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Treaty Verification Program

Deterrence of Arms Control Treaty Evasion by Suspect Site Inspections

By

M. J. Lippitz
R. S. Strait

Systems Research Group
Lawrence Livermore National Laboratory
Livermore, CA

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Lawrence Livermore National Laboratory

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Deterrence of Arms Control Treaty Evasion by Suspect Site Inspections

Abstract

Deterrence of evasions is an important benefit of arms control treaty verification measures in general, and suspect site inspections in particular. In this report, we present an analytical framework for evaluating the deterrence effect of verification measures and discuss the framework in the context of suspect site inspections. The framework incorporates the effects of verification measures on both the probabilities of detection and the evader's values of evasion.

1. Introduction

Future arms control treaties may provide for inspections—anywhere, anytime, on short notice—of sites suspected of harboring treaty evasion activities. The U.S. has strongly advocated these suspect-site inspections (SSIs) under START because of the need to verify residual levels of strategic weapon systems. In the Joint Summit Statement (December 10, 1987), both the Soviet Union and the U.S. agreed to "the right to implement, in accordance with agreed-upon procedures, short-notice inspections at locations where either side considers covert deployment, production, storage or repair of strategic offensive arms could be occurring."

In order to negotiate the protocols for SSIs and to implement the negotiated inspection provisions, the U.S. must have a thorough understanding of the benefits and costs of SSIs. The greatest potential benefits are the detection and deterrence of treaty evasions by the signatories. Unfortunately, it is believed that the Soviet Union will use whatever means at its disposal to prevent an SSI or other on-site inspection from ever actually detecting an evasion.[1] Nevertheless, SSIs may still serve as a deterrent to treaty evasion. Other potential benefits include building confidence in the strength of the treaty and reducing the possibility of false accusations. The costs of SSIs include the financial expenditures for fielding and hosting inspections as well as the risks of loss of sensitive information as a result of intelligence gathering by the inspecting party.

In this paper we use quantitative techniques to analyze and develop insights about the possible deterrence effects of SSIs. We present several approaches for understanding how SSIs impact the ability of one of the treaty signatories (called "the inspector" in this paper) to monitor the compliance of the other signatory (called "the inspectee" in this paper). In particular, we illustrate how SSIs could deter treaty evasion through their effect on the inspectee's perception of the expected value of evading the treaty's limitations. The results focus attention on the aspects of SSIs relevant to deterrence and provide a formal framework for assessing the benefits of SSIs in deterring inspectee evasions.

In Sec. 2 we present a general analytical framework for evaluating deterrence of arms control treaty verification measures. In Secs. 3 and 4 we discuss, respectively, the effects of SSIs on the probability of detection and on the inspectee's perceived values of undetected evasion. Section 5 combines the results of the preceding sections and presents a summary.

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2. Analytical Approach to Deterrence

Verification provisions deter treaty evasions by demonstrating that evasions are contrary to the verified country's interests.[2,3] Therefore, any analysis of the deterrence benefits of SSIs must focus on the verified country's perceptions of treaty evasions. Rowell[4] has stated that the two components of these perceptions are the "assessment of both the likelihood of being detected and of the nature of the U.S. response—likelihood, promptness, and severity." In this section we provide a general framework for analyzing the verified country's perceptions of treaty evasions. We discuss the likelihood of detecting a treaty evasion, the relative values to the verified country of evading a treaty with and without being detected, and then combine these two components into a single framework.

2.1 The Probability that Evasion Is Detected

The probability that a treaty evasion might be detected guides the actions of both the verifying (inspector) and verified (inspectee) countries. The inspectee must assess the probability of being caught evading, and the inspector must determine whether the evidence collected supports making an accusation. These joint decisions are inextricably linked and are very difficult to model. The inspectee's decision whether to evade will depend on the probability that the inspector will detect and respond to the evasion; likewise, the inspector's decision to respond will depend on some estimate of the inspectee's propensity for evasion.

For our analysis we will assume that the inspector's policy is to take action against the inspectee when the reading on some detector crosses a predetermined threshold, given a particular monitoring system. In reality, to choose such a threshold the inspector must consider the inspectee's propensity to evade and the inspector's relative values for mutual compliance, missed evasions, false accusations, and detected evasions. An in-depth discussion of the choice of a predetermined response threshold can be found in Judd et al.[5] Assuming a predetermined response threshold, the quality of the detection system—i.e., the physical detector and the policy—may then be modeled as follows:

x = the probability that the threshold is crossed if the inspectee evades,

y = the probability that the threshold is not crossed if the inspectee complies.

If the physical detector were perfect and the threshold correctly chosen, then both x and y would equal one, and the deterrence of evasions would be virtually ensured. Realistically, the inspecting side will occasionally make errors. The quantity $(1 - x)$ represents the probability that the detection system will fail to indicate an evasion when the inspectee is actually evading. This type of error is known as a "false negative." Similarly, the quantity $(1 - y)$ represents the probability that the detection system will indicate an evasion when the inspectee is actually in compliance. This type of error is known as a "false positive."

2.2 Inspectee Values for Evasion and Its Detection

A country contemplating treaty evasion must weigh the potential benefits of evading without being detected against the costs that will be incurred if the evasion is discovered and a response is undertaken. Evasions of arms control agreements may have many different characters. A large-scale, deliberate disregard of treaty terms may be undertaken in order to gain a significant military advantage. Smaller-scale evasions could represent hedging against abrogation of the treaty by the other side or a test of an adversary's monitoring capabilities and willingness to respond. It is also possible to imagine anomalous behavior due to technical ambiguity or even insubordination. The importance attributed to these evasion types depends on one's point of view. For the purposes of this analysis, however, deterrence will be considered effective if militarily significant evasion is prevented.

The matrix in Fig. 1 is one way to represent these costs and benefits. The two rows correspond to the inspectee's choice between complying or evading; the two columns correspond to whether or not the inspector takes a countervailing action. Each box in the matrix thus represents a different scenario defined by the inspector's and inspectee's decisions.

Inspector

		No action	Respond
Inspectee	Comply	V3	V1
	Evade	V4	V2

Figure 1. This matrix of inspector and inspectee actions defines the inspectee's relative benefits and costs of evasion, where V4 is the highest valued outcome and V1 is the lowest valued outcome.

The variables V4, V3, V2, and V1 inside the boxes represent a possible preference ranking by the inspectee for the different outcomes defined by each scenario, where V4 is the highest value and V1 is the lowest. This particular set of values expresses the assumptions that the inspectee considers successful evasion to be the best outcome, followed by accepted compliance, challenged evasion, and challenged compliance. In other words, if the inspectee cannot evade the treaty without being detected, the next best outcome would be for the treaty to remain in force with both sides complying. The preference for the challenged evasion outcome over challenged compliance assumes that, if the inspector takes action, the inspectee would prefer to have actually been evading rather than to face a groundless challenge. (This latter assumption is not critical and could be reversed without affecting the major results of the analysis.)

2.3 Value and Detection Probability Conditions for Deterrence

The four detection probabilities—x, y, $(1-x)$, and $(1-y)$—are directly related to the four scenarios defined by the inspector's and inspectee's actions. One way to represent the relationship is in a decision tree, as pictured in Fig. 2. The square node at the left represents the inspectee's decision whether to comply or evade. The circular nodes represent the uncertainty about two possible outcomes that will follow each decision, based on the probabilities of the inspector's response or inaction. At the end of each possible path, one of the values V4-V1 will be realized by the inspectee.

The net value to the inspectee of compliance and evasion may be calculated as a weighted average, based on the probabilities of detection, of the two outcomes that could follow from each action. This weighted average is known as the "expected value" of the action contemplated. The inspectee's decision whether to attempt evasion may thus be modeled as a comparison of the expected value of evasion versus the expected value of compliance. Expressed mathematically, the expected value of compliance is $(1-y)\text{V1} + y\text{V3}$ and the expected value of evasion is $x\text{V2} + (1-x)\text{V4}$. It is in the inspectee's interests to comply with the treaty only so long as the expected value of compliance is greater than the expected value of evasion. Mathematically, the inspectee will comply only as long as

$$(1-y)\text{V1} + y\text{V3} > x\text{V2} + (1-x)\text{V4} \ .$$

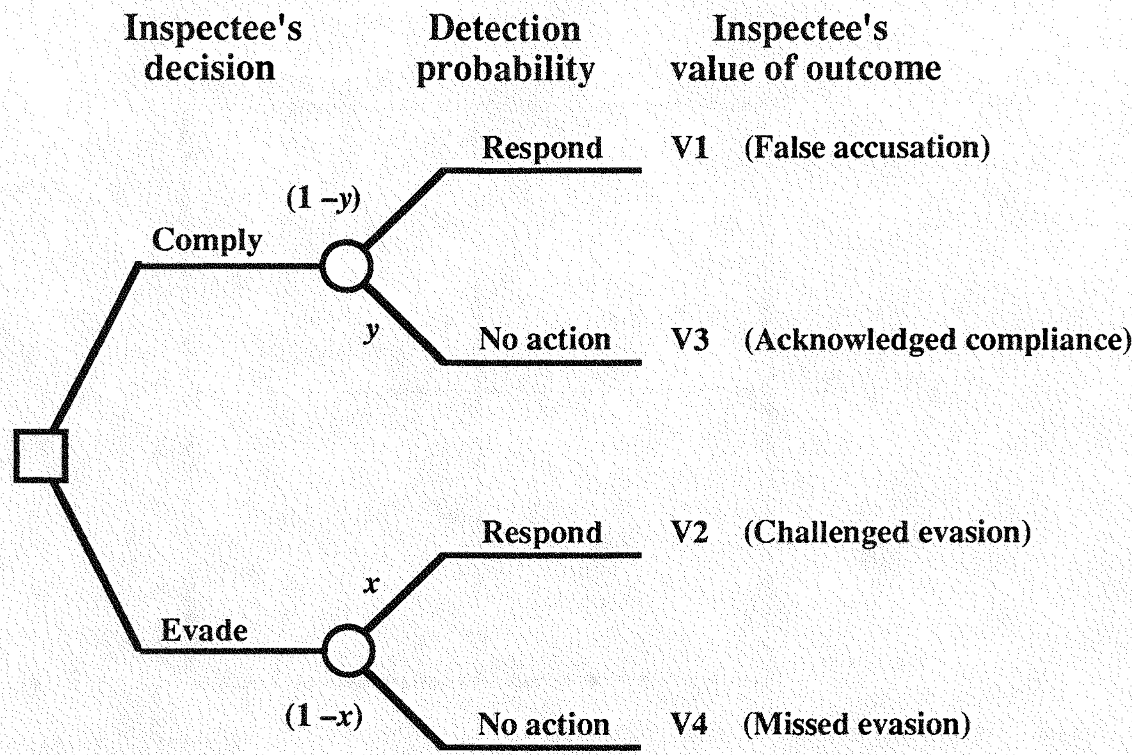

Figure 2. Inspectee's decision tree illustrating the relationship among the detection probabilities and the inspectee's perceived values for the possible outcomes.

Because the inspectee's values for the possible outcomes represent only relative rankings, the exact numbers in themselves are not important, and we may arbitrarily set V4 = 1 and V1 = 0 without sacrificing the generality of our approach. The above inequality can then be expressed as

$$x(1 - \text{V2}) + y\text{V3} > 1 \quad .$$

This expression may be thought of as a condition for compliance to be enforced by the inspector.[6] The graph in Fig. 3[6] represents this expression as a "compliance region" in which the values of V2 and V3 determine the required detector quality (x and y). A situation in which the detector quality is sufficient to enforce compliance is illustrated by the hypothetical point (x^*, y^*).

For a given verification system, x and y are inversely related and the inspector must choose the level of evidence that is sufficient to justify making a response. Responding to minimal evidence will mean that few violations are missed but many false accusations are made; and waiting too long to respond might allow many violations to go unpunished. Neither of these extreme positions is likely to enforce compliance. In the first case, x is large but y is small; in the second case, y is large but x is small. Both of these points could lie outside the compliance region in Fig. 3. In setting the sensitivity of the detection system, false accusations and missed violations should be traded off to move (x^*, y^*) into, or as close as possible to, the compliance region. Only by changing the verification system can both x and y be increased.

The deterrent value of SSIs must be assessed with respect to the deterrence of inspectee evasions without SSIs. In terms of Fig. 3, one would compare the point on the figure corresponding to the probabilities of detection under a treaty that did not include SSIs versus the point corresponding to a treaty that did. If other detection means alone were sufficient to place the inspectee in the compliance region for a given treaty—at the point (x^*, y^*), for example—then SSIs, although possibly a positive influence in other ways, might not enhance deterrence. On the other hand, for a verification regime without SSIs in which the inspectee has an incentive to evade, an SSI regime could make the difference between inspectee evasion or compliance. This could be done by reducing the inspectee's values of evasion whether or not the evasion is detected and/or by increasing the probabilities of correct detection.

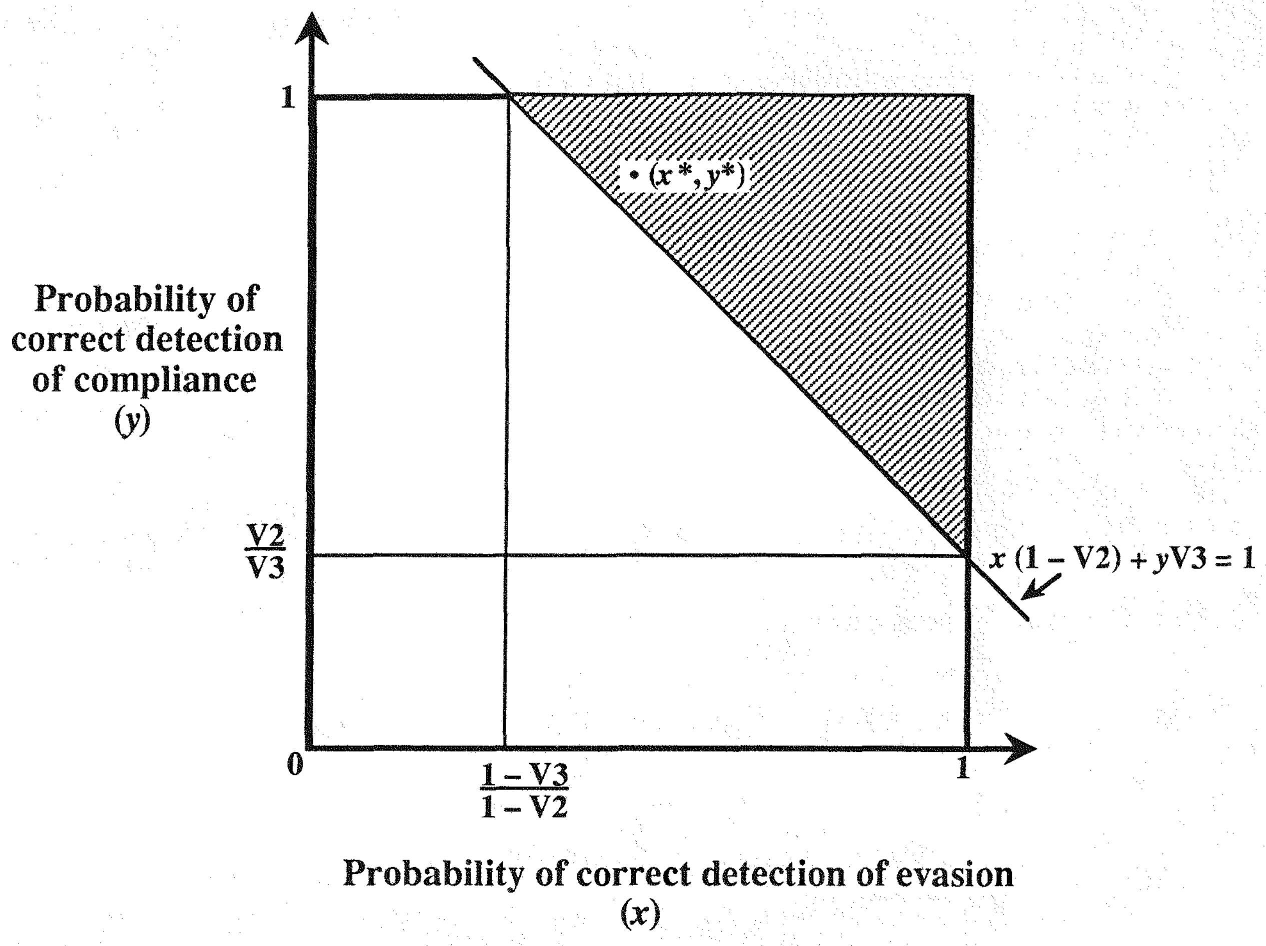

Figure 3. The possible detection abilities for which inspectee compliance can be enforced are illustrated by the shaded region. This region is defined by the inspectee's relative values for the possible outcomes.

In the following sections, we will use this analytical framework to evaluate the deterrence benefits of SSIs. First, the effect of SSIs on the inspector's detection capabilities will be examined. Then, we will turn our attention to how SSIs might reduce the value of cheating. These two effects will then be considered simultaneously.

3. Effects of SSIs on the Probabilities of Detection

In the previous section we introduced the quantities x and y to represent the quality of a detection system. The term "system" included both physical monitoring devices and the inspector's response policy. This particular framing of the issue assumes that, from the inspectee's point of view, evidence that does not lead to a response is of little concern. In order to elucidate how SSIs could affect x and y—how the inclusion of SSIs in a treaty regime could either raise or lower these probabilities of detection—we will explore more deeply how detection systems with and without SSIs might work and how the decision to respond might be formulated in each of these cases.

By their very nature, SSIs cannot stand alone as a means of treaty verification. The fact that sites are "suspect" indicates that some other verification measure must have provided the impetus for closer inspection. In any foreseeable treaty domain, the use of SSIs would be predicated on evidence provided by national technical means (NTM), a variety of intelligence sources routinely used by the U.S. and U.S.S.R. to monitor each other's military activities around the world, including satellite reconnaissance and electronic eavesdropping. The data from these sources is interpreted to make judgments of the type and scale of activities of possible strategic significance. For most sites in the Soviet Union there will probably not be any other treaty-provided verification measures; thus SSIs and NTM will be the only sources of evidence on which to base judgments about inspectee evasion attempts. In this section we will first discuss a model of the probability of detection by NTM and then use the model to provide a basis for assessing the impact of SSIs.

3.1 Treaty Verification by National Technical Means (NTM)

It is possible that NTM might detect an item explicitly limited by the treaty. But more likely, NTM will detect only related items and activities. Due to ambiguities in evidence obtained by NTM, however, it is also possible that legitimate activities will be interpreted as treaty violations. In the INF treaty, for example, various cooperative measures were included—e.g., opening the roofs of storage buildings, specifying how missiles would be transported, etc.—in order to minimize the probability of false positive detections by NTM.

To simplify our analysis, we assume that the inspector will respond with certainty if and only if a treaty-limited item (TLI) is detected by NTM. The quantity x thus corresponds exactly to the probability that a TLI is detected given that cheating is actually occurring, and the quantity y corresponds to the probability, given compliance, that either nothing is detected or only a related item (RI) is detected. The situation of verification by NTM alone may thus be expressed in Fig. 4 in the same form as the decision tree in Fig. 2.

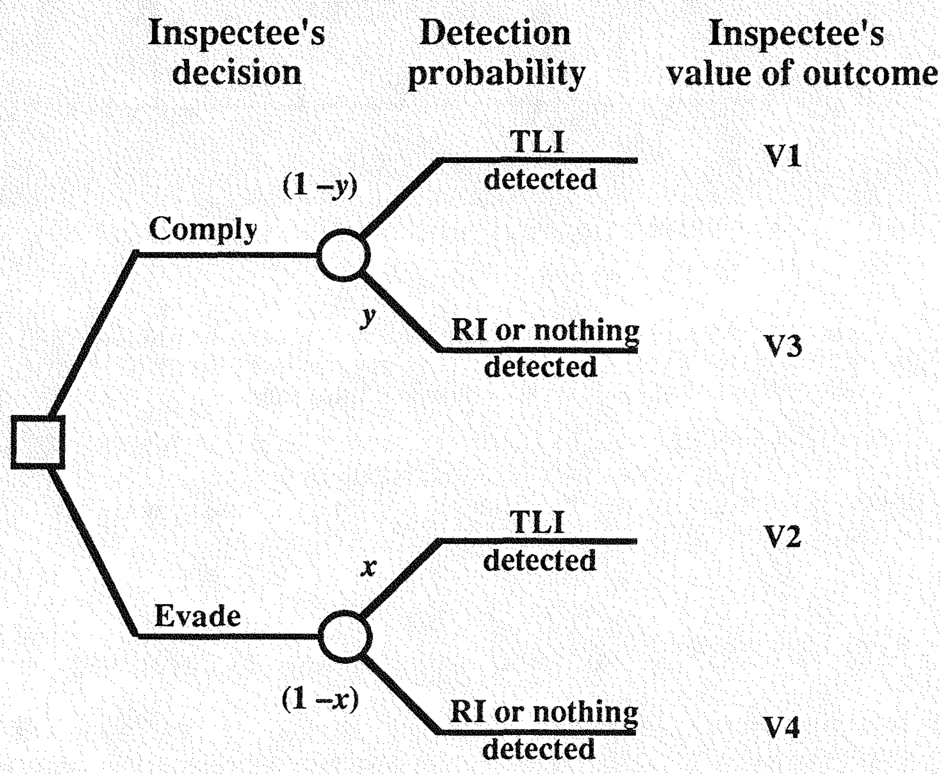

Figure 4. Inspectee's decision tree illustrating possible evidence from NTM and its detection probabilities.

3.2 Treaty Verification with NTM and SSIs

With the introduction of SSIs as an additional means of detection, the inspector faces two decisions: when to use SSIs and when to respond, given new evidence uncovered by them. Depending on the specific SSI protocols in force, the costs of such inspections could be significant to the inspector, both financially and politically. In order to illustrate the effect of SSIs on detection probability in the best case, we will assume that protocols have been written that make the inspections per se politically neutral and that their financial cost is small compared to the costs associated with responding to evidence of a violation. We will assume that an SSI is routinely requested any time either TLI or RI evidence is discovered through NTM.

If the inspectee is in compliance, the benefit of an SSI is obvious: compliance will be confirmed. Confusion about evidence suggesting an evasion will be resolved and a false accusation avoided. For a well-designed SSI protocol, the detection system might confirm compliance perfectly. For such a system, $y = 1$. Realistically, occasions could arise in which access to a site is denied for reasons other than to hide an evasion. False accusations, therefore, while minimized, would not be eliminated.

The effect on the quantity x, the probability of correctly detecting and responding to a violation, due to the inclusion of SSIs is more complicated. The value of x may tend to be increased by the fact that SSIs improve the sensitivity of the detection system and the probability of response. In our example, detection of an RI with NTM was insufficient for action. An SSI could be undertaken with just this evidence. If the presence of an RI is confirmed, or perhaps even a TLI found that was undetectable by NTM, it would be much easier to muster the political will to respond. The value of x may be lowered, however, if the inspector requires detection by an SSI to challenge the inspectee and if, in response to the SSI request, the inspectee denies access to the site, removes the TLIs, or conceals the TLIs. The failure to confirm the NTM detection of a TLI would make it difficult to justify an accusation of evasion. However, if the inspectee attempts to remove TLIs, there is some chance that NTM will detect this movement.

The trade-off between the increased sensitivity of a detection system including SSIs versus the possibility that the SSI will be manipulated may be expressed in the decision tree in Fig. 5. We assume that incriminating evidence uncovered during an SSI, or NTM detection of TLI removal, is unambiguous and leads to a response with certainty. Similarly, a failure to detect evasion removes any justification the inspector might have to respond. From the inspectee's point of view, therefore, the decision to evade may be based solely on the probability that evidence of cheating will be detected by NTM and confirmed by an SSI.

Comparing Fig. 5 with the lower branch of Fig. 2 illustrates the sources of improvement and degradation of the quantity x. With NTM alone, x was equivalent to the probability of TLI detection. With SSIs included, such a detection is not enough to ensure a response. If the inspectee successfully removes or conceals the evasion or if the SSI simply fails to detect the illegal activity, a response may not be forthcoming. These outcomes correspond to the three paths following NTM detection of a TLI for which the outcome value to the inspectee is V4. (In Sec. 4 we will examine the costs to the inspectee of attempting such manipulations.) The value of x is therefore reduced by the probabilities associated with these three branches. On the other hand, given that NTM detection of an RI was insufficient to justify a response, the eight paths following NTM detection of an RI for which the outcome value to the inspectee is V2 increase the quantity x. In Fig. 2, NTM detection of an RI led to outcome value V4 always. Now, it is possible that a response will be forthcoming if SSIs uncover evidence undetected by NTM. This is the conventional notion of improved deterrence by SSIs. The interaction between the sources of increases in probability of detection of evasion (e.g., the detection of suspicious evidence during an SSI based on NTM detection of an RI) and the sources of decreases (e.g., successful evasion of an SSI given NTM detection of a TLI) is guided by the probabilities one assigns to different inspectee actions and the decision rules adopted by the inspector.

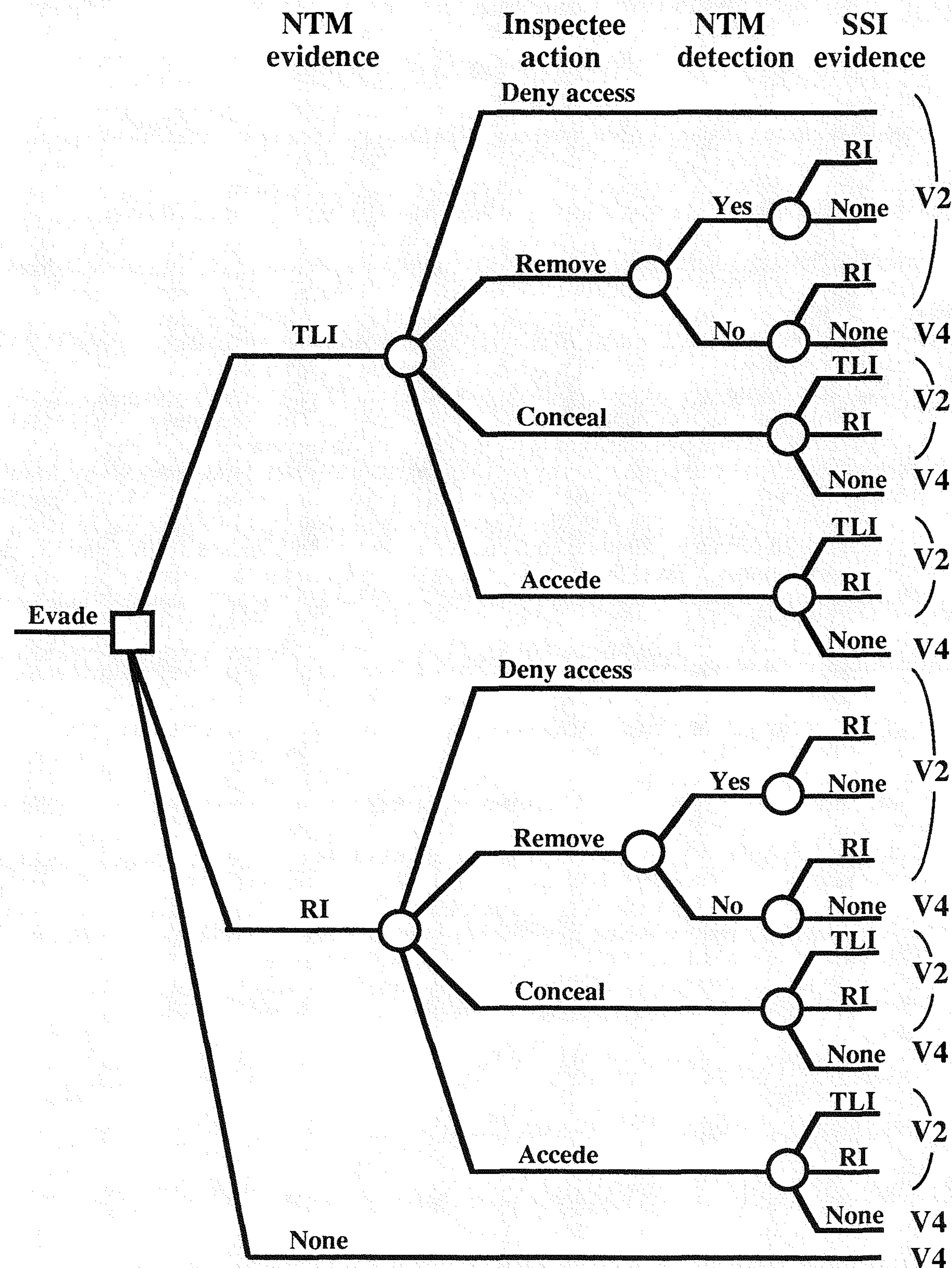

Figure 5. Decision tree, given inspectee evasion, illustrating interaction between NTM and SSIs.

3.3 Possible Deterrence by SSIs

The possible deterrent effects of SSIs due to improvements in the probabilities of detection are illustrated in Fig. 6, where the point (x^*, y^*) represents the situation without SSIs. If, for example, adding SSIs increases x^* without changing y^*, so that the point (x^*, y^*) moves to the new position (x', y') within the shaded deterrence region (see Fig. 3), then the addition of the SSIs will deter Soviet evasions. Likewise, adding SSIs could increase y^* (i.e., decrease false accusations) enough to move (x^*, y^*) into the shaded deterrence region even though x^* might be somewhat decreased in the process, as for the point (x'', y'').

The above analysis provides insight into how the net effect on detection probabilities due to the inclusion of SSIs in a treaty depends on the combined influence of detection technology, decision rules, and expectations about inspectee behavior. We showed that SSIs tend to enhance deterrence by reducing the probability of false accusations. The effect of SSIs on the problem of missing violations depends on the probability of successful manipulation of SSIs by the inspectee. The specific decision rules used by the inspector and protocols for inspections must be carefully designed to gain the maximum deterrence benefit from SSIs. Figure 5 provides a formal framework for assessing different protocols and rules. To complete the analysis of deterrence by SSIs, we now examine the potential effects of SSIs on the inspectee's values of evasion.

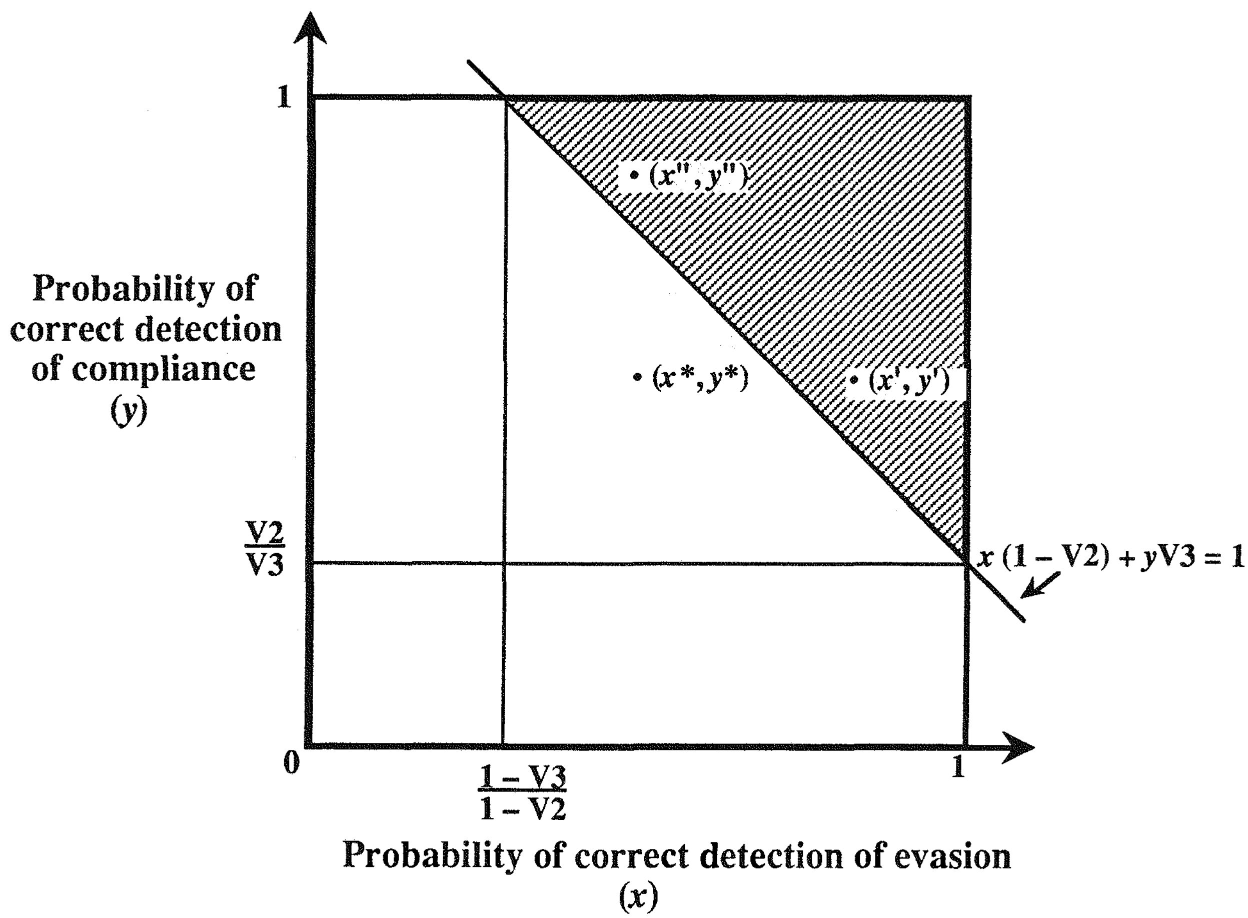

Figure 6. The effects of SSIs on detection probabilities can enhance deterrence.

4. How SSIs Affect the Relative Value of Evasion

The deterrence model of Sec. 2 illustrated that the probability of detection alone does not provide sufficient information to assess the full deterrent effect of a verification technique such as SSIs. One must also model the effects of SSIs on the inspectee's relative values of evasion. The two factors are not totally separable, however, because each of the inspectee responses to an SSI request or the potential of an SSI has an associated cost. In this section we will analyze the key value variables in the deterrence model and discuss the possibility that, for a price, the inspectee may attempt to lower the probability of detection by NTM and/or SSIs.

4.1 Modeling the Values and Costs of Weapons

Weapons are generally built and deployed to meet unfulfilled military missions or to shore up high priority missions to which other weapons have already been assigned. The value of a weapon depends on many factors associated with these missions. To the extent that the weapons in question are assigned a counterforce role, the number of weapons possessed by the adversary will determine the number of weapons required to fulfill a given mission. Technological breakthroughs and changes in force structure will also affect the utility of a weapon system. Finally, the possession of certain weapons may have political utility.

We put forward here a simplified model of value that will allow us to represent the possible deterrent effects of SSIs and to draw insights. The determination of a general value function for all possible weapon portfolios would be very difficult, and any analysis performed would need to take into consideration how the function might change over time. Implicit in any such value function is a particular state of the world. We will ignore the effects of SSIs on the inspectee's political values and focus instead on the incentives for evading in completely military terms.

Assuming that the weapons are deployed in order of value, it follows that each additional weapon deployed contributes marginally less than the one deployed before it. Therefore, the military value of having increasing numbers of weapons may be represented as a monotonically increasing curve with decreasing slope. An illustrative curve is shown in Fig. 7.

In order to work simultaneously with both the cost of treaty evasion and the value of weapons, we express costs of weapons and their values in similar units. Because costs may be expressed fairly directly in a monetary unit, we've selected this as a basis. In order to express weapon value in money terms, we will assume that, for each mission, some monetary figure may be derived which represents the point of indifference between fulfilling the mission and having the money available for other programs. In other words, each mission may be assumed to have some monetarily equivalent opportunity cost which serves as a measure of its value.

The use of a monetary-equivalent measure of value naturally suggests economic arguments for characterizing the decision to deploy weapons. For example, each additional weapon may be thought of as providing some marginal "revenue" to military planners. The building and deployment costs of these weapons represent a marginal cost. The calculating inspectee would seek to maximize "profit" by continuing to deploy weapons until the marginal revenue of the n^{th} weapon equals the marginal costs of building and deploying it.

Figure 8 depicts how the maximum net value point might be determined. Superimposed on the value graph in Fig. 8 is an illustrative cost function in which each batch of weapons produced requires some fixed capital cost (a factory) plus equal per-unit manufacturing and deployment costs. Each vertical step represents the fact that another factory needs to be built in order to increase production. The lines between the steps have a slope equal to the marginal cost per weapon. The optimal building point is determined by finding the point at which the distance between the value and cost curves is greatest.

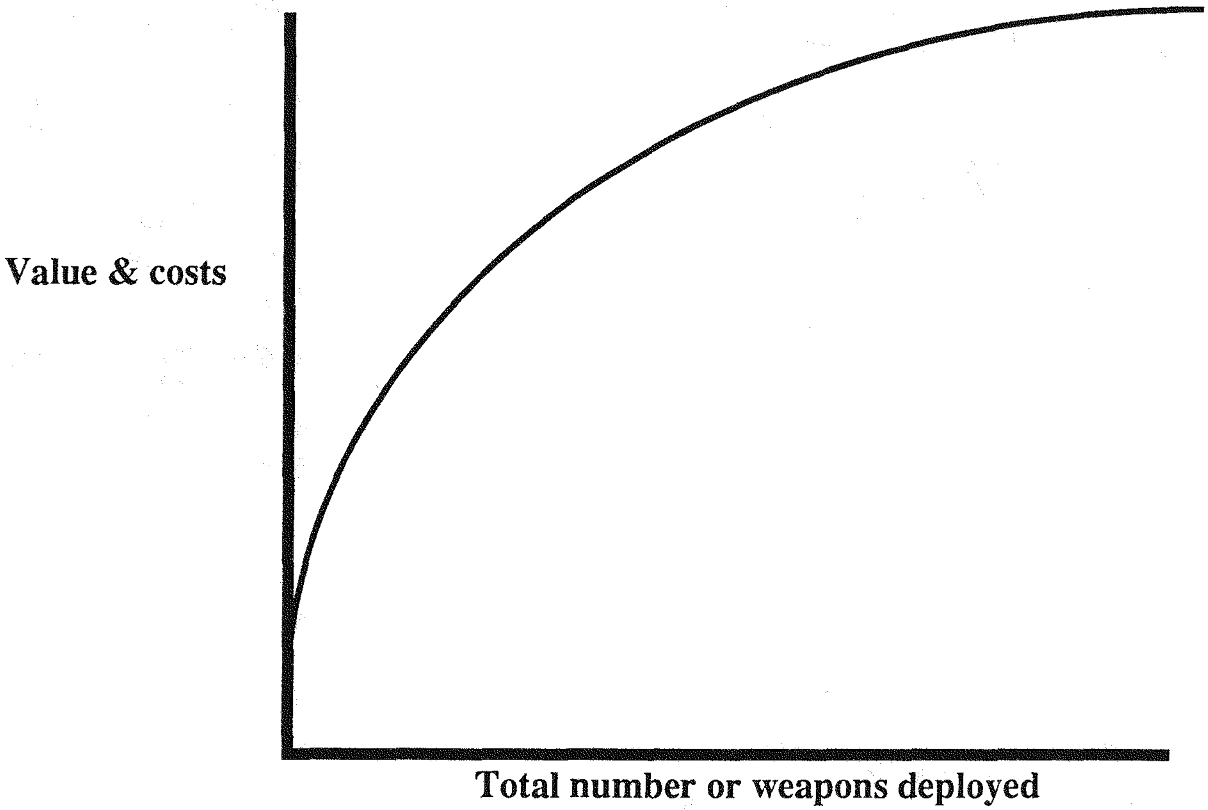

Figure 7. Illustrative graph of Soviet values for the total number of weapons deployed. Value for additional weapons is assumed to exhibit decreasing returns to scale.

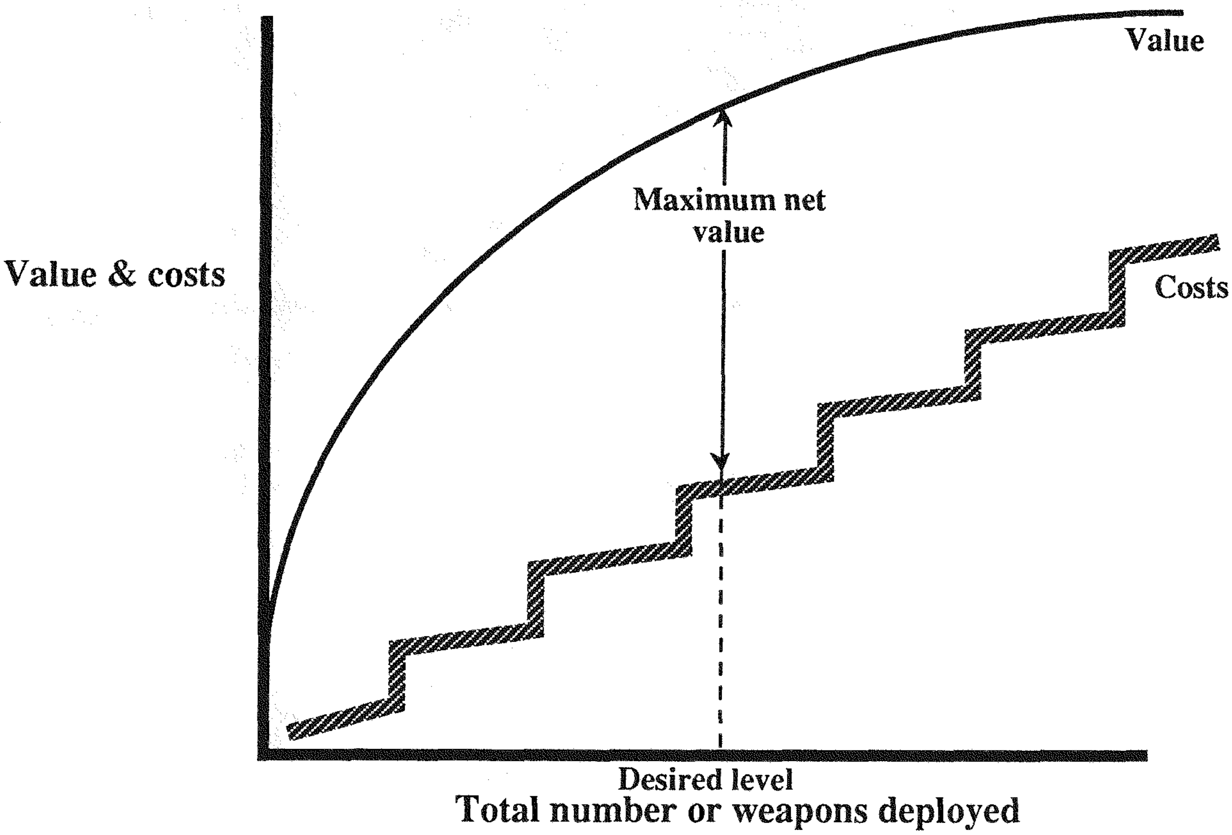

Figure 8. The inspectee's desired level of weapons to deploy is the level that maximizes the net value of the weapons above their costs.

4.2 Effects of Treaty Limits

In Fig. 9 the limits prescribed by the treaty are superimposed on the inspectee's weapon value and cost curves and the desired weapon level. We will assume that these limits are below the desired levels of weaponry given that the inspector is complying with the treaty limit indicated. Otherwise, deterring evasions of the treaty would not be an issue.

The values for weapons shown in Fig. 9 are only relevant for the situation in which the treaty limits are as indicated. This qualification is necessary because the inspectee's values of weapons are clearly dependent on the inspector's weapon levels and mix. We will assume that the inspector is observing the treaty limits.

The value V4 would correspond to the "maximum net value" at the desired level of weaponry, while V3 would correspond to the value achieved by the inspectee if the treaty threshold is observed.

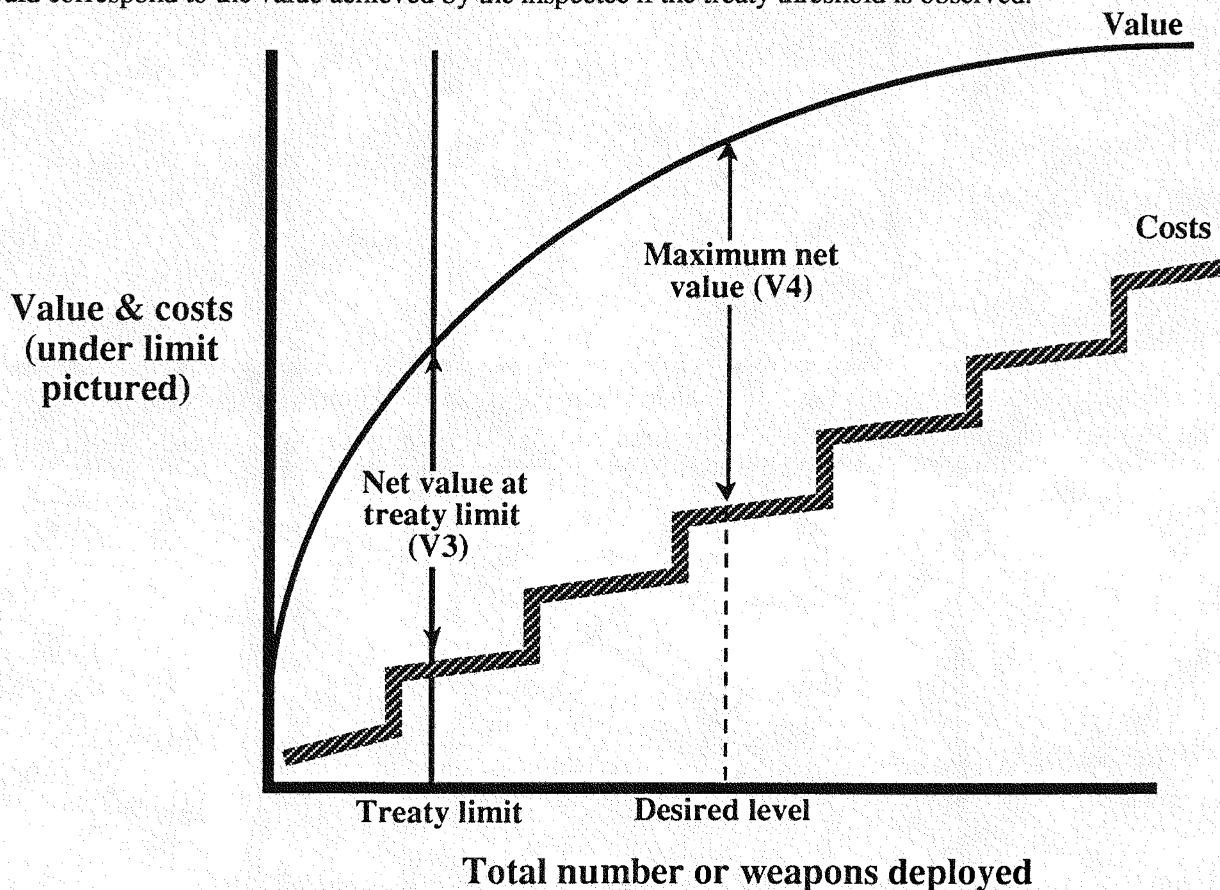

Figure 9. Treaty terms will impose limits on the inspectee's weapons at a level below the level otherwise desired by the inspectee, given that the inspector is complying with the treaty.

4.3 Possible Deterrence by SSIs

The key factor in assessing deterrence is whether the expected value of violating exceeds that of compliance, as defined in Sec. 2. In Sec. 3, we discussed how the inclusion of SSIs could affect the probability of detection and move the inspectee into the compliance region defined in Fig. 3. Now, using the value model described above, we will turn our attention to how the compliance region itself may be enlarged by including SSIs in a treaty.

If the inspectee is intent upon violating a treaty, one could assume that more precautions than normal will be taken to conceal the activity. For example, weapon manufacturing might be distributed over a wide area so that satellite reconnaissance and other NTM would not detect a concentration of activity. If intrusive measures such as SSIs substantially raised the cost of concealing violations, then these measures could render even successful evasion less attractive, thus enhancing deterrence.

The costs to an inspectee to avoid detection may be included in our value model by assuming that some additional expenditure per missile (above and beyond normal manufacturing and deployment costs) is required for all deployed weapons above the treaty limit. The fixed costs for new factories and the slope of the marginal cost lines both increase to reflect the higher fixed and marginal cost for missiles built in violation of the treaty. The additional expenditures required to evade NTM alone are represented in Fig. 10 by introducing a discontinuity in the cost function for missiles at the point at which the number of missiles equals the treaty threshold. Assuming that the inspectee performs the same net value maximization as before, the desired number of weapons including the costs of evading NTM is determined by finding the maximum distance between the value curve and the new cost curve. In our example, the incentive to cheat still exists, but the new V4—represented by the "maximum net value: evading NTM"—is lower.

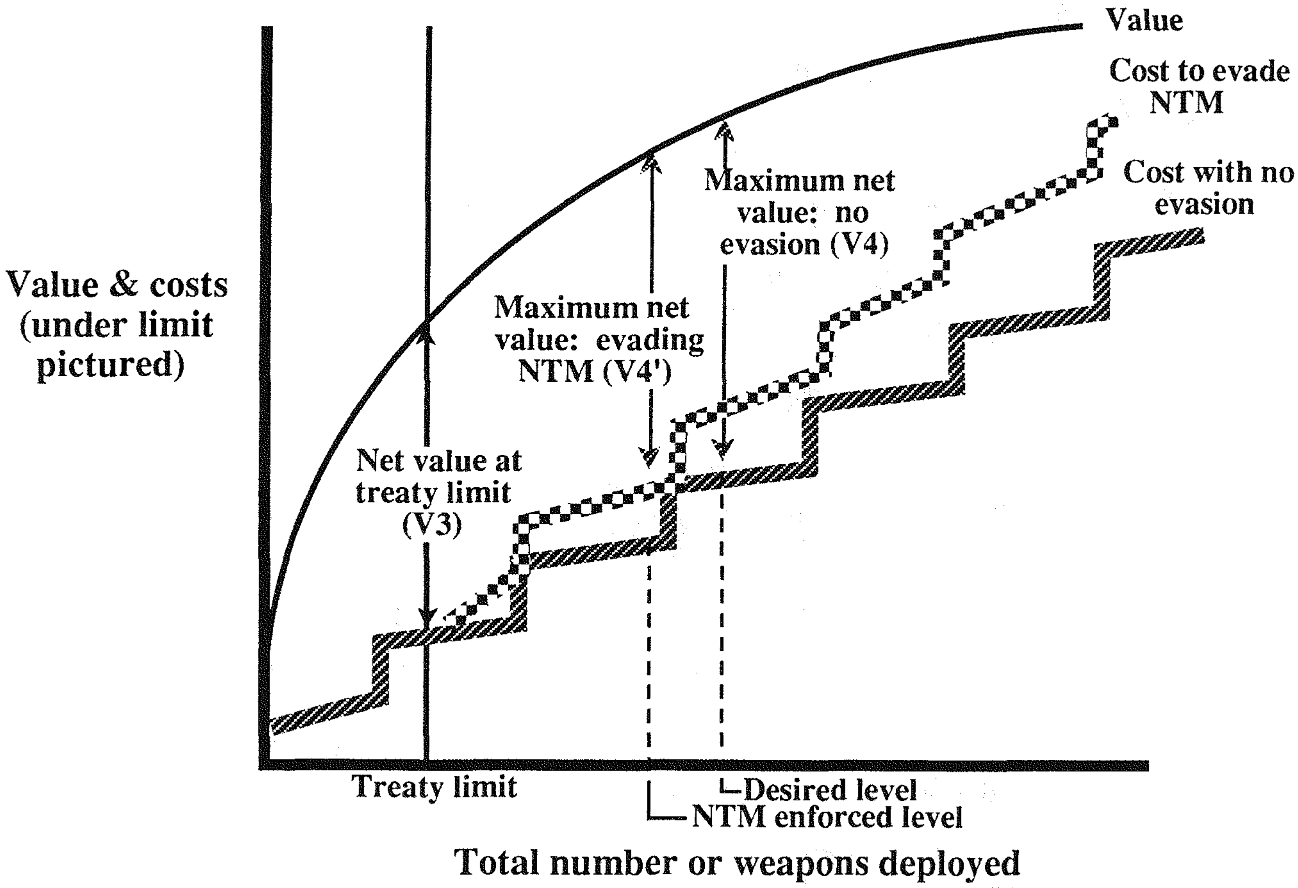

Figure 10. NTM verification measures increase the cost of weapons above the treaty limits and reduce the desired level of weapon deployment.

The potential deterrent effect of SSIs may be modeled by assuming that evading an SSI is more costly than evading NTM alone. This would be represented by increasing even further the fixed costs associated with weapon manufacturing and drawing a cost line with a slope greater than the cost line for NTM evasion alone, as shown in Fig. 11. Indeed, strict compliance might be enforced by the addition of SSIs if the military value of evasion approaches the value of mutual compliance. In other words, evasion of the treaty could be so costly that it dominates the benefits of evasion. This reduction of the benefits of evasion is shown in Fig. 11 by the smaller maximum net value under SSIs. Similarly, depending on the shape of the value function, it is possible that the additional cost to evade SSIs will eliminate some rather than all missions. In this respect, SSIs could be said to have had some deterrent effect even though they did not completely deter cheating.

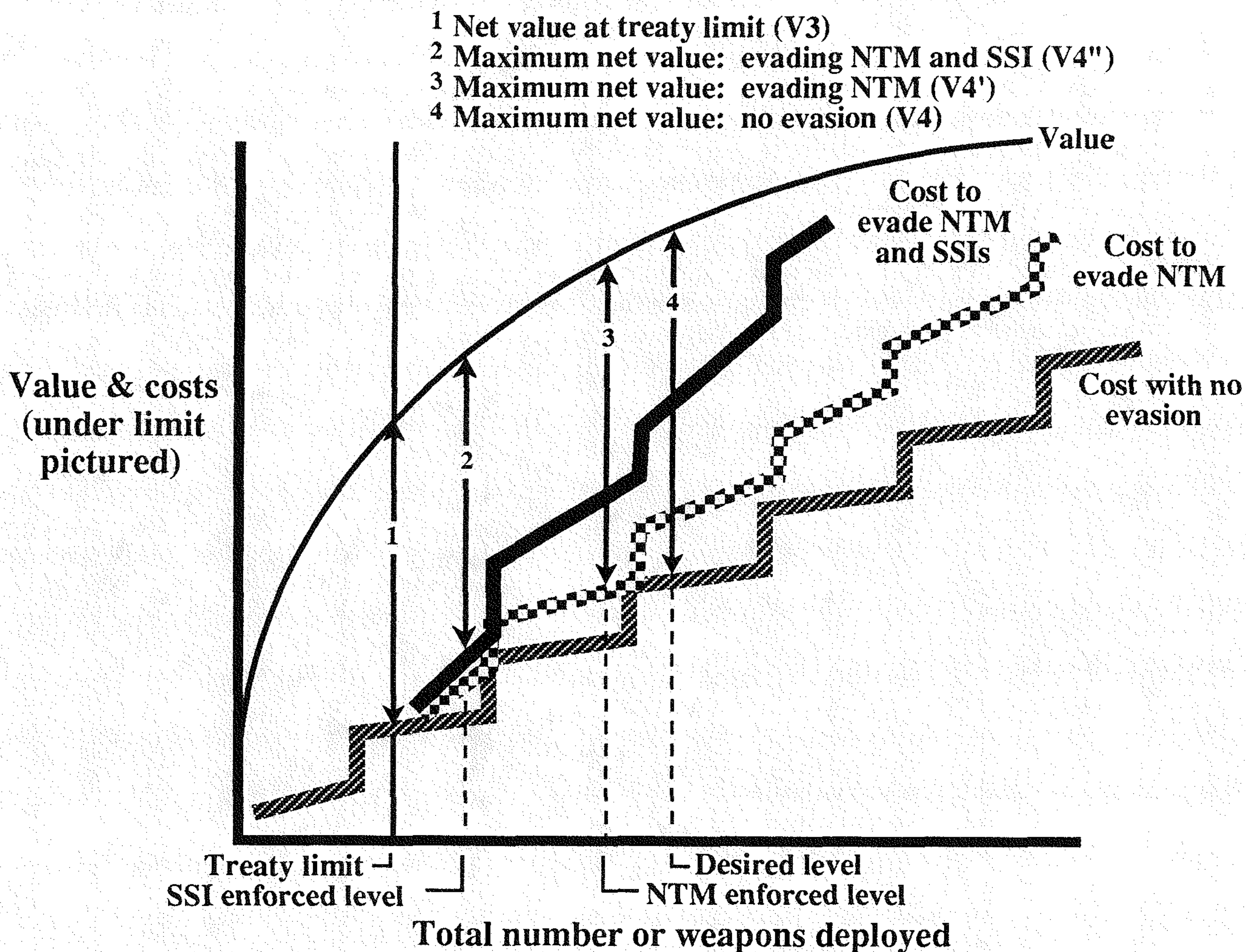

Figure 11. SSIs combined with NTM further increase the costs of weapons above that treaty limit and further reduce the desired level of deployed weapons.

The possible deterrent benefits of SSIs by increasing the costs of evasion can also be illustrated using the region of enforced compliance from Fig. 3. As shown in Fig. 11, SSIs can increase the costs of evasion and thereby decrease the inspectee's relative values V2 and V4 compared to V3. By doing so, the compliance region is expanded, possibly to include a set of detection probabilities (x^*, y^*) that were not previously in the compliance region. This case is illustrated in Fig. 12 by the decrease in V2 to V2". (In Fig. 12, V3 was also changed, to V3", because V3 is quantified on a scale of 0 to 1 where V4 = 1. When V4 is decreased to V4", the quantity V3 must be renormalized relative to V4". The underlying worth of V3 does not change.) The deterrent potential effect of SSIs can thus be understood in terms of not only the possibility that they will increase the probability of detection but also that they may raise the cost of cheating beyond an acceptable level. In Secs. 3 and 4 we examined each of these possible deterrent effects separately. In the next section we summarize and consider the two effects together to obtain a complete picture of SSIs and evasion deterrence.

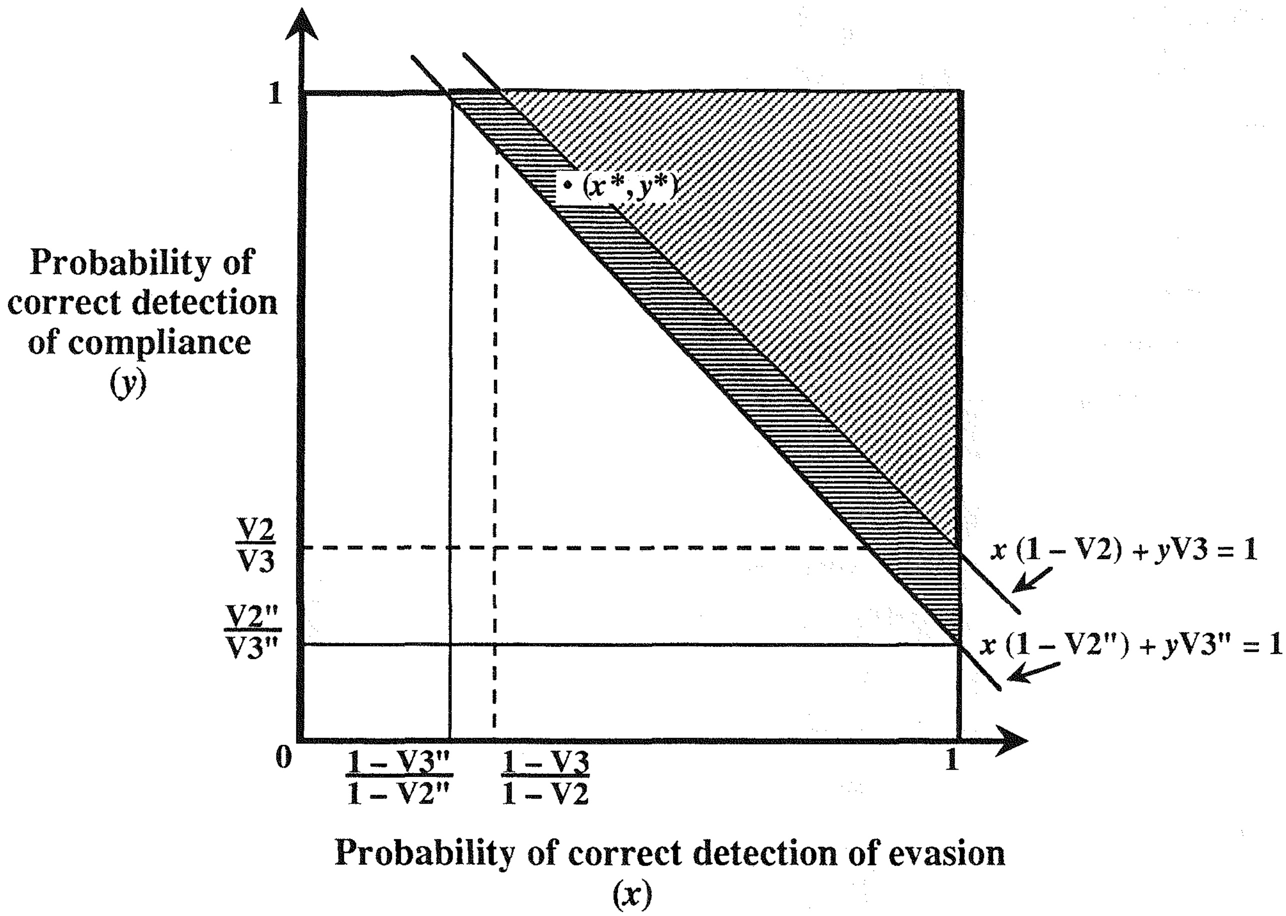

Figure 12. SSI effects on inspectee values can expand the compliance region and enhance deterrence.

5. Combined Deterrent Effect of SSIs

In the preceding sections we presented a general model of the deterrence of arms control treaty evasions by verification measures. This deterrent effect was a function of both the probability of detecting an evasion and the evader's values for circumventing the treaty. We first discussed how SSIs may have possible deterrent effects by improving the probabilities of detection. We then presented an approach for understanding how SSIs increase deterrence by decreasing the inspectee's value of evasion.

The effects of SSIs on detection probabilities and inspectee values will, of course, occur jointly. Both effects will reduce the inspectee's expected value for evasion, $x\text{V2} + (1 - x)\text{V4}$, as presented in Sec. 2.3. These joint effects can be illustrated by combining Figs. 6 and 12 to obtain Fig. 13. In Fig. 13 the compliance enforcement region is expanded by reducing V2 to V2" and the detection probabilities are changed from (x^*, y^*) to (x', y'), which is closer to the compliance enforcement region, but still outside it.

The regions in Fig. 13 and similar figures in this paper that show the detection probabilities x and y for which compliance can be enforced are simply illustrative. In the real world of arms control and treaty verification, which is rife with uncertainties, multi-faceted governments, and constantly changing values and states of information, precisely defining the compliance enforcement region is not possible and probably not appropriate. However, the ability of SSIs to deter treaty evasions can be evaluated by the extent to which they tend to expand the region of compliance enforcement or move detection probabilities closer to the upper right-hand corner of the plot in Fig. 13.

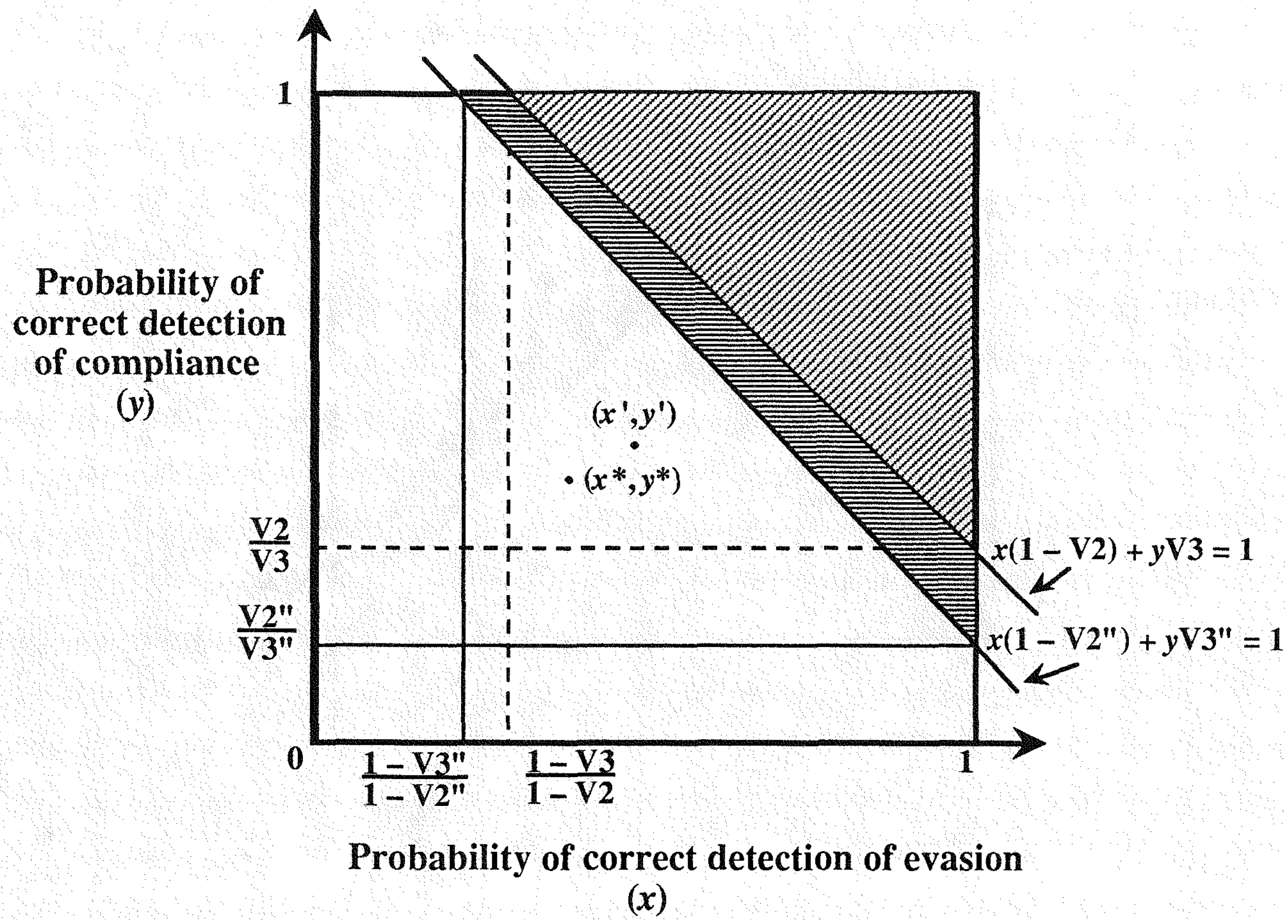

Figure 13. SSIs can simultaneously improve detection probabilities and expand the compliance region.

We have presented an analysis of the deterrence benefits of suspect site inspections. We evaluated the effect of SSIs on both the probabilities of detection and the evader's values for evasion. However, deterrence is only one factor to consider in determining the advisability and implementation of SSIs. Consideration must also be given to the instrusiveness of inspections, their costs, and the confidence-building aspects. Furthermore, SSIs should not be evaluated alone, but should only be analyzed as part of a larger verification system.

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