N405 S/AE

SAW/147 R

Copy II 2

STABILITY - A CRITERION FOR EVALUATING INSPECTION AND CONTROL SYSTEMS

by

Vincent V. McRae

Philip H. Lowry

Joseph O. Harrison, Jr.

October 29, 1958

This document consists of 42 pages
No. 2 of 40 Copies, Series

TABLE OF CONTENTS

STABILITY - A CRITERION FOR EVALUATING
INSPECTION AND CONTROL SYSTEMS

SUMMARY

The purpose of this paper is to present and explain criteria for evaluating the stability of various strategic postures of the US and USSR with respect to surprise attack. Part I explains the concept upon which the criteria are based, defines the criteria, and relates them to stability against surprise attack. Part II applies the criteria numerically to pure ICBM systems.

In Part I a situation is defined to be unstable when either the US or USSR finds it in his national interest to attack the other by surprise attack. A rational aggressor will attack only when he can inflict at least a specified level of damage on the enemy while limiting his own damage from retaliation to a second specified level which he can tolerate. The stability of any situation can be determined by relating strategic postures to these levels of potential damage.

In Part II, the stability of ICBM systems with various technical characteristics is determined numerically under specific assumptions concerning the vulnerability of population and industry and the magnitudes of the levels of damage postulated in Part I. The effects of the response times of the missile systems, the dispersion of the missile systems, active defenses, and passive defenses are discussed.

Although the substance of the paper is largely expository, certain general conclusions concerning the stability of possible present and future postures of the US and the USSR can be drawn.

Conclusions

1. Damage to cities is the proper measure of stability for strategic systems.

2. The value of agreements for inspection and limitation can only be determined by a detailed examination of the relative damage to US and USSR cities, comparing the case when the USSR makes a surprise attack to the case when the US makes a surprise attack.

3. The degree of stability deteriorates as ICBM technology improves unless this improvement is balanced by a corresponding improvement in base hardness, base configuration, population shelter, and active defenses.

4. It appears to us that, since less than 100 successfully delivered second-generation Soviet missiles could destroy the United States beyond hope of recovery, the best stability we could get is a stability based on fear of mutual annihilation in the absence of almost perfect controls or effective anti-ICBM systems.

STABILITY - A CRITERION FOR EVALUATING INSPECTION AND CONTROL SYSTEMS

1. Applications to Pure ICBM Systems

PART I - A CONCEPT OF STABILITY

THE PROBLEM

This paper is the first in a series aimed at developing the criteria for judging the merits of various proposals for inspection systems as safeguards against surprise attack. Only the problem of strategic surprise attack is considered in a mathematical model which permits the gross quantification of the results of surprise and retaliatory attacks. This model is applied to various problems relating to securing missile forces against surprise attacks by other missile forces. However, the concepts on which the model is based are equally applicable to surprise attack by more complex strategic and tactical systems.

DISCUSSION

The work of the Summer Study group, reported in the Interagency memorandum, led to the qualitative conclusion that inspection and reporting procedures by themselves were of little value in preventing surprise attack. It was carefully pointed out that such procedures would yield a large amount of information which would of course have great intelligence value, but that such information is unlikely to remove incentives for surprise attack which might be possessed by East or West. In recent staff discussions it has been suggested that the information revealed by an inspection system could increase the current instability of the two strategic postures so far as surprise attack is concerned, and by others that, if this information were combined with actions which could be taken unilaterally, the situation would become more stable and the probability of surprise attack reduced. In the first case the result could be disastrous to either East or West or to both, but in the latter case the results would be quite the contrary. It is therefore most important that the concept of stable strategic postures be fully explored and defined and that as far as possible quantitative aids be developed to evaluate the relative stability of postures with inspection and without inspection. This study is aimed at developing such aids.

Now, just when are the strategic postures of East and West unstable with respect to surpise attack? A complete answer to this question is beyond the scope of this discussion, but it is clear that if either East or West judges that it is within his total national interest to attack the other, then since the benefits of surprise are so great, a surprise attack is likely and the situation is unstable. An understanding of the basis on which such judgements might be made is very difficult to acquire since East and West tend to attribute different values to various elements of their national substance. Whereas the West considers its most valuable national substance to be population, the East tends to place a much lower value on human life. The East on the other hand places a very high priority on economic capability, industrial production, and real estate in relation to that placed on human lives than does the West. In addition to these asymetries in values assigned to national assets, there are also differences in the strengths of desires to increase one's influence in international affairs and to bring other areas of the world under direct or indirect control. These political factors as well as many economic factors must be considered in assessing the strength of any desire to inflict a level of damage upon the other party which is either critical or perhaps lethal. It is unfortunate but perhaps true that these politico-economic factors are not very susceptible to numerical evaluation. However, since such desires must be viewed against a background of capability to inflict damage on one's opponent while not sustaining a critical or perhaps lethal level of damage to one's self, and since such capabilities are more susceptible to mathematical treatment, it appears appropriate to examine mathematical models of strategic stability. We propose to examine a mathematical model which requires for its input, estimates of enemy force levels and operational procedures as well as estimates of our own force levels and of course of the operational capabilities of our weapons systems. We expect to obtain as outputs from this model gross estimates of the stability of the postures involved. The use of such a model should therefore aid in evaluating the extent to which the probability of surprise attack would be reduced if various inspection procedures were adopted. We propose that the model be extremely comprehensive in scope since it is our opinion that one cannot adequately evaluate the stability of a strategic posture even with respect to central war without looking at a very large number of weapons systems simultaneously, at their interactions and at the levels of damage that might arise if employed using their best tactics.

Since the inputs required are estimates of force levels, warning times, response times, and the like, it is clear that this model will be useful in examining the effects of errors in estimating enemy capabilities at future time periods. It also is clear that the effect of arms limitations and restrictions could be explored using the same model.

It is recognized that within the scope of the conference as outlined the USSR might not be willing to enter into technical discussions relative to limitations. It is also recognized that many of our allies might not be prepared to enter into these discussions. However, it has been suggested by many that the attempt to arrive at a reasonably secure system of inspections which would in fact severely reduce the probability of surprise attack might lead to the conclusion that such a system could not exist unless some limitations on arms were imposed. Consequently, it has been felt that our delegates ought to be aware of the implications of such limitations on our own strategic posture. Moreover, it has been suggested that if it were possible to present a concept of stable strategic postures which involved such limitations at this point, fruitful discussion might ensue on a conceptual basis and a way might be opened towards the exploration of controls and inspection procedures which would be useful in arms limitations. As a result, it is also one of the purposes of this document to present such a concept and to illustrate it by considering limitations imposed on ICBM forces only.

A MODEL FOR STRATEGIC STABILITY

The model for strategic stability is a two-sided gaming model in which either the US or the USSR may initate a surprise attack. The aggressor has the option of allocating his strategic striking force in any proportion between cities and population targets and offensive forces. He does so with the knowledge that the attacked country may devote all of its remaining strategic power to the destruction of the aggressor's cities. We assume that the decision to attack or not to attack is based upon a combined estimate of population and economic damage to be received by both sides and their relation to each other. Such a decision must be based upon estimates of outcomes when the Red forces strike first and when the Blue forces strike first. We shall establish two sets of criteria on which such decisions could be based.

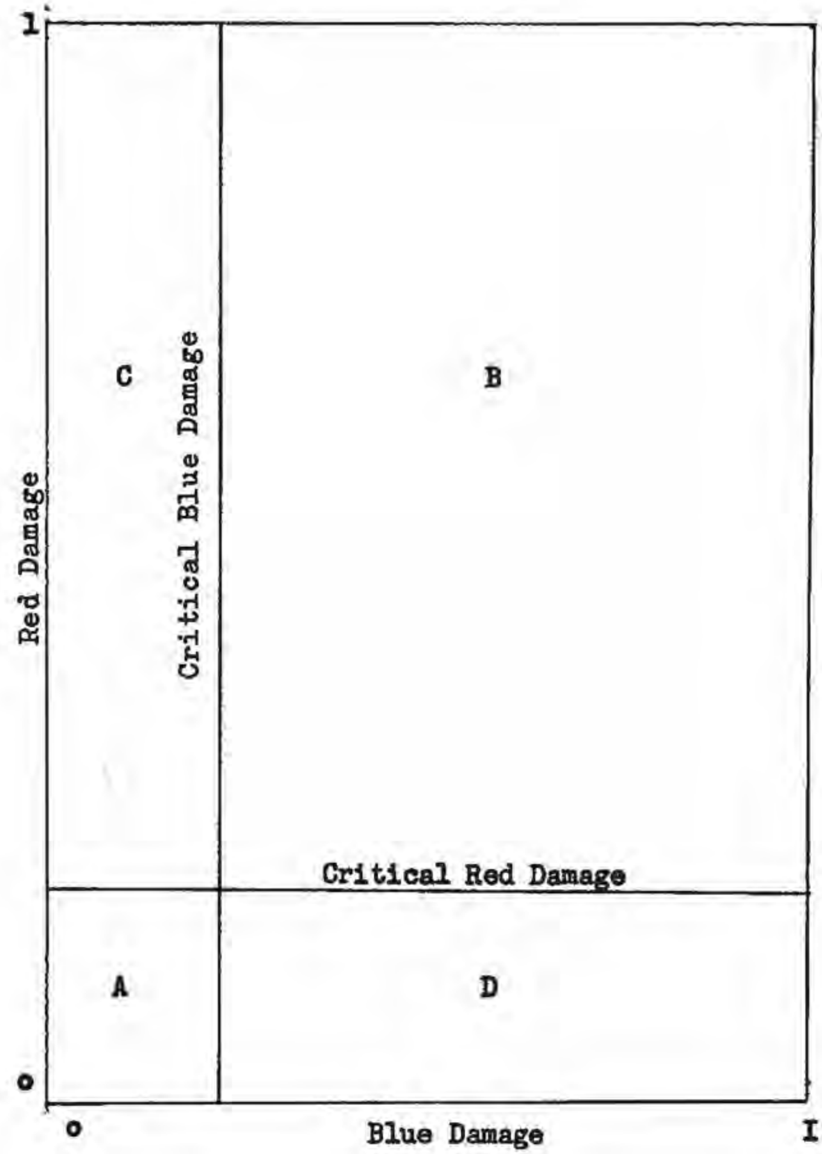
Criteria A

We postulate that a potential aggressor, when rational, sets some level of damage to his cities and population that he is willing to accept but that he is deterred from making such an attack if he expects greater damage than the postulated level. We also postulate that there is a level of damage to the enemy's cities and population which the aggressor sets as being a critical level of damage and one which he would like to exceed if an attack is to be successful.* We illustrate these levels in Figure 1.

*This level is based on the assumption that without clear evidence that he is about to be attacked, no nation knowingly attacks an enemy which he believes he cannot defeat decisively.

FIGURE I

THE OUTCOMES OF CENTRAL WAR
Criteria I



The levels of critical damage to each nation are presented as fractions of national substance which for simplicity will be referred to in terms of industrial population deaths in this study. We have however insisted in our calculations that all attacks aimed at destroying population include attacks on cities which will give at least a comparable level of economic damage. Consequently, our value criteria are based upon both population and economic losses.

In terms of Figure 1, a potential Red aggressor would assess the outcome of his aggression as falling in one of the four areas indicated. If this outcome fell in area A then the attack would be considered indecisive though tolerable by the Red. If the outcome fell in region D, from capability considerations, Red might be motivated to attack, since he would inflict critical damage on Blue but would sustain less than critical damage himself. If the outcome falls in region B or in region C, then the potential Red aggressor would be deterred, if rational, by considerations of his own damage.

A potential Red aggressor must also consider the possible results of a first strike or surprise attack by Blue. If he assesses the results of such a blow to be in areas A or D, then he has little fear of a surprise attack by Blue. This is certainly the case if he estimates the outcome to be in area A, and even more the case if he estimates the outcome of a Blue surprise attack to be in area D. In this region he may be confident that Blue will not initiate a surprise attack, for here Blue's damage is critical whereas Red's damage is not. However, if the outcome were estimated to be in area C, then Blue has strong motivation for an initial first strike of his own, and Red must reconsider and reevaluate the desirability of a first strike by himself.

Estimating that he will sustain more than a critical level of damage if Blue strikes first, Red probably increases the damage that he is willing to sustain as a result of a surprise attack of his own. At the very least he is motivated to increase his counterforce capability so that in the future he can eliminate this very real threat to his existence, and also his city defenses so that he can absorb a more severe blow. We regard this situation as unstable even though inspection agreements and/or agreements on arms control might have been reached; for Red would be motivated strongly to abrogate these agreements and to increase his military effort covertly. The converse situation applies equally to Blue and hence it must be concluded that the probability that a surprise attack will be initiated depends not only upon the capability of Red to inflict intolerable damage upon Blue while sustaining less than critical damage himself, but also very much upon Blue's capability to inflict intolerable damage on Red while sustaining less than critical damage to himself.

The relationship to stability of the differences in outcomes of first strikes by Red and Blue can be better seen if we order the outcomes in terms of preference. Assuming that Red, say, accords preventing damage to himself a higher priority than inflicting damage on Blue, but that for equal levels of damage to himself, he prefers higher levels of damage on Blue, and conversely for Blue's preferences, we obtain the ordering in Table 1.

TABLE 1

Outcome Preferences

Order of Preference	Red	Blue	Outcome Description
1	D	C	Attacks Motivated
2	A	A	Indecision
3	B	B	Deterrence
4	C	D	Positive Deterrence

Red prefers the outcome D most of all because it represents the least damage to himself and at the same time the greatest damage to Blue. He prefers A over B and C because A represents less than critical damage to himself while B and C represent critical damage to himself. He prefers B to C even though the damage to himself is the same because in B Blue sustains greater damage than in C. By combining similar Blue preferences with the Red preferences we are able to order the joint outcomes and hence the strategic postures which lead to these outcomes with respect to stability.

Referring to Table 1 it is obvious that the most stable posture is one in which a surprise attack by Red results in outcome C and a surprise attack by Blue results in outcome D. Neither side is motivated to attack the other side because to do so would not only result in an intolerable level of damage to himself, but also would not damage his opponent critically. An attack by either side would accomplish nothing but would be very painful. At the other extreme we find that an attack by Red would result in a critical level of damage to Blue, but the retaliatory strike would not damage Red beyond his tolerable level; conversely, a surprise attack by Blue would be critical to Red and the retaliatory strike by Red would be tolerable by Blue. This pair of outcomes represent extremely unstable postures because either side is motivated to attack not only because he can do so successfully, without critical damage to himself while inflicting critical damage to his opponent, but also because if he doesn't attack and his opponent does, his opponent is successful both in limiting his (the opponent's) own damage and damaging the potential aggressor critically. Representing the most stable case by C/D, the most unstable case by D/C, and the intermediate cases in a similar manner, and applying the relative preferences in Table 1, we arrive at the varying degrees of stability presented in Table 2.

TABLE 2

Degrees of Stability, Criteria A

Stability Level	Outcomes of Surprise Attacks USSR Attacks US // US Attacks USSR
I	Deterrence - deterrence
	C/D
4	C/B, B/D
3	B/B
II	Deterrence - Indecision
2	C/A, A/D
1	B/A, A/B
III	Indecision - Indecision
	A/A
IV	Indecision - Attacks Motivated
-1	A/C, D/A
V	Deterrence - Attacks Motivated
-2	C/C, D/D
-3	B/C, D/B
VI	Attacks Motivated - Attacks Motivated
-4	D/C

Now how do these results relate to inspection systems? It is clear that if an inspection system is proposed which results in an unstable posture (indicated in Table 2 by Stability Levels IV, V, or VI and by stability indices -1 through -4) then either one side or the other will reject the system if they assess its potentialities correctly. The strengths of the objections raised ought to be ordered according to the magnitude of the negative index. In contrast, both sides probably would accept Level III postures if convinced of their reality and stability over time, and if the strategic capabilities permitted them to deal adequately with third countries. Restrictions and/or merely inspection systems aimed at achieving Level III, or limiting the outcomes of surprise attacks and retaliatory blows to area A, are shown to be so unlikely as to require little consideration. It might be worthwhile to point out that with nuclear weapons with megaton yields the critical level of population loss, or population and industrial loss combined, generate extremely low operational requirements. Hence, if we consider inspection agreements which restrict the outcomes to area A, we are speaking of severe limitations in operating procedures and of almost impossible inspection and control procedures. As will be shown later in this report, even if limitations are considered, they involve numbers of ICBMs alone which are of the order of 15-100, depending on technological progress and ignoring the effects of manned bomber and submarine attacks. Agreements to limit just the number of ICBMs, and certainly the total level of strategic forces, to this level of capability would therefore require the destruction of numerous forces in being. Accordingly, restriction to area A will not be considered further in this report. There remains, therefore, only the Level I and Level II postures which are strategicly stable and which may possibly be attained by inspection systems accompanied by unilateral actions or even perhaps by a combination of arms controls and inspection procedures.

Inspection systems assessed as representing Level II stability denote postures in which neither side has motivation to attack. At stability Level 1, one side could launch an ineffective but non-painful attack, while the other side could launch an attack which inflicted critical damage to his enemy but only at the cost of critical damage to himself. At stability Level 2 one side is still able to launch an ineffective but non-painful attack; here one side, the second, is more "deterred" than at Level 1. Note that at Level 2, the side with the ineffective attack could provoke the side with the ineffective but also painful attack. But at Level 3 neither side can provoke the other for he fears that the other might react irrationally, in which case he will be injured critically; at this level both sides seek assiduously to avoid accidents and to prevent irrational behavior by the other side. At Level 4 we find that if one side attempts an attack which limits his own level of damage to less than critical in the process of doing so he will fail to inflict a critical level of damage upon his enemy. Thus he is less motivated to attack than before. The opposite side is still able to launch a critical but painful attack, but he has less fear of irrational behavior or of quick response to accidents than before; he is, of course, more able to bluff or provoke than before, but has no greater motivation to launch a surprise attack. Since one side is less capable of launching a surprise attack at Level 4 than he was at Level 3, while the other side has equal capability but less fear, we regard Level 4 as the more stable one. As indicated previously Level 5 is obviously the most stable of all.

The lack of symmetry in offense effectiveness and other secondary constraints such as greater ability to provoke one's enemy through actions less than but including "accidental" single nuclear explosions will make Levels 1, 2, and 4 difficult to attain by inspection or control agreement, but they are preferable to the unstable postures. Level 3 is regarded as a more likely goal, certainly for the early sixties when missile forces will be not too well protected; however, Level 5 remains the ultimate goal so far as stability with respect to surprise attack is concerned. This level is so stable in fact that if it were achieved there would be very little fear that strategic forces would ever be used by rational opponents.

Agreements aimed at limiting the outcomes of strategic thermonuclear exchange to those in area B require, first of all, that in the face of a surprise attack, each side have the capability of doing a critical level of damage to the aggressor. This implies that these levels of damage set absolute minimum force requirements, but in fact they also specify the quantity of strategic power which must remain after a surprise attack by the enemy. Inspection systems accompanied by unilateral actions might in fact change the forces involved in a surprise attack and/or modify timing so that the strength of a surprise attack would be reduced and the required quantities of strategic power would remain after a surprise attack by either East or West. It is also clearly possible that without appropriate unilateral actions, the information produced by inspection systems might reveal vulnerabilities or improve target information to the point where such quantities of strategic power would definitely not be left after an attack. These are points which obviously must be investigated in great detail and the effectiveness of an inspection system or of limitations superimposed on inspection systems in restricting outcomes to area B cannot be assessed without such detailed study in a broad strategic framework.

Even within Area B there are some asymmetries which might lead to unstable strategic postures. It should be recognized at once that the critical levels of damage which we have postulated are not very clearly defined, and that a more accurate representation would show these critical levels as bars rather than as lines. The width of the bars would indicate a region of uncertainty or a region in which recovery was insured but in which the length of time required for such recovery would be limited but might not be definitely determinable. We might consider the case in which a Red surprise attack would result in Red damage which was only slightly more than critical, but would result in Blue damage which was clearly beyond any level from which Blue might recover. In terms of times required for recuperation Red might be able to rebuild his economy and become a viable nation, say, in a period of 5 years. On the other hand it might take Blue something of the order of 20 to 25 years to do the same thing, or in fact, he might be so severely damaged that he could never rebuild his country and would always be a second-rate power. If the converse situation were also true when Blue attacked first, then one would have to consider the strategic postures relatively unstable. Both sides would be motivated to launch a surprise attack in order to prevent his own country from being devastated, agreeing to accept a fairly critical level of damage, but a level at which his recovery would be assured in a reasonably short period of time. According to the criteria already established, an attack by either party would be considered irrational, since he would be subjecting himself to a fairly critical level of damage. However, if the international situation became very tense, or if he had any reason to believe that his opponent was irrational and/or if he distrusted his opponent's intentions, as appears to be the case between East and West today, then such an attack might assume a much greater degree of rationality. In order to take care of circumstances such as these we have attempted to consider a second level of damage which we call lethal level of damage.

<u>Criteria B</u>

We postulate a second level of damage which we consider to be on the threshold of national destruction. We shall refer to this level as the lethal level in subsequent discussions. This threshold is taken in terms of the nation's ability to recuperate over a very long period of time, say 15 to 20 or 25 years. Damage at the lethal level would not merely be critical but would tend to be catastrophic and would subject the nation to the clear possibility that a now second-rate power could in fact dominate it completely. We suggest that a nation would be absolutely deterred from initiating a surprise attack if the retaliatory capability were such that this level of damage would be inflicted with a reasonable probability. This level provides some degree of protection against irrationality and against premature retaliatory strikes as a result of misinformation or accidents. In either inspection or control systems we suggest that this level ought to provide a limit to the damage that could be inflicted by either side no matter what their intentions might be, and believe that at the very least unless such systems assured lethal damage to both sides when lethal damage was inflicted on one side, agreement to accept these systems could not be reached.

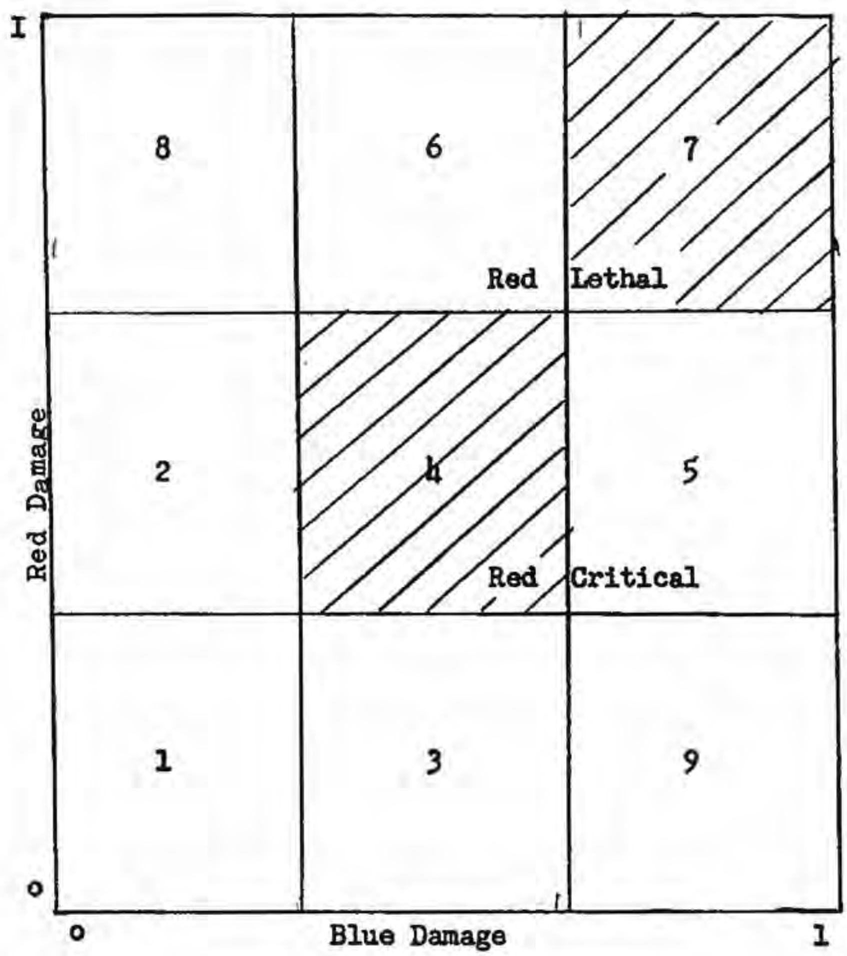
The combination of criteria A and criteria B requires that the relative levels of strategic power aimed at an inspection or control agreement must be sufficiently high to permit effective retaliation in the face of surprise attack, but not large enough so that covert production by either side or evasion would not permit a greater than lethal damage to either side asymmetrically regardless of intent in a surprise attack.

The combined result of the two sets of criteria is illustrated in Figure 2. Here the shaded area and the two heavy lines represent the region of outcomes resulting from total war initiated by surprise attack in the early sixties. The upper right hand corner of this region represents a situation in which neither side pays any attention at all to enemy retaliatory capability, but merely fires away at cities attempting to destroy the nation. The lines leading from the lower left-hand corner to the axes, on the other hand, represent the outcome when both powers employ their strategic forces in an attempt to destroy each other's retaliatory capability in a surprise attack.

It should be observed that no actual outcomes would arise along these heavy lines in practical cases because of the coupling which exists between population and offensive forces. For suppose that Red attacks Blue by surprise and concentrates the bulk of his strike on retaliatory forces. Because of this coupling between offensive forces and national substance, the damage done to Blue cannot be zero. The damage done to Red in the return strike would depend entirely on Blue's tactics. If he chose to use all of his retaliatory capability against Red's cities, then Red would sustain the critical level of damage. On the other hand, if Blue's retaliatory strike attempted to eliminate the strategic power which had not been launched in the initial surprise attack, then the damage done to both sides would be limited to that involved in the coupling between strategic striking forces and cities. In some cases this could be quite high, but for the pure missile exchange with

FIGURE 2

THE OUTCOMES OF TOTAL WAR
Criteria I & II



currently stockpiled weapons, it appears that this coupling is somewhat less than the critical level of damage even in the absence of fallout shelters; but under future technology, a strategic posture which would result in outcomes confined essentially to area 4 may be impossible without arms control.

Stability with respect to surprise attack under the combination of criteria now takes on a somewhat different meaning. Not only are there postures in which one side may produce critical damage without sustaining critical damage, but also postures in which one may produce lethal damage without sustaining critical or lethal damage. It is quite simple to order both Red's and Blue's preferences in terms of outcome. However the number of combinations is much larger in this case than in Figure 1. For example, Red obviously prefers areas 9, 3, 1, 5, 4, 2, 7, 6 and 8 in that order. Blue prefers 8, 6, 7, 2, 4, 5, 1, 3 and 9 in that order. The possible pairs of outcomes have not been analyzed in the same detail as in the case of criteria A alone. However Table 3 is suggestive of an ordering of a number of these outcomes. We see that the most stable cases are those in which the attacker regardless of which side he happens to be receives a lethal level of damage. The most unstable cases are obviously those in which either side receives a lethal level of damage if he does not attack, but inflicts a lethal level of damage on his opponent if he does, and at the same time reduces his own damage to less than critical. It appears that the pairs of outcomes for the two criteria can be ordered with respect to the stability of the postures which they denote. However, not as simply as in the case of Criteria A alone.

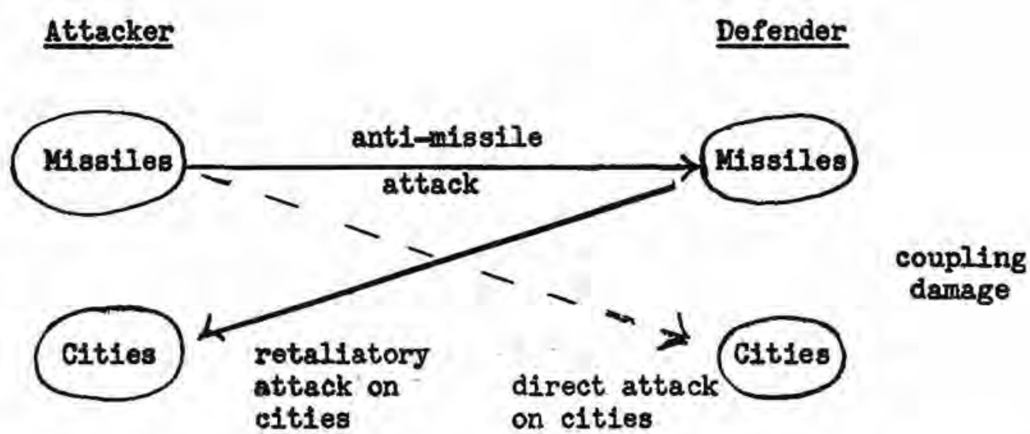
In summary, in this Part we have related the probability of a surprise attack being initiated to the combined outcomes of surprise attacks by Blue and by Red. We have ordered the pairs of outcomes with respect to stability when only criteria A are considered, and suggested a partial ordering of the outcomes for the combined criteria. More importantly we have presented a concept of a two-sided war game and of a strategic framework within which we believe inspection and/or control systems must be evaluated if the total effect of such systems on the strategic posture of the United States vis-a-vis that of Russia is to be determined.

PART II - STABILITY OF PURE MISSILE SYSTEMS

INTRODUCTION

As an application of the concept developed in Part I, the stability of postures resulting from pure missile systems alone will be determined numerically for a range of conditions. These conditions pertain to the force levels, technological efficiency of missiles, configuration of missile bases, and hardness of missile bases. Specifically, the strategic posture under each combination of these conditions will be equated to one of the postures 1, 2, —— 9 shown in Figure 2 of Part I.

The calculation of the strategic posture will be carried out according to the following model.



a. The attacker launches a surprise anti-missile attack upon the defender's missile sites.

b. In conjunction with his attack on the defender's missile bases, the attacker damages the defender's cities. If the coupling damage (i.e., bonus damage to cities by an attack on missile bases) reaches the requisite level (critical or lethal, both cases are considered) no direct attack on cities is made. If the coupling damage does not reach the requisite level, a direct attack on cities is made so as to bring the defender's city damage up to the requisite level.

c. With his remaining missiles, the defender launches a retaliatory attack upon the attacker's cities. Whether the retaliatory attack does less than critical damage, between critical and lethal damage, or greater than lethal damage is determined.

In order to carry out calculations according to this model, it was necessary to select numerical values for the critical level of damage and the lethal level of damage. Obviously, specification of these levels must be quite arbitrary at best. The critical level of damage was taken to be 20% urban population deaths; the lethal level of damage was taken to be 50% urban population deaths.

The rationale for the selection of the 50% urban deaths as the lethal level was as follows. If the 50% urban deaths was incurred in an attack against cities, something over 50% of industrial floor space would be destroyed. This combined with 50% urban deaths and 19% additional urban casualties should sufficiently impair the economy of the country and disrupt and social organization that neither the USSR or the US could continue to exist as a nation. One might question that 50% urban deaths to the USSR when incurred by fall-out coupling in conjunction with an anti-missile attack would constitute a lethal level. But in this case 50% of the entire population is killed and many are injured. The 20% urban deaths for the critical level was selected as being roughly equivalent to 30% industrial floor space — certainly critical level of damage to both sides, but probably not lethal.

CONDITIONS AND ASSUMPTIONS

The calculations were carried out under conditions of symmetry between the two sides so far as force levels, technological efficiency of missiles, configuration of missile bases, and hardness of missile bases were concerned. The calculations are also based on conditions of symmetry so far as the degree of shelter afforded the populations is concerned.

a. Force Levels. The two sides were given the same numbers of ready missiles, namely: 100,200, 400 or 800. The term "ready missiles" is interpreted here to mean missiles which are physically located at the launching sites and could be fired during the initial attacker's blow or the defender's counter blow. Duds and non-operational missiles at the launch sites were not specifically considered. However, they are taken care of implicitly by considering them to be non-ready according to the above definition.

b. Missile Base Configuration. On both sides, all bases were assumed to possess three ready missiles. The bases were considered to be sufficiently dispersed so that no more than one base could be knocked out with one bomb. This is not a strictly accurate picture of the planned US base structure either on the near term or the long term, but is a rough average over bases which will in fact vary from a 1x1 configuration to a 1x9 configuration. In the absence of information on the planned USSR base structure, it was assumed to be a mirror image of that of the US. Both sides were assumed to have perfect intelligence on locations of their opponent's missile bases.

c. Technological Efficiency. Yields and CEP's were selected so as to bracket those which might be expected to occur in practice. Yields of $\frac{1}{2}$, 2 and 10 MT and CEP's of $\frac{1}{2}$, 1, 2, and 5 nautical miles were used. The yields and CEP were varied independently, giving 12 combinations. Each of the 12 combinations was given symmetrically to the two sides.

d. Hardness of Missile Bases. The hardness of the missile bases was varied from 2 psi, taken to be representative of bases presently under construction by the US, to a degree of hardness such that the target missile must be within the area of the crater and lip of a surface burst (abbreviated "CPL"). Numerical values of 2, 10, 25 and 100 psi and CPL were used in the calculations. The same degrees of hardness were attributed to both sides.

e. Vulnerability of Urban Population to Blast Damage. Vulnerability of the USSR urban population to blast damage was taken from Urban Blast, Weapon Yields, and Delivery Accuracies (U) by Norman Hanunian (RM-1671). This document gives the fraction of urban population killed by blast in each USSR city of over 100,000 population as a function of yield, CEP and number of weapons. A doctrine of targeting is used which destroys the largest fraction of industrial floor space. Analagous figures on the vulnerability of the US urban population were taken from Thermonuclear Weapon Effects on United States Industry and Population Concentrations (U) (ORO-R-16, Vol I). This document gives number of deaths in each of the principal US cities for one weapon burst at a specified ground zero as a function of yield and ground zero. By a graphical method, the effect of a number of bombs with specified CEP's targeted against specific points may be obtained.

f. Vulnerability of Urban Population to Fallout. The vulnerability of urban populations to fallout, both for the US and the USSR, were taken from Simple Formulas for Calculating the Distribution and Effects of Fallout in Large Weapon Campaigns (with Applications) by Everett and Pugh. Although total population deaths rather than urban population deaths were given, for purposes of this paper, the urban population is considered to receive its pro rata share of the total deaths. Fallout deaths from two types of attacks were used: direct attacks on cities and attacks on missile sites. In the document, curves are given for attacks to maximize population deaths, attacks on airbases, and attacks uniformaly distributed over the country. Fallout deaths from direct attacks on cities were taken from the first case. Fallout deaths from attacks on missile sites were assumed to be halfway between the airbase and uniform attack curves, since it is reasonable to assume that future missile sites would be correlated with population centers only to half the degree of present airbases.

STABILITY FOR VERY FAST RESPONSE SYSTEMS

The effects of warning and response time is a critical factor in estimating the success of an attack or a defense. In this paper two cases will be considered to provide upper and lower limits in warning and response time. At one extreme we will assume that the defender can fire all his missiles before the first attacking missile lands. This is a case of perfect warning and perfect response. At the other extreme, we will assume that the defender can fire no missiles until after the attacker's last missile lands. All real cases lie somewhere in between these two extremes. We will deal first with the fast response system.

Our purpose is to provide estimates of the number of missiles required by the US and the USSR to damage the population and economy of the other. These estimates will indicate how few missiles, in some cases, are needed to annihilate a country and how the Soviet requirements to damage the United States can differ markedly from the US requirements to inflict the same damage on the USSR. We will use the concepts of critical and lethal damage introduced earlier in this paper to calculate these requirements. Finally, we will draw some rather obvious conclusions regarding the effects of these missile requirements on inspection systems and the possibilities of achieving stability by inspection and by inspection plus limitations.

The basic data is given in Table II-1. Here we show the number of weapons required to inflict 20 and 50 percent blast deaths to the population in cities over 100,000 in the US and USSR, for the yields and accuracies likely to be achieved in the period from 1960 to 1970.

TABLE II-1

WEAPON REQUIREMENTS

		CEP in n. mi.			
		½	1	2	5
500 KT	20% US	70	75	80	85
	20% USSR	35	50	85	240
	50% US	250	260	290	450
	50% USSR	200	380	560	1600
2 MT	20% US	50	55	60	75
	20% USSR	20	20	40	100
	50% US	210	220	250	370
	50% USSR	100	110	210	620
10 MT	20% US	20	20	20	35
	20% USSR	10	15	15	35
	50% US	90	90	95	140
	50% USSR	70	85	85	220

Two facts stand out when this table is examined: the very low number of missiles required to inflict decisive damage on a nation; and the asymmetric situation of the US vis-a-vis the USSR in requirements. Between 10 and 240 missiles on Soviet cities will kill 20 percent of his industrial population and destroy 30 percent of his industry. Between 20 and 100 missiles on US cities will do the same. More weapons are required to kill a fraction of the US industrial population than to kill the same fraction of Soviet industrial population, except for very large yields or very inaccurate missiles. This is because US cities are larger in area and less densely populated than Soviet cities. To raise the damage from 20 percent to 50 percent requires about four times as many missiles on US cities, about six times as many missiles on Soviet cities.

Table II-1 considers only blast deaths. If we include fallout deaths, the requirements for fast response systems are not reduced as far as damage to industry and industrial populations are concerned. Fallout deaths in blasted cities are negligible. Damage to farms and deaths to farmers cannot be treated in a straightforward manner for a variety of reasons.* They can be considered purely as a bonus effect for the attacker.

Fallout deaths on cities resulting from attacks on missile bases will be treated only for slow response systems, since there is no reason for fast response systems to attack missile bases.

* Two among many reasons for the complexity of the farm damage problem are the relationship between reduced crop production resulting from fallout and fewer mouths to feed resulting from deaths to city populations on the one hand; and the callous Soviet attitude toward farm populations on the other.

The conclusions from this brief analysis are simple and direct.

First: parity in numbers of missiles rarely means parity in damage because US cities present a different target system from that of the USSR.

Second: the number of missiles needed to inflict critical damage on industry and population is less than 100 today and, with progress in technology, may be no more than 20 by 1970.

The implication of the conclusion to the question of stability by inspection relates to the Soviet penchant for parity. The imbalances in the concentrations of population and industry of the US compared to the USSR are such that numerical and qualitative parity in missiles practically guarantees that the results of an attack will favor one side or the other. Parity and stability, therefore, are not synonymous but antithetical.*

The implications of the second conclusion to the problem of creating a stable situation by inspection are also simple and direct. Both sides have the capability of producing covertly enough missiles to inflict critical damage to the other. If 10 megaton missiles with ½-mile CEPs are built, neither side could ever hope by inspection to prevent the other from inflicting critical damage by these missiles if they were deployed covertly and were consequently invulnerable to attack.

The stability which is achieved under these conditions, therefore, is the stability of mutual deterrence or mutual annihilation, until and

---

* The fact that Table III-1 indicates that parity in missile favors the US should not be taken too seriously. The table does not represent the results of a war game, but an extreme case to provide a lower bound to the numbers of ICBMs required to inflict a certain amount of damage.

unless an active anti-missile missile defense can be created. Without such a defense, both sides will live with the certainty that the other could, if it wished, deploy enough covert force to insure effective retaliation. If both sides create simultaneously an anti-missile missile capability, the effectiveness of such covert deployment drops rapidly. As the AICBM improves, the problem of covert deployment disappears. On the other hand, if one side creates even a marginally effective anti-missile missile capability, stability itself disappears. The side possessing the AICBM can attack with considerable assurance that the covert and hence unknown missile sites of the other will pose no threat.

Our general conclusion, therefore, is that advancing technology in ICBMs will prevent inspection from achieving more than a marginal kind of stability, and that the introduction of the AICBM by one side can destroy even that margin of stability.

STABILITY FOR VERY SLOW RESPONSE SYSTEMS

We now examine the other end of the spectrum — the case when the attacker can fire all of his missiles before the defender can fire back. This single-attack model was described in Section II.* The attacker fires enough missiles at his opponent's bases to reduce his own damage to 20 percent. If he has any missiles left, he fires them at cities. The defender fires all of his missiles at cities. This extreme case should be the most favorable possible for the attacker so far as

*CONDITIONS AND ASSUMPTIONS

response times are concerned. Even then as we shall see, the attacker sometimes inflicts more damage than he receives.

The analysis considers both critical (20 percent) and lethal (50 percent) damage to the industrial plant and/or population. Both blast and fallout were considered as lethal agents. Fallout sometimes can cause critical or lethal damage to the nation solely as a by-product of attacks on missile bases.

The model assumes identical numbers of missiles, identical characteristics, and identical base deployments and vulnerabilities. The widely varying outcomes are another demonstration of the dangers of assuming that parity in any of these things make for parity in the outcome of a war or for stability in peace.

Stability has been discussed at length in Part I. For this section we use the 12 steps between the most stable to the least stable situations to illustrate the effect of varying yields, CEPs, base hardening, and numbers on the stability.

The definition of stability requires an analysis from the Soviet point of view of the outcome if he makes a surprise attack on the US as compared with the outcome if the US makes a surprise attack on him. The most stable situations are those in which the initiative leads to disaster for both. The least stable situations are those in which the initiative on both sides leads to annihiliation of the other without damage to the initiator. The in-between cases include mutual deterrence, mutual ineffectiveness, and attack without risk and, hence, without fear of retaliation. The most stable case we will designate + 6; the most unstable case -5; and 0 the case where neither side by surprise attack either produces or receives critical damage.

The results are shown in Table II-2. We have shown the degree of stability for each of three missile yields, and four missile stockpiles, ranging from 100 to 800 ICBMs, for various CEPs and base hardnesses.

The patterns in these charts are straightforward.* Soft bases, accurate delivery, and larger yields make for instability. Numbers seem much less important. The chief effect seems to be that larger numbers make unstable cases more unstable and stable cases more stable, with a very slight trend toward increasing stability as the number of weapons increases.

Base hardening will compensate for yield to some extent, but it cannot compensate for increased yield and lower CEPs in combination. 10-MT missiles with a ½-mile CEP are unstable for all stockpiles, even against bases which can be destroyed only if they lie within the crater-plus-lip of a surface burst weapon.

The conclusions drawn from this table are not unexpected. Technological advances will make stability more difficult rather than less difficult to achieve. Parity in numbers and in quality has little effect on stability. The asymmetries in the geography and population concentration of the US and USSR make it unlikely that parity in numbers of identical missiles and missile bases would create stable

* There are a few apparent anomalies, for example, the 2 MT, 5 n.m. CEP, Crater plus lip case which is unstable. This results from the asymmetry between US and USSR cities. The USSR is incapable of inflicting 20 per- cent deaths on the US with 100 2 MT weapons, so that the entire US attack, in both attack and retaliation can be directed at Russian cities. The same thing nearly occurs 500 KT.

TABLE II-2

STABILITY FOR SLOW RESPONSE ATTACKS

500 KT

100 missiles

	CEP n.mi. ½	1	2	5
2	-4	-4	-4	0
:0	-4	-4	-1	0
25	-4	-1	0	0
.00	-1	+2	+2	0
:PL	+5	+5	+5	+2

200 missiles

	CEP n.mi. ½	1	2	5
2	-4	-4	-4	0
:0	-4	-4	-1	+2
25	-4	-2	+5	+2
.00	-1	+5	+5	+2
:PL	+5	+5	+5	+2

400 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	-2
:0	-5	-4	+5	+5
25	-5	+5	+5	+5
.00	+5	+6	+5	+5
:PL	+2	+6	+6	+2

800 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	-2
:0	-5	-5	+5	+6
25	-5	+5	+6	+6
.00	+5	+6	+6	+6
:PL	+5	+6	+6	+2

2 MT

100 missiles

	CEP n.mi. ½	1	2	5
2	-4	-4	-1	-1
10	-4	-4	-0	-0
25	-4	-4	-2	+2
.00	-4	-1	+2	+2
:PL	+5	+5	+5	-2

200 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-4	-4
10	-5	-5	-4	+5
25	-5	-5	+5	+5
.00	-5	+5	+5	+5
:PL	+6	+6	+5	+5

400 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	-4
10	-5	-5	-4	+5
25	-5	-5	+5	+6
.00	-6	+6	+6	+6
:PL	+6	+6	+6	+6

800 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	+6
10	-5	-5	-5	+6
25	-5	-5	+6	+6
.00	-5	+6	+6	+6
:PL	+6	+6	+6	+6

10 MT

100 missiles

	CEP n.mi. ½	1	2	5
2	-5	-4	-4	-4
10	-5	-4	-4	-4
25	-5	-4	-4	+5
.00	-5	-4	+5	+5
:PL	-4	+5	+5	+5

200 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	-5
10	-5	-5	-5	+5
25	-5	-5	+2	+5
.00	-5	-1	+6	+6
:PL	-2	+6	+6	+6

400 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	-5
10	-5	-5	-5	+4
25	-5	-5	+4	+6
.00	-5	+1	+6	+6
:PL	-2	+6	+6	+6

800 missiles

	CEP n.mi. ½	1	2	5
2	-5	-5	-5	-5
10	-5	-5	-5	+6
25	-5	-5	+3	+6
.00	-5	+3	+6	+6
:PL	-2	+6	+6	+6

situations. The areas of Soviet cities differ radically from those of US cities. The vulnerability of the populations as a whole to fallout is almost precisely in the ratio of the average population density in the two countries.

Not shown in the table are the excess missiles remaining on both sides for the unstable cases. The excess on the Soviet side would then be available for attacking IRBM bases, SAC bases, surface-to-air missile defenses, and radar installations. If we consider only unstable cases for 400 and 800 missiles with ½-mile CEPs, we find approximately one-half of the missiles remain unused for attacks against either ICBM or population targets. This is the reason for neglecting reliability in the analysis. For reliabilities of 80 percent or better, few unstable cases would become stable.

The slow response case indicates that inspection, even coupled to limitations of ICBMs alone can have little chance of achieving ICBM stability in a world of advancing technology. It appears that AICBM and perhaps progressive disarmament, keeping pace with advancing technology are needed. Even if both sides could be reduced to no more than 100 missiles, which were placed in extremely hardened sites (vulnerable only if within the crater plus lip), we will have instability when 10 MT warheads on ½-mile CEP missiles become available. Since the fast response case indicated that 10-20 such missiles could inflict catastrophic damage, there is little hope that inspection and ICBM limitation alone would provide stability against strategic attack with thermonuclear weapons.

EFFECT OF FACTORS OMITTED FROM THE ANALYSIS

The model for the analysis has been grossly over-simplified. The purpose of this section is to estimate the effect of some of the things omitted from the analysis on the stability of the strategic postures of the USSR vs the US. It should be recalled that we are <u>not</u> concerned with the outcome of realistic campaigns, but only with the degree of stability resulting from the views of each side regarding the ease or difficulty of the other's making a successful surprise attack. Five factors will be considered: response times intermediate between the two extremes covered in the preceding sections, population warning and shelters, active defenses and warning systems, more dispersed ICBM deployments, and other strategic attack systems. In each case, we will discuss briefly the effects when the US and USSR doe not have identical capabilities.

1. <u>Intermediate Response Times</u>. It is, of course, unrealistic to assume that the attacker can complete his attack before the defense can retaliate or that the defender can complete his retaliation during the time of flight of the attacker's missiles. To gain some quantitative insight into the effect of an intermediate case, a two-attack model was set up and roughly analyzed. Here, the attacker fires part of his capability in the initial wave; his remaining missiles are vulnerable to the defender's initial retaliation; the defender's remaining missiles are vulnerable to the second attack, which, to avoid overcomplexity, we will assume completes his attack. The defender's terminal capability is fired to complete the exchange.

For initial attacks of one-half to two-thirds of the attacker's capability and initial retaliations of one-third to one-half of the defender's capability, the attacker's ability to reduce his own damage from the defender's retaliatory missiles is lower by 5 to 20 percent than for the single-attack model. A more realistic analysis of response times, therefore, tend to increase stability, but the increase is not large. For accurate, large-yield weapons, it is negligible. Our overall conclusion is that the single attack model is an adeuate representation of the situation.

2. Population Warning and Shelters. Deaths to the urban population and damage to industry from both blast and fallout were calculates on the assumption of no warning and no shelter. The number of missiles required to kill by blast 20 or 50 percent of the industrial population in shelters is from four to ten times as many missiles as are required when the people are not in shelters. On the other hand, it is impossible for an attacker to warn his own population without also warning the enemy population. It is reasonable, therefore, to assume that both the attacker's and defender's populations are initially without shelter.* The fallout deaths, on the other hand, can be radically altered by shelter. Since it takes times for fallout to reach areas beyond immediate blast damage, it should not be difficult to reduce sharply the fallout deaths in cities

* There is one case which might radically alter this conclusion: if the one side made a surprise attack while a nation-wide air-raid drill was in progress. It might be well for both countries to hold simultaneous air-raid drills, if stability is desired. An agreement to do this might be on the agenda for the conference.

from attacks on missile sites. If fall-out deaths by attacks on missile sites are eliminated, examination of the pattern of stability shows that there is a very slight increase in stability for large numbers of large yield weapons. Since these cases are stable anyway, this factor does not appear to be important.

Let us now consider the asymmetric case where one power has protected its population from fall-out more than the other. Two facts should be recalled: the Soviet urban population is more vulnerable to blast than the US urban population; but the Soviet population is much less vulnerable to fall-out than the US population. Leaving aside any consideration of the relative values given to human life by the two governments, it is apparent that fall-out shelters in the US would affect stability to a greater extent than shelters in the USSR. If the US undertook an extensive fall-out shelter program, many unstable cases would become stable. This is because Soviet attacks on US missile sites would no longer produce critical or lethal damage in terms of urban deaths. The comparable case of an attack on Soviet missile sites affects stability to only a minor degree since fall-out deaths in cities are low, even without shelters.

We may conclude, therefore, that hardening the population tends to increase stability. The tendency is more pronounced if the US provides shelter than if the Soviets do.

3. <u>Active Defenses and Warning Systems</u>. In Section III* we indicated that the development of AICBM defenses seems to be the only way to achieve stability in the fast response case, when both sides

*STABILITY FOR VERY FAST RESPONSE SYSTEMS can inflict decisive damage by only 10-20 covert missiles. In the slow response case, although there are also instances when a very few missiles may make the difference between stability and instability, there are many more situations in which AICBMs may contribute to stability.

Table II-2 shows clearly the effect of base hardening and CEP on stability. Suppose each ICBM base were given the capability of three ICBM kills, on the average. Three is also the average number of missiles fired at a missile site for those cases which lie very close to the boundary between stability and instability. The AICBM capability doubles the attacker's requirements to keep his own damage from retaliation below the critical level.

There has been talk of the capability of AICBMs to increase the CEP of missiles by near misses. If this capability exists and it is possible to double the CEP of ICBMs from ½-mile to 1-mile, the attacker would require 3 to 4 times as many missiles on the enemy's capability in order to be safe from retaliation. Even a modest AICBM program might make it possible to achieve stability in the face of very accurate high-yield ICBMs.

The assumption has been, in the preceeding discussion, that both sides have identical AICBM capabilities. It has been pointed out, however, that geography favors the US over the USSR so far as early warning is concerned. It is doubtful whether a Soviet ground-based, ballistic missile early warning system could achieve warning times under 10 minutes of an ICBM attack. The US, on the other hand, appears to possess an average capability of more than 20 minutes. This asymmetric position could place the USSR at a substantial disadvantage in the BMEWS-AICBM race. The advent of the reconnaissance satellite, however, may restore the balance from the Soviet point of view.

One further point deserves mention. It may become more and more difficult to distinguish between ICBMs and AICBMs, as missile technology improves. Arguments such as these demonstrate that the effectiveness of AICBMs in producing stable strategic postures cannot be treated in a simple manner. The problem requires far more study before reasonably valid conclusions can be drawn.

4. Missile Site Configuration. The slow response system assumed a single missile base configuration: 1x3. This means that a single perfectly delivered ICBM can destroy three ICBMs by surprise attack with slow response. Let us now examine the effect on stability of other types of missile bases.

One extreme is the 1x1 configuration. In this case, one perfectly delivered missile can never destroy more than one missile. If the number of bases is the same for both sides, this configuration would be the most stable one, other things being equal, by making it most difficult for either side to eliminate by surprise attack the other's retaliation on himself.

Despite the asymmetries in missile requirements to inflict equivalent damage on the US and USSR, possession of 1 x 1 bases by both sides increases stability for both small and large yield missiles. The important asymmetry is asymmetry in missile base configuration. If Soviet missiles, by surprise attack, could kill 3 US missiles, while US missiles in a surprise attack could only kill one Soviet missile, the situation would be rather unstable. Here, perhaps, is one direct and obvious advantage of an inspection system in improving stability. It would allow both sides to keep ICBM base configuration from being a source of instability.

5. Other Strategic Systems. We have examined only a small part of the problem of strategic stability in our discussion of pure ICBM systems. The present analysis will become more relevant to the overall problem as missile forces replace bombers as the principal means of strategic attack and retaliation. This will not occur in the US for at least 5 years, although by the late 60's it will be true. To the extent that ICBMs can be regarded as the hard core of a nation's attack and retaliatory capability, the stability of these systems will indicate the stability of the general strategic posture of the US vis-a-vis the USSR. It then becomes necessary to determine the extent to which such a stability, if it could be achieved, could be upset by the existance of other strategic systems.

Manned bombers, submarine-launched missiles, merchant ships and other surface ships capable of launching cruise of ballistic missiles, and IRBMs are all capable of attacking ICBM bases. With reasonable warning systems and a reasonably large number of bases, manned bombers do not appear to have the capability of making a surprise attack on ICBM sites with a reasonable chance of success, particularly if the ICBM bases are deep in the interior of continents. Manned bombers appear to be more effective in attacking a nation's population and economy. If anti-aircraft and interceptor defenses are weak, even a small bomber force could achieve decisive damage with multiple loads of thermonuclear weapons. Such a situation would upset any established stability with respect to ICBMs only. The bomber force, itself, would require a portion of the missile force for its destruction which would not then be available for the destruction of missile bases or cities.

Submarine-launched missiles could be a force for stability as well as a force against stability. In the immediate future, the relative invulnerability of the submarine is balanced by the small warhead carried by the POLARIS. Their part in a counterforce action may be restricted also because of communication difficulties. Overall, it does not appear that the submarine-launched missile will play a major role in creating or destroying stability until and unless very large numbers of very large yield warheads are available.

IRBMs could have an asymmetric effect on stability. They contribute directly to the US capability of making a surprise attack on the USSR but they do not contribute substantially to the US retaliatory force because of their exposed position and soft condition. The mere existance of IRBMs in overseas bases may change the timing of USSR surprise attacks, particularly if inspection systems are agreed to and may contribute indirectly to the US retaliatory capability by providing a means of early warning.

There are many other strategic attack systems which could be considered, but little would be gained by further listing of possible developments during the next few years. Most of these systems increase stability when the size of the ICBM force is low. Most of them also have little effect when the ICBM stockpile is large with high-yield accurate warheads because the requirements in such missiles to destroy the retaliatory capability and inflict catastrophic damage are so small that additional systems cannot have a significant effect.