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**AIRCRAFT ATTACKS ON
MOBILE MISSILES**

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APRIL, 1993

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PREFACE

This report was prepared to examine the possibility of using aircraft to hunt for mobile missiles as one potential method of forcibly implementing future counter-proliferation policies. It should be of interest to those concerned with arms control issues, commanders of air forces, and policy analysts.

The views expressed in this report are those of the author, and may not reflect the official views of any U.S. Government Agency or Department. The sponsor of this report is Nyland Enterprises, a private consulting firm. Any errors are those of the author. Comments or discussion are welcome.

CONTENTS

| |
|---|
| Introduction, 2 |
| Hunt With Low Flying Aircraft, 3 |
| Hunts With Stealthy Aircraft, 6 |
| Target Identification Issues, 8 |
| Confidence and Size of Surviving Residual, 11 |
| Observations, 15 |
| References, 18 |

INTRODUCTION

The purpose of this report is to examine the possibilities of employing two types of aircraft to implement a policy of countering the proliferation of mobile missiles after they have been developed, manufactured, and deployed in a third world country.* The potential implementation would be carried out by conducting search and destroy missions against the deployed missiles. One set of concepts for countering proliferation has been discussed by Carter, Perry, and Steinbruner [1]. The analyses contained in this report represent a framework for examining the various issues, and may overlook some detail.

Two types of aircraft are examined. The first would be a long range bomber which would fly at low altitudes to avoid attrition by anti-aircraft weapons. The second type of aircraft would be a tactical fighter-bomber that could fly at higher altitudes and would suffer no attrition because of its stealthy qualities. In the analysis to follow, the numbers of aircraft and their effectiveness are examined under a variety of conditions.

In a subsequent section of this report, it is assumed that the location of real targets (IRBMs or other short range ballistic missiles) and decoys would be well known. The issue of interest here is the ability to discriminate between the real targets and the decoys, and its effect on force sizes needed to destroy the ballistic missiles in question.

Finally, issues concerning confidence in attack outcomes will be examined. What is the probability that at least 1, 2, or more deployed missiles would survive given various sizes of attack and numbers of targets? Before committing aircraft to attacks such as described here, a decision maker may wish to know the answer to such a question. Planners should be prepared to supply this information.

In analyses such as those in this report, many assumptions must be made. Each set of assumptions will be described as part of the analysis of each major issue. Some of these assumptions may be in error, but variations will be shown to indicate trends and the effects of parameter uncertainties.

* The missiles could be cruise missiles, short range, medium range, or intermediate range ballistic missiles.

HUNT WITH LOW FLYING AIRCRAFT

The hunt for ballistic missiles could be carried out by very long range heavy bombers. In this analysis, we have assumed that such aircraft might be similar to the B-1B. It has been assumed that such an aircraft could fly to a distant area of the world and fly about 1000 n mi at an altitude of 400 ft. At this altitude, it is assumed that air defenses would be ineffective. Under these conditions the swath width of sensors aboard the aircraft would be about 3 n mi, assuming that the terrain is characterized by an unmasking angle of 35 milliradians. This unmasking angle is typical of gently rolling farmland [2]. The swath width of 3 n mi corresponds to a probability of having the target within line of sight of 0.7 at the edge of the swath. Thus, the search capacity of one aircraft is about 3000 sq n mi.

The overall probability of target engagement is the product of the probability that the target is within line of sight of the observer (0.7 in this case) and the probability that the target is detected and classified [2]. For our example hunt, we will assume that the probability of target engagement is as given in the following table for a large range of variables. Indications of sensor performance in terms of the number of lines across the minimum dimension of the target are also provided [2].

Table 1 - Estimates of Probability of Target Engagement

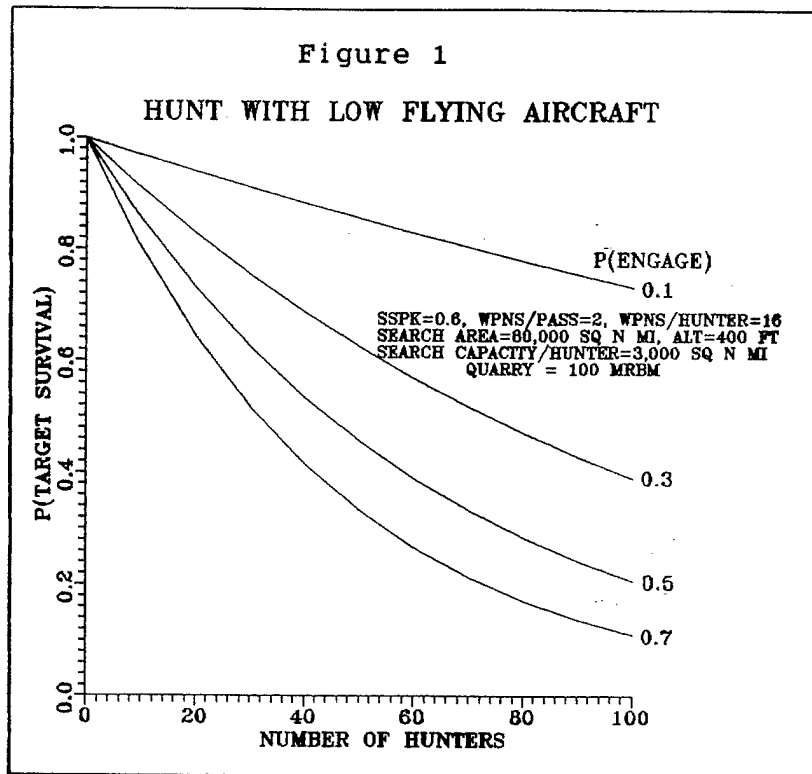
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|----------------------|-----|------|------|------|
| P(line of sight) | 0.7 | 0.7 | 0.7 | 0.7 |
| P(detect & classify) | 1.0 | 0.71 | 0.43 | 0.14 |
| Lines across target | 18 | 9.4 | 6.3 | 3.5 |
| P(target engagement) | 0.7 | 0.5 | 0.3 | 0.1 |

In searching for ballistic missiles, it has been assumed that the search area is about 60% of the area of Iraq, or about 80,000 sq n mi. The warheads carried by the bomber are assumed to have a single shot probability of damage of 0.6. Each bomber can carry 16 such weapons, and two are used whenever a target is encountered.

The results of a hunt conducted by low flying bombers is shown in Figure 1. The estimates shown in this figure were calculated by using the penetration integral [3]. The probability of target survival is shown as a function of the number of hunters with the probability of engagement as a parameter.

If the probability of engagement is low (between 0.1 and 0.3), then the bombers' effectiveness seems very low. If the probability of engaging the targets is greater than about 0.5, then the bombers' capability for destroying targets is improved.

In the best case, 100 bombers could reduce the survival probability of the targets to about 0.1. If the ballistic missiles were equipped with nuclear warheads, then the residual survivors remaining after an attack by 100 bombers could still pose a significant threat to allied forces or other assets in the region. The political implications could be profound if the residual nuclear armed missiles were to be sent against cities. Would the use of intelligence information assist in reducing this residual?



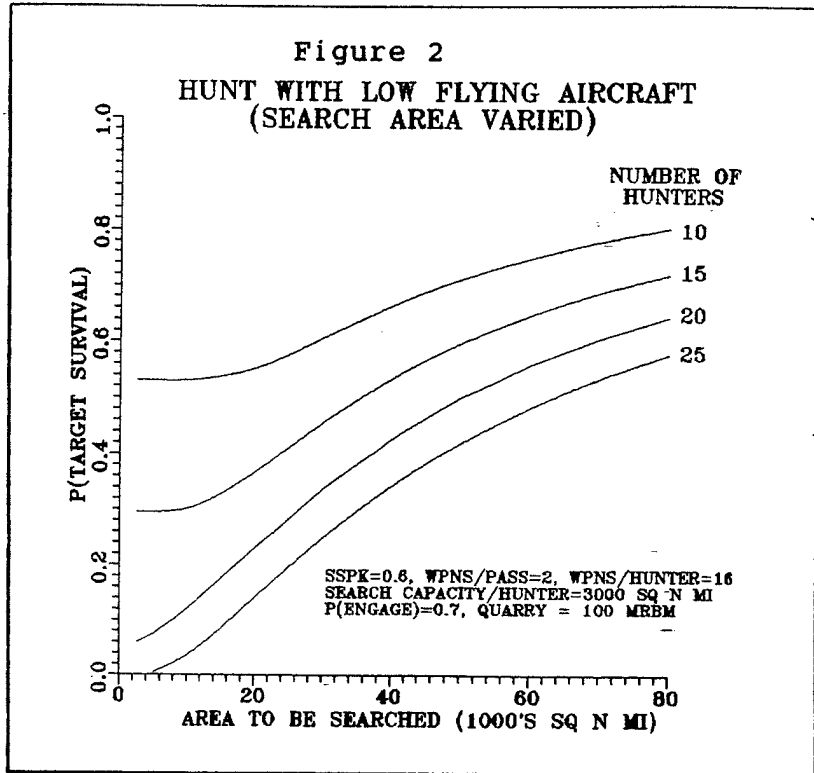
We next address the potential effect of intelligence information on the outcome of a hunt by low flying bombers. In the previous example, it was assumed that the entire 80,000 sq n mi area must be searched. If intelligence information could reduce the area to be searched, or could localize the targets, then fewer bombers might be needed to hunt for and destroy the ballistic missiles.

To examine the effect of target localization, we have varied the area to be searched for substantially smaller sizes of the bomber force. In this analysis, it is assumed that the probability of engaging the targets is fixed and has a value of 0.7. The number of bombers is now a parameter.

Figure 2 shows the effect of limiting the area to be searched through the use of intelligence information. For a force of about 20 to 25 bombers, the probability of survival of the ballistic missiles would be quite low, if the bombers needed to search an area of 5000 sq n mi or less. With 100 ballistic missiles as targets, the 5000 sq n mi area corresponds to localizing each ballistic missile target to about 50 sq n mi. Smaller force sizes, about 10 or 15 bombers, simply do not have the firepower needed to reduce the target probability of survival to very low values (less than about 0.1 or so).

From this examination, we conclude that the effectiveness of low flying bombers would be improved substantially if their targets could be localized through the use of intelligence information. For the parameters assumed in this analysis, it appears that a force of 25 bombers could inflict substantial damage and assure a very small residual of survivors.

Without localization, about 100 bombers would be needed to achieve a low level of target survival, but not sufficient to assure a very small number of surviving ballistic missiles.



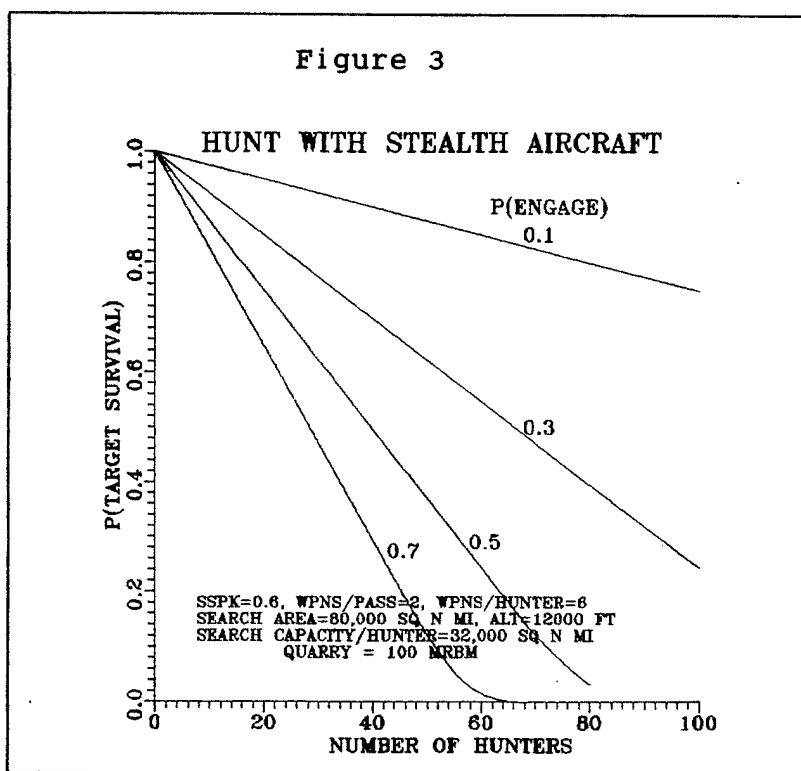
HUNTS WITH STEALTHY AIRCRAFT

Stealthy aircraft could fly at higher altitudes than the low flying bombers, since they would not suffer attrition from hostile anti-aircraft weaponry. In this section the analysis is based on the assumption that stealthy tactical fighter-bomber aircraft could be employed for such missions.

Tactical fighter bombers would have a much shorter range of operation than the large bombers discussed above. We assume that their operating range in hostile territory while searching for targets would be about 400 n mi. At an operating altitude of about 12,000 ft they would have a much better view of the search area. Assuming a terrain unmasking angle of 35 milliradians and an operating altitude of 12,000 ft, the swath width would be about 80 n mi with a probability of having the target within line of sight of about 0.7. Thus, the search capacity of each fighter-bomber would be about 32,000 sq n mi, much larger than that of a low flying bomber.

Under these conditions, the probability of target survival as a function of the number of hunter aircraft is shown in Figure 3. The parameter is the probability of target engagement. Engagement probabilities less than 0.5 are not promising for the attacker. If the probability of engagement were about 0.7, then about 60 fighter-bombers would nearly eradicate hostile ballistic missiles. From this chart we conclude that

employment of stealthy aircraft could provide an alternative method for searching out and destroying targets, under the assumption that their stealth characteristics provide essentially no attrition by hostile air defenses.



An excursion to this analysis indicated that the use of intelligence information to localize targets had very little effect on improving the outcome of the hunt by high flying stealth aircraft. The reason for this result is that the very large search capacity of each stealthy aircraft precluded the need for such information. This result is critically dependent on the assumption that the sensors used to detect the targets perform extremely well at the higher altitude, even though the range to far targets is more than ten times larger than ranges between low flying bombers and their targets. If the sensors do not perform well, then the outcomes of search and destroy missions would follow the results shown in Figure 3 assuming a much lower probability of target engagement. Table 1 indicates the effect of lower sensor performance in terms of the number of resolved lines across the minimum target dimension.

If sensors aboard stealthy aircraft were lacking in performance for locating and classifying targets from the high altitude suggested here, then intelligence information could be used in several ways to improve the hunt outcome. First, rough target locational data could be used to aim the sensors to more thoroughly scan the specific area of interest, and may improve the probability of detecting a target. Secondly, the aircraft could fly to a lower altitude in the specific target area, thus improving its chances of detecting and classifying the target at the much shorter ranges involved. If this latter mode of operation were employed, one might question why large low flying bombers would not be a better solution since they would carry a larger load of munitions.

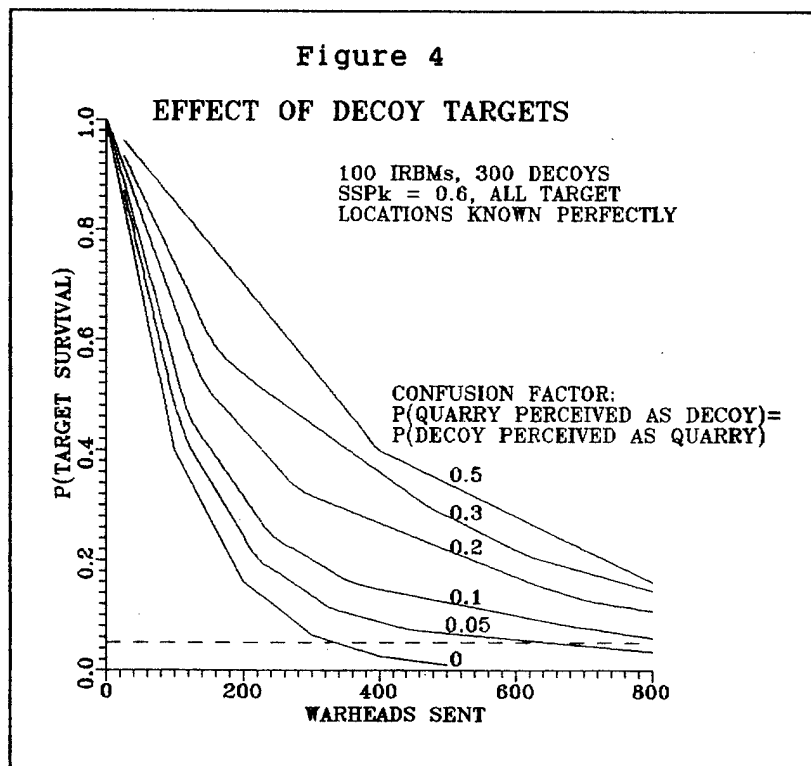
TARGET IDENTIFICATION ISSUES

This section is devoted to the probability that a hunter detects, identifies, and attacks prime targets rather than decoys or false targets. In what is to follow, we group false targets and decoys into one category -- decoys. There may be confusion on the part of a hunter as to whether or not his aim point is a real target or a decoy. We treat this confusion explicitly.

The different targets consist of quarry (real targets) and decoys. We define confusion as the probability that a quarry is perceived as a decoy. We also assume that the inverse, i.e. the probability that a decoy is perceived as a quarry, takes on the same value. When weapons are assigned to targets, the allocation algorithm is based on an assumption that the exact degree of confusion is known by the attack mission planning staff.

To provide an example, it is assumed that there are 100 ballistic missiles (real targets) and 300 decoys (or false targets). Further, we assume that the hunters know exactly where all of these targets, real or decoy, are located. The hunters go to each perceived target or decoy and choose whether or not to fire their weapons. The approach used here is based on an analytical framework developed by Layno [4] and revised somewhat by Nyland [5]. As in previous examples, we assume that the single shot probability of damaging a target is 0.6.

The results of the analysis are shown in Figure 4 where the probability of real target survival is a function of the attack size. The parameter is the confusion factor as defined above. Thus, this figure addresses only the capability of the hunter to discriminate. With perfect discrimination (confusion = 0) about 300 to 400 warheads will nearly eradicate the ballistic missiles, i.e., the probability of



target survival would be less than 0.05. With non-zero values of confusion, many more warheads would be needed to achieve a similar level of damage. When the confusion reaches 0.5, the hunters cannot tell the difference between real targets and decoys, and uniformly allocate their weapons against all targets, whether real or decoy. Underlying this analysis is the assumption that the hunters have tested their discrimination means against suitable targets and know the exact state of their confusion before going into battle.

When attackers are confused, they would hedge their bets by aiming some of their weapons at targets they perceive to be decoys. The allocation algorithm used here produces a minimum probability of survival of real targets and results in the number of warheads to be aimed at perceived real targets. The remaining warheads in a given attack size would then be aimed at targets thought to be decoys. In some instances, the perceived decoys would be real targets. Figure 5 indicates the number of warheads aimed at perceived decoys as a function of attack size. The confusion factor is shown as a parameter. When there is no confusion, then no warheads are ever aimed at decoys. As the confusion grows, then more and more warheads are aimed at perceived decoys. It is this trend that forces much larger attack sizes to achieve a low level of survivability of real targets in the presence of confusion. For example, if confusion = 0.1, then about 130 warheads are aimed at perceived decoys for an attack size of 600 weapons. For a fixed attack of 600 weapons, more and more weapons would be aimed at perceived decoys as a hedge against increased confusion.

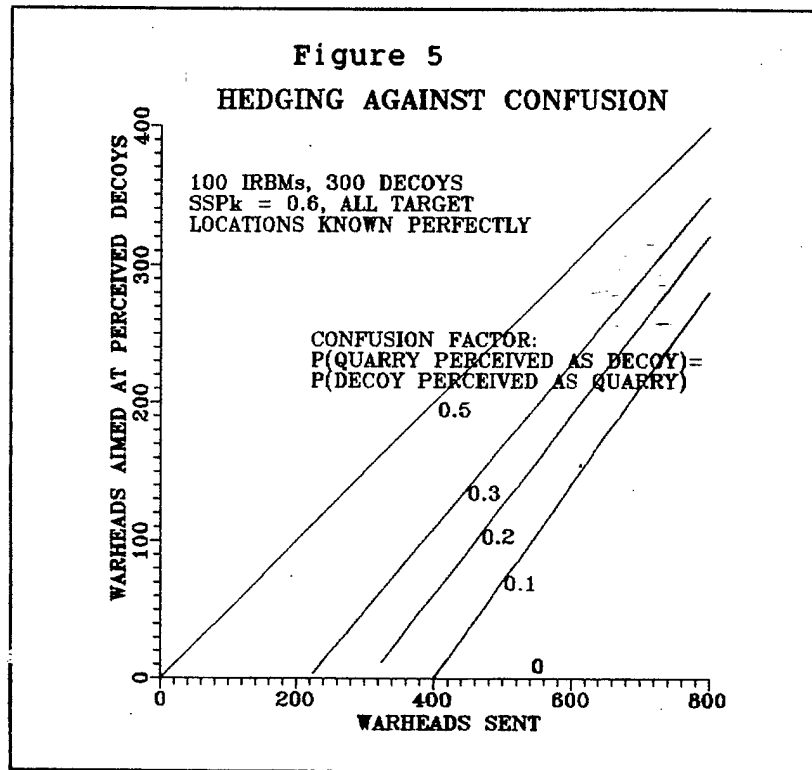
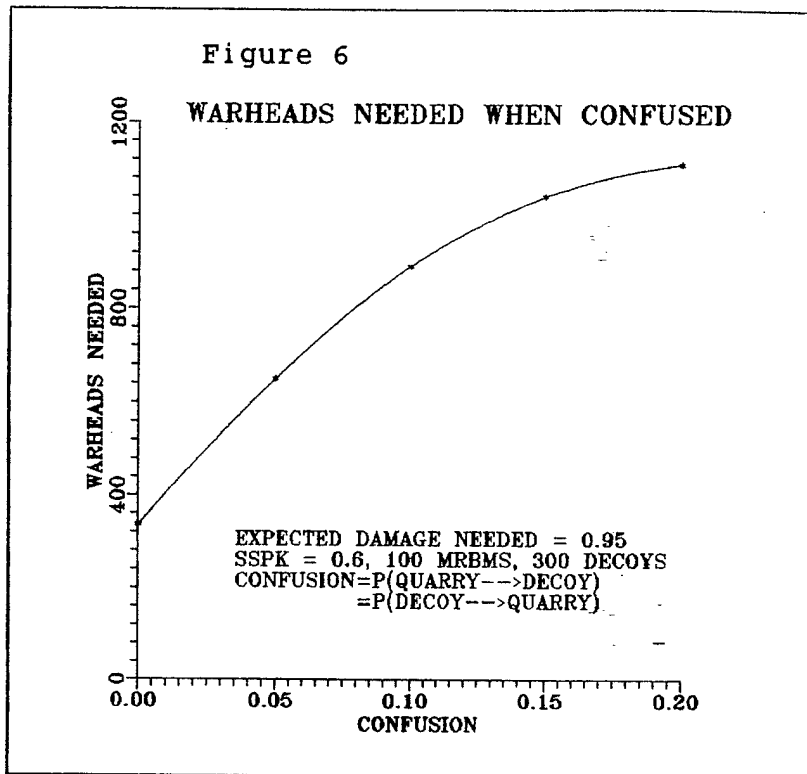


Figure 5 indicates the number of warheads aimed at perceived decoys as a function of attack size. The confusion factor is shown as a parameter. When there is no confusion, then no warheads are ever aimed at decoys. As the confusion grows, then more and more warheads are aimed at perceived decoys. It is this trend that forces much larger attack sizes to achieve a low level of survivability of real targets in the presence of confusion. For example, if confusion = 0.1, then about 130 warheads are aimed at perceived decoys for an attack size of 600 weapons. For a fixed attack of 600 weapons, more and more weapons would be aimed at perceived decoys as a hedge against increased confusion.

In implementing a counter-proliferation policy employing bombers, the fraction of the ballistic missiles destroyed should be large so that the immediate residual threat would be small. In this discussion, we assume that the desired damage to the real targets would be 0.95, or about 5% survival rate. How many warheads would be needed as a function of the confusion to achieve this damage expectancy? Figure 6 indicates one

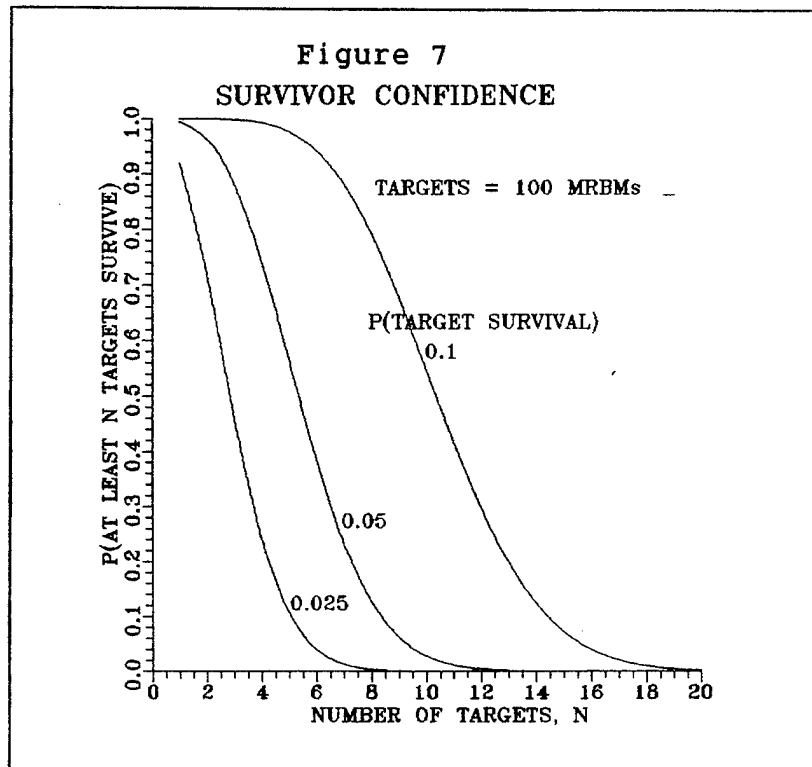


answer to this question in terms of an expected value analysis. In this analysis, it is assumed that the location of each real target and decoy is perfectly known. When there is no confusion, about 335 warheads would be needed. As confusion increases, the number of warheads needed to inflict damage on 95% of the real targets increases dramatically, even with a small degree of confusion. For example, if the confusion is 0.05, the number of warheads needed almost doubles (about 650). Further increases in confusion, even though comparatively modest, have a pronounced effect.

From these analyses, we observe that the discrimination capabilities of an attacker could have a profound effect on the attack effectiveness. If the number of attack weapons is fixed, then the better the discrimination capability, the more effective the attack. If the desired damage to the targets is fixed and the discrimination capability is less than perfect, then the attack size needed to nearly eliminate hostile ballistic missiles is very sensitive to the degree of confusion.

CONFIDENCE AND SIZE OF SURVIVING RESIDUALS

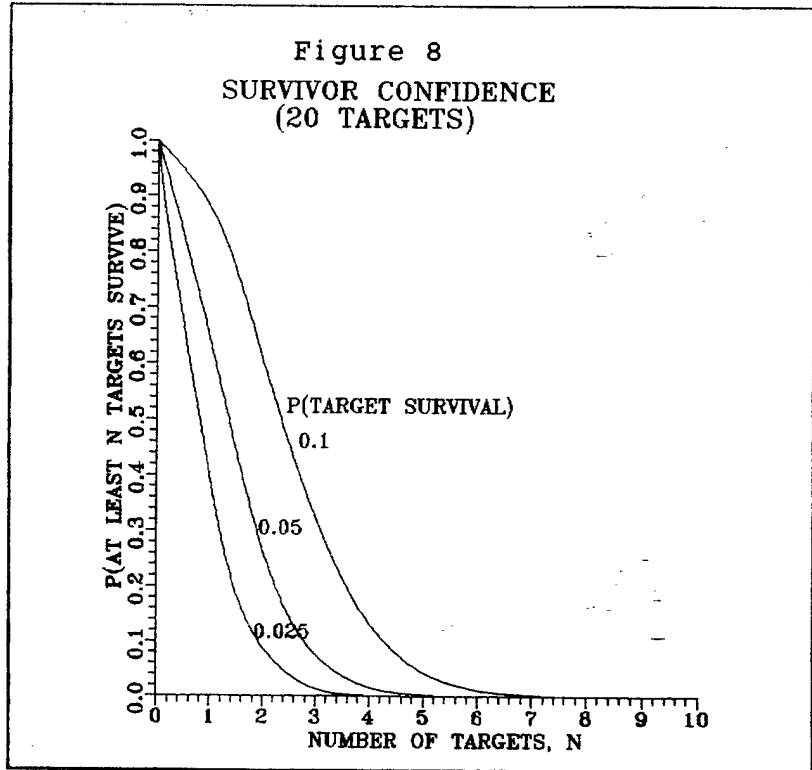
What confidence would a decision maker have that all of the deployed ballistic missiles were eliminated? Even with high damage goals set, there would be bound to be a few surviving targets. To illustrate this point, the probability that at least one, two, three, or more targets would survive is shown as a function of the number of targets. These curves were generated assuming a binomial distribution involving 100 targets, and some representative low values of survival. If a smaller number of targets were involved, then mission planners should present similar curves covering changed situations. In Figure 7, the probability that at least N targets survive is shown as a function of the number of targets. For example, if the probability of target survival is 0.05 (damage expectancy = 0.95), then the probability that at least two targets survive is very high (0.96). Other examples can be drawn from a chart such as this one, but all will show that the probability of at least one or two survivors may be unacceptably high particularly if they are armed with nuclear warheads.



If the number of targets were much less than 100, for example, 20 mobile missiles, then the outcome would be somewhat different. Figure 8 illustrates this effect. If the desired damage probability were 0.95 (probability of survival = 0.05), then the probability that there would be more than three surviving mobile missiles would be about 0.1. Even so, an attack planner might wish to raise the desired probability of damage to 0.975 to assure higher confidence. Under these conditions, at least two missiles might survive with a probability of 0.1. Thus, decision makers would still face a threat of one surviving missile armed with a nuclear warhead.

The trends involving the number of residual survivors and confidence can be examined in a much more general way. The

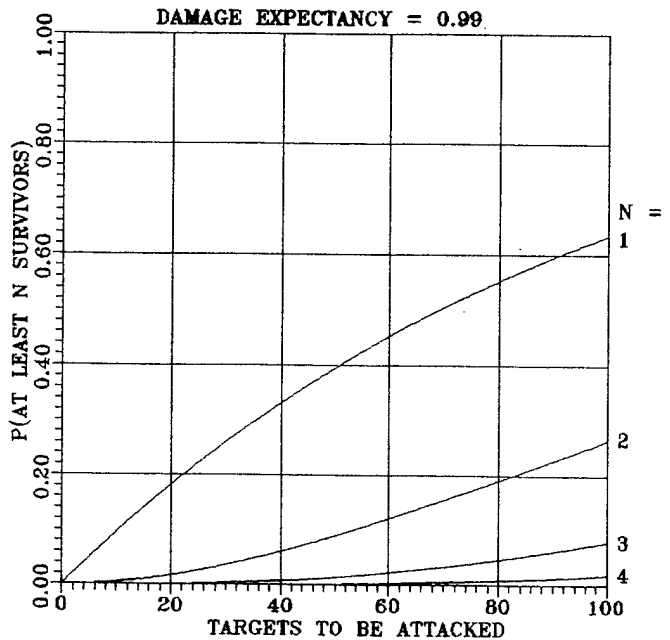
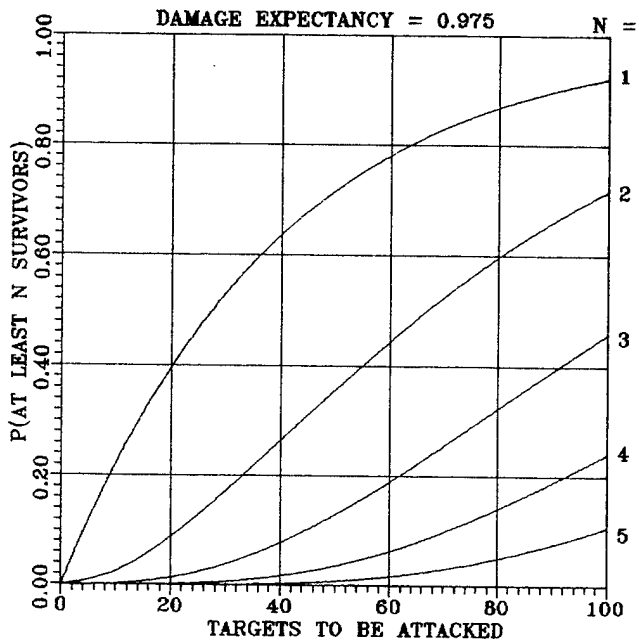
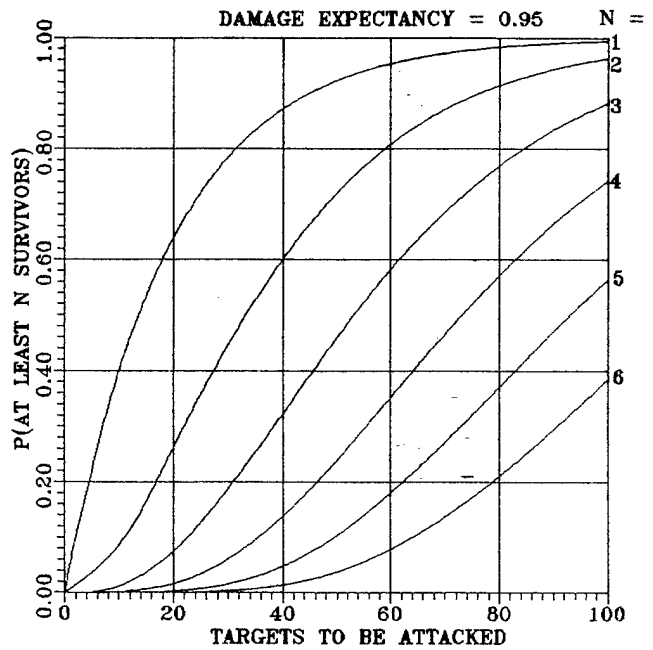
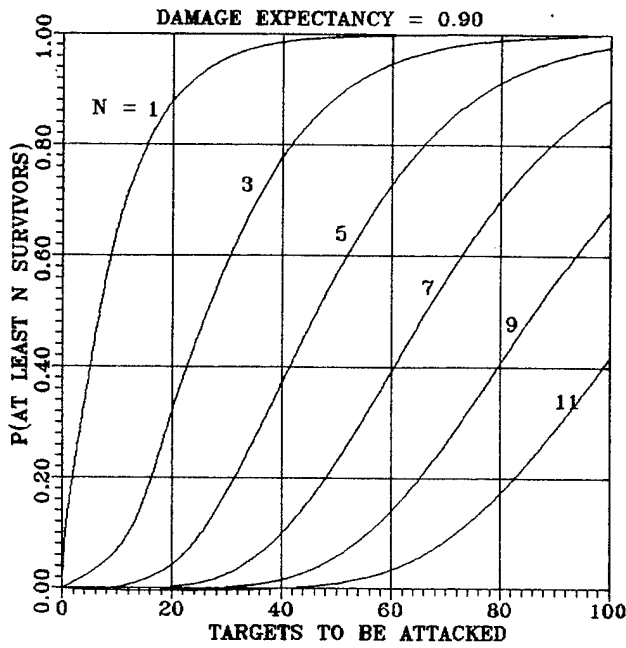
number of missiles that a country may have deployed will be the independent variable for four different values of desired damage expectancy, 0.9, 0.95, 0.975, and 0.99. The results of the analysis are contained in figure 9 which presents a separate set of curves for each desired damage expectancy. The probability of there being at least N survivors is shown as a function of the number of deployed missile launchers with N being the parameter.



If the damage expectancy of an attack were 0.90, then the probabilities that at least 11 missiles might survive amongst 100 targets may not be considered negligible by a commander or his superior. As the number of targets lessened to perhaps 10 or 20, then the probabilities of at least 1 to 3 survivors decrease substantially, but still may be considered disturbingly high. More bombers supplied with accurate targeting information would need to be sent to achieve a higher damage expectancy. Raising the damage expectancy to 0.975 and dealing with a small number of missile launchers begins to provide some relief from the possibility that one or more nuclear armed missiles might survive. In the extreme, a very high damage expectancy of 0.99 could provide low probabilities that at least one target might survive if the target set is limited to 20 or fewer elements.

Achieving such a high damage expectancy could involve very high force levels, depending on the single shot probability of inflicting damage. If aircraft could be equipped with weapons that could achieve very high damage probabilities, on the order of 0.9 or so, then such a change (from the 0.6 assumed earlier) could lead to the commitment of smaller numbers of aircraft. Whether or not such high probabilities of damage are realistic must be left for discussion in another arena of analysis, prototyping, and extensive testing.

Figure 9
 RESIDUAL SURVIVORS AFTER ATTACK
 with Varying Damage Expectancies
 and Various Target Set Sizes



From the examples and the analytic generalizations presented in this discussion, we conclude that if any high confidence strikes are to be made against mobile missiles, they should be planned long before an adversary has a chance to deploy many mobile missile launchers.

Advocates of active defense measures could point out that theater defenses may provide yet another method of dealing with the residual of one to three missiles surviving an air attack. This possibility would be strongly dependent on having an active defense appropriately deployed to protect allies, their cities, military targets, or the forces of the U.S. We suggest that a separate analysis is needed to examine this alternative means of dealing with small residual forces armed with nuclear or other weapons of mass destruction.

OBSERVATIONS

This report has presented an overview of some of the problems involved with the possible use of aircraft for destroying the mobile cruise or ballistic missiles as a means of implementing a counter-proliferation policy. The issues addressed here are surely a minimum of those that might be considered in a detailed planning exercise preceding such an attack. Employing aircraft in an attempt to eliminate proliferated mobile missiles in one country may serve to deter others from following their example. In spite of this aspect of deterrence, less than completely successful enforcement of a ban on the proliferation of ballistic missiles could have immediate consequences in a crisis.

In this report, we have addressed the choice of aircraft to be used to search out mobile missiles, the effect of using intelligence information to narrow the search, and the effect of confusion amongst real and false targets (such as decoys). The final examination dealt with mission success in terms of confidence that all but a few missiles had been destroyed or damaged.

The choice of aircraft to employ in a search and destroy mission presented here was either the option of using low flying heavy bombers or the use of stealth aircraft. Heavy bombers, such as the B-1B, flying at low altitudes to avoid attrition would have a limited view of the area to be searched, but they would carry a large number of weapons per aircraft. A number of stealthy fighter bombers could be used to view much larger areas in question because of their assumed ability to fly at higher altitudes without suffering attrition. In this analysis, we assume that they would carry fewer weapons than the heavy bombers. The uncertainty concerning the high flying aircraft capability to detect and recognize targets at much longer ranges remains problematical, compared to the much shorter ranges between heavy bombers and their targets. Could a sensor in a high flying aircraft (we assumed 12,000 ft) perform as well at slant ranges of 40 n mi as would a similar sensor mounted in a low flying bomber (400 ft AGL) where slant ranges might be on the order of 1.5 n mi? Some may object that our assumptions concerning the number of warheads carried by each type of aircraft is in error. The values selected in this analysis were chosen to highlight the differences between heavy bombers and fighter bombers. We believe that our assumptions have captured this contrast between aircraft types in sufficient detail to demonstrate the different problems faced in choosing between each type.

The use of intelligence information on the location of the targets improved the mission performance of low flying heavy bombers. Could such intelligence information be made available?

If not, the greater and more accurate (assumed) target location information obtainable by a high flying stealthy aircraft might tip the scale as to choice of attack aircraft.

If one assumes that the location of targets is perfectly known, then the question of discrimination between real and decoy (or false) targets becomes a critical issue. In this analysis, it was shown that even modest values of perceiving a real target as a decoy, or vice versa, could seriously degrade the effectiveness of a strike mission. Planners would have to choose between employing more strike aircraft, or improving the discrimination between real and false targets. If improving discrimination capabilities proved impossible, then providing more aircraft would be another option. Achieving success with limited bomber assets would depend strongly on knowing the performance of discrimination sensors before going into battle. If the probability that a real target was perceived as a decoy, and vice versa, were about 0.05, then this analysis indicated that the number of warheads needed to achieve an overall damage expectancy against 100 real targets and 300 decoys would be about twice as high as a bomber force equipped with perfect discrimination sensors. A discrimination error rate of 5%, although seemingly rather modest, would have an enormous effect on the size of the bomber force used in such an operation.

How confident would a decision maker have to be before committing a force of bombers to attack mobile ballistic missiles? We cannot answer this question. Even if mission planners set the desired overall damage probability to very high values (0.9 to 0.975), there is a non-zero probability that some of the targeted mobile missiles would survive. Some readers may argue that bomber effectiveness would be much better if a higher probability of damage by a single warhead were assumed. While we would agree to this suggestion, it must be pointed out that issues related to confidence are not sensitive to improved single shot damage probabilities. Such improvements would only affect the number of bombers used. If a few surviving missiles were armed with nuclear warheads, they could be aimed at soft area targets (cities), or could be used to severely damage friendly or allied forces in the theater. Thus, one or two surviving missiles could pose a serious potential threat. Such a threat might be countered by some other courses of action. First, planners might investigate the use of other means of applying force. Second, if force is to be used, it should be used early, long before a potential third world opponent has time to deploy as many as 100 mobile missiles.

One aspect of countering proliferation of mobile missiles through the use of aircraft has not been considered in this analysis -- damaging or destroying missiles hidden in warehouses or other facilities. Targeting such missiles and their production facilities may prove to be very difficult. Such

difficulties were highlighted during the Persian Gulf War and during the tour of United Nations inspection teams through Iraq after the war was over. If decision makers cannot be convinced that the locations of ALL nuclear armed missiles are known, then they may seek other means of resolving the issue.

Finally, we conclude with the observation that the use of aircraft as a means of forcefully countering proliferation of mobile missiles may have doubtful utility. Even making optimistic assumptions about bomber performance has not led us to high confidence in attack outcomes. If the uncertainties we have examined can be resolved, there still remains the problem of assuring confidence in the outcome of such search and destroy missions. We can only suggest that estimates of the potential number of surviving missiles be presented as an integral part of any offensive strike plans. If theater defenses are deployed before or during a crisis to protect allies or friendly forces, then the defending interceptors may be able to deal with a small residual of nuclear armed cruise or ballistic missiles.

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