviet statesmen to strike first in time of crisis...?[12]

Thus, the proponents of assured destruction identify two requirements for deterrence: the maintenance of assured second strike forces to ensure the mutual vulnerability of the societies and, to guarantee deterrence in crises, the maintenance of forces which deny either side an ability to significantly cut its national fatalities by striking first.

The countervailing school, in contrast, has only one requirement for deterrence, which is applicable both in peacetime and in crisis. Proponents argue that the United States must be able to deny the Soviet Union an advantage at any level of conflict. This school's conception of crisis instability is any situation - ranging from limited nuclear war to total war - in which the Soviets achieve an advantage by pre-empting. In the case of total nuclear war, the Soviet 'advantage' is measured by the war outcome. The countervailing school, possibly because of its emphasis on traditional warfighting, defines war outcome with regard to the relative damage of the two countries. As T.K. Jones and W. Scott Thompson have said:

> Relative strength at each point in a potential or ongoing conflict affects the ... terms that each side could exact upon cessation of hostilities ... A relatively slow rate of postwar recovery could subject a nation to both military and economic domination because the opponent might recover strength and, hence, coercive capability more quickly. Because relative damage at all points in a potential conflict can be estimated, it is reasonable to expect that the results of such estimates would influence behavior of opponents in a crisis.[13]

This is essentially incentive 'C' in the example discussed earlier: a side has an incentive to pre-empt if pre-empting enables it to achieve an advantageous relative environment. Interestingly, Paul Nitze has argued that the United States should be able to deny the Soviets a warfighting advantage by maintaining 'sufficient survivable reserve forces ... to hold the enemy's population and industry disproportionately at risk'.[14] Nitze's statement points out some inconsistencies in the countervailing approach. Clearly, if the United States had sufficient reserve forces to hold the enemy's population disproportionately at risk, it would deny the Soviets an incentive in these terms to pre-empt. However, this same US capability would cause the Soviets to perceive that the United States had an incentive to strike. The countervailing strategy has tended towards this analytical one-sidedness. Proponents have often failed to appreciate that what seems threatening to the United States, may have an equivalent which seems threatening to the Soviets. Similarly, the strategy's emphasis on traditional warfighting has resulted in a tendency to assume the worst about the enemy. Thus, when proponents think about relative war outcome they focus exclusively on Soviet incentives to pre-empt to achieve an advantageous post-war environment (incentive 'C'), while overlooking the other, and more compelling incentive based upon a desire to prevent a negative post-war relative environment (incentive 'B'). This important omission will be discussed further below.

But, the countervailing strategy does not measure 'Soviet advantage' exclusively in terms of war outcome. Proponents argue that the USSR might still be tempted to launch a limited nuclear strike in a crisis if doing so gave them some advantage in terms of 'escalation discipline' or in some measure of force effectiveness (such as counter-military potential, numbers of warheads, etc.) - even if that 'advantage' did not translate into an ability to improve the relative outcome after total war. This was the essence of the debate over the 'window of vulnerability'. As William Van Cleave has said,

> Instead of the simple model of aggressive Soviet first strike and U.S. retaliation, we may face a situation where the Soviets could strike first and still retain their own assured destruction retaliatory force, leaving the United States in a position of being the initiator of nuclear war against civilian populace and the Soviet Union being in the position of retaliator.[15]

The knowledge of this situation, the argument went, might force the United States to back down in a crisis:

> If the Soviets can strike effectively at our land-based ICBMs while our land-based deterrent does not have comparable capability, the Soviets might believe that they have a significant advantage in a crucial dimension of the strategic balance: they could seek to gain political leverage by a threat of nuclear blackmail. Without arguing the question of whether the Soviets are prepared to launch a nuclear first strike, such a crucial imbalance in the strategic capabilities could well make them bolder in a regional conflict or in a major crisis.[16]

Two points need to be made here. The first is that supporters of the 'window of vulnerability' have failed to differentiate their view of general deterrence from crisis stability. They argued that the 'window of vulnerability' was a threat to crisis stability because it enabled the

Soviets to achieve an 'advantage' by striking first, and that this might give the Soviets an incentive to strike in a crisis. Since the countervailing strategy's general requirement for deterrence is to deny the Soviets an 'advantage' at any level of conflict, it is not surprising that the 'window of vulnerability' seemed threatening. But, crisis instability is much more than simply the ability of one side to achieve a post-exchange advantage. Crisis instability involves a situation in which a fleeting opportunity exists for both to strike, and where each is aware of the other's opportunity. Crisis instability describes how the existence of these opportunities can create a fear of attack which affects each side's own decision to attack. The proponents of the 'window of vulnerability' thesis have neither articulated the nature of the United States' incentive to pre-empt, nor the 'fleetingness' of both countries' opportunities. The 'window of vulnerability' can not be considered a threat to crisis stability until these two issues are resolved.

The second point is that it is unclear why a numerical or psychological 'advantage' after a limited nuclear exchange must have relevance to the further conduct of the war, if such 'advantages' do not have some basis in the outcome of total war. What does it mean to have a 2:1 advantage in counter-military potential if ultimately that 'advantage' has no effect on the war outcome? What reason would the enemy have for surrendering in the face of a numerical disadvantage only? Proponents of the countervailing strategy respond that these numerical advantages in limited nuclear warfighting can be meaningful in that they suggest to the other side that any further attacks on the military forces of the opponent can be countered or dominated. In pre-nuclear thinking this was the way to 'win': dominate the military weapons of the enemy with a greater number of your own weapons. However, the mutual vulnerability of the two societies has made this type of thinking obsolete. The United States might surrender the war after a Soviet limited strike because of a lack of resolve, but not necessarily because of a 'numerical disadvantage'. Even in the face of this 'disadvantage', the United States would retain the ability to cause 'unacceptable damage' to the Soviet Union, and could continue to raise this threat with counter-strikes. The Soviets might have an incentive to launch a limited strike in a crisis only if they calculated that it would significantly improve their war outcome in total war. (The actual significance of the 'window of vulnerability' will be established in Chapter 3, where the war outcome possibilities for wars initiated by limited nuclear strikes will be presented.)

Assured Destruction and Countervailing Strategy: Flawed Approaches to Crisis Stability

We have seen that in their treatment of crisis stability each school has focused on only one of the four basic incentives to pre-empt. Supporters of assured destruction concentrate on incentive 'A' and supporters of the countervailing strategy on incentive 'C'. Neither school's approach may be sufficient to assure stability in crises. What is needed is for both schools to appreciate that any or all of incentives 'A', 'B', and 'C' (as was indicated earlier, incentive 'D' may be so insignificant as to be irrelevant) could be important in a crisis - and therefore that the requirements for deterrence should be expanded accordingly.

A hypothetical example should help to point out the deficiencies of the assured destruction approach (see Figure 3). The countervailing strategy will be examined separately below. Imagine that a crisis develops between the US and the USSR. War seems certain to both. If the US struck first it would end up with 50 million fatalities and the Soviets with 130 million fatalities. If the USSR pre-empted it would finish the war with 125 million fatalities and the US would have 130 million fatalities. The assured destruction school would argue that the United States has a strong incentive to pre-empt because it would enable the US to cut its national fatalities by 80 million. However, the school would say that to determine precisely how unstable the situation was in the example would also require examining the Soviet incentives to pre-empt, as this could influence US perceptions of the probability of war (i.e. if both sides had strong incentives to pre-empt, then war would seem more certain as each would know that the other felt compelled to strike). The figures reveal that the Soviets have little incentive to pre-empt to limit their national damage. In the example, pre-emption decreases the Soviet fatalities by only 5 million, from 130 million to

125 million. But, the proponents of assured destruction might be wrong if they conclude from this that the Soviets would not pre-empt. The USSR might still strike to balance the relative damage of the two sides. If war seems certain to a Soviet planner - and that belief is likely to be reinforced by the strong US incentive to pre-empt - then pre-emption might not enable the USSR to significantly cut its own fatalities, but it might assure that the United States ends up with damage similar to that of the Soviet Union. The choice facing a Soviet leader might be stated simply as follows: war seems certain; if the USA strikes first it 'survives' the war and the Soviet Union does not; if the USSR strikes first, neither nation survives. This is essentially incentive 'C': striking first prevents a negative (or in this case a 'more negative') post-war relative environment. Of course, war must seem certain for the mutual vulnerability of the societies to become irrelevant and for these incentives to become strong. It follows that, with war a certainty, even less dramatic incentives than the one suggested by this example could become compelling.

Figure 3
Hypothetical Nuclear Exchange US, USSR (No.2)

	Fatalities
USA strikes first	50 million American fatalities
USA strikes second	130 million American fatalities
USSR strikes first	125 million Soviet fatalities
USSR strikes second	130 million Soviet fatalities

It is unclear why the assured destruction school has focused on incentive 'A' and omitted incentives based on relative damage ('B' and 'C') in its analysis. Incentives 'A', 'B' and 'C' are each concerned with warfighting. They each involve a strategy for fighting the war that achieves a net advantage in terms of the war outcome (although each strategy is based on a different conception of war outcome). One can disagree as to which sorts of incentives are most important in a crisis, but this is different from believing - as many in the assured destruction school seem to do - that only one type of incentive is relevant. If one is speaking of deterrence in conditions of stability, then the only war outcome calculus likely to affect the decision-making of both sides is the certain knowledge that both will end up with 'unacceptable damage' if war occurs. However, in conditions of crisis instability, where it is already assumed that war will occur, more traditional military concepts of war outcome - such as the relative damage of the two sides - can be significant. The proponents of assured destruction often (and justifiably) criticise the countervailing strategy's emphasis on the relevance of traditional concepts of warfighting for deterrence. However, when one is speaking of crisis instability, it is the supporters of assured destruction who can be criticised for overlooking the potential importance of these traditional ways of measuring advantage.

It should be reassuring to supporters of assured destruction that their acceptance of the significance of incentives based on relative war outcome does not mean that they must join the ranks of the countervailing strategy. However, it is not immediately apparent why this is so. After all, if one accepts that we must design our forces so that neither side achieves a post-war relative advantage by striking first, does not that also mean preventing either from achieving any post-exchange advantages? And is not that the substance of the countervailing strategy? Not necessarily. We have already seen that the countervailing strategy suggests that a post-exchange advantage need not translate into a post-war advantage for the advantage to be meaningful. For example, at various times it has been argued that the US needs the MX missile to provide a prompt counterforce capability, or to enable the US to match the Soviet ICBMs, warhead for warhead. Neither of these arguments speaks to how the MX missile will affect the relative war outcome. So proponents of assured destruction can still part company with the countervailing strategy when the latter demands responses to 'disadvantages' that have no basis in war outcome.

Secondly, it may be possible to disagree with supporters of the countervailing strategy concerning the importance attached to the four basic incentives. The MX missile may decrease a Soviet advantage in terms of the relative war outcome, while at the same time (because of its high accuracy) increase the US incentives to pre-empt to cut national fatalities. If one believes, as proponents of assured destruction apparently do, that incentives involving national fatalities are the most important, then one can argue that on balance the MX harms stability. If one believes incentives based upon relative war outcome are most important, one can argue the opposite.

Finally, proponents of assured destruction need not always advocate steps which decrease instability on one level and increase it on another. Crisis stability can be improved on all levels by increasing the survivability of the strategic forces and by balancing their capabilities for retaliatory damage. With invulnerable and equal nuclear forces, a pre-emptive strike would result in the same war outcome for a side as striking second. The weapons on both sides could be designed for delivery by the slowest, least accurate, and least vulnerable systems available, and still accomplish the goal of decreasing the incentives - on all levels - to pre-empt. This theme will be developed further in Chapter 4.

The Countervailing Strategy

The countervailing strategy has also omitted important incentives in its treatment of crisis stability. Proponents of this school, for reasons suggested earlier, concentrate on preventing the Soviet Union from obtaining an incentive to pre-empt in order to achieve an advantageous post-war environment. However, this concentration could lead to policies which harm crisis stability on a number of levels. The MX missile is a good example. As indicated above, the missile may decrease the Soviet incentives to pre-empt to achieve a relative post-war advantage, but it may also increase US incentives to strike. It is possible to support the MX in spite of this if one has decided that preventing a relative disadvantage is the most important of the four incentives. However, it is not at all clear that supporters of the countervailing strategy have ever consciously considered the existence or relevance of the other three incentives.

The strategy also gets into trouble because of its tendency toward analytical one-sidedness. Supporters tend to think in terms of an exclusively Soviet threat. This makes it difficult for them to appreciate that the Soviets perceive an American threat. Thus, advocates of the strategy focus on incentive 'C' (Soviet incentives to pre-empt to achieve an advantageous post-war relative environment) while overlooking incentive 'B' (Soviet incentives to pre-empt to avoid a negative post-war relative environment). For example, Colin Gray has written:

> An American warfighting-oriented strategic posture, if well designed, should not contribute to crisis instability ... A central purpose informing U.S. strategic posture would be its denial of any plausible Soviet theory of victory. Why the Soviet Union would be interested in starting a war that it would stand little, if any prospect of winning is, to say the least, obscure.[17]

Gray is apparently not only arguing that the US should prevent the Soviets from obtaining the capability for a post-war relative advantage, but also that the United States should, itself, strive for this capability. In the hypothetical example below the US has obtained a relative post-war advantage. A US first strike and Soviet retaliation leaves the USSR with 130 million deaths and the US with only 50 million deaths. A Soviet first strike and US retaliation results in 125 million Soviet deaths and 110 million US deaths. Clearly, as Gray says, the Soviets by pre-empting 'would stand little if any prospect of winning'. They would, in fact, end up with 15 million more fatalities than the USA. However, if war seemed certain, the Soviets might nevertheless choose to strike to avoid the situation which would obtain if the US struck first. For the USSR, a post-war world in which neither nation survived might be preferable to one in which only the United States survived. What Gray and the proponents of the countervailing strategy have failed to recognise is that in a crisis a side chooses to pre-empt because it is preferable to not pre-empting. In one situation the choice may be between victory and defeat; in another it may be between victory and stalemate; in a third it may be simply a matter of cutting losses.

Figure 4
Hypothetical Nuclear Exchange US, USSR (No.3)

USA Strikes First	50	
USA Strikes Second	110	Soviet Incentive 'B'
USSR Strikes First	125	
USSR Strikes Second	130	

Conclusion

We have seen that at least four basic incentives can be identified for a side to pre-empt in a crisis. These four incentives are derived from the three ways in which a side can choose to define 'war outcome'. If war outcome is defined in terms of national fatalities, then an incentive exists if pre-empting can cut national fatalities. If war outcome is defined in terms of the damage absorbed by the state relative to that absorbed by the enemy state, then two incentives are possible: one in which pre-emption enables the side to avoid a negative post-war environment, and another in which pre-emption enables the side to achieve an advantageous post-war environment. Finally, if war outcome is defined exclusively in terms of the damage in the enemy state, an incentive exists if pre-emption enables the home side to cause more damage to the enemy side than it could cause (to the enemy side) by striking second.

It is possible to rank these four incentives in order of importance, although this process may be somewhat subjective. The supporters of assured destruction have focused on what is probably the most compelling of the four incentives, but have ignored other important incentives, while the proponents of the countervailing strategy have focused exclusively on what is probably a less compelling incentive. These omissions represent flaws in both schools' approaches to crisis stability.

What constitutes a substantial incentive for a side to strike first? It seems the closest we can come to answering this question is to present the war outcome figures in each country for the two options (striking first or second) to determine if any or all of the four incentives mentioned earlier ('A'-'D' above) exist. If the difference between striking first and second is of the order of ten or twenty million fatalities, then we will conclude that there is little instability. However, if the fatality estimates are significantly greater than that amount for the most important of the four incentives, we will conclude that crisis instability is high. Finally, it is important to appreciate that the process of calculating war outcomes is precarious at best. This is the subject of the next chapter and a theme that will be repeated throughout this monograph.

CHAPTER 2
THE ASSUMPTIONS AND UNCERTAINTIES INVOLVED WITH CALCULATION OF NUCLEAR EXCHANGES

One experiences a healthy uneasiness when calculating nuclear exchange scenarios involving tens of millions of casualties. There is a sense that the figures one is manipulating back and forth are entirely inadequate expressions of the untold human misery and devastation involved and that it is somehow immoral to think about the unthinkable. No doubt this uneasiness stems from the awesome implications involved. But also, there is little reassurance in the scenario calculation process itself, which is replete with assumption and uncertainty. This chapter will explain the calculations used in this monograph and then discuss some of the weaknesses involved in determining outcomes of nuclear exchanges.

The ability to destroy a fixed site enemy ICBM with another ICBM is primarily a function of the target hardness and the yield and accuracy of the attacking warhead. What must be determined first is the lethal radius (L) of the target - that is, the radius in which a given warhead will destroy a target of a given hardness - which will then enable calculation of the 'kill probability'. The equations used here to determine L and single shot kill probabilities (SSKP) are from the General Electric Missile Effectiveness Calculator, which has modified the theoretical relationship between the various factors based upon observed results of missile flight tests. The expressions for lethal radius are:

for $50<H<1000$

$$L = 2.9W^{1/3} / H^{.35}$$

for $H>1000$

$$L = 2.62W^{1/3} / H$$

where L = Lethal radius in nautical miles
H = Hardness in PSI overpressure
W = Yield of warhead in megatons

The SSKP is the expression for the probability that a missile with a given accuracy (CEP) and warhead yield will destroy a target of a given hardness. The expression for SSKP is:

$$SSKP = 1 - e^{-0.69315 \left(\frac{L}{CEP}\right)^2}$$

where

SSKP= Single shot kill probability
CEP = Circular error probable in nautical miles
L = Lethal radius in nautical miles

It is generally accepted as prudent to designate at least two warheads for each target regardless of the SSKP of the missile in question. The cumulative kill probability (Pk), when more than one warhead is used, is related to the SSKP by the following expression:

$$Pk = 1 - (1 - SSKP)^n$$

The apparent simplicity of these equations should not disguise the fact - indeed it should suggest - that the process of calculating missile exchanges involves much uncertainty. Problems occur in determining numbers for each of the variables in the equations and in other aspects of the process. An ICBM passes through three phases in its flight, each of which can experience difficulties not reflected in the equations: the boost phase, beginning at launch and ending when the rocket motors of the propulsion system have burned out (3-5 minutes); the mid-course stage, beginning when the boost stage ends and continuing while the missile pierces the atmosphere and ending as the force of gravity draws the missile back to the upper limit of the atmosphere on its way down to target (about 25 minutes); and the terminal phase, as the missile's warheads re-enter the atmosphere and detonate over the target. Additionally, mishaps are possible even before the missile is fired, in the pre-launch mode. The extent of human reliability, for example, has not been tested under realistic conditions. Would the military men and women assigned the task of launching the missiles actually carry out their duties?

> Indeed, in a counter-force first-strike, there would be an additional complicating factor: launching such a strike, involving some 2000 warheads would require the timely cooperation of several tens, more probably hundreds of people. Their behaviour under such circumstances is fundamentally unpredictable...the possibility that significant numbers of critical personnel will refuse to perform their assigned roles, or even attempt to sabotage the effort, will never be completely insignificant.[18]

In the United States operational missile tests are conducted by removing both missiles and crews to special test facilities where conditions are highly regulated and therefore not very representative of actual combat conditions.[19] There have been three Minuteman tests from operational silos, all of which were unsuccessful. One of these missiles failed to take off because a speck of dust drifted into one of the electromechanical firing circuits.[20] The Soviets, who do have an active test program from operational silos, may be better able to simulate these conditions for their missile crews. There are also certain technical problems that can occur at this stage. For example, missile guidance systems depend on measuring changes in velocity after launch, which, in turn, requires an accurate measurement of velocity before launch. For ICBMs this is less of a problem than for ballistic missile firing submarines (SSBNs), where both velocity and exact position are more difficult to determine. To some extent these and other biases discussed below are taken into account by military planners in determining missile capabilities. However, any miscalculation of these biases - not unlikely given our imperfect knowledge of phenomena such as gravity anomalies - can significantly degrade performance, and therefore missile exchange results.

Similar technical problems are possible during the boost, mid-course and terminal phases. Are the instruments properly calibrated and unaffected by the launch? Has the thrust terminated at exactly the right instant? Is the on-board computer functioning correctly? Of particular interest are the possible effects during the terminal or re-entry stage. Warhead re-entry will be influenced by variations in atmospheric density, winds, and other weather conditions, all of which are highly unpredictable. Warheads are designed with a special coating which heats up and then flakes off (carrying the accumulated heat energy away with the flakes) as the warhead re-enters the atmosphere. Poor weather conditions can speed up this flaking process, potentially disabling the warhead. It has been estimated that severe weather conditions can decrease the accuracy of an ICBM by 25 percent or more. This is not typically a factor taken into account in determining ICBM accuracy and reliability levels.[21]

Other factors involving great uncertainty include variations in warhead yield and target hardness. A given warhead yield can be plus or minus 20 percent (or more) of the officially stated figure.[22] US silos can range in hardness from 1200 to 2200 psi depending on the geological surroundings of the particular site (the figure typically quoted is 2000 psi).[23] Even these estimates may be inaccurate as no silo has ever been exposed to a nuclear detonation in any test. Both warhead yield and silo hardness are critical variables in the SSKP formulation.

Possibly most important is that the figures used in calculations of nuclear exchanges for accuracy and reliability are derived from a very small number of missile flight tests conducted under ideal conditions. No US missile has ever been fired on short notice from an operational silo randomly chosen over an actual intercontinental flight path.[24] Soviet ICBMs have been tested from operational silos[25] and the Soviets may test their missiles over a broader spectrum of possible operational conditions,[26] but they nonetheless suffer considerable restrictions. No Soviet or American ICBM has been fired over the North Pole, the route an attacking ICBM would take, and where the polar magnetic field and other geophysical features and anomalies may affect accuracy. Geodetic and magnetic anomaly satellites have, however, flown in quasi-ballistic paths over the North Pole, thereby removing much uncertainty.[27] Also, testing is not conducted with real nuclear warheads in place so that fusing systems are not examined under operational conditions.[28] The US Air Force has indicated that the number of tests it conducts with a particular guidance configuration - i.e. the same software, warhead materials and aerodynamics - is quite small. 'A half dozen, or a dozen in one case I'm aware of, would represent the kind of numbers we're talking about. It would more frequently be 6 rather than 12.'[29]

Finally, problems of coordinating and timing nuclear attacks are often overlooked in the calculations of exchanges. Fratricide is the word used to describe the situation whereby an attacker's warheads can disable each other by poorly coordinated detonations. To avoid fratricide literally requires split second timing. For example, 'there are missile fields in the northern, middle, and southern latitudes of the United States. An attack on them must be conducted so that the effects of detonations on northern missile fields do not interfere with RV's designed for southern bases. This means hitting southern fields at the same time as those further to the north. The exquisite problem for the attacker, then, is not launching his missiles all at once, but, rather, sequencing them to arrive more or less 'imultaneusly at widely separated points'.[30]

With so many unpredictable variables involved, how meaningful can calculations of force exchanges be? As Henry Kissinger once remarked:

> initiation of an all-out surprise attack would depend on substantial confidence that thousands of re-entry vehicles launched in carefully coordinated attacks - from land, sea and air - would knock out all their targets thousands of miles away, with a timing and reliability exactly as predicted...Any miscalculation or technical failure would mean national catastrophe.[31]

Even slight changes in any of the assumptions can drastically alter the results. Tsipis and Bunn have used a hypothetical attack by Soviet SS-19s on US Minuteman silos to demonstrate this point.[32] In the ideal case, in which the Soviet missiles are 100 percent reliable, there is no bias in their accuracy, no fratricide effects, and no other unfavourable variations, they showed that the SS-19s could be expected to destroy 86 percent of the Minuteman silos. But if the accuracy is decreased by just 0.05 nautical miles and the effects of light fratricide are subtracted, then the percentage of ICBMs destroyed drops to just over 75 percent. In the case of a Minuteman force of 1000 missiles, this slight variation in assumptions represents a difference of 110 missiles or 330 warheads. In a worst-case situation, where accuracy is decreased by 0.15 nautical miles, the missiles are only 75 percent reliable, and there is both light fratricide and unfavourable variations, Tsipis and Bunn show only 31 percent of the Minuteman force is destroyed. Thus, when Paul Nitze[33] argues that a successful Soviet counterforce first strike against the US may be possible, it becomes important to ask under what assumptions is such an attack likely to seem favourable to a Soviet planner and whether any Soviet leader could possibly put faith in assumptions which, if only modestly inaccurate, could result in a tremendous variation in war outcome.

John Steinbruner and Thomas Garwin have looked at Soviet counterforce first strike scenarios not only in terms of how variations in the assumptions affect surviving US ICBMs, but also in terms of the differing ratios of surviving US ICBMs to Soviet ICBMs.[34] They have shown that even incremental changes in reliability and accuracy can mean the difference between destroying 90 percent of the US ICBMs at a rather low cost in warheads used, and achieving that 90 percent figure at the cost of virtually disarming the Soviet ICBM force.[35] As Steinbruner and Garwin put it:

> belief in the relative vulnerability of land-based missiles can be constructed only on the basis of a narrow and rigid criterion of analysis, one which requires that any technically conceivable threat to the missiles be covered - no matter how fantastic the conceived threat might be when viewed from the practical world in which an offensive force must operate...under some plausible assumptions even rather modest shifts in the pertinent assumptions are sufficient to change the apparent advantage from the attacker to the defender...[36]

What emerges from this brief discussion is that official models of nuclear exchanges, while necessary in that we have no other way of visualising nuclear war, should not be taken too seriously. Nevertheless, these and similar models are used by the military for purposes of contingency planning. The Department of Defense calculations are, not surprisingly, more complex than the ones used in this monograph. For example, the Department of Defense target hardness estimates are based on intelligence information concerning idiosyncratic characteristics of individual targets, while this paper utilises an average hardness figure. The Defense Intelligence Agency, while identifying the same basic variables used here,[37] adjusts the Lethal Radius (LR) equation to allow the target some probability of survival if the warhead lands within the LR and some probability of destruction if it lands outside of the LR. We simply assume that the target is automatically destroyed if the warhead lands within the LR. This is known as the 'cookie cutter' approach. Also, the Defense Intelligence Agency relies on a more sophisticated model of target sensitivities to overpressure considerations (i.e. they take into account not simply the maximum overpressure, but also the overpressure duration, which increases with warhead yield).[38] As it turns out, modifications of the equation to compensate for the weaknesses in the 'cookie cutter' approach and target sensitivity to overpressure tend to cancel each other out.[39] Adjustment for pulse duration produces higher SSKPs and adjustment for the cookie cutter approach produces lower SSKPs. Thus the formulae used in this paper would seem to be relatively accurate approximations.

The Air Force SNAPPER Damage Assessment Model, developed by the RAND Corporation, combines a Damage Expectancy model with a target base and weapons allocation system.[40] It defines Damage Expectancy (DE) as follows:

$$DE = 1 - (1 - R \times Pk)^n$$

where

DE = Damage expectancy
R = Reliability times probability of successful penetration
Pk = Kill probability of the weapon against the target
n = Number of weapons of the same type allocated to the target

One way the SNAPPER model determines weapons allocation is by assigning values to the various targets and then assigning attacking warheads to the most valuable targets. Alternately, a desired level of damage can be selected - say destruction of 80 percent of the industrial target set - and then warheads can be allocated to meet that criterion.

Given the potential inaccuracies of these models, how important might they be in influencing decision-making? One can point to numerous examples in which decision-makers have allowed optimistic military estimates to influence policy. It was President Kennedy, recently embarrassed by the failure of the Bay of Pigs operation (which was championed by the Central Intelligence Agency with the Joint Chiefs of Staff), who complained to Arthur Schlesinger, 'If someone comes in to tell me this or that about the minimum wage bill, I have no hesitation in overruling them. But you always assume that the military and intelligence people have some secret skill not available to ordinary mortals'.[41] In Vietnam, the Department of Defense constantly assured the President 'we're winning the war' and 'the corner will be turned' with the commitment of just a few more troops.[42]

But would calculations of nuclear exchange outcomes actually be critical in a crisis that risked escalation to nuclear war? It seems reasonable that if there were a serious risk of nuclear war it would be rational for a decision-maker to contemplate the various alternatives (i.e. strike first, wait, launch on warning, launch under attack, etc.) and their effects on the war outcome. However tragic the consequences of any nuclear war, different options for waging that war might have different results, possibly in terms of tens of millions of fatalities,[43] which one could argue it would be irresponsible of a leader to ignore. The models, as the only way presently available of gauging the significance of the alternatives, might thus play an important role. How important a role is impossible to say. One decision-maker might appreciate the uncertainty involved in the calculations and therefore choose to view the alternatives as artificial. Another might accept the integrity of the alternatives assuming, to re-quote Kennedy, that they derive from 'a secret skill not available to ordinary mortals'.

CHAPTER 3
THE CALCULATIONS AND RESULTS

The previous chapter described some of the uncertainty involved in estimating the outcome of a nuclear attack. But there are some more fundamental assumptions, concerning the compilation and characteristics of the forces each country has and will have, the types of nuclear exchanges selected for modelling, and the procedure used to determine fatalities, which could also affect the conclusions. These assumptions will be presented below, followed by the results of the models of nuclear exchanges projected for 1985 and 1990. The findings of the calculations will suggest answers to four main questions: (1) Does either side have a substantial incentive to pre-empt in a crisis? (2) What do the calculations suggest about the significance of the 'window of vulnerability'? (3) Is it possible that the Soviets perceive a 'window of vulnerability' of their own? And (4) How will the answers to (1)-(3) change between 1985 and 1990?

The force posture assumptions are shown in Figures 5, 6, 7 and 8 (the 'U.S. Strategic Force - 1985', 'USSR Strategic Force - 1985', 'US Strategic Force - 1990', and 'USSR Strategic Force - 1990', respectively). The Soviet Union is currently testing at least two 'new' ICBMs, the SS-24 and the SS-25.[44] It is assumed in Figure 8 that in order to stay within SALT limits, the SS-25 gradually replaces the older SS-11s and SS-13s. Although SALT II allows each side to deploy one new 'light' ICBM, it seems likely that the superpowers will each deploy two new ICBMs: the SS-24 and SS-25 for the Soviet Union, and the Peacekeeper and Midgetman for the United States. Thus, when we assume that SALT is 'observed' in 1990, we do not mean adherence to every term of the agreement (in fact, the Soviet Union presently exceeds the limits on ICBMs, SLBMs and heavy bombers), but that neither side will undercut the basic framework of the Treaty. In SALT II the Soviets agreed to a sub-limit of 820 MIRVed ICBMs. Since this number has already been reached with the SS-17, SS-18, and SS-19 ICBMs, this paper assumes the new SS-25 is a single warhead system[45] and that if the SS-24 is deployed, it will be at the expense of the SS-17, which has

Figure 5
US Strategic Forces and Capabilities 1985

System	No. of Delivery Vehicles	Throw-Weight/ 000s lbs	No.of War-heads	Yield/ War-head (MT)	EMT per War-head	CEP (ft)	CMP per War-head	Total No.of War-heads	Total MT	Total EMT	Total CMP	System Hard-ness (psi)	Day to Day Alert Rate	Gene-rated Alert Rate	Relia-bility	SSKP vs 10 psi	SSKP vs 300 psi	SSKP vs 4000 psi
Titan II	26	8.3	1	9.000	3.00	3040	0.47	26	234.0	78.00	12.17	550	.85	.85	.75	.99	.84	.30
Minuteman II	450	1.6	1	1.200	1.10	1200	0.78	450	540.0	492.95	352.89	2200	.95	.95	.80	.99	.95	.44
Minuteman III																		
MK-12	250	2.4	3	0.170	0.31	600	0.67	750	127.5	230.16	504.80	2200	.95	.95	.85	.99	.97	.47
MK-12A	300		3	0.335	0.48	600	1.34	900	301.5	434.12	1205.88	2200	.95	.95	.85	.99	.99	.64
31 Poseidon SSBN 16 Tube													.55	.78				
5 Trident SSBN 24 Tube													.66	.78				
Poseidon C-3 (on 19 Poseidon SSBNs)	304	3.3	10	0.050	0.14	1470	0.04	3040	152.0	412.59	128.06		.55	.78	.80	.99	.22	.04
Trident C-4 (on 12 Pos and 5 Trident SSBNs)	288	2.9	8	0.100	0.22	1470	0.07	2304	230.4	496.38	168.98		.55-.66	.78	.85	.99	.33	.07
B-52G													.30	.80	(.8)			
Penetration role	61	4 bombs		1.000	1.00	600	2.78	244	244.0	244.00	677.78				SRAM.6*	.99	.30	.16
		4 SRAMs		0.200	0.34	1200	0.24	244	48.8	83.45	57.95				ALCM.6*	.99	.99	.90
															Bomb.8	.99	.99	.88
Penetration standoff role	90	4 bombs		1.000	1.00	600	2.78	360	360.0	360.00	1000.00							
		4 SRAMs		0.200	0.34	1200	0.24	360	72.0	123.12	85.50							
		12 ALCMs		0.200	0.34	300	3.80	1080	216.0	369.35	4103.94							
B-52H													.30	.80	(.8)			
Penetration role	70	4 bombs		1.000	1.00	600	2.78	280	280.0	280.00	777.78							
		4 SRAMs		0.200	0.34	1200	0.24	280	56.0	95.76	66.50							
Penetration standoff role	20	4 bombs		1.000	1.00	600	2.78	80	80.0	80.00	222.22							
		4 SRAMs		0.200	0.34	1200	0.24	80	16.0	27.36	19.00							
		12 ALCMs		0.200	0.34	300	3.80	240	48.0	82.08	911.99							
FB-111A	56	4 bombs		1.000	1.00	600	2.78	224	224.0	224.00	622.22		.30	.80	(.8)			
		2 SRAMs		0.200	0.34	1200	0.24	112	22.4	38.30	26.60							
TOTALS	1915							11054	3252.6	4151.62	10944.27							

Figures are 'combined' probabilities i.e. SRAM = .8 (bomber reliability) x .75 (SRAM reliability) = .60.
Numbers in parenthesis represent aircraft.

Figure 6
USSR Strategic Forces and Capabilities 1985

System	No.of Delivery Vehicles	Throw-Weight/ 000s lbs	No.of War-heads	Yield/ War-head (MT)	EMT per War-head	CEP (ft)	CMP per War-head	Total No.of War-heads	Total MT	Total EMT	Total CMP	System Hard-ness (psi)	Day to Day Alert Rate	Gene-rated Alert Rate	Relia-bility	SSKP vs 10 psi	SSKP vs 550 psi	SSK vs 220 psi
SS-11 Mod 1	520	2.0	1	1.000	1.00	4578	0.05	520	520.0	520.00	24.81	300	.35	.75	.65	.95	.11	.04
SS-13 Mod 1	60	1.0	1	0.750	0.83	6540	0.02	60	45.0	49.53	1.16	300	.35	.75	.65	.75	.05	-
SS-17 Mod 1	150	6.0	4	0.750	0.83	1472	0.38	600	450.0	495.29	228.58	4000	.35	.85	.80	.99	.65	.34
SS-18 Mod 2	34	16.7	8	0.900	0.93	1472	0.43	272	244.8	253.55	117.02	4000	.35	.85	.80	.99	.68	.38
SS-18 Mod 3	50	16.0	1	20.000	4.47	1145	5.62	50	1000.0	223.61	281.00	4000	.35	.85	.80	.99	.99	.99
SS-18 Mod 4	224	16.7	10	0.500	0.63	800	0.98	2240	1120.0	1411.11	2204.86	4000	.35	.85	.80	.99	.93	.66
SS-19 Mod 2	20	7.5	1	5.000	2.24	600	4.57	20	100.0	44.72	91.38	4000	.35	.85	.80	.99	.99	.99
SS-19 Mod 3	340	8.0	6	0.550	0.67	800	1.05	2040	1122.0	1369.43	2139.73	4000	.35	.85	.80	.99	.94	.99
16 Golf & Hotel II (3 tubes) 23 Yankee Class (16 tubes) 18 Delta I Class (12 tubes) 4 Delta II Class (16 tubes) 14 Delta III Class (16 tubes) 1 Hotel III Class (6 tubes) 2 Typhoon Class (20 tubes)																		
SS-N-5 (on Golf & Hotel II)	45	3.0	1	1.000	1.00	9156	0.01	45	45.0	45.00	0.54		.40	.65	.60	.55	-	-
SS-N-6 Mod 2	112		1	1.000	1.00	2943	0.12	112	112.0	112.00	12.93		.40	.65	.60	.99	.25	.10
SS-N-6 Mod 3 (on 22 Yankee Class)	256	1.5	2	0.200	0.34	4578	0.02	512	102.4	175.10	8.35		.40	.65	.60	.65	.04	-
SS-N-8 Mod 2 (on 18 Delta I, 4 Delta II, 1 Hotel III)	292	8.0	1	0.800	0.86	2943	0.10	292	233.6	251.64	29.05		.40	.65	.80	.99	.22	.10
SS-N-17	12	2.5	1	1.000	1.00	4905	0.04	12	12.0	12.00	0.50		.40	.65	.80	.94	.10	.04
SS-N-18 Mod 2	64		1	0.450	0.59	1962	0.15	64	28.8	37.58	9.76		.40	.65	.80	.99	.32	.15
SS-N-18 Mod 3 (on 14 Delta III)	160		7	0.200	0.34	1962	0.09	1120	224.0	383.03	99.50		.40	.65	.80	.99	.20	.09
SS-N-20 (on 2 Typhoons)	40	5+	9	0.500	0.63	1824	0.19	360	180.0	226.79	68.17		.40	.65	.80	.99	.40	.18
Tu-95 Bear B/C	100	8.0	4	1.000	1.00	3000	0.11	400	400.0	400.00	44.44		.10	.65	.60	.99	.25	.11
Mya-4 Bison	43	8.0	4	1.000	1.00	3000	0.11	172	172.0	172.00	19.11		.10	.65	.60	.99	.25	.11
Tu-26M Backfire	130	4.0	2	1.000	1.00	3000	0.11	260	260.0	260.00	28.89		.10	.65	.60	.99	.25	.11
TOTAL	2652							9151	6371.6	6442.38	5409.79							

Figure 7
US Strategic Forces and Capabilities 1990 (SALT observed)

System	No. of Delivery Vehicles	Throw-Weight/ 000s lbs	No.of War-heads	Yield/ War-head (MT)	EMT per War-head	CEP (ft)	CMP per War-head	Total No.of War-heads	Total MT	Total EMT	Total CMP	System Hard-ness (psi)	Day to Day Alert Rate	Gene-rated Alert Rate	Relia-bility	SSKP vs 10 psi	SSKP vs 5000 psi
Minuteman II	450	1.6	1	1.200	1.10	900	1.39	450	540.0	492.95	627.36	2200	.95	.95	.80	.99	.60
Minuteman III																	
MK-12	200	2.4	3	0.170	0.31	500	0.97	600	102	186	582	2200	.95	.95	.85	.99	.55
MK-12A	300	2.4	3	0.335	0.48	500	1.93	900	301.5	434.12	1736.46	2200	.95	.95	.85	.99	.72
Peace Keeper (MX)	50	9.2	10	0.300	0.45	300	4.98	500	150	224.07	2489.67	2500	.95	.95	.85	.99	.97
31 Poseidons SSBNs													.55	.78			
10 Trident SSBNs													.66	.78			
Poseidon C-3 (on 19 Poseidon SSBNs)	192	3.3	10	0.050	0.14	800	0.14	1920	96.0	260.58	273.08		.55	.78	.80	.99	.13
Trident C-4 (on 12 Poseidons and 8 Trident SSBNs)	384	2.9	8	0.100	0.22	800	0.25	3072	307.2	661.84	760.75		.55-.66	.78	.85	.99	.20
Trident D-5 (on 2 Trident SSBNs)	72	6.0	10	0.475	0.61	400	3.80	720	342.0	438.32	2739.52		.66	.78	.85	.99	.90
B-52 G	105		12 ALCM	0.200	0.34	300	3.80	1260	252.0	430.91	4787.93		.30	.80	ALCM .6	.99	.89
B-52 H	96		20 ALCM	0.200	0.34	300	3.80	1920	384.0	656.63	7295.90		.30	.80	ALCM .6	.99	.89
FB-IIIA	60		2 bombs	1.000	1.00	450	4.94	120	120.0	120.00	592.59		.30	.80	Bomb .8	.99	.82
			4 SRAMs	0.200	0.34	900	0.42	240	48.0	82.08	101.33				SRAM .6	.99	.23
B-1B	100		8 bombs	1.000	1.00	450	4.94	800	800.0	800.00	3950.62		.35	.80	Bomb .8	.99	.82
			16 SRAMs	0.200	0.34	900	0.42	1600	320.0	547.19	675.55				SRAM .6	.99	.23
TOTALS	2009							14102	3762.7	5334.69	26612.76						

Figure 8
USSR Strategic Forces and Capabilities 1990 (SALT observed)

System	No. of Delivery Vehicles	Throw-Weight/ 000s lbs	No.of War-heads	Yield/ War-head (MT)	EMT per War-head	CEP (ft)	CMP per War-head	Total No.of War-heads	Total MT	Total EMT	Total CMP	System Hard-ness (psi)	Day to Day Alert Rate	Gene-rated Alert Rate	Relia-bility	SSKP vs 10 psi	SSKP vs 2200 psi
SS-24	150		10	0.350	0.50	500	1.99	1500	525.0	744.97	2979.87	5000	.35	.90	.80	.99	.99
SS-18	308	16.5	10	0.750	0.83	500	3.30	3080	2310.0	2542.48	10169.90	5000	.35	.90	.80	.99	.99
SS-19	362	7.5	6	0.750	0.83	500	3.30	2172	1629.0	1792.95	7171.79	5000	.35	.90	.80	.99	.99
SS-25	490	2.0	1	1.000	1.00	500	4.00	490	490.0	490.00	1960.00	5000	.35	.90	.80	.99	.99
15 Yankee Class 18 Delta I Class 4 Delta II Class 15 Delta III Class 7 Typhoon Class																	
SS-N-6 (on 15 Yankees)	230	1.6	1	0.750	0.83	3040	0.09	230	172.5	189.86	20.54		.40	.70	.65	.99	.09
SS-N-8 (on 18 Delta Is and 4 Delta IIs)	280	1.8	1	0.750	0.83	3040	0.09	280	210.0	231.13	25.01		.40	.70	.80	.99	.09
SS-N-18/23 (on 15 Delta IIIs)	240	2.5	3	0.200	0.34	1824	0.10	720	144.0	246.24	74.01		.40	.70	.80	.99	.10
SS-N-20 (on 7 Typhoons)	140	5.0	9	0.500	0.63	1824	0.19	1260	630.0	793.75	238.58		.40	.70	.80	.99	.18
Backfire	205	4.0	2	1.000	1.00	3000	0.11	410	410.0	410.00	45.56		.1[illegible]	.70	.60	.99	.12
Blackjack	50	8.0	5	1.000	1.00	1200	0.69	250	250.0	250.00	173.61		.15	.70	.65	.99	.50
TOTALS	2455							10392	6770.5	7691.4	22858.90						

the fewest warheads of the Soviet MIRVed ICBMs. Thus the figures for the Soviet ICBM force in 1990 are projected as: 150 SS-24, 308 SS-18, 362 SS-19, and 490 SS-25.

There is a further SALT limit of 1200 on the number of MIRVed ICBMs, MIRVed SLBMs and MIRVed ASBMs each side is permitted. There are three Soviet MIRVed SLBMs, two of which are already deployed - the SS-N-18 and SS-N-20 - and one of which - the SS-N-23 - is in testing. As 820 of the 1200 sub-limit is assumed to be satisfied by ICBMs, at most 380 SLBM launchers can be MIRVed.

The Department of Defense has estimated that seven Typhoon SSBNs will be deployed by 1990.[46] This translates into 140 SS-N-20 SLBMs (7 x 20 tubes per submarine). This leaves at most 240 SS-N-18 and SS-N-23 SLBMs that can be deployed within the limits. It is assumed here that if the SS-N-23 is deployed, it will be at the expense of the SS-N-18, the SLBM with the fewest warheads in the fleet. The figures for strategic bombers (50 'Blackjacks') bring the total number of strategic nuclear delivery vehicles up to the maximum SALT limit of 2250.[47] The 'Backfire' is not included in SALT counting limits; however, it is assumed here that 205 of the aircraft will be allocated to a strategic mission.[48]

The US force in 1990 is much easier to determine. With the exception of the figure of 50 Peacekeeper missiles, there is a high degree of confidence in the estimates listed. Peacekeeper has had a variety of problems since its inception in 1971, the most recent of which is the reluctance of the Congress to authorise funds for the missile's procurement. Nevertheless, the figure of 50 Peacekeepers represents the best estimate presently available. Also assumed is that 50 Minuteman III Mark 12s are retired to make way for the Peacekeeper and that Poseidon C-3s are retired as Trident D-5 is deployed.

The column headings in Figures 5 to 8 deserve some attention. There are basically four measures of force capability used - number of warheads, megatonnage (MT), equivalent megatonnage (EMT) and counter-military potential (CMP) - each of which emphasises a different aspect of the force's utility.[49] The number of warheads gives an indication of the number of targets a force can cover, although 1000 warheads could not necessarily cover 1000 targets (unless the targets were spaced together conveniently) because warheads carried by the same bus can only be released within certain distances of each other.[50] MT is a rough indicator of soft target destructive capability, and EMT is a refinement of MT which compensates for the fact that increases in weapon yield do not proportionately increase the amount of destructive capability. EMT = yield (EXP) 1/2, where yield is greater than one megaton, and EMT = yield (EXP) 2/3, where the yield is less than or equal to one megaton. CMP is the most meaningful index of hard-target destructive capability. It is a function of the yield and accuracy (measured in Circular Error Probable (CEP), the radius of a circle around the target in which 50 percent of the attacking warheads will land) of the force and is represented by the equation, where yield is greater than or equal to 0.2 MT:

$$\text{CMP} = \text{Yield}^{2/3} / \text{CEP}^2$$

or, where yield is less than 0.2 MT:

$$\text{CMP} = \text{Yield}^{0.8} / \text{CEP}^2$$

Another measure of force effectiveness (included in Figure 14) is 'prompt counter-military potential' (PCMP). This measure was much discussed during the 'window of vulnerability' debate. PCMP describes the rapidly available, hard-target capability of the force. Essentially, only ICBMs, because they are the most easily controlled leg of the triad, contribute to PCMP. The new SLBMs, such as the Trident D-5, will be able to destroy hard targets but, as sea-based systems, they suffer from greater command and control problems.

The equation used in this paper to determine SSKPs was listed in the last chapter. As the vulnerability of a given target is also determined by its hardness (primarily for ICBMs) and by the extent to which it remains hidden from the enemy (primarily relevant for SLBMs and bombers) assumptions for both hardnesses and alert rates are included in the charts.

The ability of a weapon to launch as expected, penetrate to the enemy target and detonate correctly is reflected in the 'Reliability' column. Finally, the SSKP columns record the effectiveness of the given weapon against targets of given hardnesses. For the United States in 1985 there are three types of enemy hardened targets: the newest Soviet ICBMs (4000 psi), the oldest Soviet ICBMs (300 psi), and all other targets including submarine bases, aircraft bases, etc. (10 psi). In 1990 the US engages: the newest Soviet ICBMs (5000 psi) and all other targets (10 psi). The Soviets in 1985 engage: the newer US ICBMs (2200 psi), the older ICBMs (550 psi) and other targets (10 psi). In 1990, the US has retired all of its older ICBMs leaving the new MX missile (2500 psi),[51] the Minuteman ICBMs (2200 psi) and all other targets (10 psi).

It is interesting to note some of the changes which occur between 1985 and 1990 under these assumptions (see Figure 9). The United States increases its force levels in all categories: strategic nuclear delivery vehicles by 5%, warheads by 30%, MT by 19%, EMT by 32%, PCMP by 163% and CMP by 164%. The Soviets also expand their force levels. For example, the Soviets increase their warheads by 13%, EMT by 19%, CMP by 323% and PCMP by 340% over their 1985 levels. Also, the position of the United States relative to the USSR has changed between 1985 and 1990. There are modest improvements in the US SNDVs, warheads, MT and EMT (vis-a-vis the USSR) of 16%, 19%, 32% and 14% respectively. In the other measures the US worsens its position. By 1990 the Soviets have improved their relative position by 74% in CMP and 66% in PCMP.

The data in Figures 5-8 may provide all the technical information necessary to calculate nuclear exchanges, but there still remains the question of what type of nuclear exchange to calculate. Is the first strike massive or limited? Are the targets other missiles, factories, or people? Is the retaliation massive or limited and against what types of targets? What is the nature of any subsequent exchanges? The answers to these questions might influence the casualties and damage one could realise in a war and therefore, potentially, crisis decision-making. Before a leader can attach any meaning to 'cutting losses', he has to have some conception of the direction a war would take, which may require assumptions concerning the way in which the

Figure 9
Comparison of US, USSR Force Postures 1985-1990

1985

	SNDV	WHS.	MT	EMT	CMP	PCMP
USA	1915	11054	3253	4152	10944	2075.7
USSR	2652	9151	6731.6	6442.3	5409.7	5088.5
Numerical Advantage	USSR 737	USA 1903	USSR 3479	USSR 2290.3	USA 5534.3	USSR 3012.8
Percentage Advantage	USSR 38%	USA 20%	USSR 105%	USSR 53%	USA 100%	USSR 245%

1990

	SNDV	WHS.	MT	EMT	CMP	PCMP
USA (change over 1985)	2009 (+5%)	14452 (+30%)	3887.2 (+19%)	5510.8 (+32%)	28956.6 (+164%)	5435.49 (+163%)
USSR (change over 1985)	2455 (-7%)	10392 (+13%)	6770.5 (+0.1%)	7691.4 (+19%)	22858.9 (+323%)	22379.6 (+340%)
Numerical Advantage	USSR 446	USA 4060	USSR 2883.3	USSR 2180.6	USA 6097.7	USSR 16944.11
Percentage Advantage	USSR 22%	USA 39%	USSR 73%	USSR 39%	USA 26%	USSR 311%

Percentage Change 1985 to 1990
USA vis-a-vis USSR.

SNDV	WHS.	MT	EMT	CMP	PCMP
+16%	+19%	+32%	+14%	-74%	-66%

opponent would wage war. This raises the question of the extent to which the incentive to pre-empt in a crisis is influenced by perceptions of the pre-emptive and retaliatory options available to the enemy. If we assume there are two levels of attack open to both countries, striking massively (counterforce plus countervalue)[52] and striking in a more limited fashion (initially a counterforce attack only), then in a crisis a decision-maker would have to calculate the war outcomes for many possibilities.

Two types of potential nuclear exchange scenarios have been chosen for examination in this monograph. The first is meant to respond to the 'window of vulnerability' thesis by enabling us to determine what relationship numerical advantages after limited nuclear strikes have to the war outcomes for both countries. Thus, the scenario modelled is: one side strikes first with a comprehensive counterforce attack, the other retaliates also with a counterforce attack, and then the remaining forces are used against economic targets with the resulting high civilian fatalities. The theory behind this scenario is that each side in the early stages of the war would attempt to destroy the other's weapons before they could be used to cause damage in subsequent retaliations. Each would be deterred, in these early stages, from initiating attacks against population centres until the last possible moment for fear of a retaliation in kind. This view has it that the targeting 'firebreak' between counterforce and countervalue targets is a force for restraint in nuclear war waging (US strategic policy has increasingly reflected the belief that it is possible to exploit the supposed existence of this firebreak by controlling and therefore potentially dominating the escalation process).[53] Thus, in his calculations Nitze assumes 'the Soviet Union had attacked US forces, and the United States has retaliated by trying to reduce Soviet strategic throw-weight to the greatest extent possible'.[54] And one of the phases of nuclear war examined by the Strategic Air Command is an exclusively 'counterforce exchange' by the two sides, at the end of which is measured the 'static indicators (number of warheads, MT, EMT and CMP) as well as the amount of damage incurred by both sides'.[55]

One of the weaknesses of those who argue that this form of exchange is the most likely has been a tendency towards analytical one-sidedness. The threat is always conceptualised in terms of a Soviet threat to the United States, and rarely the other way around. This is not to suggest that the United States is not highly threatened, but if one is going to conclude that the US is menaced by a Soviet first strike counterforce advantage, it would be prudent to also calculate the US first strike counterforce capability in order to determine if the Soviets perceive a similar threat. If, as Paul Nitze argues,[56] the Soviet first strike counterforce advantage has upset crisis stability, then improving US forces may be stabilising. But if the United States has a similar capability against Soviet systems, and the USSR accepts this scenario of war, then improving US forces will in Soviet eyes simply further undermine crisis stability. Therefore, exchange scenarios for both a war generated by the USSR and one generated by the USA will be calculated.

However, it is at least possible, if not probable, that the Soviets do not accept this view of nuclear war - and this would be a more serious flaw than one-sidedness. For this reason a second type of scenario will also be calculated in which the first strike is a massive counterforce and countervalue attack and the retaliation is equally massive. The primary difference between the Soviet and US warfighting approaches is that the US' concept assumes restraint and intra-war bargaining and the Soviets' apparently does not. The US warfighting school envisages numerous levels of nuclear war, from very limited strikes up to total war. The Soviets, in contrast, believe that arguments about the possibility of fighting a limited nuclear war ignore the 'very nature of nuclear weaponry as a means of mass destruction which can be delivered in short time over huge distances...[it is this] that predetermines a decisive and quick response, a full-scale response'.[57] The Soviets believe that the best way to deter a war is by maintaining an ability to fight one. Thus, if war comes, their goal is to limit damage and perform as well militarily as possible.[58] But this does not mean limiting nuclear exchanges. 'Such ideas simply do not fit into the Soviet view of fighting to win, once the conflict is unavoidable. 'Bargaining' after hostilities have begun but before decisive blows have been struck does not make sense. From the Soviet point of view, these are dangerous attempts to prolong the political utility of nuclear weaponry past the point where warfighting concepts obviously dominate decision-making.'[59] As Benjamin Lambeth and Kevin Lewis have said:

> Nothing in Soviet thinking remotely approximates the western idea of sparing enemy cities for 'intrawar bargaining'...The Soviet conception of the initial period of war envisages rapid, intense, and simultaneous nuclear strikes against very large numbers of counter military and countervalue aim points in combination.[60]

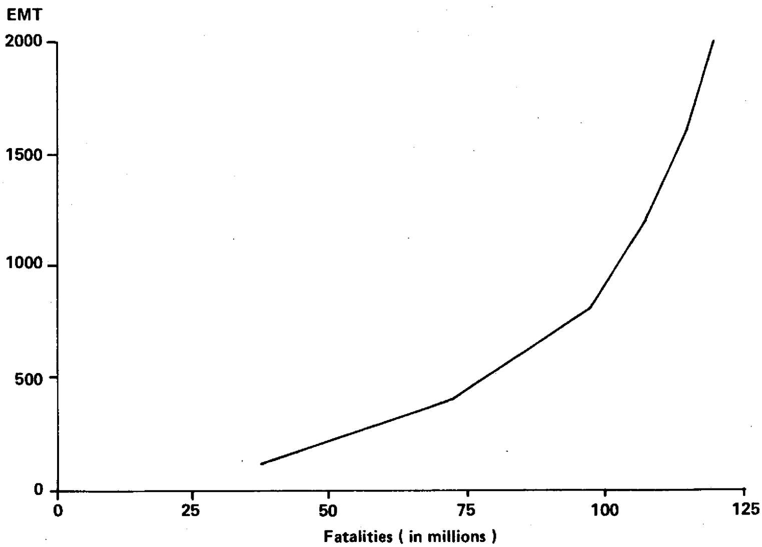
But, what precisely is a counterforce exchange? What are the weapons used in such an exchange and what are the targets? Targets could be anything from an Army base to an ICBM. Certainly a comprehensive counterforce strike designed to destroy as much of the retaliatory capability of the opponent as possible would involve attacks against ICBMs, their launch control centers (LCC), strategic nuclear submarine bases, and strategic bomber bases. But they could just as likely involve attacks against National Command Authority targets, other C3I targets, IRBMs, MRBMs, and conventional military targets. In fact, there are many more counterforce targets than there are weapons for use against them.[61]

This monograph does not attempt to precisely simulate a counterforce exchange or for that matter a massive counterforce/countervalue exchange. The numbers of potential targets, combinations of weapons that can be allocated to those targets and other variables involved would require more, and more complex calculations than are possible here and would probably not affect the general thrust of the results. Rather, this paper has simplified the exchange scenarios so that they are only representative of the real world. If they do not exactly reflect the ways in which the superpowers might wage nuclear war, they do at least provide a sufficiently accurate model for examining an important aspect of crisis stability. Counterforce attacks are assumed to involve strikes against all ICBMs, ICBM launch control centers (LCC), major strategic bomber bases, and strategic nuclear submarine bases. Counterforce targets are roughly arranged in terms of their 'value' (number of warheads, accuracies, yields) and attacking warheads are allocated based upon their capabilities to destroy those targets. Thus a highly capable Minuteman MK12-A is targeted against the extremely valuable SS-18 M.4, and as MK12-As are exhausted, the next best US ICBM is directed against the remaining untargeted, most valuable Soviet ICBM. Two warheads are allocated to each target in a counterforce first strike to compensate for potential malfunction, etc. However, a counterforce second strike is assumed to involve a one-warhead attack against all missile silos (many of which should be empty) to ensure that any missiles that have malfunctioned or that are kept in reserve are not left untargeted - and two-warhead attacks against the other counterforce targets. This means that it is additionally assumed that neither country has the capability to determine precisely which enemy missile silo has launched its missiles. This is certainly true today, although by 1990 it may be that the US will have developed this capacity.

It is possible to target one warhead from each of two different ICBMs in an attack. In this way, the SSKP effectiveness of a force can be enhanced. For example, if one has 100 Minuteman III MK12-A warheads (SSKP - 0.64) and 100 Minuteman III MK12 warheads (SSKP - 0.47) to fire at 100 targets, combining 50 MK12-As with 50 MK12-As and 50 MK12s with 50 MK12s would destroy 79 targets. However, combining the MK12-As with the MK12s would destroy 81 targets. This warhead mixing has been done whenever practical in the calculations. The counterforce/countervalue attacks are identical to the counterforce attacks and retaliations except that they will generally allow the side striking first more megatonnage for countervalue attacks than would a war which started with counterforce exchanges only. This is so because the pre-empting side would not have to absorb an enemy retaliation on his missiles before beginning the countervalue attacks. However, if the side pre-empting uses all of its ICBMs in the counterforce aspect of a first strike, then a counterforce second strike by the enemy will not significantly reduce the weapons available for the countervalue retaliation, and therefore the fatalities estimates for both types of wars will be virtually identical.

Determination of fatalities at each stage in the war is yet another area in which uncertainty can drastically affect results. Fallout patterns, for example, vary with the height of nuclear detonations, the design of the weapons themselves (some weapons are 'dirtier' than others), the weather patterns in the area, and the surrounding terrain. It is not unusual to find official fatality estimates in which the low end figure differs from the high end figure by as much as 50 million fatalities. This monograph has relied upon the Office of Technology Assessment's study, The Effects of Nuclear War for determination of fatalities resulting from the counterforce attacks and retaliations. (Counterforce retaliations are assumed to result in half the deaths of counterforce attacks because the retaliations target one warhead per ICBM silo, instead of two.) The additional fatalities resulting from the countervalue aspects of the attacks are determined by calculating the equivalent megatonnage available for those attacks and then utilising the graph reproduced in Figure 10.[62]

Figure 10
US, USSR Population Killed as a Function of Equivalent Megatonnage



This graph is used in this monograph to determine both Soviet and US fatalities, although it was designed by its authors to apply to Soviet fatalities only. It may be more accurate to do this than it might seem, because the Soviet urban population density, while greater than that of the USA, represents a much smaller percentage of the total population. This means that a 100 MT attack against the USSR, for example, might destroy a much higher percentage of the urban population than would an identical attack against the US, but that the total fatalities would be similar.

To review, two types of exchanges will be calculated. The first, involves a pre-emptive counterforce attack by one country, a counterforce retaliation by the other, and then countervalue exchanges. The second involves a massive 'spasm' pre-emptive strike and a similarly unrestrained retaliation. Each view will be calculated for both Soviet and US generated attacks and the resulting damage levels measured. It will then be possible to determine if any substantial incentive exists for either side to pre-empt under these attack assumptions. This will clarify the debate over the 'window of vulnerability' not only by translating numerical indicators of advantage into war outcome figures, but also by presenting what Soviet acceptance or rejection of this US view of nuclear war would mean for Soviet perceptions of the strategic balance and crisis stability.

Finally, it is important to point out some further assumptions. The first is that the nuclear exchanges occur during a period of high tension which has enabled both sides to place their forces on generated alert. There is a significant difference between the force levels on day-to-day alert and those on generated alert (see Figures 5-8). This is a reasonable assumption because we are speaking of incentives to launch in a crisis - i.e. when the probability of war is high. A second assumption is more controversial: that neither side launches its missiles on warning of the enemy attack (LOW). It is assumed that missiles 'ride out' each attack before retaliating. Launching earlier would enable survival of many more missiles but potentially at a greater risk of unintentional war. Nevertheless, both sides have reserved the option to LOW. US officials have indicated in Congressional testimony that

Minuteman ICBMs presently have a LOW capability,[63] and some Soviet leaders have explicitly acknowledged this option:

> Any aggressor who begins a nuclear war will not remain unpunished, a severe and inevitable retribution awaits him. With the presence in the armaments of troops of launchers and missiles which are completely ready for operation, as well as systems for detecting enemy missile launches and other types of reconnaissance, an aggressor is no longer able suddenly to destroy the missiles before their launch on the territory of the country against which the aggression is committed. They will have time during the flight of the missiles of the aggressor to leave their launchers and inflict a retaliatory strike against the enemy.[64]

One last assumption is that command, control and communications systems function smoothly enough to enable retaliations of the sort described in the scenarios. It is by no means certain that C3 systems could absorb a first strike and still be able to coordinate effective retaliations.[65]

The Results

See Figures 11-13

1. Does either side have a substantial incentive to pre-empt?

If we define 'substantial incentive' in terms of cutting national fatalities (incentive 'A'), in 1985 the United States has a moderate incentive, and the Soviet Union has virtually no incentive, to pre-empt in a crisis. The difference between striking first and striking second in the counterforce war scenario for the US could be the difference (in the worst case) between 87 and 107 million fatalities, respectively. In the 'spasm' war scenario striking first would cut losses by (again, in the worst case) 23 million lives. Although these differences are significant, the uncertainties in the calculations process may prevent them from being perceived as a strong incentive to pre-empt. For the Soviet Union, in contrast, the margin is insignificant, largely because the United States maintains a high proportion of its weapons on survivable launch platforms. In both the counterforce and 'spasm' war scenarios, striking first results in less than 10 million fewer fatalities.

In 1985 each side has a substantial incentive to pre-empt to improve its war outcome relative to the other (incentives 'B' and 'C'). In both the counterforce war and the 'spasm' first strike the Soviets can achieve an 'advantageous' post-war environment in which they have over 35 million fewer fatalities than the United States. Conversely, the United States has an even more compelling incentive to pre-empt to avoid that result (incentive 'B'). However, it is important to recall that incentives 'B' and 'C' are probably less compelling sorts of incentives.

In 1990 there is a significant change. The United States increases its counterforce capability while maintaining its emphasis on survivable basing. The Soviet Union also improves its counterforce abilities but continues to base the majority of its force on vulnerable ICBMs. Thus, the Soviet position is much the same in 1990. In both the counterforce and 'spasm' war scenarios the USSR does not greatly decrease its national fatalities by pre-empting. In contrast, the US substantially improves its national war outcome by striking first. In the counterforce war scenario, the US improves its position by, in the worst case, 23 million less fatalities, and in the 'spasm' war by over 40 million less fatalities.

Also, by 1990 the incentives involving the relative damage in the two countries (incentives 'B' and 'C'), which were considerable in 1985, have decreased. A Soviet 'spasm' first strike would result in just over 26 million fewer fatalities in the Soviet Union than in the United States - about 10 million less than the 1985 figure, but still potentially significant. In the counterforce war scenario, however, the Soviet incentive is even lower. Nevertheless, with the probability of war sufficiently high in a crisis, the Soviets might appreciate that striking first or second will have little impact on their own damage, but that striking first will mean that the US will emerge with equal if not greater damage. Similarly, the United States will understand (and the Soviets will know that the US understands) that by pre-empting their country might 'survive' the nuclear war, while waiting would mean (assuming war came) the certain destruction of the nation as an entity. US nuclear 'superiority' in this sense might still trigger the crisis instability dynamics if one can conclude that the Soviets are concerned both with national damage and relative war outcome. If this is so, then the changes between 1985 and 1990 are not only likely to be perceived by the Soviets as highly threatening, but also they are likely to create a 'window of crisis instability' for both countries.

2. The significance of the 'window of vulnerability'?

Proponents of the 'window of vulnerability' thesis argue that any post-attack advantage in the numerical indicators of the balance (such as in counter-military potential) creates instability, but fail to translate these indicators into war outcome figures. It is therefore difficult to determine how much emphasis they place on the indicators themselves rather than what those indicators mean in terms of war outcomes. A Soviet counterforce first strike and US counterforce retaliation in 1985, not surprisingly, results in some Soviet advantages in the numerical indicators (see Figure 14). The USSR has over 1000 more SNDVs, over 800 more megatons, and about 1000 more EMTs after the exchanges. However, these are the same areas in which the Soviets hold an advantage before the war. In numbers of warheads and CMP the US maintains an advantage even after the counterforce exchanges. We have already seen that the Soviets could not significantly reduce their national fatalities in a counterforce first strike. However, these numbers do mean that the Soviets can inflict at least 34 million more fatalities on the US than the US can inflict on the USSR (incentive 'C'). This is not an insignificant 'advantage', but, as indicated in Chapter 1, it is a less compelling incentive to pre-empt than is striking first to limit national fatalities (incentive 'A') or striking to prevent a negative post-war environment (incentive 'B'). Neither of these latter two incentives is strong for the Soviets in 1985. Yet, if one chooses to believe that this sort of incentive is compelling, then one can conclude that the 'window of vulnerability' remains open and continues to contribute to crisis instability in 1985.

In 1990 some of the numerical indicators of the balance are also favorable to the USSR after a Soviet counterforce first strike and a US counterforce retaliation. The USSR has over 900 more SNDVs, over 600 more MTs, and 22 more EMTs. The US maintains an advantage in CMP (by over 7000) and in numbers of warheads (by over 3000). These Soviet numerical advantages allow the Soviets to cause only 19 million more fatalities in the US, than the US can cause in the USSR - a significant decrease from the 1985 figure. This occurs because attacks against populations become less efficient once they exceed a certain level (see Figure 10). Thus, at best, the Soviets have only a moderate incentive to pre-empt in these terms in 1990.

In short, a 'window of vulnerability' exists in 1985 only if it is defined narrowly as a Soviet ability to inflict (in a war begun with a Soviet counterforce first strike) substantially greater damage on the United States than the United States could inflict on the USSR in a retaliation. By 1990, even this 'window' has essentially closed.

3. Do the Soviets have their own 'window of vulnerability'?

How do the Soviets perceive their strategic position if they accept this Western view of limited nuclear exchanges? After a counterforce first strike by the US in 1985 and a Soviet counterforce retaliation, the US maintains an advantage in all the numerical indicators of the balance save SNDVs and MTs. The US has over 2000 more warheads, over 500 more EMTs, and almost 7000 more CMP units. This means that the Soviets might also be concerned about a 'window of vulnerability'. It also means that US efforts to close its own 'window of vulnerability', through development of more and more accurate systems, might simply further open the Soviet 'window'. But, again, the numerical indicators have to be translated into war outcome figures before the implications (beyond the perceptual implications of such discrepancies) of these 'advantages' can be drawn. In fact, a US counterforce first strike in 1985 could cut damage to the US by as little as 20 million fatalities and would result in no significant ability to inflict greater damage on the USSR. It therefore seems particularly true that if the Soviets worry about a 'window of vulnerability' in 1985, they are attaching more importance to the numerical indicators of the balance than to what those indicators mean in terms of the increased damage the US could cause in the USSR.

Again, there is a change between 1985 and 1990. A US counterforce first strike and Soviet counterforce retaliation results in a significant US numerical advantage in all areas except SNDVs: warheads - 7000, MT - 900, EMT - 1760, CMP - 14,100. While this advantage does not indicate a US ability to significantly increase the damage it could inflict on the USSR at war's end (primarily because of the way in which the remaining weapons are allocated to military and civilian targets), a US counterforce first strike does result in a US capability to decrease national damage by at least 33 million and possibly as many as 40 million fatalities. The Soviets have good reason to worry about a 'window of vulnerability' in 1990 because the numerical indicators of the balance at that time might, indeed, translate into a significant incentive for the United States to pre-empt in a crisis.

Figure 11
Detail of Nuclear Exchanges US, USSR 1985

No.	Scenario	No.of Delvy Vehls	No.of War-heads	Total MT	Total EMT	Total CMP	Fatalities (Millions)
	USA Before War	1915	11054	3253	4152	10944	0
	USSR Before War	2652	9151	6372	6442	5410	0
I	Counterforce War of Attrition - US Generated						
	USA CF Strike						
	Before strike	1915	11054	3253	4152	10944	0
	After strike	685	7296	1828	2437	8707	0
	USSR CF Retaliation						
	Before	1313	3676	2257	2556	1524	3.7-13.5
	After	1079	2265	1369	1154	250	3.7-13.5
	USA CV Response						
	Before	559	4378	1177	1693	7193	1-10
	After	0	0	0	0	0	1-10
	USSR CV Counter-Response						
	Before	1079	2265	1369	1154	250	81.7-91.5
	After	0	0	0	0	0	81.7-91.5
	USA After						78-87
II	Counterforce War of Attrition - USSR Generated						
	USSR CF Strike						
	Before	2652	9151	6372	6442	5410	0
	After	2138	6016	3643	4127	2072	0
	US CF Retaliation						
	Before	781	8387	2120	2941	8947	2-20
	After	521	5446	1492	1035	6967	2-20
	USSR CV Response						
	Before	1602	4024	2306	2040	1721	1.9-6.8
	After	0	0	0	0	0	1.9-6.8
	USA CV Counter-Response						
	Before	521	5446	1492	1035	6967	107-125
	After	0	0	0	0	0	107-125
	USSR After	0	0	0	0	0	67.9-72.8

Figure 11 - Detail of Nuclear Exchanges US, USSR 1985 (contd)

No.	Scenario	No.of Delvy Vehls	No.of War-heads	Total MT	Total EMT	Total CMP	Fatalities (Millions)
III	'Spasm' War - US Generated						
	USA CF/CV Strike						
	Before	1915	11054	3253	4152	10944	0
	After	0	0	0	0	0	0
	USSR CF/CV Retaliation						
	Before	1313	3676	2257	2556	1524	81.7-91.5
	After	0	0	0	0	0	81.7-91.5
	USA After	0	0	0	0	0	78-87
IV.	'Spasm' War - USSR Generated						
	USSR CF/CV Strike						
	Before	2652	9151	6372	6442	5410	0
	After	0	0	0	0	0	0
	USA CF/CV Retaliation						
	Before	781	8387	2120	2941	8947	110-128
	After	0	0	0	0	0	110-128
	USSR After	0	0	0	0	0	67.9-72.8

Figure 12
Detail of Nuclear Exchanges US, USSR 1990

No.	Scenario	No.of Delvy Vehls	No.of War-heads	Total MT	Total EMT	Total CMP	Fatalities (Millions)
	USA Before War	2009	14102	3763	5335	26613	0
	USSR Before War	2455	10392	6771	7691	22859	0
I	Counterforce War of Attrition - US Generated						
	USA CF Strike						
	Before strike	2009	14102	3763	5335	26613	0
	After strike	926	10535	2322	3547	18488	0
	USSR CF Retaliation						
	Before	973	2883	1790	2258	3055	3.7-13.5
	After	785	1603	971	1107	288	3.7-13.5
	USA CV Response						
	Before	777	8696	1874	2871	14463	1-10
	After	0	0	0	0	0	1-10
	USSR CV Counter-Response						
	Before	785	1603	971	1107	288	90.7-100.5
	After	0	0	0	0	0	90.7-100.5
	USA After	0	0	0	0	0	68-77
II	Counterforce War of Attrition - USSR Generated						
	USSR CF Strike						
	Before	2455	10392	6771	7691	22859	0
	After	2208	7405	4551	5437	14577	0
	USA CF Retaliation						
	Before	838	9321	2168	3240	17102	2-20
	After	623	7708	1768	2640	14717	2-20
	USSR CV Response						
	Before	1534	4299	2374	2662	6896	1.9-6.8
	After	0	0	0	0	0	1.9-6.8
	USA CV/CF Counter-Response						
	Before	623	7708	1768	2640	14717	110-128
	After	0	0	0	0	0	110-128
	USSR After	0	0	0	0	0	85.9-90.8

Figure 12 - Detail of Nuclear Exchanges USA, USSR 1990 (contd)

No.	Scenario	No.of Delvy Vehls	No.of War-heads	Total MT	Total EMT	Total CMP	Fatalities (Millions)
III	'Spasm' War - US Generated						
	USA CF/CV Strike						
	Before	2009	14102	3763	5335	26613	0
	After	0	0	0	0	0	0
	USSR CF/CV Retaliation						
	Before	973	2883	1790	2258	3055	90.7-100.5
	After	0	0	0	0	0	90.7-100.5
	USA After	0	0	0	0	0	68-77
IV	'Spasm' War - USSR Generated						
	USSR CF/CV Strike						
	Before	2455	10392	6771	7691	22859	0
	After	0	0	0	0	0	0
	USA CF/CV Retaliation						
	Before	838	9321	2168	3240	17102	117-135
	After	0	0	0	0	0	117-135
	USSR After	0	0	0	0	0	85.9-90.8

Figure 13
Summary of Nuclear Exchanges US, USSR 1985, 1990

Nos.	Scenarios	Fatalities at War's End
	1985	
	USA Strikes First	78-87
I & II	USA Strikes Second	107-125
'CF War of Attrition'	USSR Strikes First	67.9-72.8
	USSR Strikes Second	81.7-91.5
	USA Strikes First	78-87
III & IV	USA Strikes Second	110-128
'Spasm'	USSR Strikes First	67.9-72.8
	USSR Strikes Second	81.7-91.5
	1990	
	USA Strikes First	68-77
I & II	USA Strikes Second	110-128
'CF War of Attrition'	USSR Strikes First	85.9-90.8
	USSR Strikes Second	90.7-100.5
	USA Strikes First	68-77
III & IV	USA Strikes Second	117-135
'Spasm'	USSR Strikes First	85.9-90.8
	USSR Strikes Second	90.7-100.5

Figure 14
Figures After Counterforce Exchanges Only 1985, 1990

Scenario	No.of Delvy Vehls	No.of War- heads	Total MT	Total EMT	Total CMP	PCMP	Fatalities (Millions)
1985							
USA Strikes First	559	4378	1177	1693	7193	0	1-10
USA Strikes Second	521	5446	1492	1035	6967	0	2-20
USSR Strikes First	1602	4024	2306	2040	1721	1324	1.9-6.8
USSR Strikes Second	1079	2265	1369	1154	250	39	3.7-13.5
1990							
USA Strikes First	777	8696	1874	2871	14463	75	1-10
USA Strikes Second	623	7708	1768	2640	14717	0	2-20
USSR Strikes First	1534	4299	2374	2662	6896	7039	1.9-6.8
USSR Strikes Second	785	1603	971	1107	288	0	3.7-13.5

CHAPTER 4
STRENGTHENING CRISIS STABILITY

Crisis instability involves significant incentives for each side to strike first in tense situations. For these incentives to become compelling the probability of war must seem extremely high. Crisis stability can be enhanced, then, by decreasing the likelihood of war - through crisis prevention and crisis management techniques - and by designing the strategic forces so as to deny either side a first-strike advantage.

There already exist a number of crisis prevention/management measures intended to decrease the probability of war. In 1963 a direct communications link was established between Washington and Moscow, which enabled cyphered, teleprinter consultation between adversaries during crises. Prior to this 'Hotline Agreement', communication between the superpowers was time consuming (as was demonstrated so clearly during the Cuban Missile Crisis) precisely when time was the least available resource. In 1971 the US and USSR signed the 'Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War', which dealt with notification of nuclear accidents, and other events that could be misconstrued as acts of aggression. Also in 1971, the Hotline Agreement was modified to include direct communication via satellite relays. Less than one year later the 'Incidents at Sea Agreement' was signed to help manage occurrences at sea with the potential of escalating into serious confrontations. And in 1973 the superpowers agreed to consult with each other in any situation carrying a higher than normal risk of nuclear war and to refrain from the threat of use of force against each other (the 'Prevention of Nuclear War Agreement'). The two countries have also participated in a number of Confidence Building Measures (CBMs), such as prior notification of major troop movements and information exchanges.

Each of these initiatives is a valuable contribution to the management of superpower competition and to the prevention and satisfactory resolution of crises. But much more can be done. With regard to crisis prevention, there are as many initiatives possible as there are sources of nuclear crises. A crisis could develop as the result of manoeuvering of the two superpowers for global and regional advantage,[66] or from a European or Third World crisis. A superpower crisis could also develop from an accidental limited nuclear strike (based on false alarm or human error) or from the use of a nuclear weapon by a third country against a superpower or against a fourth country. A terrorist group might obtain a nuclear device and threaten a superpower, or terrorists might hope to trigger a superpower war by exploding the device unexpectedly. Many more sources of crises could be listed, and each might suggest a slightly different crisis prevention/management response. In the case of the terrorist scenario, for example, an agreement might be reached to exchange intelligence information concerning terrorist organisations and their access to nuclear materials. Whereas in the case of the 'accidental launch' scenario, a response might be for the superpowers to unilaterally improve their command and control apparatus.

One proposal for generally improving crisis prevention has been the establishment of a nuclear crisis control centre[67] which would enable the exchange of information between the United States and the Soviet Union. The centre, staffed by highly trained diplomatic and military officials from both sides, would exchange and interpret information, pool intelligence, and generally cooperate to prevent crises from developing. Of course, there are problems with this proposal. Secretary of Defense Weinberger has complained that such a centre might compromise sensitive US intelligence procedures, and be used to distribute disinformation by the Soviets during a crisis.[68] There is also a tendency in a truly serious crisis for decision-making to be concentrated at the very highest levels of government, which could make a crisis control centre irrelevant. If so, then the most useful role for such a centre might be crisis prevention rather than crisis management.

An important area of crisis prevention which has been much neglected is, simply put, diplomacy. The Four Powers Agreement of 1971 on the Status of West Berlin is an example of a diplomatic settlement which helped to diffuse the potential of a crisis developing in a particularly sensitive area (similar examples of this type of cooperation were Laos in 1962 and Austria in 1955).[69] One could argue that the superpowers should be expending maximum effort to develop rules of conduct and consensus in other potentially explosive regions such as the Persian Gulf. The US and USSR have been reluctant in the past to do this because they have believed that such rules might limit their flexibility. Although this criticism is partially justified, some restraint in foreign policies is desirable if it lessens the chance of war.

Any moves which generally decrease tensions between the superpowers also contribute to crisis prevention. Arms control agreements are important here, as are other forms of contact (economic, political, and military) and Confidence Building Measures. CBMs recommended in the past have included restrictions on military manoeuvres, limitations on the scale of troop rotations, permission for low altitude surveillance flights, stationing of international observers at NATO and Warsaw Pact installations and troop exit and entry ports,[70] and the creation of buffer zones surrounding the lines of demarcation in Europe.

Once a crisis develops the main task is to manage it so that the probability of war does not seem to either side to be high enough to trigger the crisis instability dynamics discussed earlier:

> To each side the greatest danger is the other's anxiety, given the acknowledged advantage, in the event of nuclear war, of being the initiator. Further: if the fundamental danger of strategic nuclear war arises from the advantage of haste and the reciprocated fear of each other's anxiety in a crisis, anything that lowers anxiety on both sides ... reduces the danger of a war that neither wants.[71]

One way of lessening anxiety in a crisis is by eliminating misunderstanding. It is not difficult to imagine a situation where, in the heat of a crisis, an accident occurs which is misconstrued as a deliberate act of escalation. Without a reliable means of communicating intentions, things could rapidly get out of hand. An inescapable reality of crisis behaviour is that anxiety can be created and manipulated by the participants. Resolve can be demonstrated, among other ways, by a willingness to increase the risks of war. The management problem is thus to increase the risks enough to demonstrate resolve, but not so much as to actually trigger war. Communication is important to ensure that each side interprets the moves of the other the way they are intended to be seen.

Misunderstanding is still possible, even with the best of communication systems, and an additional approach suggested has been to require decision-makers to regularly practise crisis control techniques. But first there are some difficulties to be overcome:

> Ideally, political leaders should be compelled to anticipate the competing incentives they would face in an unprecedented near-war crisis, and to think through how they would deal with them ...[Unfortunately,] few political men, successful enough to have reached the top, are likely to have the scholarly temperament...or lack of self-confidence...to doubt their decision-making performance in advance. And almost none have the time to sit back and reflect at length on the hypothetical question of how they would deal with a very improbable situation of an approaching apocalypse. They are too busy putting out minor fires from day to day.[72]

Other proposals have been advanced for diffusing crises. For example, each side might develop and share with the other a list of activities which it would consider particularly threatening for the other to conduct in time of tension. This would enable the superpowers to choose defensive preparations with the aim of reassuring each other that war was not imminent.[73] It has also been suggested that the superpowers might respond to the risk of nuclear detonations from unknown sources by sharing data about aircraft or missile trajectories that might be relevant to the detonation; or by having each country insert small amounts of distinctive elements into their bombs which, upon the bomb's detonation, would enable identification of its origin.

However,

> even more important than arrangements to facilitate reassurance in a crisis in which decisions have to be made in haste, is designing the weaponry itself so that the decisions are less

> preoccupied with the need for haste, and with the fear of the adversary's shared awareness that anxiety itself and about each other's intentions and each other's anxiety can be the precipitant.[74]

If there is a significant capability to improve the war outcome by pre-empting, then this fact alone could weigh heavily on decision-makers in a crisis, potentially increasing their assessments of the probability of war. Any capability to significantly cut losses is essentially a reflection of the vulnerability of strategic nuclear forces. If both sides maintained 100 percent survivable nuclear forces, then a pre-emptive strike by one would have no relationship to the amount of damage it would suffer in a retaliation. The assured destruction school's view of the minimum incentive for Country A to pre-empt was described earlier as the condition whereby the damage that would be suffered by A in a first strike by B, times the probability of war, is greater than the damage that would be suffered by A in a retaliation by B following a pre-emptive strike by A. With invulnerable forces on both sides, the damage that would be suffered by A in a first strike by B would be identical to that suffered by A in a retaliation by B after A's pre-emptive attack. As the probability of war will be less than one, invulnerable forces on both sides will never yield the conditions necessary for the minimum incentive to pre-empt.

Having equal and invulnerable strategic forces also satisfies the crisis-stability requirements of the countervailing strategy, as under these conditions the relative war outcome would be identical for both sides, regardless of who struck first.

To enhance crisis stability the goal thus becomes to design forces which are as invulnerable and equal as possible. ICBMs, because of their fixed locations, are generally considered the most vulnerable of the strategic weapons. The United States has wisely distributed its nuclear forces among a triad of ICBMs, SLBMs, and strategic bombers, so as to remain secure if any one 'leg' of the triad becomes threatened. About 20 percent of the US warheads are on ICBMs, 45 percent on submarines, and about 35 percent on long-range bombers. Thus, the most vulnerable system, ICBMs, carries the smallest percentage of the US nuclear force. The Soviets also use these three types of delivery systems, but base 60 percent of their warheads on ICBMs, about 30 percent on SLBMs, and only 10 percent on bombers.

By 1990, the figures for the US remain about the same, but the USSR has actually increased the proportion of its warheads based on ICBMs to 70 percent and decreased the percentage of its force made up of submarine-based warheads to 25 percent. One explanation for this Soviet reliance on vulnerable ICBMs may be Moscow's desire to maintain tight control over its forces. Another may be that the Soviets have less confidence in the survivability of their SSBNs. The United States maintains a powerful Anti-Submarine Warfare (ASW) network which includes fixed undersea listening arrays connected by cable to the shore, powerful surface ships and submarine sonars and dipping sonars suspended in the water from helicopters or from expendable buoys (sonobuoys) which are usually dropped from and monitored by aircraft. This world-wide network gives the US an excellent ability to place enemy forces.[75] These standard ASW systems coupled with meteorological and satellite surveillance data have given the United States Navy a capability (under some circumstances) to locate a submarine at a range of 9600 miles within a ten-mile radius.[76] The Navy's job is facilitated by Soviet submarine technology that seems in some respects to be inferior to that of the US.[77] Even the titanium-hulled Alpha-class submarines, while able to dive to much greater depths, are extremely noisy and suffer from the same low alert levels discussed earlier.[78] The Soviet attack submarines[79] have similar disadvantages. In 1980 75 percent of them were diesel-powered, making them too slow to defend against American nuclear-powered attack submarines (SSNs) - in 1980 only 10 percent of the US attack submarines were diesel-powered.[80] The problems are compounded by a geographic disadvantage. The exits to both the Polyarny and Vladivostok SLBM bases are through geographic 'choke-points' at which US ASW activity is intensified. SSBNs from Polyarny must pass through the Greenland-Iceland-United Kingdom Gap and the Vladivostok SSBNs through the South Korea-Japan Gap. Both Gaps are covered by the US SOSUS system. This geographic disadvantage is not likely to be overcome soon,[81], nor is the undisputed US lead in ASW technology and submarine noise dampening.

According to the US Navy's Director of Research and Engineering, the Soviets 'show no major trends toward quieting ... which would entail sizeable and costly new approaches to submarine construction. There are no indications the Soviets are moving in that direction'.[82] It must be sobering for the Soviets to hear a former National Security Agency officer declare:

> As far as the Soviet Union is concerned, we know the whereabouts at any given time of all its naval forces, including its missile-firing submarines ... We know where their submarines are.[83]

The survivability of Soviet strategic systems will improve between 1985 and 1990 in ways not reflected by the numbers on the charts. For example, the Soviets are beginning to emphasise long-range SLBMs and the coastal defence forces (SSNs, aircraft, surface ships, mines, etc.) necesary to allow them to cruise safe from US ASW in coastal sanctuaries (the new SS-N-20 SLBM has a range of 8300 km and can operate under Arctic Ocean ice). It is also probable that the Soviets will eventually deploy their new ICBMs in a mobile basing mode. According to the US Department of Defense, both the SS-24 and SS-25 have been designed with mobile basing in mind.[84]

Two additional ways in which force survivability can be improved (and which are reflected in the charts) are by increasing ICBM hardness, and SLBM and bomber alert rates. The US had originally planned to harden Peacekeeper silos to 5000 psi, but later dropped the idea, settling instead for about the same hardness as existing Minuteman ICBMs.[85] Thus, in 1990 US ICBM hardness levels will be virtually unchanged. Some improvement in survivability of US SLBMs will occur as the Trident SSBN programme continues. The Trident has a day to day alert rate of 0.66, as compared to the 0.55 rate of the Poseidon SSBNs, and can more easily cruise undetected than its predecessor.[86] Also, the deployment of air-launched cruise missiles and the B-1B bomber should ensure that those aircraft surviving a first strike can more easily carry out their retaliation.

In contrast to the US, the Soviet Union has an agressive silo-hardening programme: presently about 40 percent of the Soviet ICBMs are hardened to approximately 300 psi and the remainder to approximately 4000 psi. This monograph estimates that by 1990 the majority of the Soviet ICBM force will be hardened to 5000 psi. Once attacking warheads achieve accuracies of only a few hundred feet, however, even hardnesses of this magnitude will have little effect on kill probabilities. Soviet bomber and SLBM alert rates - particularly day to day alert rates - are significantly lower than those of the US force. A small improvement in this area could be significant. Typhoon SSBNs and the new Blackjack bomber should also improve survivability - the Typhoon for reasons already mentioned and the Blackjack because of its possibly greater ability to target once in the air.

Survivability is also a function of the durability of C3I systems and of the reliability of retaliating warheads. A surviving force of 1000 missiles would be relatively useless if the authorities with the job of issuing the commands for retaliation had been killed in the pre-emptive strike, or if the missile reliabilities were so low that few missiles could be expected to launch successfully. Desmond Ball has gone into detail about the weaknesses of C3 systems:

> Command-and-Control systems are in fact vulnerable to all threats to which the strategic forces are subject as well as to others more peculiar to command structures and telecommunications systems...they are vulnerable to direct physical attack (and to the collateral effects of attack upon the strategic forces) and to operational failures that must be expected to occur. Physically, they are open to nuclear effects (blast and radiation), attack with conventional weapons, and sabotage. Operationally, they are vulnerable both to unintended effects - human error, natural phenomena and equipment failure - and to intentional jamming or exploitation of failures in communications security.[87]

Improvements in C3 and reliability might help to decrease strategic force vulnerability in another way. If Country A could credibly threaten to launch its ICBMs on warning of a pre-emptive attack (when early warning sensors detect that an attack has been launched, but before enemy warheads actually arrive at their targets), then Country B could not assume that its pre-emptive strike would destroy A's missiles before they were launched. The greater survivability of A's strategic forces under a LOW posture could make it more difficult for side B to imagine that its pre-emptive strike would substantially improve the war outcome. Both superpowers currently retain the option to LOW, but improvements to C3 and missile reliability and public re-emphasis of this option, will make it all the more credible. The Soviet Union presently suffers from serious deficiencies in its early warning system which could make a LOW posture problematic.[88] Soviet Over-the-Horizon radars do not cover all the compass points from which the Soviets might be attacked by submarine and air-launched weapons, nor are they linked to information processing systems with a sufficient capability to distinguish between limited and massive nuclear attacks. Additionally, the Soviet Union has experienced technical problems in developing a fully operational satellite early warning system, which to this day makes 24-hour coverage of all US ICBM and SLBM launch areas unavailable.[89]

There are dangers inherent in exercising a LOW policy. LOW requires launch very soon after detection of an attack. But early warning systems are not perfect. Spy satellites have in the past registered solar flares as plumes from rocket engines and low level nuclear alerts have been triggered by flocks of birds on radar screens and by equipment failures.[90] In the United States, for example, the failure of an integrated circuit in 1980 was responsible for two nuclear alerts in just one month. And the previous year a test tape simulating nuclear attack was accidentally broadcast to Strategic Air Command units. That alert lasted six minutes, long enough for interceptors to be scrambled and Minuteman missiles to be placed on high alert.[91] In a crisis there would always be the chance that an equipment error of this sort could spark a war which otherwise might have been avoided. But there is no need to actually adopt a LOW policy if the goal is to influence the assessments made by an opponent before nuclear war has begun. All that is required is to convince the enemy that LOW is the operational policy so that pre-empting seems unattractive. It may make more sense to declare that LOW is operational policy than to actually make it so. A related danger is that the more credible one makes LOW - by refining C3, improving reliability, etc. - the greater the temptation might be to actually exercise the capability in a crisis.[92]

Command-and-Control systems might increase instability in another way which was discussed earlier. The emergence of continuous information collection from the early warning sensors of both sides has produced tightly coupled interactions between the strategic forces of the superpowers. This has led to a potential for rapid and semi-automatic escalation in times of tension. Crisis stability can be further enhanced, then, by measures designed to decrease the pace and increase the management of the escalation process.[93] One response might be to reach an understanding with the Soviets for an automatic pause in escalation once a certain number of previously agreed upon 'danger points' had been reached. At the very least, decision-makers should be aware that manipulation of nuclear alert levels in any crisis involves some hidden and perhaps overwhelming costs.

Another way ICBM survivability might be improved is through development of active defensive measures such as Ballistic Missile Defense (BMD). An irony is that the technology that threatens ICBM survivability most, MIRVed systems, was originally designed as a means of overcoming BMDs. In 1972 the US and USSR agreed in the ABM Treaty to limit BMD to two deployment areas: the nation's capital and an ICBM launch centre distant from the capital. In 1974 a further agreement limited the deployment to only one location in each country, at which could be maintained not more than 100 ABM launchers and 100 ABM interceptor missiles. The United States for a short time deployed the Safeguard BMD at Grand Forks, deactivating it almost as soon as it became operational in 1975, while the USSR chose a modest defence of Moscow. For many years after its initial operating capability, the Soviet system consisted of only 64 of the permitted 100 launchers. More recently these were reduced to just 32 launchers.[94] The renewed interest in BMD has been stimulated by concern about ICBM vulnerability, and by improvements in the BMD technology. Defence of ICBMs is also considerably easier to accomplish than is area defence, because of the defender's ability to ignore all but the most accurate incoming warheads. If the BMD mission were population defence, then even the most inaccurate incoming warheads would have to be targeted, as they could still cause massive damage. The technology currently favoured in the US involves a layered defence of distant (exo-atmospheric), medium, and short range intercept missiles which utilise infra-red sensors, compact data processors and miniature homing vehicles.[95] Theoretically this system could increase the attack price per silo from two to possibly five or ten re-entry vehicles.

The Reagan Administration has cited evidence that the USSR may be moving towards development and deployment of an effective BMD system, in violation of the ABM Treaty.[96] The Soviets have allegedly been testing SAM air defence radars in an ABM role, deploying large ABM battle management radars, developing a rapidly deployable ABM - the ABMX-3 - and constructing a new, larger phased array radar in central Siberia. There is also some indication that the USSR is testing rapidly reloadable ABM launchers.[97] In the United States the interest in BMD, beyond the limits set down in the ABM Treaty, was, until recently, more subtle than direct. It took the form of increased discussion about 'what the US would do if the Soviets abrogate' or 'how both sides could mutually agree to abrogate'. Major General Marshall provided an example of this when he said, 'And I think, too, we could argue that it might be appropriate for the Soviet Union to tell the United States that, because of their concern about their neighbors, they feel it is necessary in their national interest to abrogate the Treaty. I think that is a very real likelihood.'[98] More recently, retired Army Lt. General Daniel Graham, former Director of the Defense Intelligence Agency, has proposed outright that 'the new US defense effort should concentrate on putting heat-seeking anti-ballistic missiles in orbit, where they can destroy Soviet missiles before they ever reach US airspace'.[99] And President Reagan's Strategic Defense Initiative (SDI) would seem to further indicate US willingness to eventually abrogate the Treaty.

Even if ICBMs are vulnerable and the BMD technology has improved, there are some good reasons why the US should not abrogate the ABM Treaty and deploy BMD systems for ICBMs. Certainly the Soviets might not perceive large-scale ABM deployment as a good idea. As Raymond Garthoff has said:

> the Soviet leaders see no prospect of improving their relative military position by launching a competition in BMD deployments. The same considerations that overrode the traditional Soviet proclivity for coupling strong strategic defenses with strong offensive forces in the late 1960s, and that led to Soviet acceptance of the ABM Treaty in 1972, continue to hold today and almost certainly will for the foreseeable future as well. These considerations were based not only on recognition of possible ephemeral U.S. advantages in BMD technology, but also on a new appreciation of the dynamics of the offensive-defensive arms interaction...In short, the Soviets see more danger than promise in reopening a competition in BMD deployment.[100]

Both countries must also be aware of the tremendous technical and political problems that remain despite improvements in the technology. It is not at all clear that the numerous BMD counter-measures available would not overwhelm the system (or that the defence would be more cost effective than the offence). Radars are vulnerable to attack, re-entry vehicles can emit decoys or chaff to confuse defences, and the complexity of the system could mean that small failures might cause synergistic effects which seriously degrade effectiveness.

To conclude this discussion of responses to crisis instability, there are some bilateral steps which can be taken to reduce strategic force vulnerability. The superpowers can, for example, attempt to negotiate agreements which encourage survivability. The MIRV limits imposed in Salt 2 were a move in this direction,[101] as would be agreements which induce a greater emphasis on submarine-based systems and the ability of these systems to cruise undetected. One development which could increase vulnerability is depressed trajectory SLBMs. An SSBN patrolling within 200 nm from shore could fire its missiles and expect them to reach their targets within 16 to 18 minutes. The same SLBM fired in a depressed trajectory mode could reduce this time to only eight minutes,[102] thereby exacerbating the threat to non-alert systems and decreasing the credibility of a LOW posture. Neither side has as yet tested depressed trajectory

SLBMs, although their feasibility was such that the issue was raised for discussion at the SALT 2 negotiations.[103] Another response to this same threat might be the creation of SSBN-free zones (where SSBNs would be prohibited from patrolling closer than a given distance from the enemy's shore). This would be helpful because each additional two hundred mile distance to target adds about one minute of flying time.[104]

CONCLUSION

This monograph has examined two models of nuclear war, one involving counterforce exchanges followed by countervalue exchanges and the other 'spasm' attacks and retaliations. The results of these exchanges were then related to the differing views of crisis stability, in order to both clarify those views and reach some conclusion as to the existence or absence of crisis stability between 1985 and 1990. What consistently emerged from defining the parameters of the calculations was the tremendous uncertainty and the importance of the assumptions involved in determining war outcomes. This is, perhaps, the most significant aspect of the analysis. For in a crisis, it is the results of similar simulations of nuclear exchanges that are presented to decision-makers and which might be used by them to determine whether or not they choose to pre-empt. The uncertainty pervades all aspects of the calculations. There are the weapons systems themselves: will they be launched successfully? Will they correctly travel and detonate over their targets with the expected accuracies and yields? Will the enemy systems perform as expected? There are the attack assumptions: will the enemy ride out an attack or launch his weapons on warning? What type of first strike should be launched? What type of counterattack can be expected? Which targets does the enemy value most, and which does he think we value most? Will the opponent leave C3 untouched or will it be destroyed early in the fighting? There are the fatality estimates: at what time of year and time of day does the attack occur? How many weapons are used in the attack and at what height and over what terrain are they detonated? What are the prevailing weather patterns? What civil defence shelter exists and how educated is the public concerning civil defence? How 'dirty' or 'clean' are the bombs?

With so much uncertainty one might conclude that crisis stability is strong indeed, as no one could possibly estimate war outcomes with any degree of accuracy. This is no doubt the most realistic conclusion to be drawn. However, in a crisis a leader may very well be unfamiliar with the uncertainty involved and choose to let the calculations influence his behaviour. To err on the side of caution would thus be to design the force postures such that neither side could produce reasonable calculations which 'demonstrated' the existence of crisis instability. What emerges from the simulation conducted in this paper is that it is, in fact, possible to demonstrate the existence at the end of this decade of crisis instability. In 1985 both sides have a significant incentive to pre-empt in terms of the relative war outcome (incentives 'B' and 'C'). But, as indicated in Chapter 1, these are less compelling incentives than is striking to cut national fatalities. By 1990 these 'relational' incentives have decreased, but at the same time the incentives for the United States to pre-empt to cut national fatalities have increased dramatically, and this could add impetus to the less compelling Soviet incentives to pre-empt.

This situation has developed as a result of the increasing vulnerability of large segments of the strategic forces of both sides thanks to dramatic improvements in missile accuracies - the Soviet Union is particularly susceptible as over 60 percent of its strategic weapons are based on vulnerable ICBMs, and the Soviet strategic bomber and submarine systems suffer from relatively lower alert rates. The US, in contrast, deploys only about 20 percent of its strategic warheads on ICBMs. This means that of the two countries, only the United States could destroy a significant number of its opponent's weapons in a first strike and thereby limit the damage from an enemy retaliation. By striking first instead of second, the Soviet Union could increase the damage it could cause to the US (by using its weapons before the US has taken them out), but it could not significantly limit a retaliation from the high percentage of nuclear weapons the US maintains on invulnerable systems.

Most disturbing is that this condition could exist concurrently with extremely vulnerable and tightly coupled command-and-control systems. Command-and-control may be the weakest link in the nuclear forces of both countries. A comprehensive strike against C3 systems might offer the highest probability of preventing a retaliation. Thus, in a crisis, command-and-control vulnerability could reinforce if not compound the existing incentives for both to pre-empt. This makes it all the more urgent for the superpowers to ensure that crises do not escalate to the point at which these incentives become compelling. However, the tight coupling of the US warning and control systems with those of the USSR may seriously erode the ability of leaders to manage escalation in a crisis. By 1990, then, there could exist a triple threat to strategic nuclear crisis stability: significant incentives to pre-empt directly against the enemy's strategic forces, significant incentives to pre-empt against the enemy's strategic forces via his command-and-control, and pressures which encourage rapid escalation of crises.

The implications of this triple threat are substantial. The most obvious is that nuclear war may be more likely - although it is impossible to say how much more likely. These threats also suggest that if nuclear war does occur, it will involve a massive use of nuclear weapons early on in the fighting, rather than a gradual, step by step escalation of the numbers and types of nuclear devices used. This would tend to detract from notions such as 'escalation dominance', 'intra-war deterrence', and other concepts of nuclear war-waging which assume restraint among the participants.

Notes

1. Xenophon, The Persian Expedition, trans. Rex Warner (Penguin Books Ltd, New York 1949), p. 82. Quoted by Thomas Schelling in 'Confidence in Crisis', International Security vol. 8, no. 4, (Spring 1984) p. 55
2. Harold Brown, Department of Defense Annual Report FY 1981, p. 69. See also Warner Schilling, 'U.S. Strategic Nuclear Concepts in the 1970s: The Search for Sufficiently Equivalent Countervailing Parity', International Security vol. 6, no. 2, (Fall 1981) p. 59
3. Richard Rosecrance, 'Deterrence and Vulnerability in the Pre-Nuclear Age', Adelphi Papers, no.160, (International Institute for Strategic Studies, London 1980) p.26. Paul Nitze makes a similar argument in 'The Strategic Balance Between Hope and Skepticism', Foreign Policy no. 17, (Winter 1974-75) p. 139
4. Harold Brown, Department of Defense Annual Report FY 1979, pp. 49-55

5. That is, damage inconsistent with any conceivable political goal the US could hope to achieve by initiating a nuclear war
6. See Paul Nitze, 'The Strategic Balance Between Hope and Skepticism', Foreign Policy no. 17 (Winter 1974-75) p. 137. Also see Albert Wohlstetter's widely quoted piece, 'The Delicate Balance of Terror', Foreign Affairs, January 1959, pp. 221-234
7. 'Selection and Use of Strategic Air Bases', Wohlstetter, Rowen, Hoffman, and Lutz, RAND Report, R-266, April 1954
8. This exercise is described in Fred Kaplan, The Wizards of Armageddon (Simon and Schuster, New York, 1983) p. 132
9. Thomas C. Schelling, The Strategy of Conflict (Harvard University Press, Cambridge, Massachusetts, 1960) p. 207
10. Paul Bracken discusses this in The Command and Control of Nuclear Forces (Yale University Press, New Haven, Connecticut, 1983) pp. 59-65
11. Glenn H. Snyder, Deterrence and Defense (Princeton University Press, N.J., 1961) p. 108
12. Schilling, op.cit., pp.51-52
13. T.K. Jones and W. Scott Thompson 'Central War and Civil Defense', Orbis vol. 23, no. 3, (Fall 1978) p.685
14. Paul H. Nitze, 'Deterring our Deterrent', Foreign Policy no.25, (Winter 1976-77) p.197
15. Quoted in Lawrence Freedman, The Evolution of Nuclear Strategy (The MacMillan Press, London, 1981) p. 389
16. George Schultz, 'Modernizing U.S. Strategic Forces', U.S. Department of State Current Policy no. 480, (April 20, 1983) p. 2
17. Colin S. Gray, 'Nuclear Strategy: A Case for a Theory of Victory', International Security vol. 4, no. 1, (Summer 1979) p. 87
18. The following discussion relies heavily on Mathew Bunn and Kosta Tsipis, Ballistic Missile Guidance and Technical Uncertainties of Countersilo Attacks (Report no.9, Program in Science and Technology for International Security, Dept. of Physics, MIT, Cambridge, MA, August 1983)

19. See John D. Steinbruner and Thomas M. Garwin, 'Strategic Vulnerability: The Balance Between Prudence and Paranoia', International Security (Summer 1976) p.169 footnote 27
20. Bracken, op.cit., p.113
21. Bunn and Tsipis, op.cit., p.42
22. Ibid., p.89
23. 'Decisions Reached on Nuclear Weapons', Aviation Week and Space Technology, (October 12, 1981) p.22
24. Minuteman tests from operational silos were attempted on four occasions years ago; they failed each time. J. Edward Anderson, 'First Strike: Myth or Reality', Bulletin of Atomic Scientists, (November 1981) p.7
25. Ibid.
26. Paul S. Mann, 'Panel Re-examines ICBM Vulnerability', Aviation Week and Space Technology, (July 13, 1981) p.148
27. William H. Kincade, 'Missile Vulnerability Reconsidered', Arms Control Today vol.11, no.5, (May 1981) p.5
28. Anderson, op.cit., p.8
29. Lt. Col. Louis T. Montulli, USAF, Aviation Week and Space Technology, (July 13, 1981) p.145
30. Kincade, op.cit
31. Quoted in International Security vol.1, no.1, (Summer 1976) p.187
32. Bunn and Tsipis, op.cit., pp.92-94
33. See Paul H. Nitze, 'Assuring Strategic Stability in an Era of Detente', Foreign Affairs, vol. 54, no. 2, (January 1976)
34. Steinbruner and Garwin, op.cit
35. Of course it would be especially foolish for the Soviets to attack under these conditions (one could argue under any likely conditions), but this is precisely the point. Slight variations in the assumptions can mean the difference between what some would call a plausible first strike option and what almost everyone would call an implausible one
36. Steinbruner and Garwin, op. cit., pp. 142-143 footnote 3

37. See statement of James R. Miller, Chief, Weapons Systems Division, Defense Intelligence Agency, before Subcommittee of the Committee on Appropriations, United States Senate, 97th Congress, 1st Session, MX Missile Basing Alternatives (Washington 1981) p. 6
38. Steinbruner and Garwin, op. cit., p. 143
39. See Lynn Etheridge Davis and Warner R. Schilling, 'All You Ever Wanted to Know About MIRV and ICBM Calculations But Were Not Cleared to Ask', Journal of Conflict Resolution vol. 17, no. 2, (June 1973) pp. 215-216
40. See Bruce Bennett, The Snapper Nuclear Damage Assessment Model, WN-9899-AF (the RAND Corporation, Santa Monica, June 1977)
41. Arthur M. Schlesinger, Jr., A Thousand Days, (Fawcett Publications, Greenwich, CT, 1967) p.242
42. Walter La Feber, America, Russia, and the Cold War 1945-1975, Third Edition (John Wiley and Sons, 1976) pp.236-237
43. Some potential war outcomes are described in Chapter 3
44 See US Department of Defense, Soviet Military Power 1984. According to Moscow, the SS-X-25 is not a new missile but a modification of their SS-13 ICBM and therefore permitted under Article IV of the SALT 2 agreement, which allows changes in the throw-weight of existing ICBMs as long as those changes do not exceed 5 percent of the original throw-weight. The Reagan Administration contends that the SS-25 exceeds the 5 percent mark and therefore must be considered a new missile. Moscow responds that the US under-estimated the original throw-weight of the SS-13
45. Ibid., p. 24
46. Ibid., p. 25
47. Blackjack estimate is from Paul Rogers, Guide to Nuclear Weapons 1984-85 (University of Bradford School of Peace Studies, West Yorkshire, May 1984) p.52
48. Soviet Military Power 1984, p.27 indicates in 1984 130 Backfires are allocated to the strategic role. We assume 15 are added to that role each year through to 1990

49. For a discussion of these measures of force capability see Jeffrey T. Richelson, 'Evaluating the Strategic Balance', American Journal of Political Science vol. 24, no. 4, (November 1980) p. 779
50. The 'footprint' is the name given to the area in which a multi-warhead missile can deliver its warheads. It is defined generally by the missile range and flight path angle, the number of objects (RVs and penetrating aids) to be delivered, and the amount of fuel on the post-boost vehicle or 'bus'. For example, the eight one-megaton warheads on a Soviet SS-18 have a footprint that is about four times that of the ten 50-kiloton warheads of the U.S. Poseidon missile
51. The MX missile will have a new shock isolation system which will modestly increase hardness
52. 'Countervalue attacks' usually refers to attacks against population centres. 'Counterforce attacks' refers to attacks against the military forces of the enemy. However, the United States no longer targets populations, per se. Therefore, in this monograph 'counter value attacks' will refer to attacks against economic/industrial targets which have, as a by-product, high civilian fatalities
53 For a description of the development of US targeting doctrine see Desmond Ball, 'Targeting For Strategic Deterrence', Adelphi Papers no. 185,(International Institute for Strategic Studies, London, Summer 1983). For a discussion of the difficulties of controlling nuclear war, see Desmond Ball, 'Can Nuclear War Be Controlled?', Adelphi Papers no. 169, (International Institute for Strategic Studies, London, Autumn 1981)
54. Nitze, 'Assuring Strategic Stability in an Era of Detente', pp.224-225
55. Testimony of Gen. Richard H. Ellis, USAF, Commander-in-Chief, Strategic Air Command, in 'Hearings Before the Committee on Armed Services', U.S. Senate, DoD Authorization for Appropriation for FY 1982, (Feb. 18, 1981) p. 3795
56. Nitze, 'Assuring Strategic Stability in an Era of Detente', p.228

57. Yuri Zhukov, one of Pravda's best known political commentators, quoted in Dimitri K. Simes, 'Deterrence and Co-operation in Soviet Policy', International Security vol. 5, no. 3, (Winter 1980-81) p.96
58 Simes, ibid. discusses this on p. 82
59. Steve S. Kime, 'The Soviet View of War', in Soviet Perceptions of War and Peace, edited by Graham D. Vernon (National Defense University Press, Fort Lesley J. McNair, Washington, D.C., 1981) p. 59
60. Quoted in Robert Jervis, The Illogic of American Nuclear Strategy (Cornell University, 1984), pp. 106-107
61. See Desmond Ball, 'Targeting for Strategic Deterrence', p.25
62. Figure 10 is derived from Alain C. Enthoven and Wayne Smith, How Much is Enough? Shaping the Defense Program 1961-1969 (Harper and Row, N.Y., 1971, p.207)
63. Modernizing U.S. Strategic Offensive Forces: The Administration's Program and Alternatives (Congressional Budget Office Study, May 1983) p.44
64. Quoted in Lawrence Freedman, Evolution of the Strategic Balance (the Macmillan Press, London, 1981) p. 267. See also William T. Lee, 'Soviet Perceptions of the Threat and Soviet Military Capabilities', in Vernon, op.cit., p. 77
65. One could argue that an additional and vital assumption is that the nuclear exchanges involved would not result in some unpredicted effect such as a 'nuclear winter'. This is presently a controversial subject. See Bulletin of Atomic Scientists vol. 40, no. 4, (April 1984) for a discussion of this phenomenon
66. See William Langer Ury and Richard Smoke, Beyond the Hotline: Controlling a Nuclear Crisis (A report to the U.S. Arms Control and Disarmament Agency, Nuclear Negotiation Project, Harvard Law School, 1985) p.9, for a discussion of potential sources of nuclear conflicts
67. Ibid. See also the Nunn-Warner Working Group on Nuclear Risk Reduction, 'A Risk Reduction Center', Bulletin of Atomic Scientists vol. 40, no. 6, (June-July 1984) p. 28
68. Ibid., p. 54

69 Krushchev and Kennedy agreed to neutralize the Laos crisis and the US and USSR signed the Austrian State Treaty which ended the occupation and division of Austria. See David A. Hamburg and Alexander L. George, 'Nuclear Crisis Management', in Bulletin of Atomic Scientists vol. 40, no. 6, (June-July 1984), p.27

70. Richard K. Betts describes these CBMs in 'Hedging Against Surprise Attack', Survival vol. 23, no. 4, (International Institute for Strategic Studies, London, July-August 1981) p.153

71. Thomas C. Schelling, 'Confidence in Crisis', p.57

72. Betts, op. cit., pp. 148-149

73. This and the following proposal are advanced in Hamburg and George, op. cit., pp. 55-56

74. Schelling, 'Confidence in Crisis'

75. Strategic Survey 1980-81 (International Institute for Strategic Studies, London), p.32 discusses the US SOSUS network

76. See Defense Electronics Magazine, June 1983, p. 80

77. Ian Bellany, 'Sea Power and the Soviet Submarine Forces', Survival vol. 24, no. 1, (January-February 1982, International Institute for Strategic Studies, London) p. 5

78. According to Bellany, op. cit., only two out of five of the Alpha-class subs are operational at any one time

79. The job of attack submarines is, among other things, to attack both enemy nuclear missile carrying submarines and enemy attack submarines that are attempting to destroy the home SSBN fleet

80 Bellany, op.cit., p. 4

81. In fact, this geographic disadvantage may be an important reason why the Soviets de-emphasized the role of SSBNs in their strategic forces

82. Quoted in Strategic Survey 1980-81, p. 32

83. Quoted in Desmond Ball, 'The U.S. Naval Ocean Surveillance Information System (NOSIS) - Australia's Role', Pacific Defence Reporter, (June 1982) p. 46

84. Soviet Military Power 1984, op.cit., p 24

85. Thomas B. Cochran, William M. Arkin and Milton M. Hoenig, U.S. Nuclear Forces and Capabilities, Vol. 1 - Nuclear Weapons Databook (Ballinger Publishing Co., MA, 1984) p. 120

86. Ibid., p. 141
87. Desmond Ball, 'Can Nuclear War be Controlled?', p.10
88. Richard Ned Lebow discusses these in 'Practicle Ways to Avoid Superpower Crises', Bulletin of Atomic Scientists vol. 41, no. 1, (January 1985) p. 24
89. See Desmond Ball, 'The Soviet Strategic C^3I System' in Fred D. Byers (ed.) The C^3I Handbook (EW Communications Inc, Palo Alto, California, First Edition 1986) pp.209-210 for a discussion of Soviet early warning weaknesses
90. Colin Gray in 'The Future of Land-Based Missile Forces', Adelphi Papers no. 140, (International Institute for Strategic Studies, London, 1977) discusses these weaknesses on p. 14
91. See Flight International Magazine no. 28, (June 1980) p.1439, for a description of these events
92. This mirrors the debate between proponents of flexible response and assured destruction: the threat to respond to aggression with nuclear weapons is only credible if options are developed for waging war short of total nuclear war. But the availability of the options, and the belief that they can be exercised without escalation, might increase the temptation to actually use them, thereby precipitating a war they were intended to deter
93. Bracken, op. cit., discusses some possible measures on pp. 244-247
94. George Schneiter mentions this in 'The ABM Treaty Today', in Ballistic Missile Defense, Ashton B. Carter and David N. Schwartz (eds.), (The Brookings Institution, Washington, D.C., 1984), p. 238. However, the reduction to 32 missiles is probably in preparation for a modernized system
95. The layered defence system is described by Ashton B. Carter in 'BMD Applications: Performance and Applications', in ibid., pp. 128-137
96. Schneiter, op. cit., p. 239
97. See 'Soviets Test Defense Missile Reload' in Aviation Week and Space Technology, (August 29, 1983) p. 19
98 Testimony of Major General Marshall Before the Senate Armed Services Committee, March 30, 1976, p. 6725

99. Graham was quoted in the Los Angeles Times May 8, 1980, part A, p.4
100. Raymond L. Garthoff, 'BMD and East-West Relations', in Carter and Schwartz, op. cit., p. 278
101. Although the establishment of MIRV limits in SALT 2 was probably a reflection more of concerns about numerical equality than concerns about stability
102. Harold A. Feiveson and John Duffield, 'Stopping the Sea-Based Counterforce Threat', International Security vol. 9, no. 1, (Summer 1984) pp. 196-197
103. Ibid., p. 197
104. Ibid., p. 198

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