A RETALIATORY FORCE SYSTEM STUDY

by

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B. S., Massachusetts Institute of Technology

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1960

Signature of Author . . . . . . Signature redacted . . . . . .
School of Industrial Management

Certified by . . . . . . Signature redacted
Faculty Advisor of the Thesis

Professor Philip Franklin
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusettes

Dear Professor Franklin:

In accordance with the requirements for graduation, I herewith submit a thesis entitled "A Retaliatory Force System Study." I would like to show my sincere appreciation to Professor Emery for his guidance and criticism in the development of the thesis.

I would also like to thank Mr Russel Shorey of The Mitre Corporation for his efforts in the development of the concepts. Thanks also go to Mr. Charles Joyce of The Mitre Corporation for technical guidance and assistance.

Sincerely yours,

Arnold Edwin Jacobson

A RETALIATORY FORCE SYSTEM STUDY

Arnold Jacobson

Submitted to the School of Industrial Management on August 22, 1960 in partial fulfillment of the requirements for the degree of Master of Science.

The purpose of this study is to consider under what conditions this country might buy defense systems to protect the nation against the ballistic missile threat for the next decade. At the present time, there is no adequate proposal for defense. As a result, concepts, boundary areas, and uses should be investigated. This knowledge will contribute to a better understanding of the problems which face the military and civilian designers, and the policy makers who determine the allocation of limited funds among the various users. A most difficult problem is to bridge this gap between the policy maker and the technical designer such that efforts between each can be coordinated along a specific direction in a way which will optimize the long term use of national resources.

Defense systems will not guarantee that a particular point will survive a Russian attack. Rather, they force Russia to increase its attack size per target. Secondly, if Russia chooses to build more missiles, Russia will face a serious cost disadvantage which will hopefully prevent an arms race. If a defense system is to be used to protect ICBM's, it should perform better than any other alternative, with respect to survivability and cost. The objective of this report is to show the maximum amount of money that this country should consider paying for a defense system, and to demonstrate how to compare alternative systems related to an overall objective.

The study is based upon an enemy objective to destroy our retaliatory force by an ICBM attack. The United States objective is to insure that an expected number of missiles survive a particular type of attack. One of the purposes of this analysis is to consider how well undefended ICBM's perform in the face of a concerted enemy effort to destroy them. In order to compare alternative defense systems, it is necessary to develop a standard basis of comparison. The known standard is to consider what would be the survivability of a number of hardened Minutemen against different size threats. A range of threats was investigated, since one does not really know what the actual enemy attack size will be.

It is necessary to make assumptions as to the enemy capability, and the expected number of Minutemen which must survive an attack. If all these facts are known or assumed, then it is possible to consider buying fewer missile sites and allocating the savings to defending the remainder against an attack. Since the United States desires to maintain the same number of surviving missiles for a given enemy threat, it is possible to derive the minimum performance and maximum cost for any type of system which can defend missile bases.

The method considered is first to study the interacting parameters which describe a defensive-offensive action in order to discover important interrelationships and sensitive areas. By specifying the total enemy capabilities, one can derive the important trade-off relationships between active defense and hardened missile bases.

The important conclusions are:

1. The specification of maximum allowable cost bounds for a defensive system.

2. The method which allows one to select optimum defense system combinations.

Thesis Advisor: James Emery
Assistant Professor of
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CHAPTER I

INTRODUCTION

1.1 THE PROBLEM OF DEFENSE PLANNING

Forty billion dollars is spent annually on a large military force for national security. Because there is a continual demand for more powerful strategic weapons, a large part of this money is spent on research and development of military systems similar to the Army's atomic cannon or the Air Force's Sage System. Unfortunately, neither can satisfactorily accomplish the task for which they were intended. They cannot adjust to changes in strategy, nor can they support long term military goals. Because there has been neither guidance nor coordination in planning systems, different defense weapons are built to perform the same task. Thus research effort is wasted on many systems that would never be used. The result of poor planning is wasted effort on undesirable systems, and long development times for those that are needed. The Bomarc and Nike air defense weapons are examples of two systems that have been developed to perform the same task. Neither satisfy the current need.

Defense planning, prior to the development of a system, is needed to obtain a desired weapon at the lowest cost, in the shortest time, and at a low rate of waste of resources. Providing the system designer with cost-performance requirements that are carefully developed from national goals may help direct research in areas that are most coincident with the national interest.

A task for a given weapon system must support a national objective, and the military goal must be carefully defined to provide useful directive information for the military weapon designer. By emphasizing goals rather than systems, a designer can direct research towards a particular product, rather than producing several systems hoping one will be accepted.

The object of this paper is to present a simple example of the effort which is desired in defense planning. The problem is to develop cost-performance requirements for a ICBM defense system which would be used to defend our retaliatory forces if attacked. Since little analytical work has been done in defining areas where a defensive system can satisfy national goals, this problem has been chosen as an initial effort of the type of future planning work which is desired. In the next section the possible need of defensive systems to protect retaliatory forces will be examined.

1.2 NEED OF ACTIVE DEFENSE FOR RETALIATORY FORCES

The most important goal of our strategic military force is to provide deterrence through retaliation. In order to appreciate the need of a strategic force which can destroy an enemy after it has been attacked, it is desirable to examine a strategy of Russia to determine the type of a strategic force needed to provide security.

If one assumes that Russia would attack the United States if it could win a strategic war, the most realistic strategy would be to attack our strategic force to prevent retaliation on her homeland. Making the assumption that Russia would attack first, this strategy would be considered if Russia felt that our surviving forces could cause little damage to her nation. Thus by insuring that a certain amount of our strategic force survives an attack, the United States deters Russia from initiating, without careful deliberation, a war in which she would be seriously damaged.

Certain strategic forces are invulnerable because they cannot be located. Polaris submarines, mobile Minuteman missiles, and bombers, that are off the ground at the time of attack are examples of such weapons. Immobile ICBM's, however, are vulnerable to attack because their location is known by the enemy.

The study will be directed towards protecting immobile ICBM's from being destroyed. A defensive system will be assumed to be collocated with each ICBM of this type in order to insure that at least a certain amount survive an enemy attack.

If other forces cannot be attacked, why build immobile ICBM's? A certain number of key targets in Russia would have to be destroyed by high yield, accurate weapons. Should Russia develop an ICBM defense system, ICBM's would need heavy decoys which aid the warhead in penetrating the defense. Unfortunately, only immobile ICBM's can satisfy these demands.

The number of ICBM's which must survive an attack is determined by the number of targets which must be destroyed. If the United States has a high confidence that at least this number survive, the theory of deterrence is strengthened.

1.3 DEVELOPMENT OF DEFENSE SYSTEM REQUIREMENTS

The methods for producing the defensive requirements are based upon meeting national objectives at the lowest total cost to the United States and the highest cost to the enemy to neutralize our investments.

A retaliatory defensive system is only an aid to help meet a specific objective. If no ICBM defense system were available, then the United States must erect a large number of bases to insure that at least a certain amount survive. If the defense system was deployed, the number of bases which would need to be built would be less, since the survivability of each base would be greater. However, the cost of the defensive system and the associated bases should be less than the cost of employing a larger number of bases only. The cost to Russia to destroy bases should be higher than the cost to the United States to build them. That is, if an arms race develops, Russian expenditures should be higher than the United States, in order to maintain equilibrium.

It will be shown later that a missile, hardened in an underground site called a silo, will cost an enemy more to destroy it than it cost the United States to build it. However, is it possible to meet the required number of surviving missiles at a lower cost by buying fewer silos and defending them? What performance and price characteristics would make the addition of fewer defended silos or more undefended ones a matter of indifference? In other words, what are the general economic trade-offs in this area? By using undefended silos as a bases of comparison, one can evaluate different system against each other to determine the maximum amount which can be saved for each system.

1.4 METHOD OF MODEL DEVELOPMENT

Chapter II presents a general defense model which describes the survivability of a point target. Since little work has been done which examines the relationship between attacking ICBM's and the defensive forces, various attacker-defense configurations are presented to show the sensitivity to a large range of possible combinations.

Chapter III is an application of the terminal defense model and a satellite defense system model to determine weapon requirements on the cost and performance of each system. The costs are a function of how well each system performs with few bases. By comparing the costs to that case where no defense system is employed, the requirements of each system can be derived. A method is also presented which determines the least cost deployment of any defense system and the number of bases needed to insure a given survival level.

1.5 CONCLUSIONS

The main area of interest of this report has been to develop working curves which show for a given range of systems, the maximum amount of dollars that one is willing to pay, for any defensive weapon to protect ICBM bases. The other are of interest has been to show how to compare different systems to find the optimum choice.

It should be understood that answers are merely gross estimates, and are useful to determine regions or trend directions. The limits are only as good as the assumptions which lead to the model.

The first part of the study is concerned with the interrelationships of the various parameters, and how slight deviations of the assumptions and fixed parameters influenced the survivability of the point target. One of the most interesting and obvious conclusions in this area is that survivability is determined by the effort which the enemy expends in trying to destroy the point. It is also quite interesting to understand that the best strategy of the enemy, for few attackers, is to attempt to over-kill each one of the targets rather than divide his attack equally among all points. Future research might be directed towards investigating attack strategies against various targets, or defense systems, depending upon the assumptions concerning the operations of the systems.

CHAPTER II

MODEL DEVELOPMENT

2.0 INTRODUCTION

A description of the various parameters will be presented that combine to form the model. The probability of target destruction when no defensive system is available, is essential to the development of the more complex model, and will be deduced prior to the investigation of the target defense system model.

In the analysis, it is assumed that the enemy can position his force over any one target at the same moment. This will be defined as a "sudden" attack. A "simultaneous" attack is one in which all targets are subjected to a sudden attack. A simultaneous attack is of greatest interest, because it places a severe strain on the retaliatory system.

2.1 INTRODUCTION TO THE DEFENSE MODEL PARAMETERS

An ICBM, and its checkout and communication equipment, will be called either a target or a silo. The system will be located beneath the surface of the ground, protected by concrete bunkers, because the underground bunkers offer more protection from the blast effects of a nuclear detonation.

The defensive system, which protects the silo, contains radars, anti-ICBM's (AICBM's), computers and control equipment. The radar and computer system can predict the trajectory of all objects whose impact area might be within a dangerous zone.

The AICBM is a small, high acceleration type missile which can intercept an attacker. The control system regulates and communicates information to the AICBM in order to intercept the enemy missile. Finally the computer predicts interception points, trajectories, and other necessary information which is required for proper operation.

The enemy attacker, or nose cone, is a nuclear warhead which is aimed at the silo. Associated with the warhead might be a number of decoys which may, or may not, appear to an observer as an actual warhead. If the enemy can conceal each warhead with decoys, it would be impossible to attack and destroy all objects. However, if all decoys but a few can be discriminated, it might be possible to build a system to destroy relatively few objects, and be sure of destroying the warheads.

The altitude of interception of the AICBM is determined by the radius of kill of the warhead with respect to the silo. If the enemy explodes the warhead outside this particular radius, the explosion will not damage the target. Therefore, there are two ways the target can survive:

1. the enemy warhead is destroyed by an AICBM,
2. the warhead is not intercepted but it explodes outside the radius of kill.

Decoys are discriminated from the warhead by the radar system whenever the objects, consisting of warheads and decoys, pass through the different density layers of the atmosphere. If the altitude of interception is high many of the decoys will not be discriminated, while at low altitudes only few objects, which have not been discriminated, remain. Furthermore, if the altitude of interception is low, the enemy has to build heavy decoys so that the warhead can be concealed by a few decoys. Thus, he must sacrifice payload weight of his ICBM to conceal his warhead. It seems reasonable to build a silo and a defense system to resist as much blast pressure as possible since the point of interception can be lower. At what point is it better costwise to build more AICBM's than blast resistant systems?

2.2 TARGET VULNERABILITY MODEL

Let us assume that each silo is independent of any other silo, and the attack is divided equally among the targets. If there is no defensive system, the survival probability of the target is determined by the number of warheads, the hardness of the target,[1] the yield of the nuclear weapon, and the Circle of Probable Error.

In order to quantify these relations, the following assumptions were made:

1. The distribution of warheads about a point target is the Gaussian Circular Distribution.
2. The bomb is exploded on the ground.
3. If the pressure contour of the bomb equals the hardness pressure of the target, the silo is destroyed.

---

[1]Hardness is a measure of the blast protection, and is measured in terms of pounds per square inch.

Derivation of P_{ro}, the Probability that a Target is Destroyed by a Single Bomb

The density function, p_r, of the Gaussian Distribution equals:

$$p_r \, dr = \left[\frac{r}{\sigma^2}\right] e^{-\frac{r^2}{2\sigma^2}} \, dr$$

$P_{ro} = p_r \, dr$ = the probability that a single bomb with a radius of destruction, r_o[1] destroys the point target. r_o depends upon the hardness of the target and the yield of the warhead.

In the military, the circle of probable error, CEP, is specified rather than the standard deviation, σ. The circle of probable error is defined by the following equation:

$$.5 = \int_0^{CEP} p_r(\sigma) \, dr$$

One can solve the equation for CEP in terms of σ. CEP is a radius which defines the area of a circle. The probability that any object lands within this area is equal to one-half. If one were to solve the equation for CEP in terms of σ, CEP $= \sigma\sqrt{2 \ln 2}$[2]

---

[1] r_o is the radius from the center of the explosion to a pressure contour from the bomb which is equal to the hardness of the silo.

[2]

$$.5 = \int p_r(\sigma) \, dr = 1 - e^{-\frac{CEP^2}{2\sigma^2}}$$

$$.5 = e^{-\frac{CEP^2}{2\sigma^2}}$$

$$\ln 2 = \frac{CEP^2}{2\sigma^2}$$

$$CEP = \sigma\sqrt{2\ln 2}$$

Now returning to p_r and integrating, $P_{ro} = 1 - e^{-\frac{r_o^2}{2\sigma^2}}$

If CEP = c;

$$\sigma = \frac{c}{\sqrt{2\ln 2}} \quad : \qquad \text{EXP = Exponent of e}$$

$$P_{ro} = 1 - \text{EXP}\left[-\frac{r_o^2}{\frac{2c^2}{2\ln^2}}\right] = 1 - \text{EXP}\left[-\ln 2\right]^{\frac{r_o^2}{c^2}}$$

But $\text{EXP}\left(-\ln 2\right) = 1/2 \quad \therefore \quad P_{ro} = 1 - (1/2)^{\frac{r_o^2}{c^2}}$

The relationship $r_o = f(W_y H)$, where W_y is the yield of a weapon, and H is the hardness, is determined from experimental data to be;[1]

$$r_o^2 = \frac{36\, W_y^{2/3}}{H}$$

Now substituting for r_o^2,

$$P_{ro} = 1 - (1/2)^{\frac{36\, W_y^{2/3}}{c^2 H}} \qquad 2.1$$

Thus we now have a relationship between the probability of destruction, P_{ro}, yield, hardness, and CEP.

r = lethal radius in nautical miles

c = circle of probable error

W_y = yield in megatons

H = hardness in PSI

2.3 TARGET SENSITIVITY

P_{ro} is plotted against hardness for various cases of weapon yield in Figures II-1 to II-5. One can easily see that hardness does influence the destructive probability of the target. For bombs with yields of 2, 5, and 10 megatons, P_{ro} has its greatest decrease for hardness up to 300 PSI. For yields between 15 and 20, hardness does not have much

[1] USAF Report on the Ballistic Missile

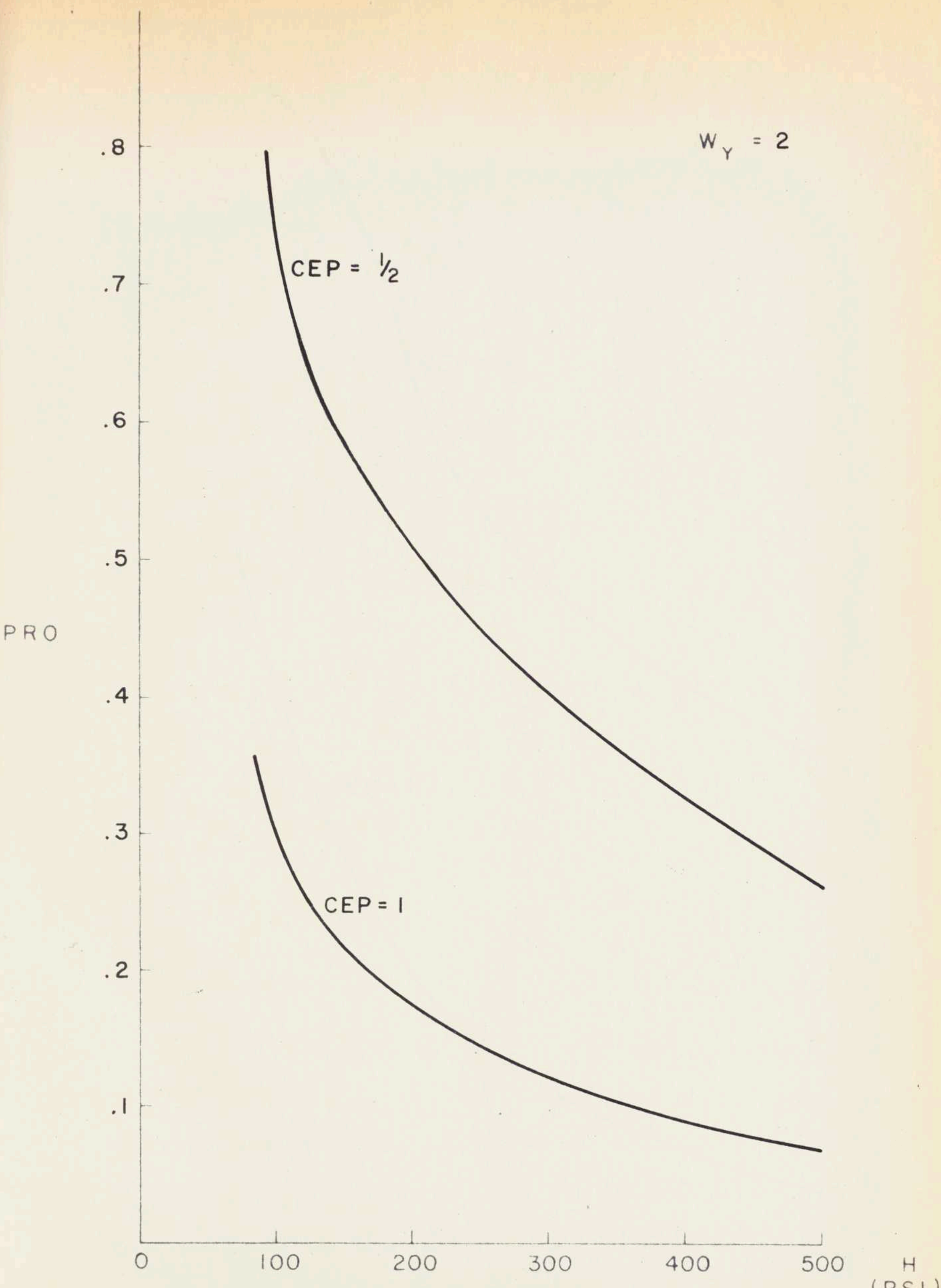

FIG. II-1

PROBABILITY OF TARGET DESTRUCTION FOR ONE BOMB, PRO vs HARDNESS H

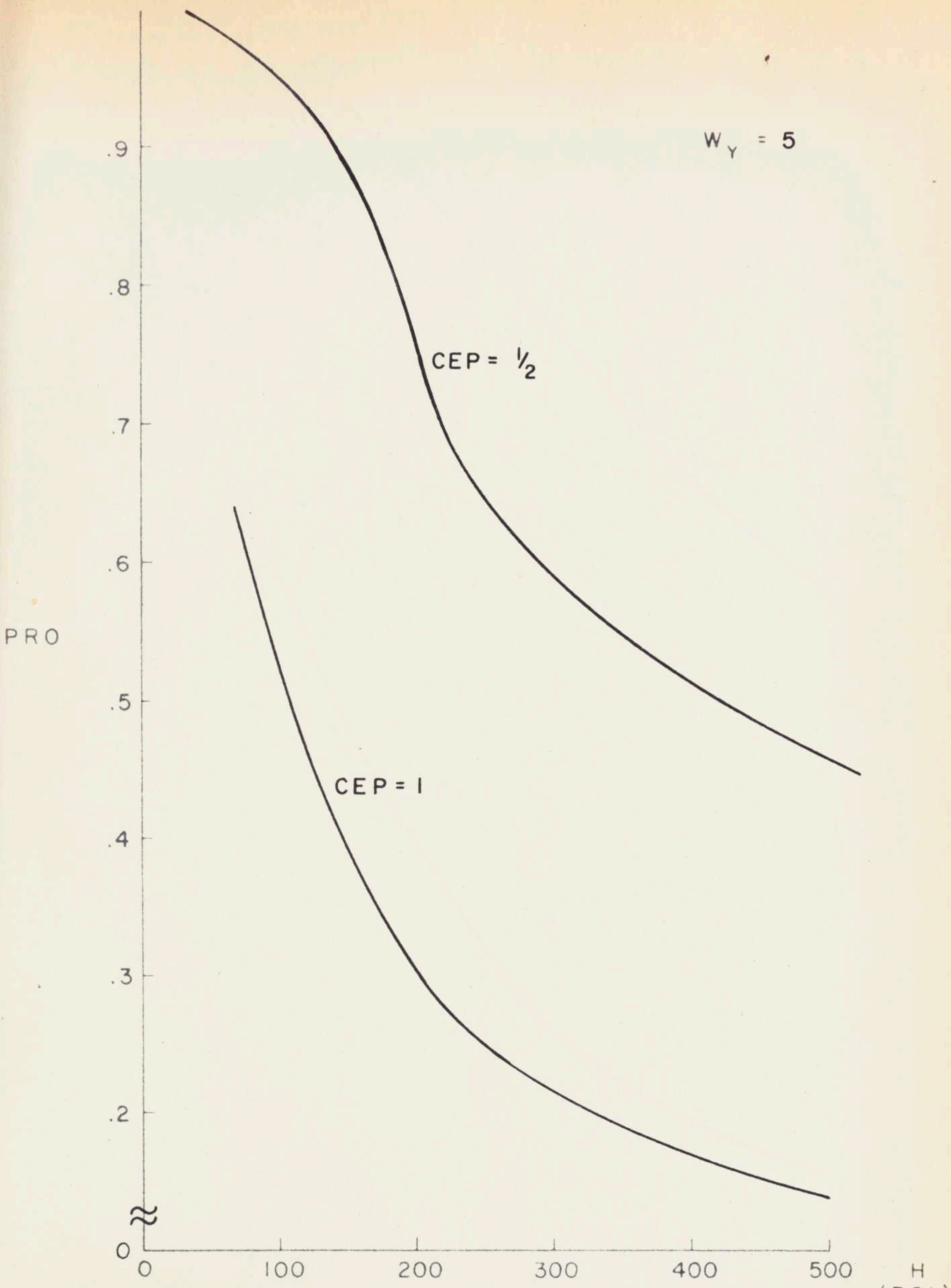

FIG. II-2

PROBABILITY OF TARGET DESTRUCTION FOR ONE BOMB,
PRO vs HARDNESS H

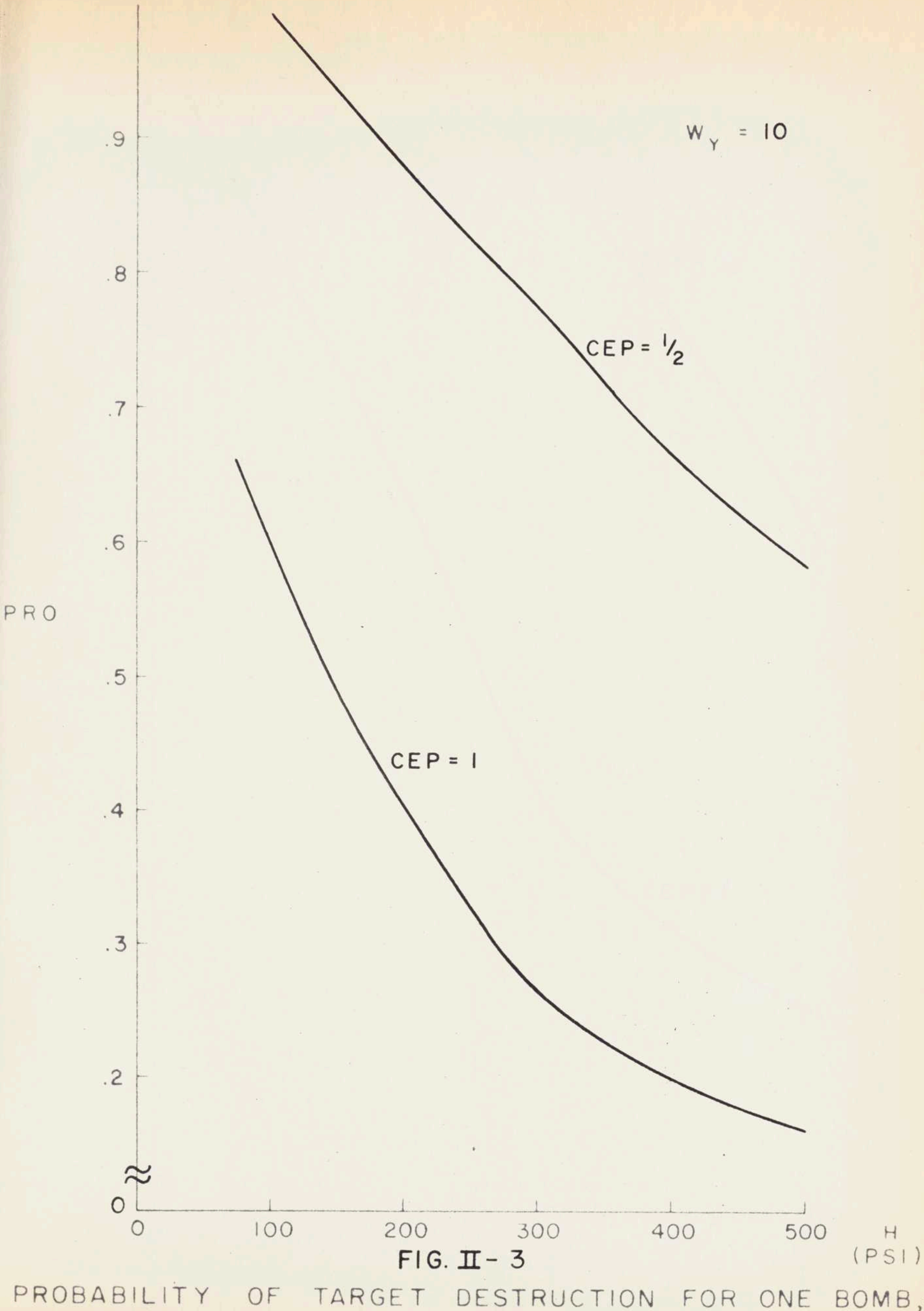

FIG. II - 3

PROBABILITY OF TARGET DESTRUCTION FOR ONE BOMB, PRO vs HARDNESS H

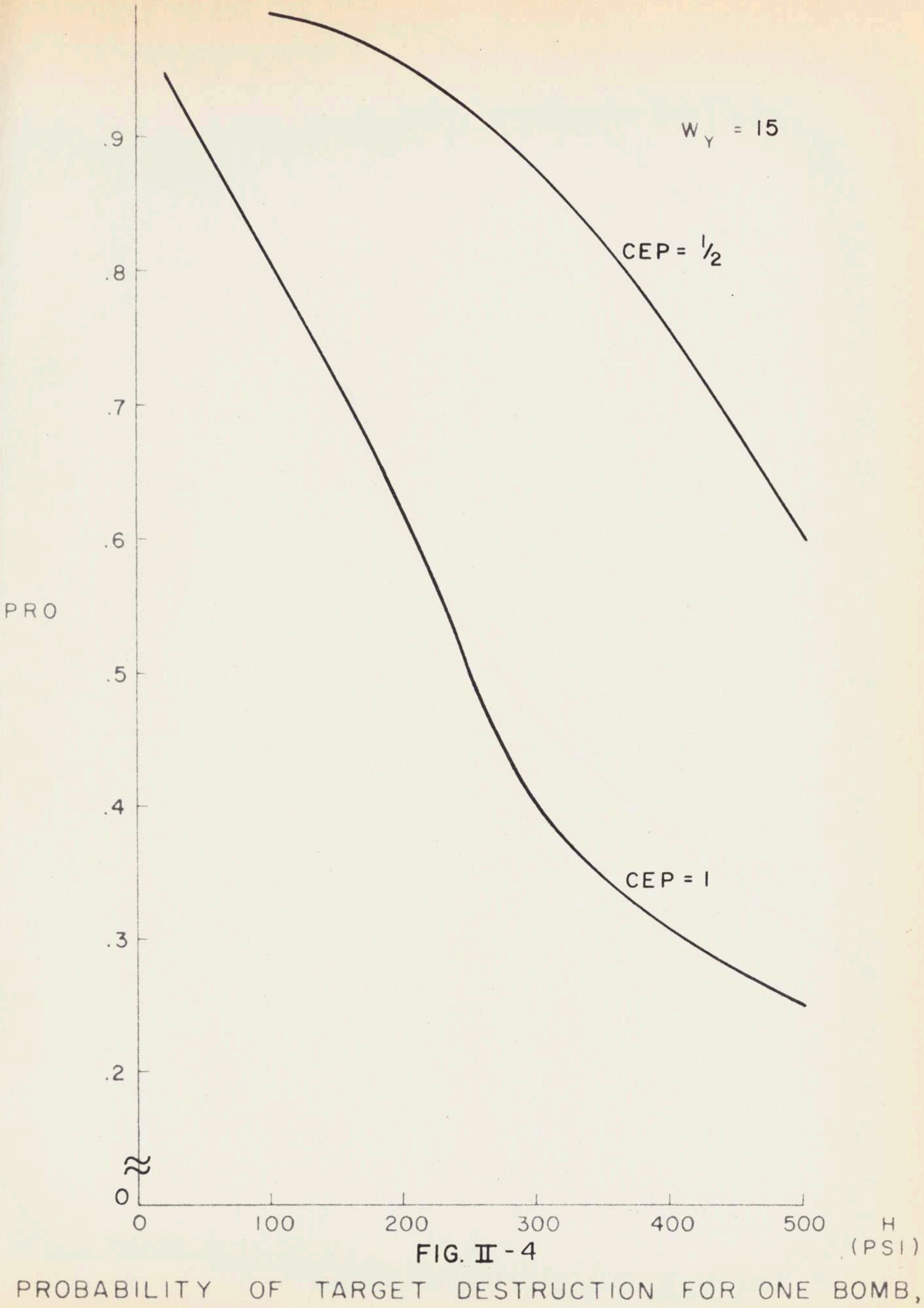

FIG. II - 4

PROBABILITY OF TARGET DESTRUCTION FOR ONE BOMB, PRO vs HARDNESS H

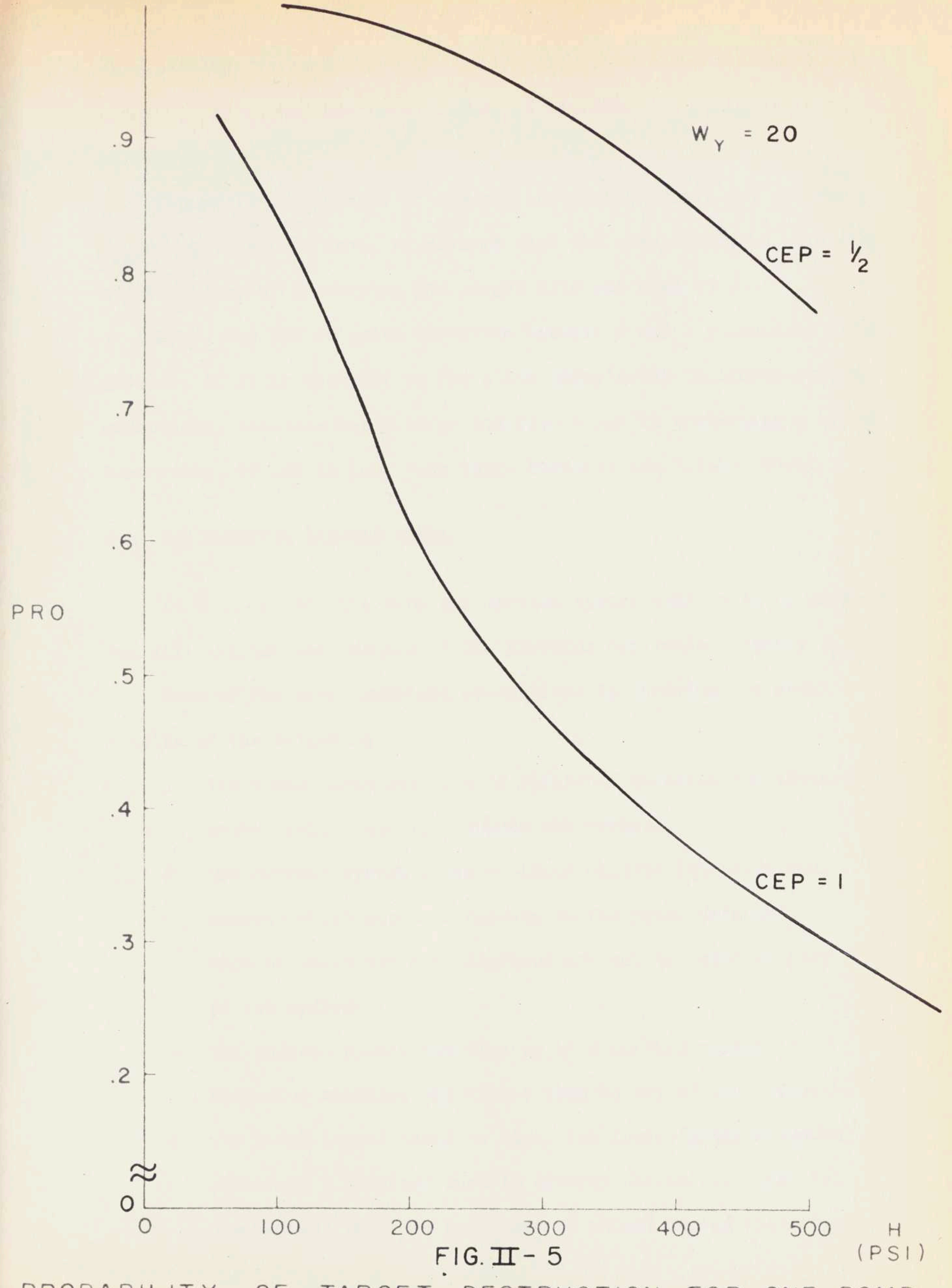

FIG. II - 5

PROBABILITY OF TARGET DESTRUCTION FOR ONE BOMB, PRO vs HARDNESS H

survivability influence for CEP of 1/2 mile. By increasing hardness, however, one forces the enemy either to increase his yield or improve his CEP.

Figure II-6 is a type of summary curve of hardness vs. CEP for a P_{ro} of .9. In this case, we assumed that the enemy wants to maintain a probability of destroying the target with one bomb of .9.

Here, the CEP is quite sensitive between 0 and 1.5 nautical miles. However, if it is possible to force the enemy's CEP to increase even moderately, hardness has a large positive value in protecting a target. Conversely, if CEP is low, very large hardness has little value.

2.4 THE TERMINAL DEFENSE MODEL

In this section the terminal defense system model will be derived, and will include the results of the previous derivation, namely P_{ro}.

Some of the more important assumptions in deriving the model consist of the following:

1. The enemy force consists of ballistic warheads and advanced decoys which exactly simulate the warhead.
2. The defense system fires at those objects (warheads and decoys) which appear dangerous to the point defended. Objects which are not dangerous are not included as part of the system.
3. The defense system can fire up to a certain number of defensive missiles and direct them to any of the attackers.
4. The model is not based on time, but investigates a sudden attack as a strategy used to destroy the point. That is, the defense does not have time to reload during the attack.

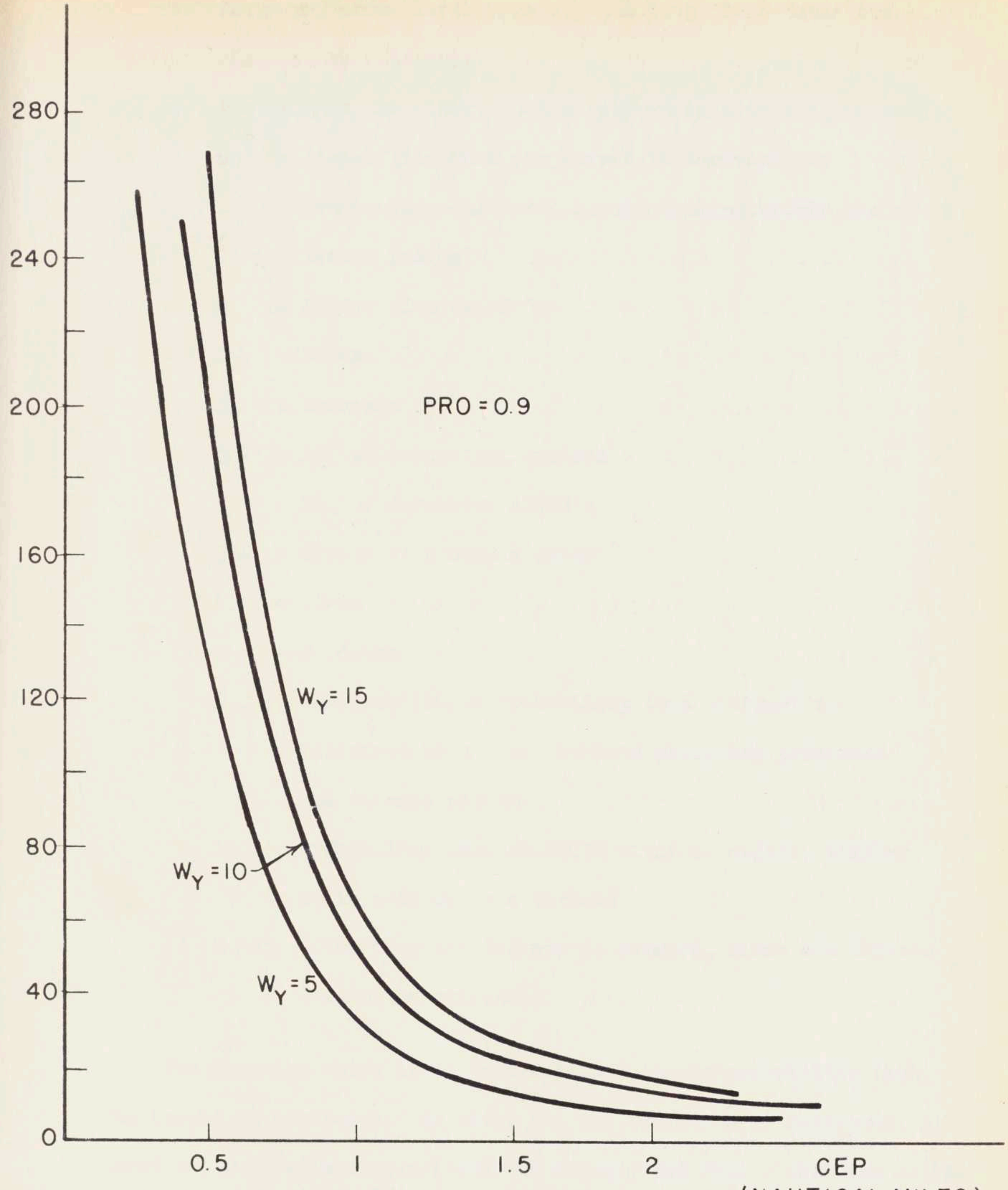

FIG. II - 6

HARDNESS H VS. CEP

5. The enemy never fires more objects than the defense has missiles to intercept.

6. The AICBM's are distributed evenly among attacking objects.

S = Probability that the target is destroyed by penetrating the defense, and falling within the lethal radius.

N = Decoys plus warheads

D = Decoys

W = Warheads

D/W = No. of decoys per warhead

M = No. of defensive AICBM's

CEP = Circle of probable error

Y = Yield

H = Hardness

P_{ro} = Vulnerability = Probability that a target is destroyed by a given warhead which has penetrated the defense system.

P_k = Probability that an AICBM kills an object, whether it is a decoy or a warhead.

$M \geq N$ (Otherwise the defense is swamped, since all objects cannot be attacked).

The function which is to be determined is the probability that the target is destroyed. In order for the target to be destroyed, at least one warhead must penetrate the defense and fall within the lethal radius.

$S_k = 1 - P_k$ = the probability that a warhead is not killed by the defensive system.

M/N = the number of AICBM's which are assigned to each warhead.

$S_k^{M/N}$ = the probability that a given warhead penetrates the defensive system.

$S_k^{M/N} P_{ro}$ = the probability that a given warhead penetrates and destroys the target.

$1 - S_k^{M/N} P_{ro}$ = probability that the target survives an attack of a given warhead.

$$1 - \left[1 - S_k^{M/N} P_{ro}\right]^W = S, \text{ the probability that the target is destroyed by an attack.} \qquad 2.4.2$$

Equation 2.4.2 is the general model for a terminal defense system. It relates the number of attacking warheads, the target vulnerability, the number of objects which are attacked, the number of AICBM's which are fired, and the individual kill probability of each AICBM.

The first problem is to consider the sensitivity of the threat to a number of independent defended silos. Assume that the United States has 180 silos whose probability of survival has the characteristics of Figure II-7.

Assume that Russia has 540 ICBM's with which to attack the silos. If the Russian objective is to maximize the total number of silos destroyed, how many should be fired at each base?

If W = 3, then S = .28. All silos can be attacked and the expected number destroyed equals .28(180) = 50.5; if 4 bombs are fired at each silo only 135 can be attacked; S = .475, and .475(135) = 64.3 silos destroyed. For W = 5, S = .85, and only 108 silos can be attacked, but the expected number destroyed is 89.4. For W = 6, S = .94, only

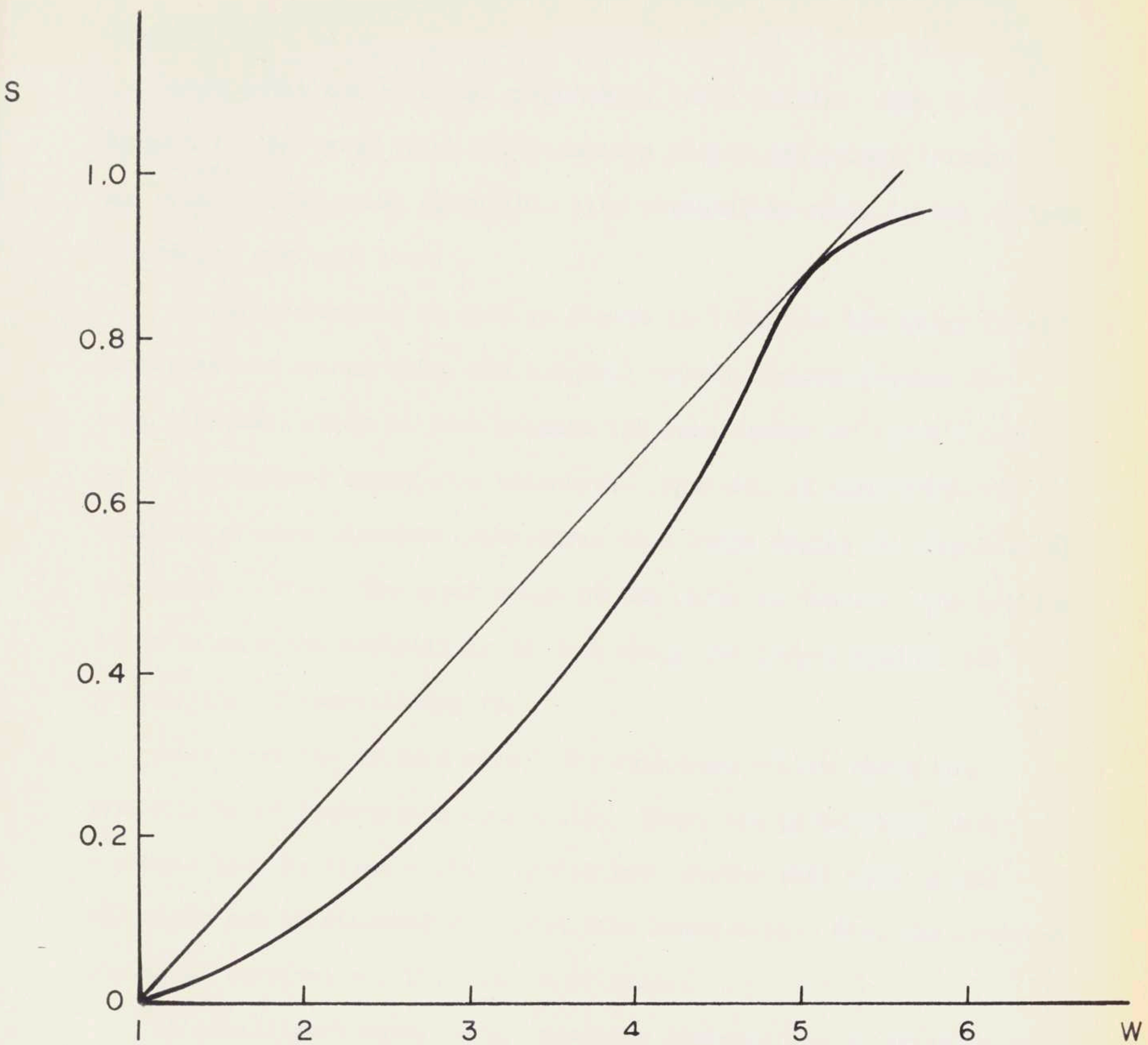

FIG. II-7

PROBABILITY OF TARGET DESTRUCTION S, vs NUMBER OF ATTACKING WARHEADS W

90 can be attacked and the number destroyed is 84.6. Thus, the maximum number of silos destroyed occurs when each silo is attacked by five missiles.

This point can be found graphically quite easily. Draw a line tangent to the curve which has a maximum slope, and passes through the origin. The point where this line touches the curve is the optimum attack for a single base.

It is interesting to note on Figure II-7 that as the enemy first increases his attack size, the marginal return becomes greater for each attacker. This is true because the same number of AICBM's have to be distributed among more attackers. However, at some point the addition of more warheads contributes to a large degree to over-killing the target. Thus, the upper range of the curve is convex. The problem is to balance the probability of destroying the target against the probability of over-killing it.

Note that the optimum attack for each base occurs where the probability of destruction equals .85. Thus, the probability that a single base survives = .15. Let us now assume that each of our 180 silos can be attacked with just five bombs each. Now, the expected number of survival = (.15) (180) = 27 silos.

An intelligent enemy cannot consider implementing an attack upon the U. S. retaliatory force, with an .85 probability of destruction, without evaluating his confidence that the attack will be a success. The confidence that he demands, depends very much on the importance of the factors that are risked. What are the consequences if the attack doesn't destroy 85% of the retaliatory forces?

One can safely say that in any type of war a combatant would like to reduce the overall risk to zero. At the same time, history has shown that the actual risks taken has been high in many instances. How is it possible to estimate the confidence limit of Russia? It cannot be done. The only other possibility is to design a system in which the enemy's confidence limit is not an important criteria in judging the systems effectiveness.

Consider the previous example to elucidate this situation. Assume the enemy has 900 ICBM's with which to attack 180 silos, and if 27 or less silos survive the enemy attack is a success.

How confident of success is the attacker actually, in this instance? The probability that more than 27 survive is .50. Will the enemy risk an attack, if the probability is .5 that it will not succeed? If he demands a .90 confidence level of success, the attacker must increase his attack by one missile per base. His kill probability now jumps to .92. Instead of using a total of 900 missiles, our attacker must use 1080 to be .90 confident of success.

If the defense system wanted at 90% confidence that more than 27 survived, one would have to build more silos and know the attacker strength. Unfortunately, this cannot be done with much confidence.

In summary, if one assumes a particular threat, and a number of defended silos, the best strategy of the enemy is not to attack each base equally, unless he has a very large number of weapons relative to the United States. He achieves the largest number of bases destroyed whenever he attacks each base with enough warheads such that the probability of destruction divided by the number of warheads is largest.

Now, when he has sufficient warheads to attack each base at least at this point, he then divides any remaining missiles among the silos equally.

Finally, one cannot assume with any confidence that the enemy will attack when he can obtain a certain kill per base. The only way around this problem is to postulate that the enemy threat is of a certain size, and decide how many bases we need to insure that we have a large confidence that his attack cannot succeed.

DESCRIPTION OF CURVES DEALING WITH DEFENSE OF SILOS

It is necessary to investigate the details of the model for a single point defense to understand the interactions between the attacker and the defense. Each of the following curves are described and interpreted as follows:

FIGURE II-8

For this and the following figures a hardness of 2,000 PSI, a CEP of 1/2 statute mile and yield of 40 mt. were picked as one of the reference points. The most interesting fact about this figure is that the values of CEP are highly sensitive to P_{ro}.

FIGURES II-9, II-10, II-11

Probability of destruction S vs. number of AICBM's M:

For this figure, it is easily seen that the survivability of the point is highly sensitive to the salvo size, M, under assumption $M \geq N$. In this case, all decoys have been discriminated, and the number of warheads is first equal to, and then becomes much less than

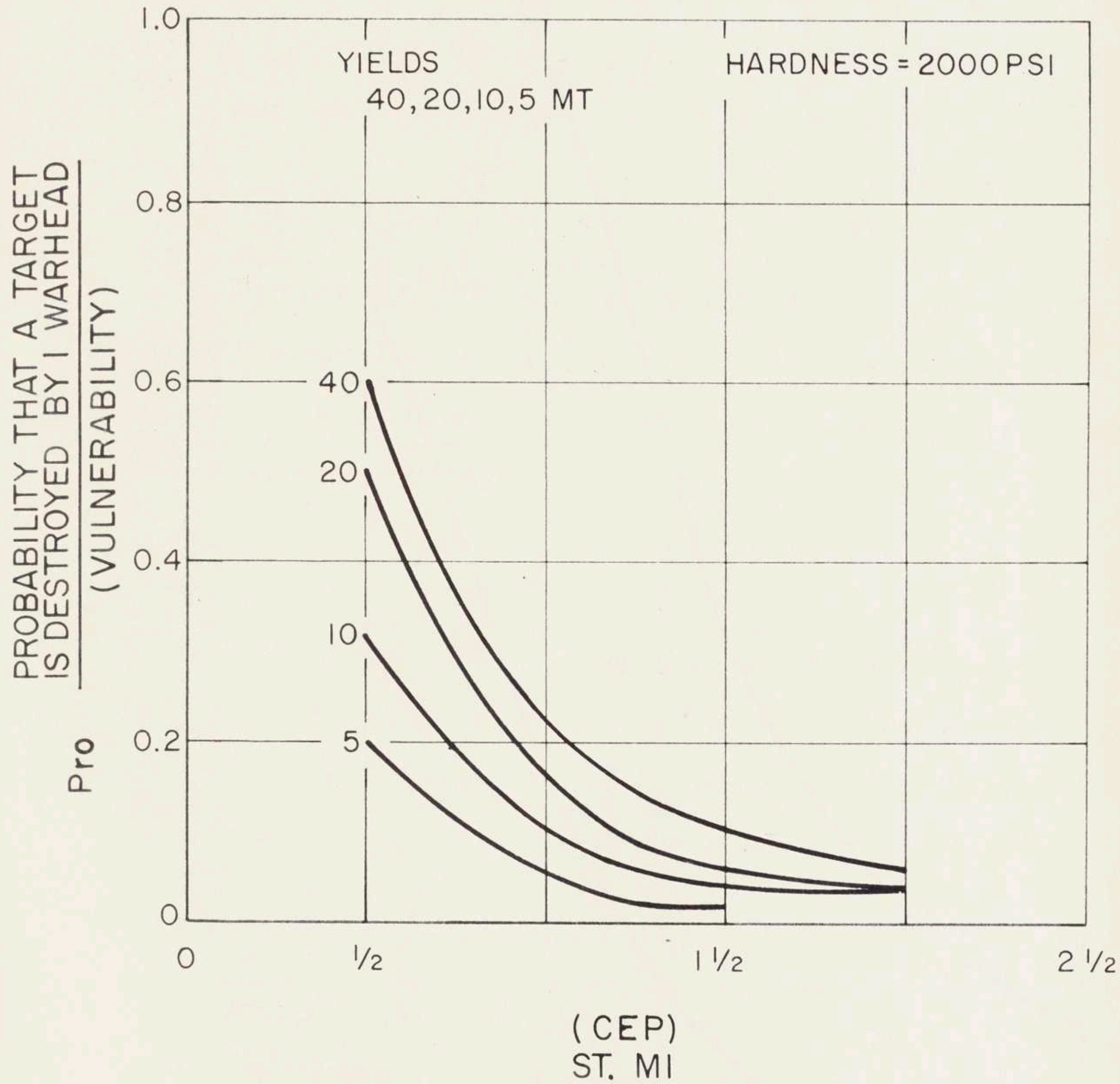

FIG. II-8

PROBABILITY THAT A TARGET IS DESTROYED vs CEP FOR ONE BOMB FOR DIFFERENT YIELDS

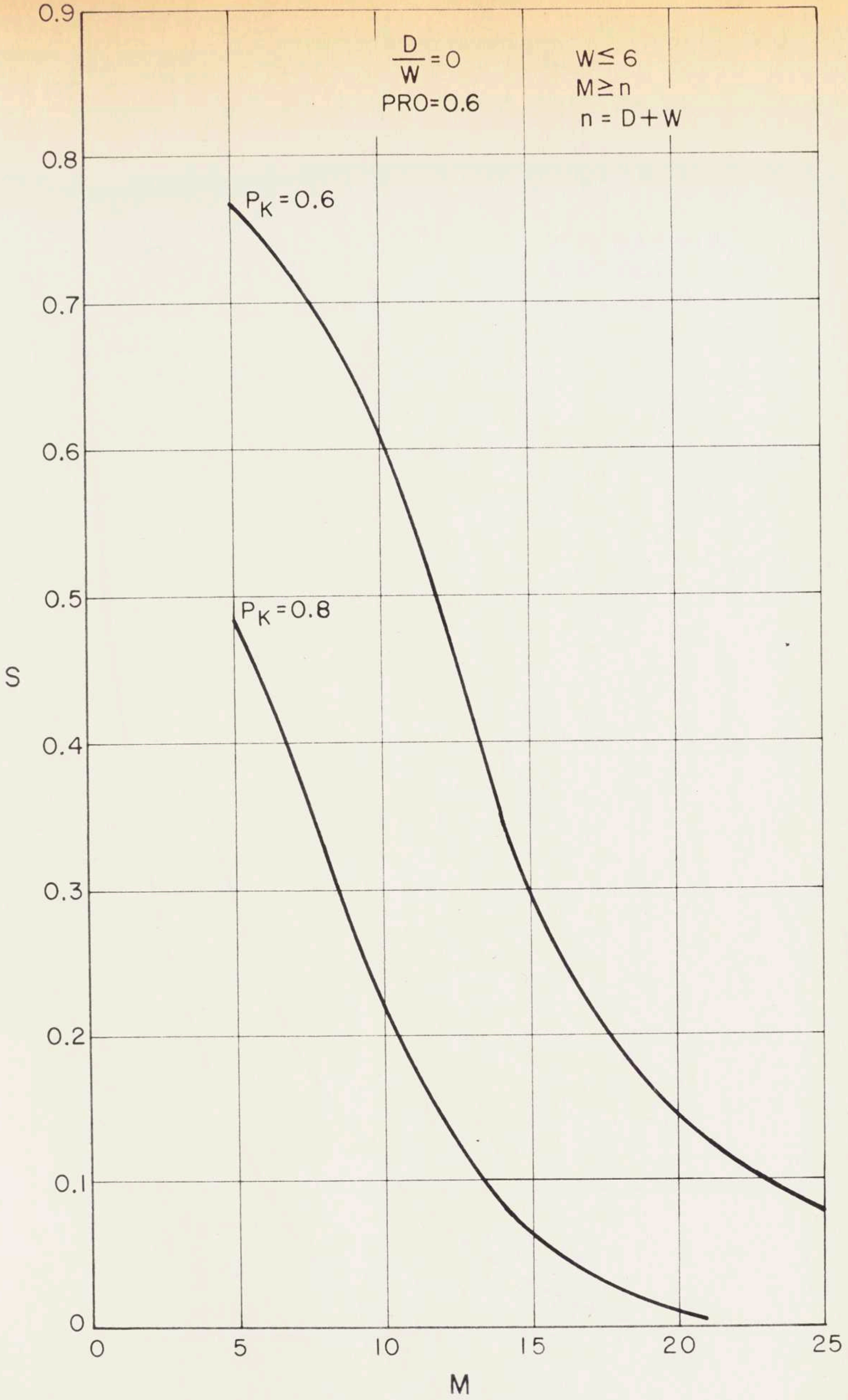

FIG. II-9

PROBABILITY OF DESTRUCTION S, vs NUMBER OF AICBMs, M

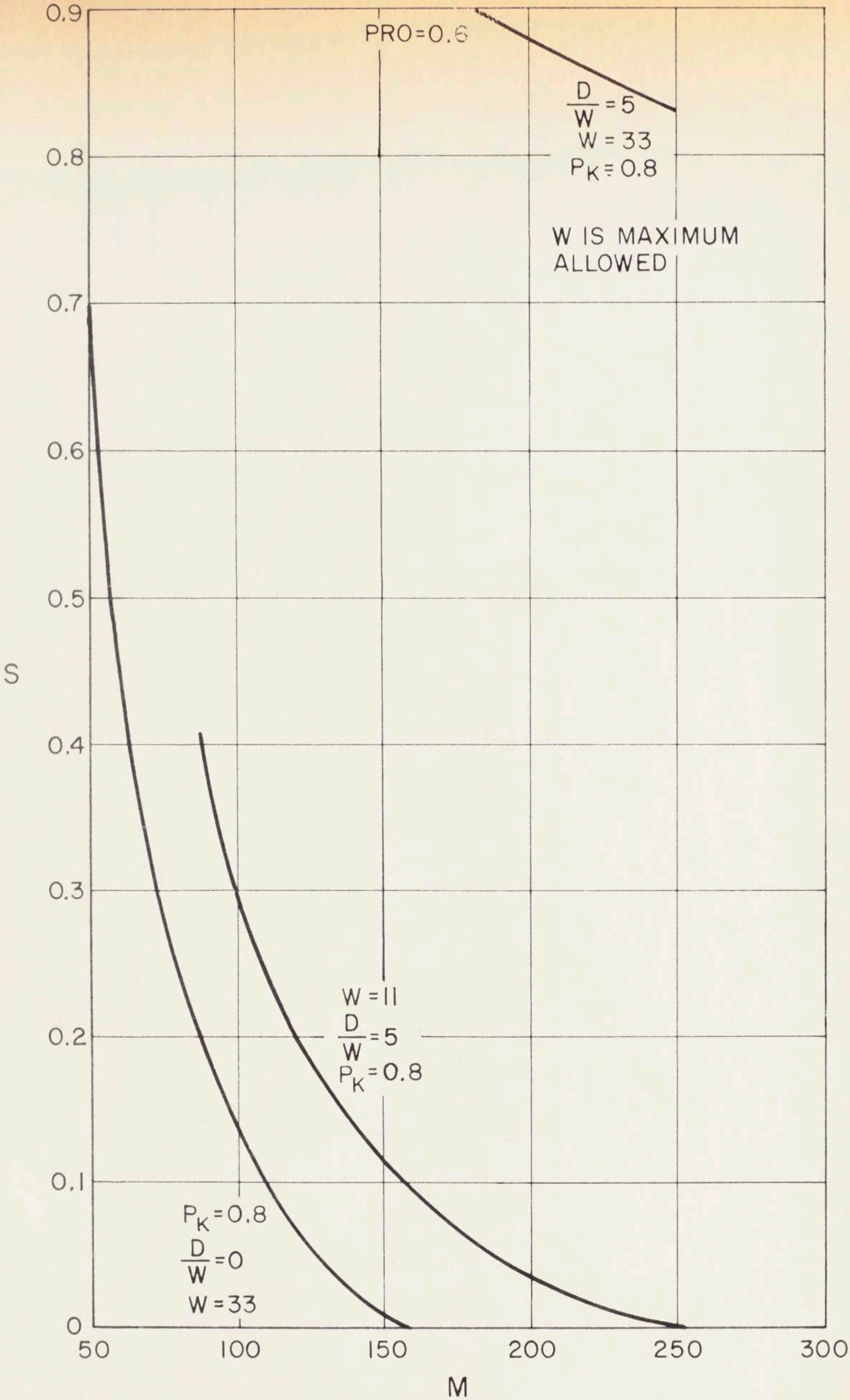

FIG. II -10

ROBABILITY OF DESTRUCTION S, vs NUMBER OF AICBMs, M

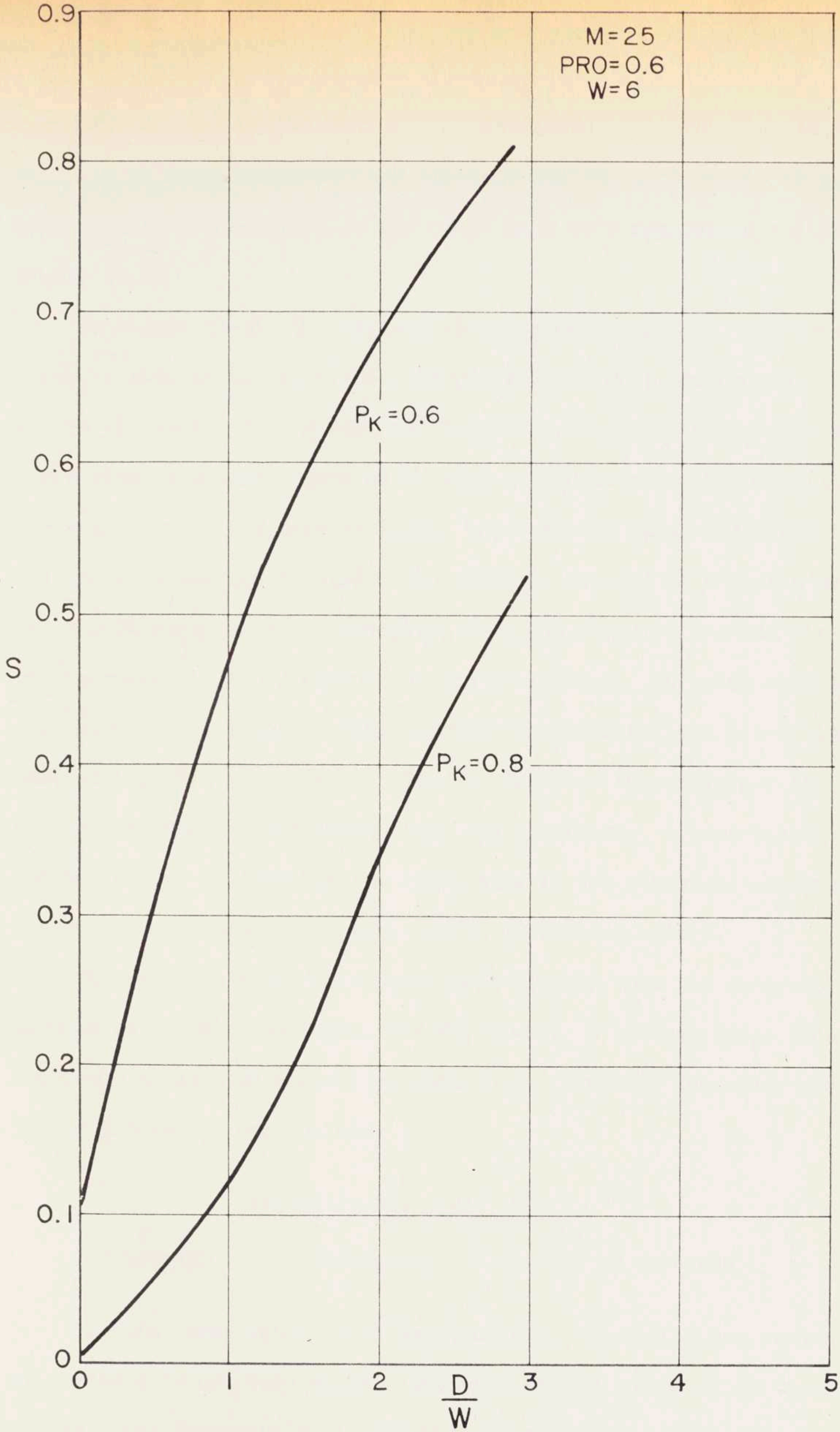

FIG. II - 11

PROBABILITY OF DESTRUCTION S,

vs DECOY TO WARHEAD RATIO $\frac{D}{W}$

the AICBM's. A large number of AICBM's per warhead significantly reduces the probability of kill of each warhead, but the probability of penetration of each warhead increases as the ratio of M to W approaches unity (see Figure II-10).

In Figure II-10, M is allwed to increase up to 250. The lowest curve is similar to the one on the preceding figure; no decoys, and P_{ro} is the same, .6. In the next higher curve, the attacker has undiscriminated decoys. Here he obtains a significantly higher kill probability with 1/3 less warheads; however, the total objects which must be attacked has doubled. The curve at the top is the same as the lowest curve with the exception that the decoy to warhead ratio has increased to 5. A rather obvious conclusion: by using more decoys per warhead (still only a small number) the attacker can almost insure destruction of a point easier than the defense can counteract it, even with an increase in the salvo size. In other words, a poor tactic for the defense is to increase the salvo size if the attackers can increase the decoy to warhead ratio with little additional effort.

Figure II-11 shows this point more clearly when the decoy to warhead ratio is almost zero, M = 25, W = 6. S becomes large when the decoy to warhead ratio increases to 3. When D/W increases above 3, the defense is overwhelmed.

FIGURE II-12, II-13, II-14

Probability of destruction vs. number of warheads

In this case, for a fixed value of D/W, increasing the number of warheads is not very significant if M is very large relative to W. However, the defensive kill probability is more sensitive than the

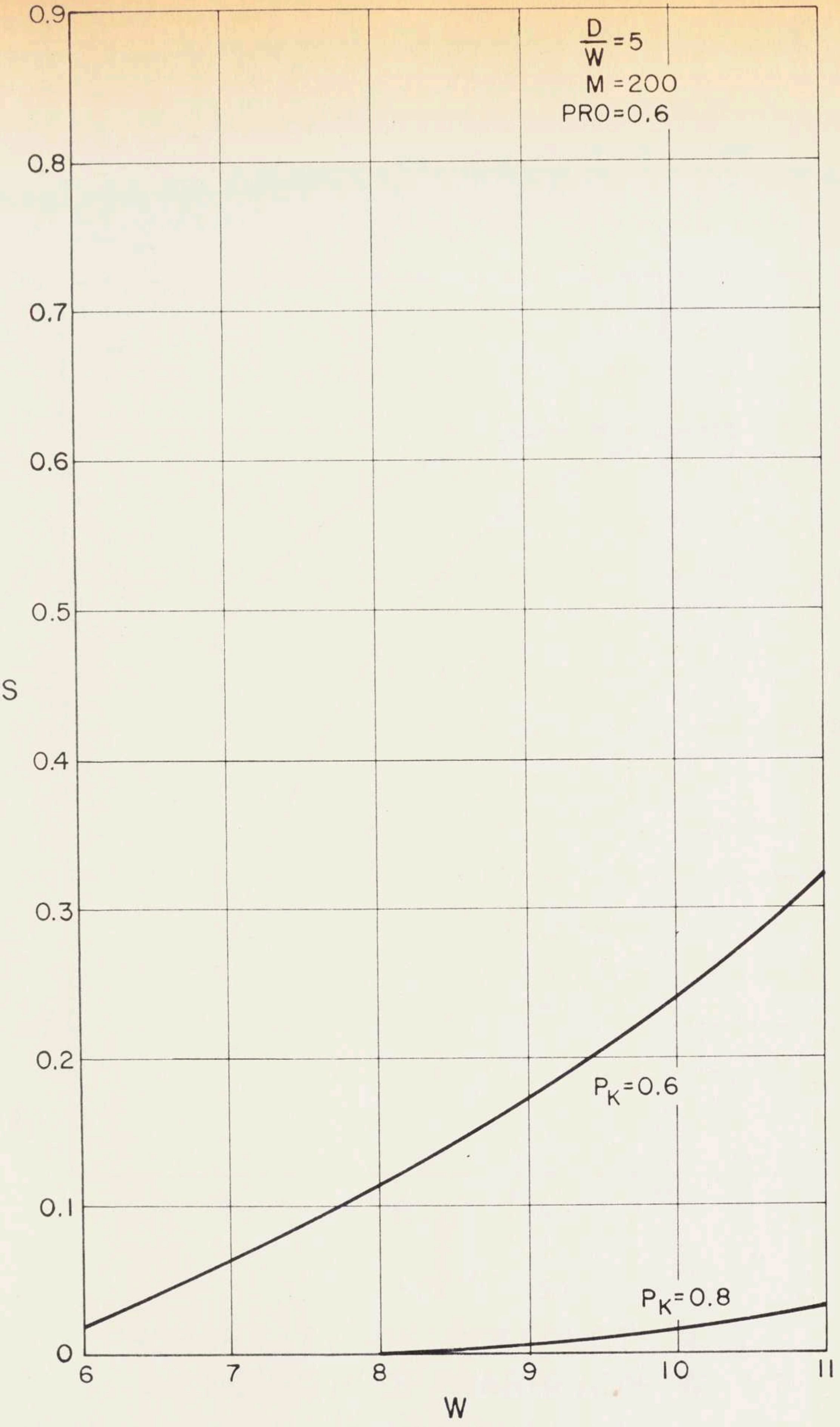

FIG. II - 12

ROBABILITY OF DESTRUCTION S, vs NUMBER OF WARHEADS W

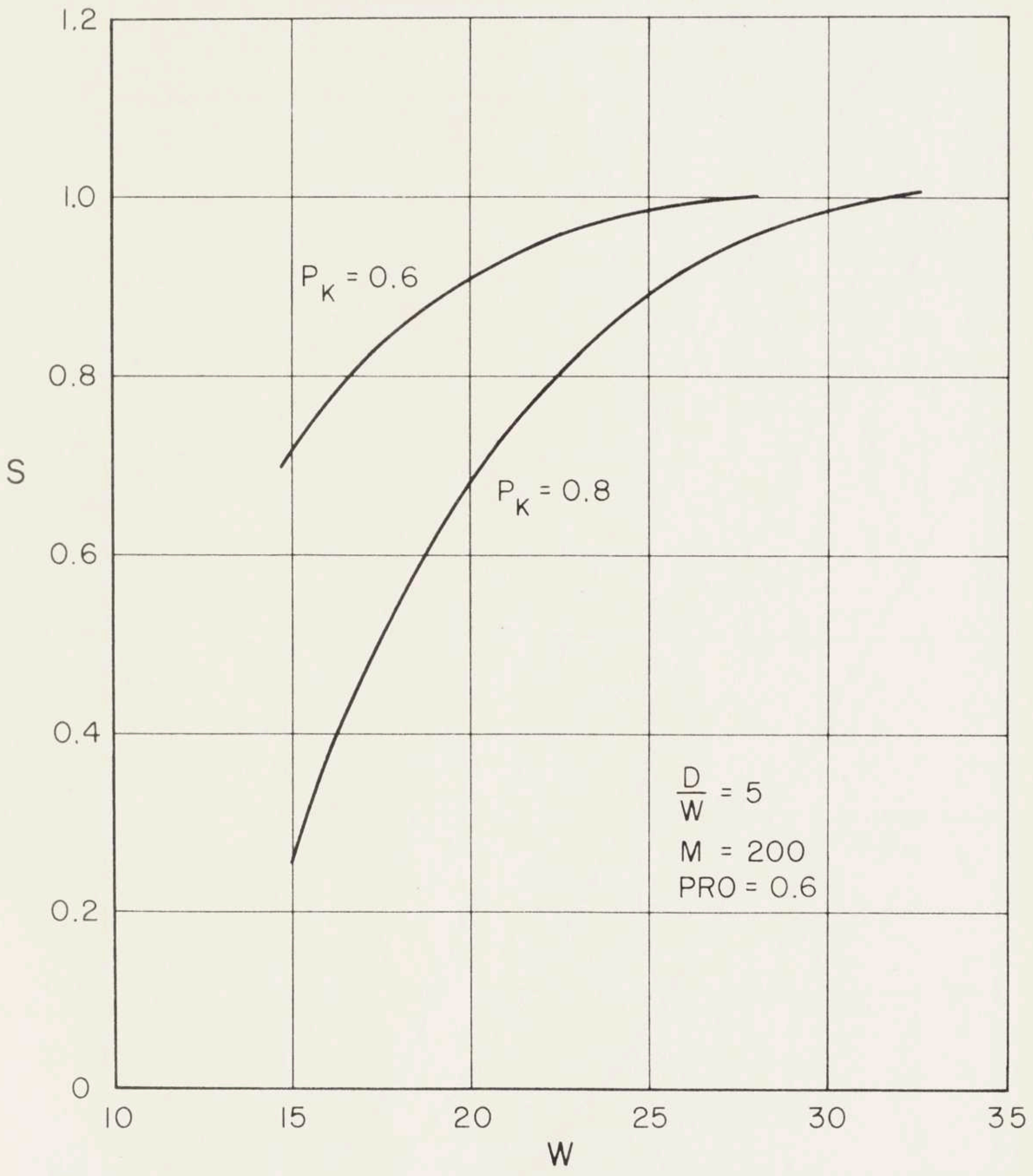

FIG. II - 13

PROBABILITY OF DESTRUCTION S vs NUMBER OF WARHEADS W

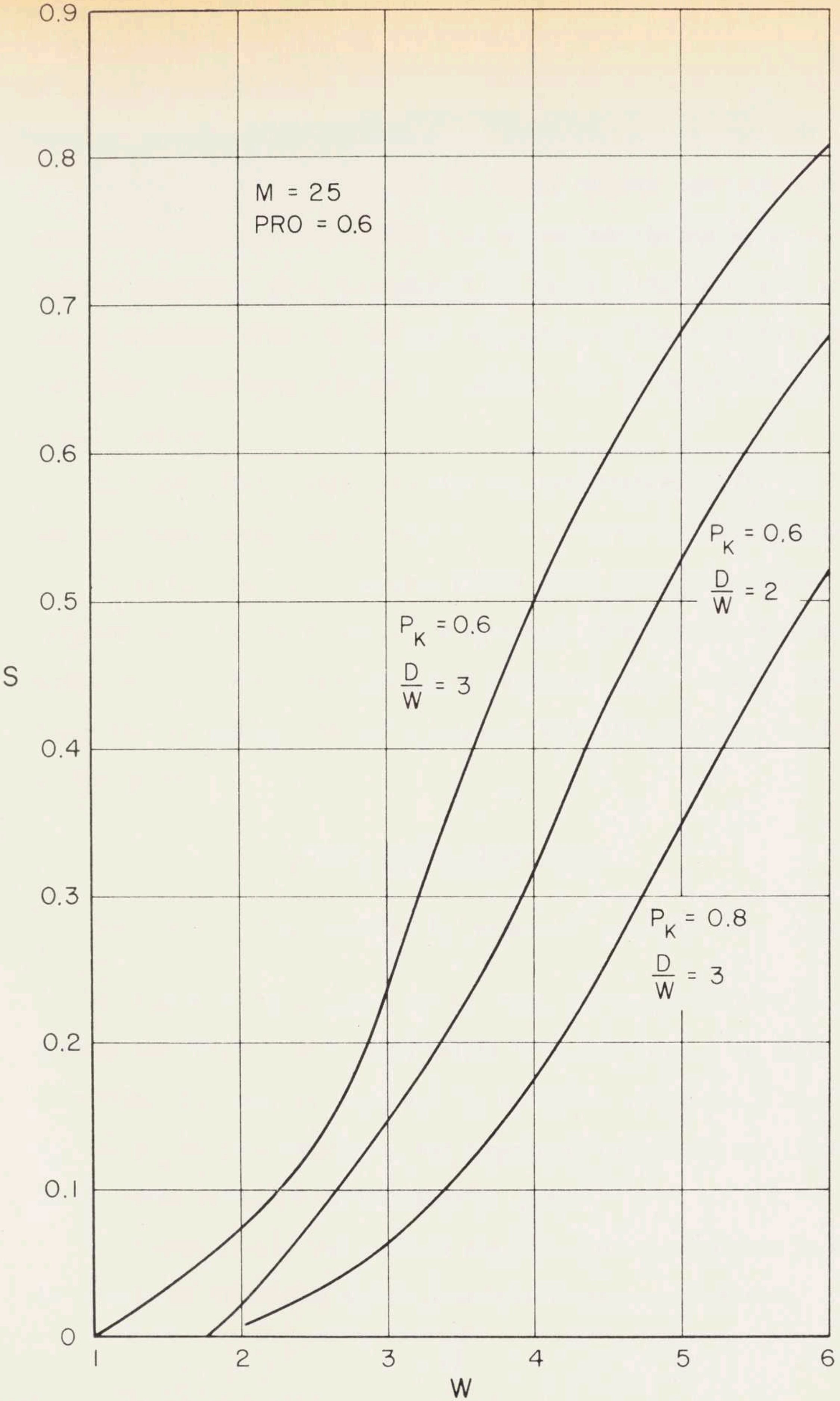

FIG. II -14

PROBABILITY OF DESTRUCTION S

vs NUMBER OF WARHEADS W

number of warheads. A world which corresponds to these characteristics would be very fine for the defense if the enemy were so foolish.

In Figure II-13 the number of warheads becomes supersensitive since the number of attacking objects approaches the number of defensive missiles. Here, in contrast to Figure II-12, the enemy has made a concerted effort to destroy the point and has succeeded quite admirably. When large numbers of attackers exist, destruction is almost certain.

In Figure II-14, the salvo size has been reduced to 25, but the same sensitivity exists, even with a low decoy to warhead ratio.

It is interesting to compare Figure II-13 and II-14. M has increased by a factor 8, while the attackers merely increased their attack by 3 1/2 with everything else constant. Thus, without adequate decoy discrimination, the defense system adds little to the survivability of the target.

FIGURES II-15, II-16, II-17

Probability of destruction vs. number of warheads

In Figure II-15 the attacker has made a concerted effort to destroy the target. With large values of W, the value S is still very high. However, in this case the defensive system has a high P_k, and P_{ro} becomes sensitive, but apparently only where the values of the ratio of P_{ro} to P_k are close to unity.

In Figure II-16, less objects are used and the defensive system is capable of destroying all objects before they can penetrate.

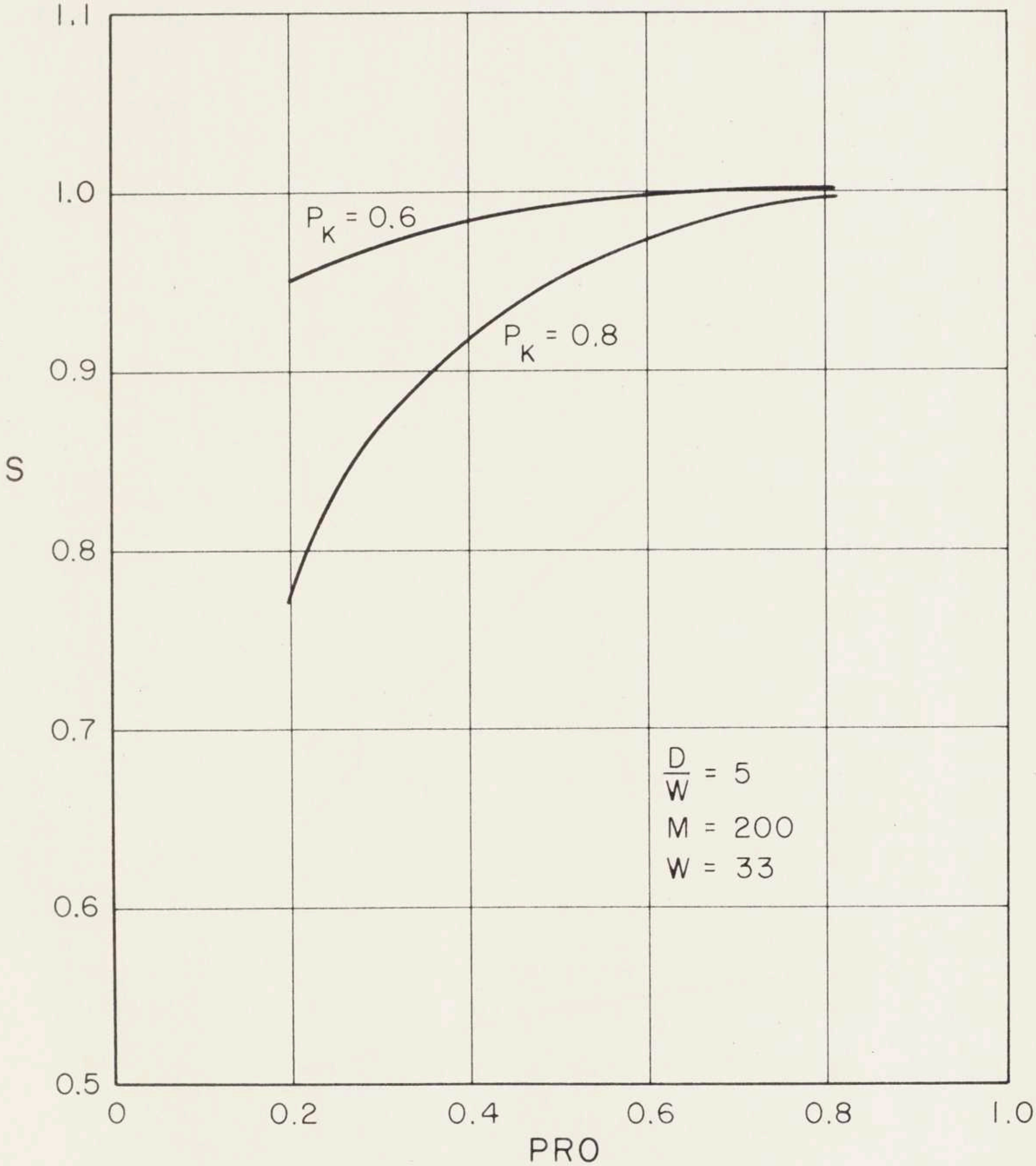

FIG. II-15

PROBABILITY OF DESTRUCTION S
vs VULNERABILITY PRO

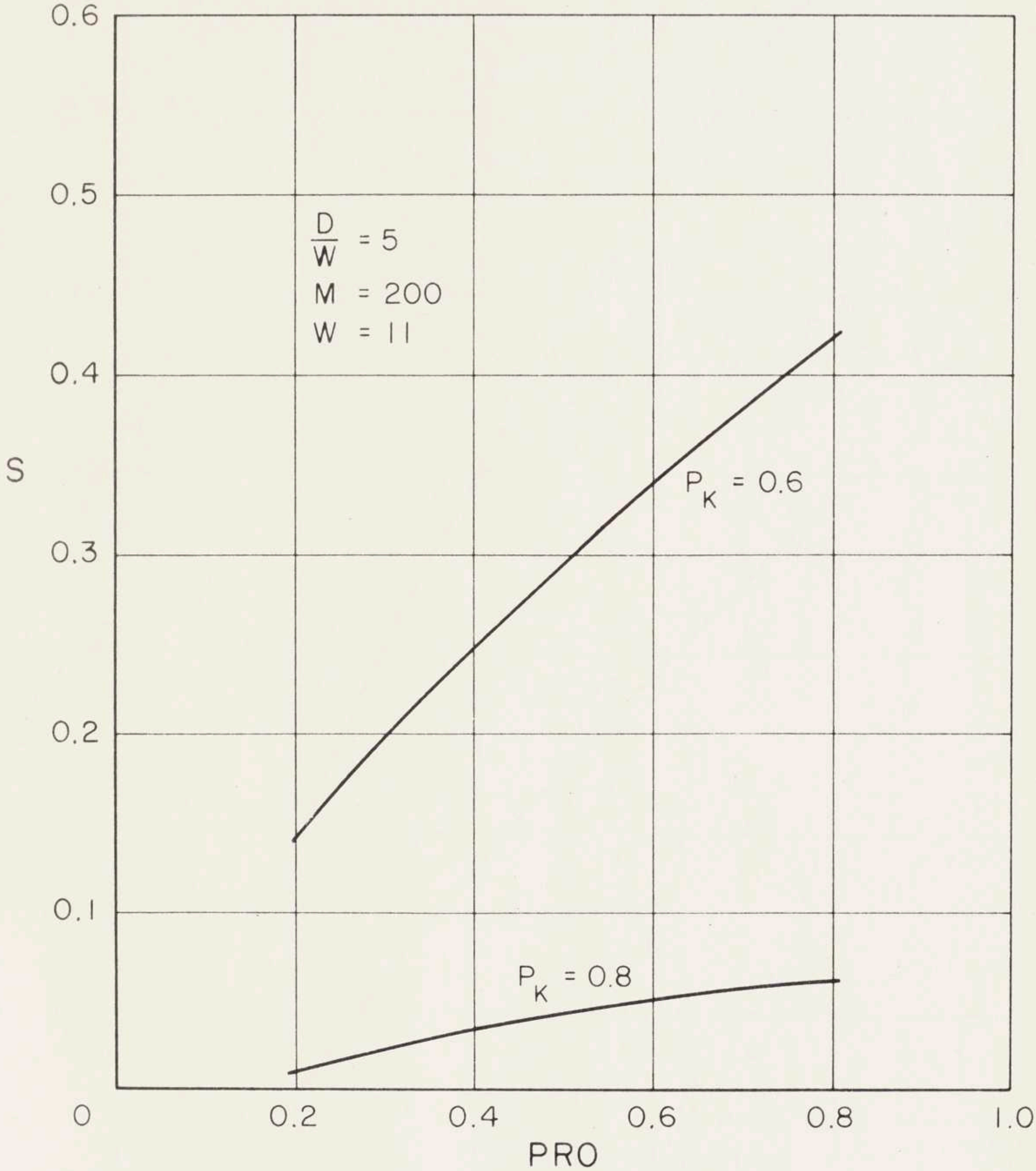

FIG. II - 16

PROBABILITY OF DESTRUCTION S
vs VULNERABILITY PRO

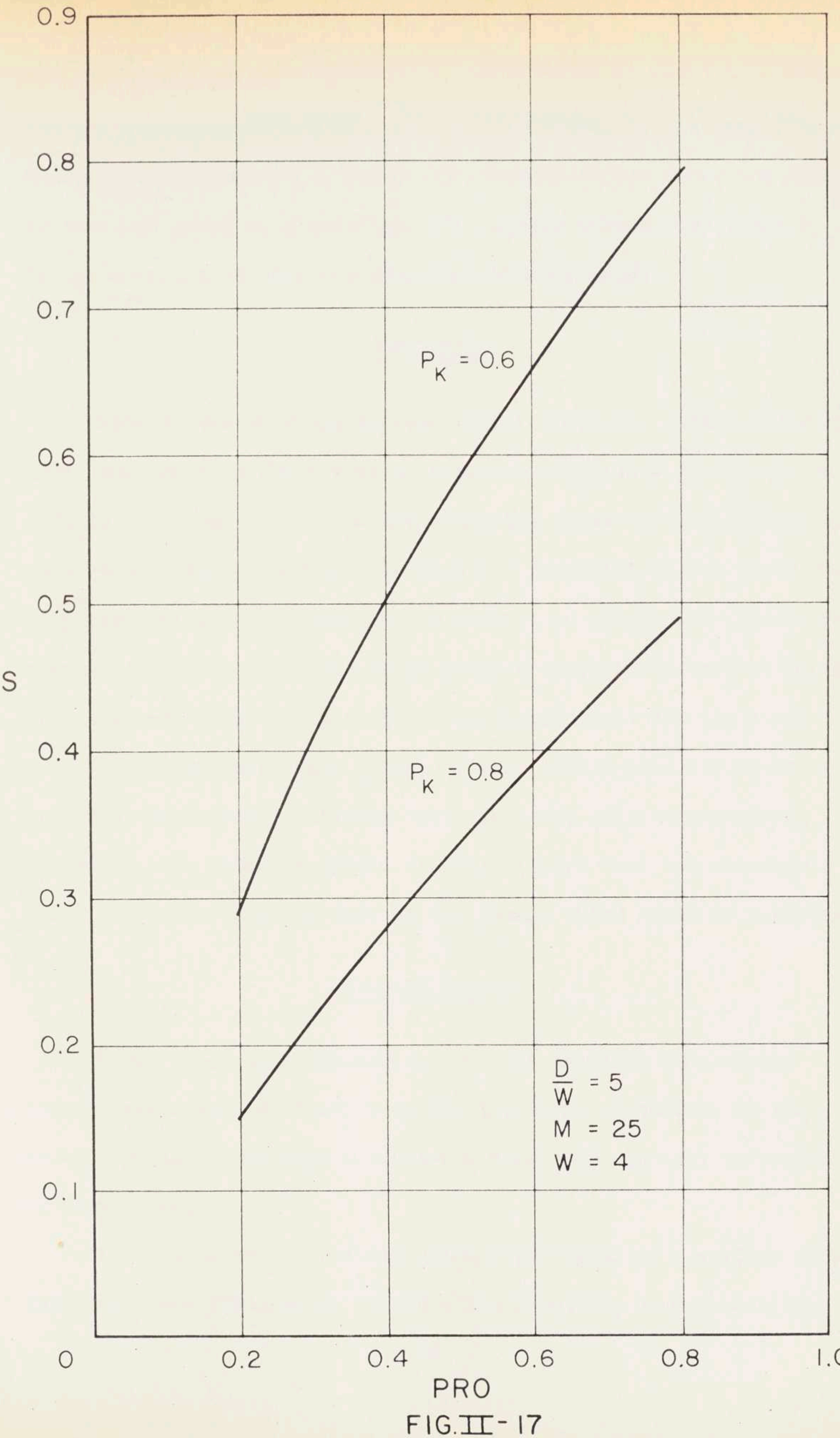

FIG. II - 17

PROBABILITY OF DESTRUCTION S vs VULNERABILITY PRO

Thus, P_{ro} is not sensitive, where P_k is small, and many warheads can penetrate. When few warheads can penetrate, P_{ro} is sensitive to changes in values of P_k. Figure II-17 shows a case where the defense is near the point of saturation, (24 objects when M = 25), and P_{ro} is quite sensitive when few warheads actually land.

CONCLUSION

These curves show the extreme ranges which the parameters might take, and how they could influence the survivability of a point target defense. Without discrimination among the parameters, a defense system seems less useful. However, it might be justified if one could build very cheap missiles. Even with no decoys, no system can insure the survival of a target, if the enemy makes a concerted effort to destroy it. However, such a tactic should be uneconomical for the enemy.

If an enemy attacks a point, he will always plan his operations, such that he is very confident that the point will be destroyed. Therefore, the defender should at least insure that the attacker's cost is greater than the cost of the damage which could be achieved.

SUMMARY CURVES

Figure II-18 is a summary curve which attempts to show the general shape and sensitivity of the important parameters of the model. It is essentially a birds-eye-view, and its only purpose is to show trends.

The diagram is a three dimensional pictorial of a surface which represents combinations of values which result in a .9 probability of destruction. Thus, the surface is one from an infinite number, but with a given value of S.

The parameters which are varied for a constant value of S are M/N, M, and W. In order to draw the surface, five values of M were considered, and for each value of M, M/N was plotted against W. Repeating the procedure for each value of M, the individual lines can be viewed as the skeleton of a surface.

Consider the first curve where M = 50; thus we are plotting M/N against W. M/N tells us how many AICBM's may be fired at each unidentified object. M/N tells us how many attackers there are per defensive AICBM fired, since N is related to W by the relationship N = (D/W + 1)W. Hence, for a particular value of W one can determine N by merely changing D/W.[1] Because we are only interested in values of S which are .9, we plot only one curve for a given W; therefore, only one D/W can be found which satisfies the equation. Next let M = 100, and repeat the procedure. Some point on each curve represents the same value of D/W. Two example curves are shown; D/W = 5, and D/W = 0.

INTERPRETATION

The enemy will choose any point on or above the surface on which to base his attack. If the actual D/W ratio is low, the attacker must use a large number of warheads, and the total system is supersensitive to P_k. If one increases P_k, the lower edge of the surface moves

[1] For each curve S, Sk, M, P_{ro} are given; W and D/W are the only variables.

$$S = 1 - (1 - S_k^{M/N} P_{ro})^W$$

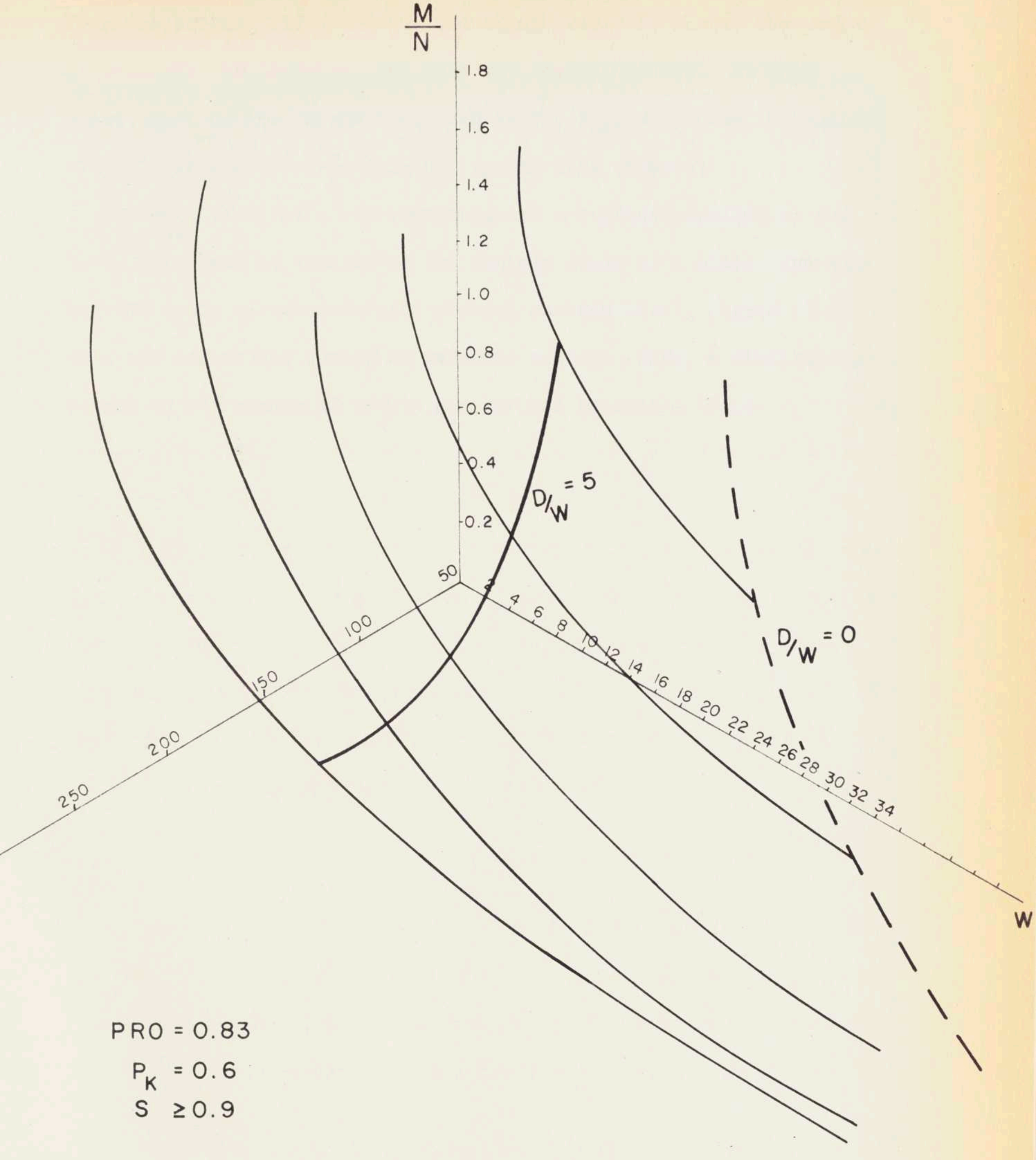

FIG. II-18

NUMBER OF MISSILES M, AS A FUNCTION OF WARHEADS W, AND COMMITTMENT RATIO $\frac{M}{N}$

from the origin. If the decoy to warhead ratio is large, the number of warheads can decrease, but only to a certain level. At this point, most of the parameters, such as P_k, P_{ro}, M, become insensitive since it is easy to overwhelm the system with objects.

Figure II-19 is a representation of a surface parallel to the M, W, plane and is similar to the contour lines of a hill. Increasing the decoy to warhead ratio above a certain level, Figure II-19, does not reduce the number of warheads needed. Thus, a diminishing return to the number of decoys per warhead becomes evident.

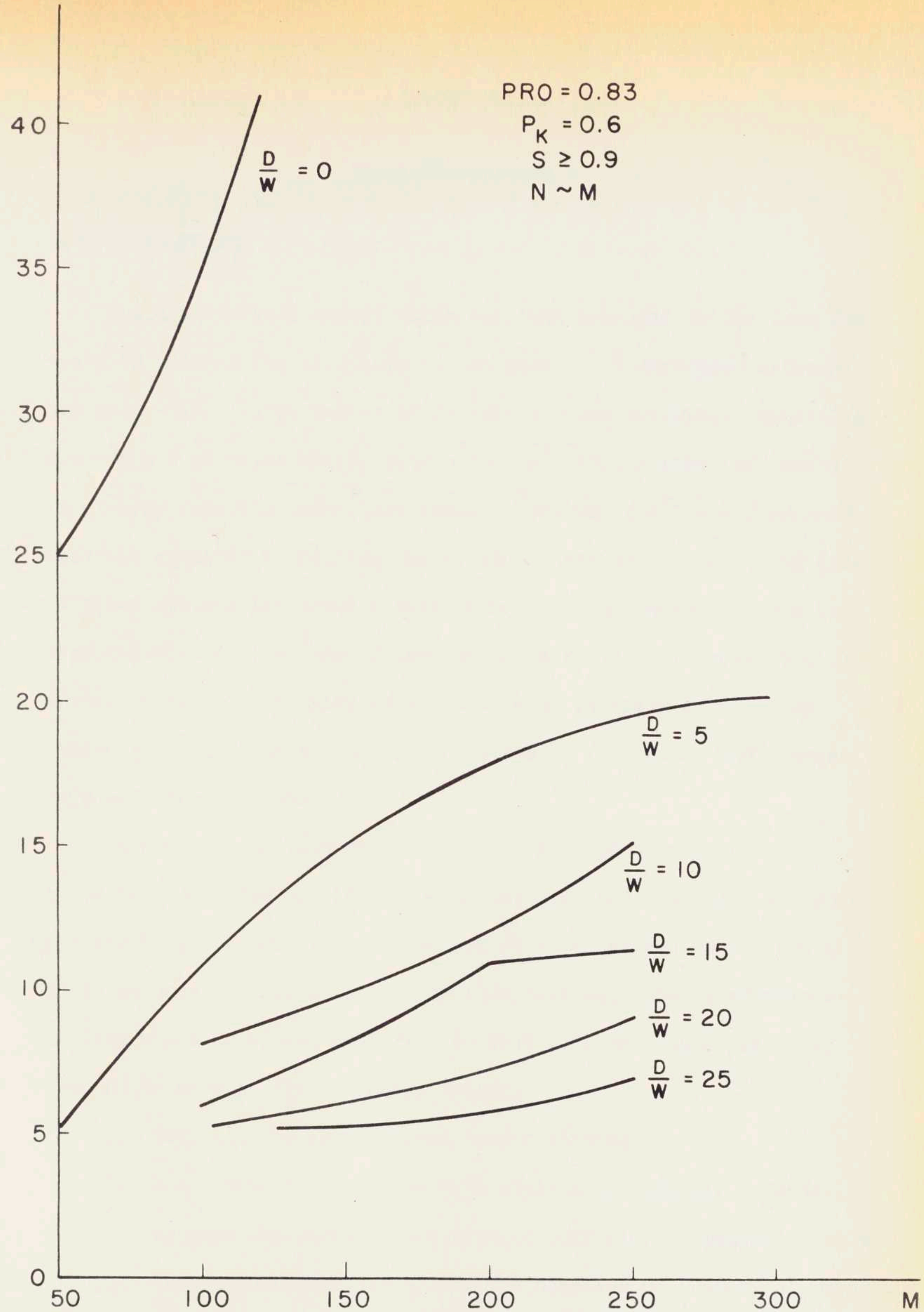

FIG. II - 19

NUMBER OF WARHEADS W, vs AICBMs M

CHAPTER III

MODEL APPLICATION

3.0 INTRODUCTION

The considerable effort which has been expended in the last few years in looking for solutions to the problem of aerospace defense has generated a large number of defense systems concepts. Generally, none of the concepts which could actually meet the expected threat is clearly feasible today, and hence a considerable R and D program would be required to realize any of these systems. Also, since none of these systems can provide more than a partial defense, there is some question whether any of them would be worth their considerable costs. These difficulties have led defense planners to delay any choice among systems and to look to industry for better and cheaper ways of doing the job.

In order to provide objectives for this industrial effort, there is a need for specification of how good and how cheap various systems (e.g., a hard target terminal defense system) would have to be to be more desirable than other alternatives. Cost performance studies which have been made fail to meet this need satisfactorily for one or more of the following reasons:

1. They fix the enemy threat and/or strategy.
2. They concern themselves with evaluating specific defense systems and hence do not produce sufficiently general results.
3. They do not consider all of the benefits or "payoff's" resulting from various defense alternatives.[1]

[1]This analysis is similar to industry proposals in that all benefits

The purpose of this chapter is to illustrate the types of results which might be useful to a system designer. The example selected is a comparison of two alternatives for maintaining a specified second strike force of ICBM's, in the face of an ICBM attack. The alternatives are:

1. deployment of a large number of retaliatory ICBM's,
2. deployment of a smaller number of ICBM's, each defended against the enemy attack by an AICBM system.

Two specific AICBM systems are considered:

1. Terminal point defense system.
2. Boost kill area defense system.

Therefore, the total budget required for the first alternative is determined. It is assumed that the cost of deploying ICBM's is known, then the maximum allowable cost of the AICBM system can be determined as a function of its performance parameters, (Figures III-1 to III-7) by requiring that the second alternative maintains the same total budget. The sensitivity of this cost performance relationship to one of the major parameters, the attack size, is shown.

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are not considered. For example, what is the benefit from defense of reduced fallout on the population?

A broad study which avoided these limitations could generate tools which would be useful at various levels, such as system design, system evaluation and defense planning. For the system designer, cost limits as a function of system performance parameters would be provided. For systems evaluation, tools for measuring the relative value of various specific systems to do specific jobs would be developed. For defense planning, measures of relative worth, from a cost-performance standpoint, of deploying various defense systems would be developed and applied. The sensitivity of the results to major uncertainties in the defense planning would be presented, and the selection of approaches applicable in a broad range of situations would be facilitated.

Next, hypothetical boost-kill and terminal systems are defined, and the desirability of these systems is indicated by the maximum percentage reduction in total budget which can be achieved by deploying the defense system, while maintaining the desired objective. Threat is again shown as a parameter (Figure III-8). Finally, the U. S. costs relative to enemy costs are shown for various alternatives, (Figure III-9).

3.1 General Assumptions

In order to produce numerical results, the problem must be carefully defined and bounded. In this section, the major assumptions will be specified.

The assumptions common to the entire report are as follows:

1. The U. S. has an objective of maintaining an effective ICBM retaliatory force in the face of an enemy ICBM attack. It is assumed that this objective can be stated in terms of the expected number of ICBM's which are to survive. A value of 150 survivors is used.

2. U. S. ICBM's are dispersed sufficiently that no more than one ICBM can be destroyed by one enemy ICBM.

3. The hardness of U. S. ICBM silos and the enemy warhead yield and CEP have been assumed to yield a kill probability (P_{ro}) of .78 for one enemy ICBM against one U. S. ICBM. This might result from a warhead yield of 10 MT, a CEP of 0.5 n mi. and a silo hardness of 300 psi. Reliability of enemy missiles is not included but may be considered to increase the cost for the enemy to obtain the required number of ICBM's on target.

4. All enemy ICBM's are launched simultaneously, and the ICBM's at any given target arrive simultaneously.

5. Attacking ICBM's are divided equally among the targets.[1]

6. The number of enemy ICBM's assigned to the U. S. retaliatory ICBM force ranges from 1000 to 6000.

3.2 Terminal Defense Cost-Performance Bounds

In this section, bounds on the cost-performance relationship will be derived for an active terminal defense system. These bounds are determined by requiring that the total budget when active defense is used be no greater than the total budget needed for the alternative of buying retaliatory ICBM's only. The defense system model will first be described and then the cost-performance relationship will be derived. Finally, examples of the use of the curves obtained will be given.

Terminal Defense System Model

The terminal defense system model is based upon the assumption that each U. S. ICBM silo will be defended equally. Hence a unit defense will be associated with each silo, consisting of some number M of AICBM interceptors, plus a proportionate amount of radars and other equipment. The cost-performance curves will show the maximum allowable cost for a unit defense as a function of the number of AICBM's and the kill probability P_k of each AICBM against an attacking warhead.

$$P_s = \left[1 - P_{ro}(1 - P_k)^{\frac{M_W}{W}}\right]^W \quad [2]$$

[1]The enemy has enough ICBM's to saturate each silo.

[2]See Page 19 Chapter II

When decoys are present, some will be discriminated by ground sensors, and the remaining ones will have to be intercepted as if they were warheads. The former do not enter this analysis, and the expected presence of the latter requires an increase in the stockpile of AICBM's to obtain the desired performance. If D undiscriminated decoys arrive at the target along with the W warheads, then in order to have M_W AICBM's assigned to warheads, the total number of AICBM's required per target is

$$M = M_W \left(\frac{D+W}{W}\right) = M_W(D/W + 1)$$

All further calculations will use only M_W; the total number of AICBM's can be found if the number of undistinguishable decoys per warhead is known.

If the U. S. deploys N_{us} silos with a defense at each, then the enemy force of N_R ICBM's is distributed evenly over the N_{us} targets, with one warhead per ICBM. The number of warheads per target W is given by

$$W = N_R/N_{us}$$

The number of survivors may be written as

$$E = N_{us}\left[1 - P_{ro}(1 - P_k)^{\frac{M_W N_{us}}{N_R}}\right]^{\frac{N_R}{N_{us}}} \qquad 3.2$$

This equation relates the expected number of surviving silos to the threat, the number of U. S. silos and the defense performance parameters P_K and M_W.

Derivation of Cost-Performance Bounds

In this section, the cost-performance bounds will be derived. It was assumed, for the purposes of this report, that the desired expected number of U. S. silos surviving (E) is 150, and that the factor P_{ro} has the value .78. Then for any fixed threat size N_R, the required number of U. S. silos N_{us} can be found as a function of M_W and P_k. If $M_W = 0$, the value of N_{us} obtained is denoted as N_o and is the number of silos required when there is no defense. If the cost per silo, C_s, is known the total budget for this alternative is $N_o(C_s)$.

If a defense system with certain values of P_k and M_W is deployed, the required number of silos is N_{us}. The total spending on silos has been reduced by an amount $(N_o - N_{us})C_s$, and this amount may be spent on active defense without increasing the budget above the level established with no defense. Since N_{us} silos must be defended, the maximum amount which can be spent for the defense of each silo (for a unit defense) is

$$C_M = \frac{N_o - N_{us}}{N_{us}} \quad C_s$$

The cost of the silo may be eliminated as a parameter by normalizing the cost of the defense to the cost of a silo, thus defining C_D to be the maximum allowable cost for the defense expressed as a fraction of a silo.

$$C_D = \frac{C_M}{C_s} = \frac{N_o - N_{us}}{N_{us}} \qquad 3.2$$

In summary, for a fixed threat and a fixed number of survivors, the total budget is fixed by the cost of the number of silos required when there is no defense. With defense, the number of silos required is a function of the performance of the defense, and the maximum allowable cost for the defense is a function of the total budget and the number of silos required. Hence the maximum cost may be plotted as a function of the defense performance (P_k and M_W) by eliminating N_{us} between 3.1 and 3.2. This has been done, and the results are shown in Figures III-1 to III-6 for threats N_R of 1000 through 6000. An axis for N_{us} has been added to show N_{us} vs. C_D (dotted line).

Use of the Cost Bound Curves

The cost bound curves, Figures III-1 to III-6, may be used in a variety of ways. A simple application would be to determine whether a terminal system with given P_k, cost, number of AICBM's and decoy/warhead ratio meets the cost requirements. If, for example, a certain system has a P_k of .5, M = 20, D/W = 4 and a cost equal to three times the cost of one silo, then M_W = 5, and the normalized cost C_D = 3 is considerably above the maximum bound for the various threat levels shown.

Consider a more general example. A manufacturer believes he can manufacture AICBM interceptors at a cost of about 1/100 that of a silo, and that he can provide the necessary ground environment for a cost which is about equal to the cost of a silo. He estimates that a P_k of 0.7 may be possible. Does this look interesting?

3.3 Random Orbit System Cost-Performance Bounds

In this section, cost performance bounds on a random inter-orbit system will be derived in the same way that the terminal defense bounds were determined. First, an expression for the probability of survival of a base will be determined, next the cost-performance bounds will be derived, and finally the use of the curves will be discussed.

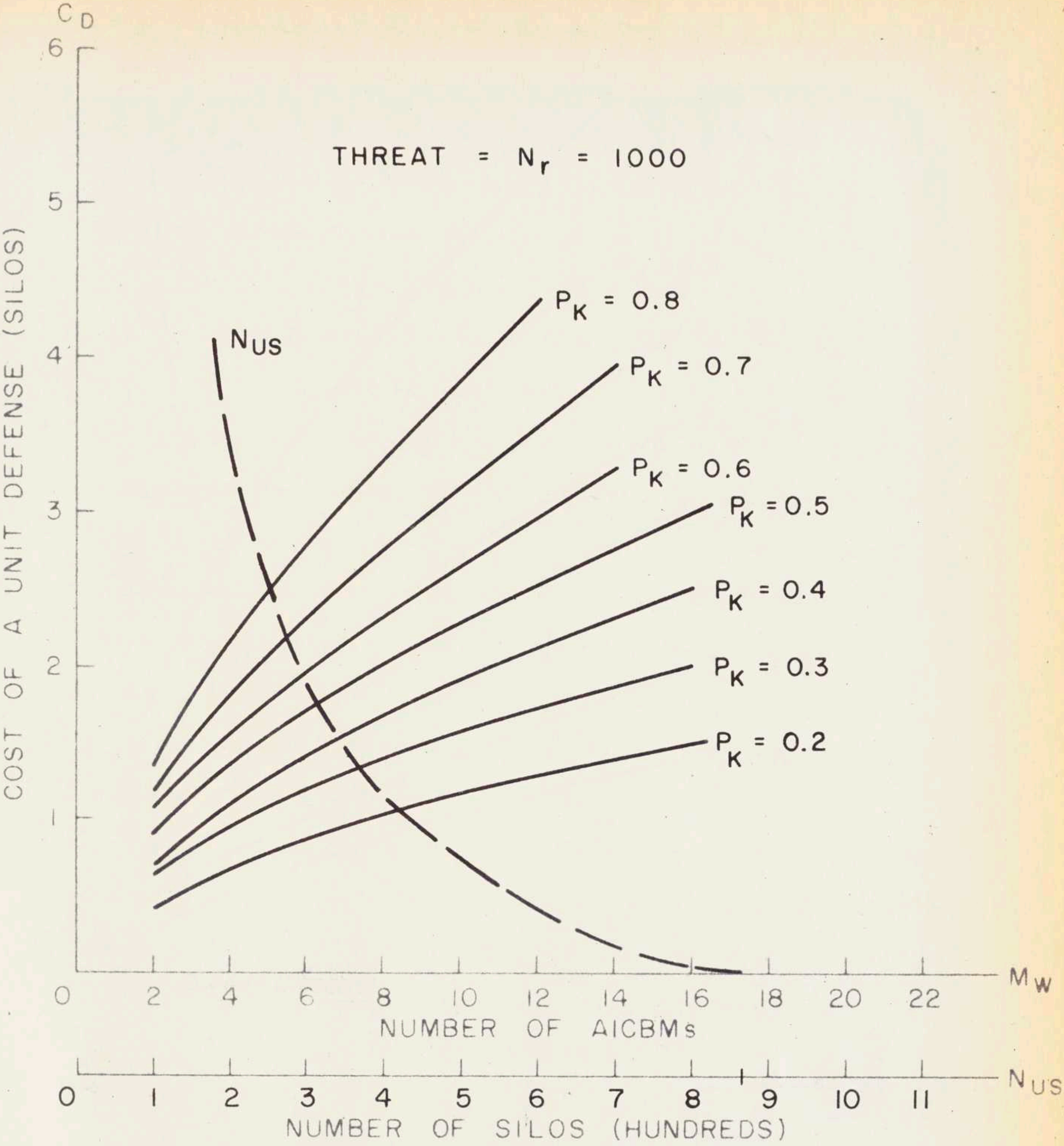

FIG. III -1

TERMINAL DEFENSE COST BOUNDS

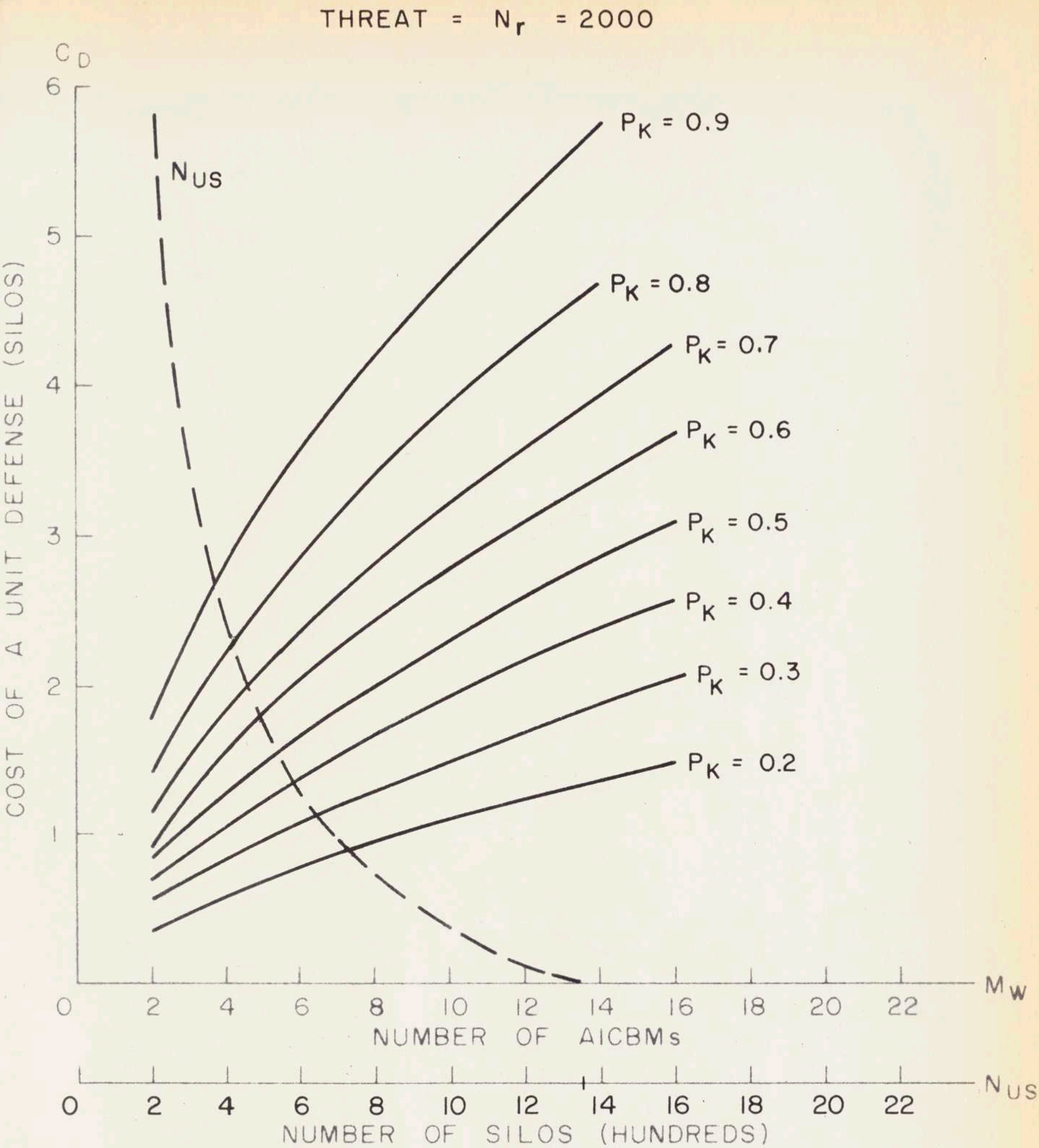

FIG. III - 2

TERMINAL DEFENSE COST BOUNDS

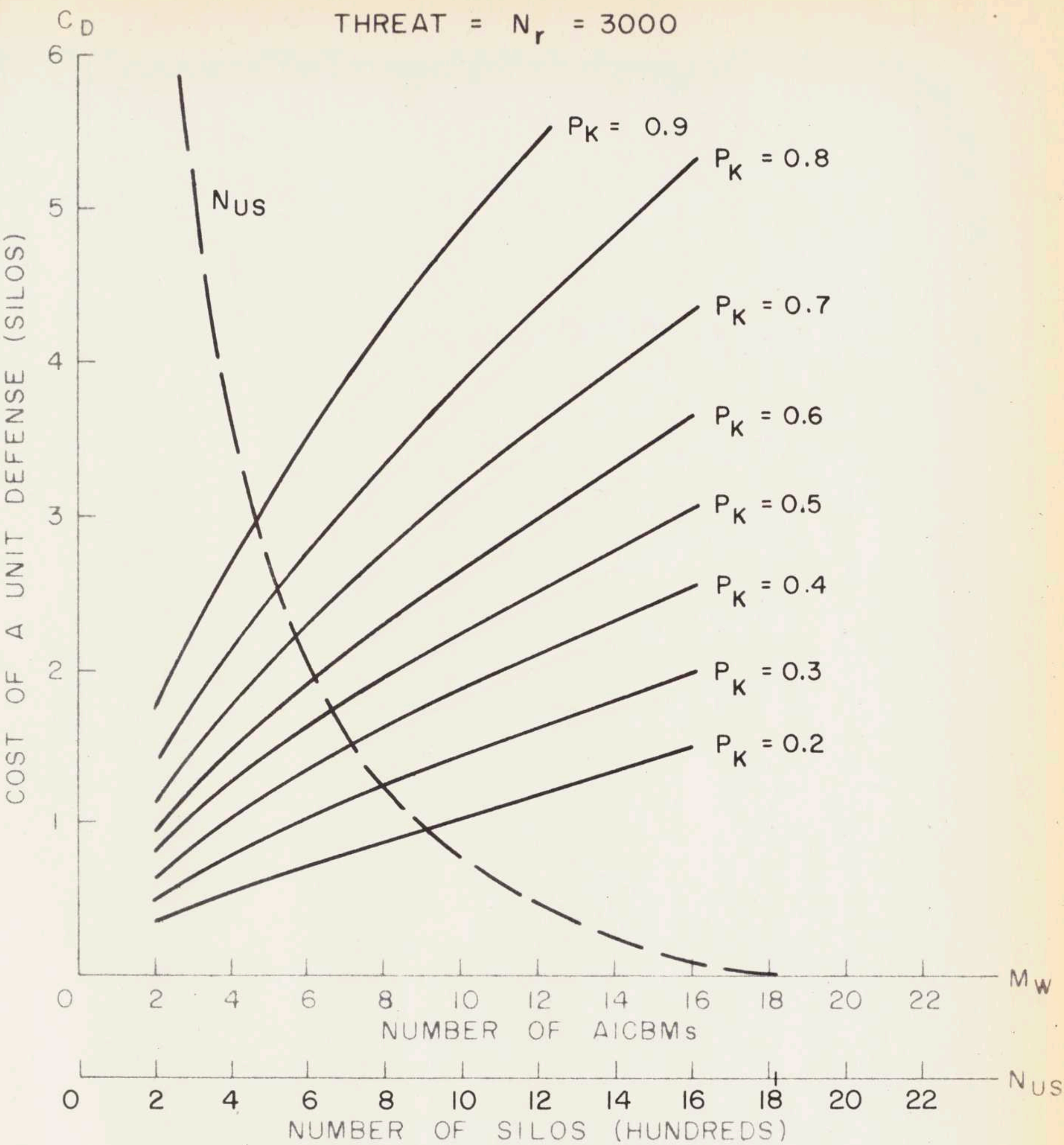

FIG. III - 3
TERMINAL DEFENSE COST BOUNDS

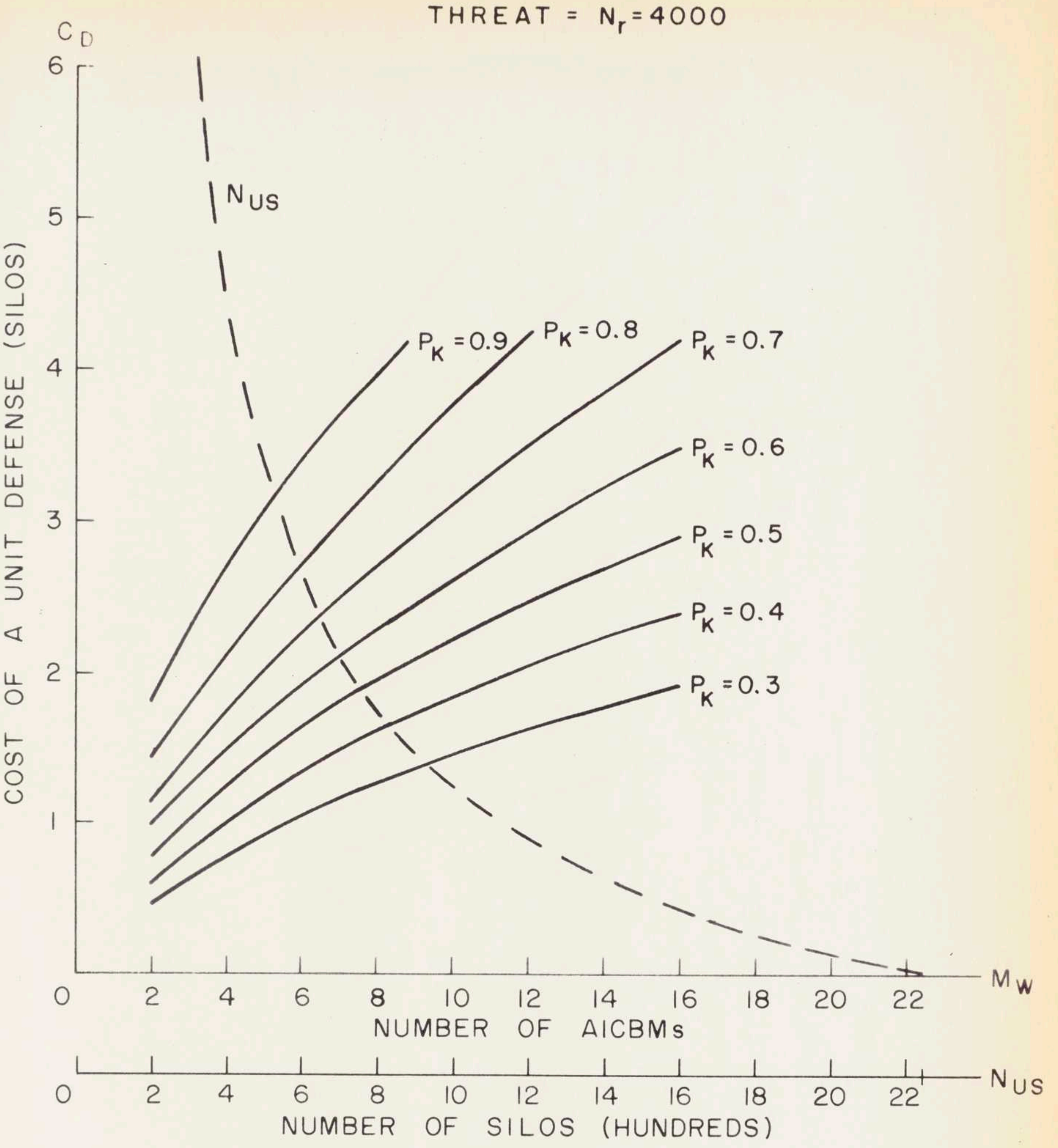

FIG. III - 4

TERMINAL DEFENSE COST BOUNDS

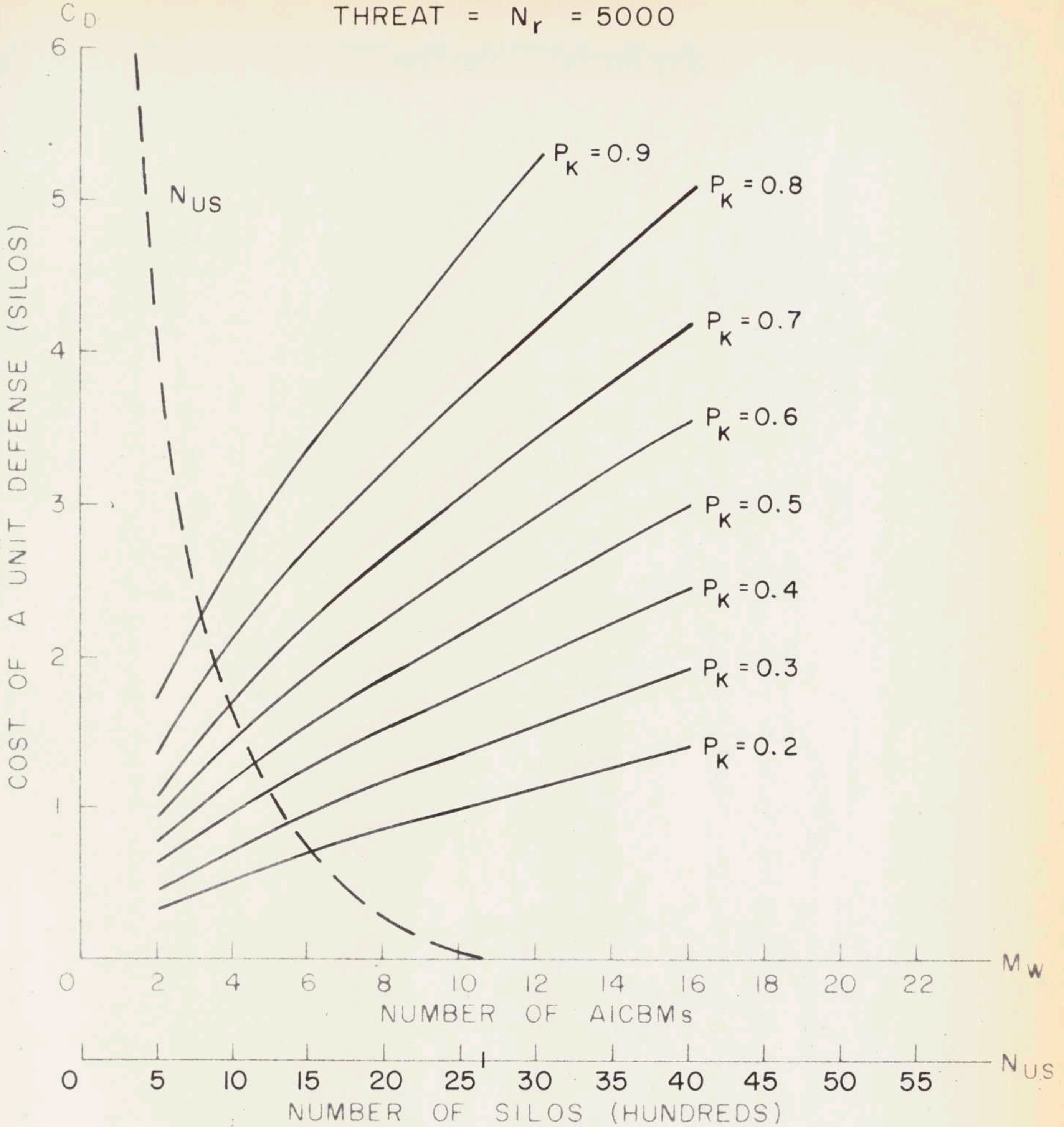

FIG. III - 5

TERMINAL DEFENSE COST BOUNDS

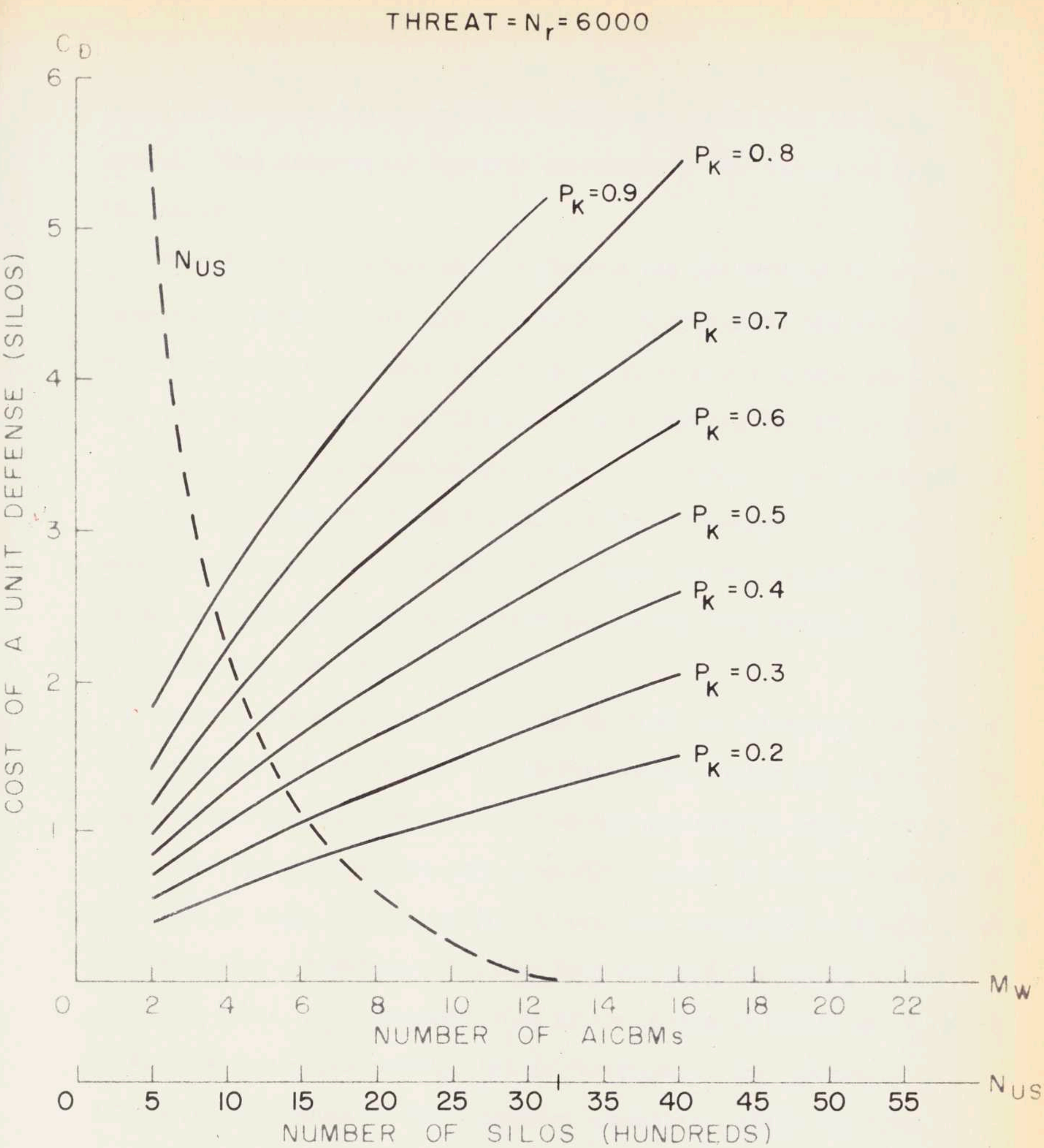

FIG. III - 6

TERMINAL DEFENSE COST BOUNDS

Random Orbit System Model[1]

The random orbit system model analyzed in this study employs a large number of light, inexpensive interceptor satellites in random orbits. Each interceptor operates autonomously once turned on from the ground.

The threat parameters which influence the performance of the boost intercept system are the burning time of the ICBM above the atmosphere, T, and the effective number of ICBM's launched from a single base, N_B. The first of these is significant because it defines the flight time available for the interceptor and hence its coverage. The second parameter, N_B, is a measure of the extent of enemy "clumping." It equals the actual number of ICBM's per base if the bases are separated sufficiently (about 800 miles) so that no interceptor can be committed against ICBM's from more than one base.

Many of the system parameters can be fixed by optimizing the system to obtain the minimum orbital weight for a given system performance. The system parameters which remain, such as the interceptor payload weight and propellant specific impulse, are generally limited by the state of the art. Hence all of these system parameters have been lumped into a single constant K. The system parameters which have been factored out are W_o the total weight in orbit, L_m operational time of the system in orbit, and P_k, which is defined as the probability that an interceptor, once committed to an ICBM within the range of its propulsion capability, kills the ICBM.

These parameters are related to the probability S_A that any ICBM penetrates the system as follows:

[1]Model derived by Charles Joyce, The MITRE Corporation.

$$S_A = e^{-\frac{K\,Wo\,T^2\,P_k\,L_m}{N_B}} \qquad 3.3$$

The probability of survival P_s of a silo under attack by W ICBM's is

$$P_s = (1 - P_{ro}\,S_A)^W \qquad 3.4$$

and the expected number E of survivors, out of N_{us} silos, under attack by N_R ICBM's is

$$E = N_{us}\,(P_s) = N_{us}\,(1 - P_{ro}\,S_A)^{N_R/N_{us}} \qquad 3.5$$

Equations 3.5 and 3.3 relate the expected number of silos surviving to threat parameters, total weight and interceptor kill probability of the boost intercept system, and the number of U. S. silos deployed.

<u>Derivation of Cost-Performance Bounds</u>

As in the terminal defense analysis, N_o silos are required to obtain the required number of survivors E, when there is no defense, and the total budget is thus established as $N_o\,(C_s)$.

When a random orbit system is deployed, the number of bases required is N_{us}, given by 3.5 as a function of the single parameter S_A. The budget saving which can be applied to the active defense system is

$$C_p = (N_o - N_{us})\,C_s \qquad 3.6$$

Hence for a fixed threat size N_R, the maximum defense system cost C_p is determined as a function of S_A.

For the moment, let us fix all of the parameters in equation 3.3 excep W_o. Let $P_k = 1$, $N_B = 100$ and $T = 4$ min. The total weight in orbit W_o is now uniquely related to S_A, and hence to the maximum total cost. Dividing the maximum cost by the orbital weight for each value of orbital weight yields a plot of the maximum cost per pound in orbit C_p as a function of total weight in orbit. Such a plot is useful because the major cost in such a system appears to be the cost of boosting the weight into orbit, which is commonly expressed in cost per pound in orbit. Figure III-7 shows this function for several values of the threat.

In order to obtain dollar figures in Figure III-7, it was necessary to assume a cost per silo C_s and a mean lifetime L_m for the boost intercept system. A value C_s = 15 million dollars was chosen for a silo including investment and five year operating cost. C_p then becomes the maximum allowable five year cost for the boost intercept system. If we assume that the ground environment cost is negligible, over the five year period compared to the booster and space hardware costs, then the maximum cost per launching may be found by dividing C_p by the average number of times the system is replaced in five years, which is $5 \div L_m$. A lifetime of one year has been assumed to obtain the normalized curves of Figure III-7.

Use of the Cost Bound Curves

The cost bound curves may be used to indicate the maximum weight in orbit which would be allowable for any given cost per pound of the system. If, for example, the expected cost per pound for hardware plus boosters were 500 dollars, a maximum of about 5 million lbs. in orbit would be justified against a threat of 2000 lbs. for

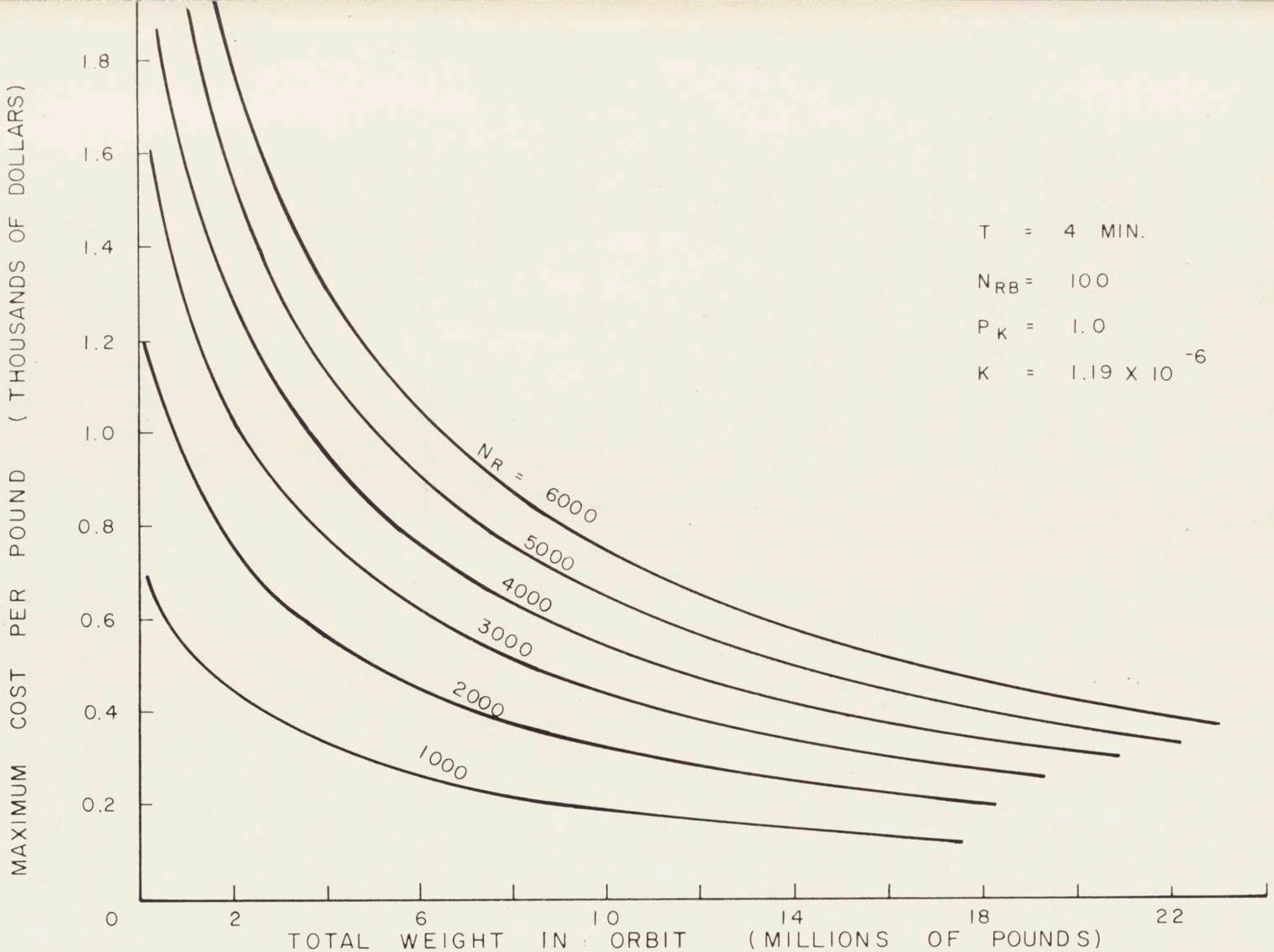

FIG. III - 7

MAXIMUM COST PER POUND VS. TOTAL WEIGHT IN ORBIT FOR VARIOUS THREAT SIZES N_R

the normalized parameters shown. There is an optimum weight in orbit for any fixed C_p which provides the required defense for the lowest total budget. This will be taken up in section 3.4.

Now consider equation 3.3. If P_k were .5 instead of 1, W_o would have to be doubled to maintain the same performance, but no more money could be spent on the system because the money available depends upon the performance. Hence the maximum allowable cost per pound would be halved. It may be seen that the maximum cost per pound, C_p, varies directly with P_k, T^2, C_s, K and L_m, and inversely with N_B. Hence the left hand axis can be adjusted accordingly for any chosen values of these parameters. If, for example, T = 2 min. and P_k = .4, C_p must be reduced by a factor of 10, and a cost per pound of 500 dollars is off the C_p scale. A cost per pound of 50 dollars would be required to justify six million pounds against a threat of 2000.

The curves allow increased cost per pound as the threat increases because it has been assumed that the threat is increased by buying more launch sites dispersed over the enemy's territory. This brings more interceptors into play and increases the average kills per satellite in the system. If the number of bases were held fixed, the desirability of the system decreases with increasing threat, as will be shown in the next section.

3.4 Evaluation of Systems

From the previous section, it was shown that a large number of possible complexes would satisfy a requirement to obtain an expected survival level. A complex contains either silos only, less silos with a low capability defense system, or a much smaller number of silos with a high capability defense system. The budget, or cost of a complex will depend on the number of silos and the defense level that are combined.

Since it is desired to obtain the required capability at the lowest cost, a method will be presented to find the minimum budget for an acceptable complex. An example random orbit system and a terminal system were selected to show the results of applying the method for determining optimum combinations.

Once the lowest budget has been found for a given threat, it is necessary to present the data such that different systems can be compared to each other. If the budget for deploying silos only is B, and the lowest total budget for any complex is B min., the net savings are B - B min. The fraction of the budget saved is

$$\frac{B - B \text{ min.}}{B}$$

The fraction of the budget saved is one measure of the cost of a complex compared to silos only. Thus the desirability of any complex can be shown as a function of the enemy threat in order to determine over what range of threat once choice is superior to another. If the cost of Russian military systems is assumed equal to the cost of U. S. systems, the relative expenditures of each side which allows the U. S. objective to be met can be portrayed as a function of the U. S. budget level.

For a given threat, and a given terminal system which is expressed in units of silos rather than dollars, the total cost of any combination is $N_{us}(C_D + 1)$ to avoid problems of calculating the cost of a silo. It has been shown that both C_D and N_{us} are uniquely related to M_W but since the relationship is rather complex the total cost is found by varying M_W and calculating the minimum combination.

Given a defensive system, the lowest cost combination is found by comparing the cost of all acceptable combinations, then all parameters can be related to dollars. An example terminal system has a $P_k = .6$, a fixed cost equal to one half the cost of a silo, and a variable cost per missile of .15 the cost of a silo assuming no decoys.[1] That is, $C_{dn} = .5 + .15\ M_W$.

The boost intercept system has a cost C_p equal to 200 dollars per pound in orbit, and its $P_k = .8$, the enemy ICBM's have a burning time of 4 minutes above the atmosphere. For each threat, two assumptions have been made concerning the enemy capability:

A. The enemy has 100 ICBM's which are launched successfully from each of many bases, $N_{RB} = 100$.

B. The enemy has 20 bases, and the total launched ICBM's are divided equally among these bases.

The total cost of any deployment is $W_o\ C_p + N_{us}\ C_s$. W_o like M_W is uniquely related to N_{us}, and again the optimum choice is the lowest budget system.

In order to present the results of these example systems, the <u>fraction of the budget saved</u> by deploying the system was plotted against the Russian threat size, in Figure III-8. Also the enemy cost to the U. S. cost for all the alternatives was plotted against

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[1] If D/W were 9, then the missile cost would have to be .15(D/W + 1) = .015 instead of .15.

total U. S. spending in Figure III-9.

In Figure III-8 the optimum deployment of the terminal system resulted in approximately a constant savings over the alternative of buying silos only. The deployment of the boost intercept system, under the assumption that $N_{RB} = 100$, produces greater savings as the threat increases in size. However, if there are only 20 launch sites, the savings decrease to zero.

The differences are due to the fact that in the first case the system is never saturated by the concentration of bases, while such "clumping" reduces the effectiveness of the system as the threat increases.

Figure III-9 shows that in all cases enemy cost is larger than U. S. cost. Thus even if no defense system is employed, enemy spending will be higher than U. S. spending. The system which saves the most over silos only, cost the Russians more to counter it.

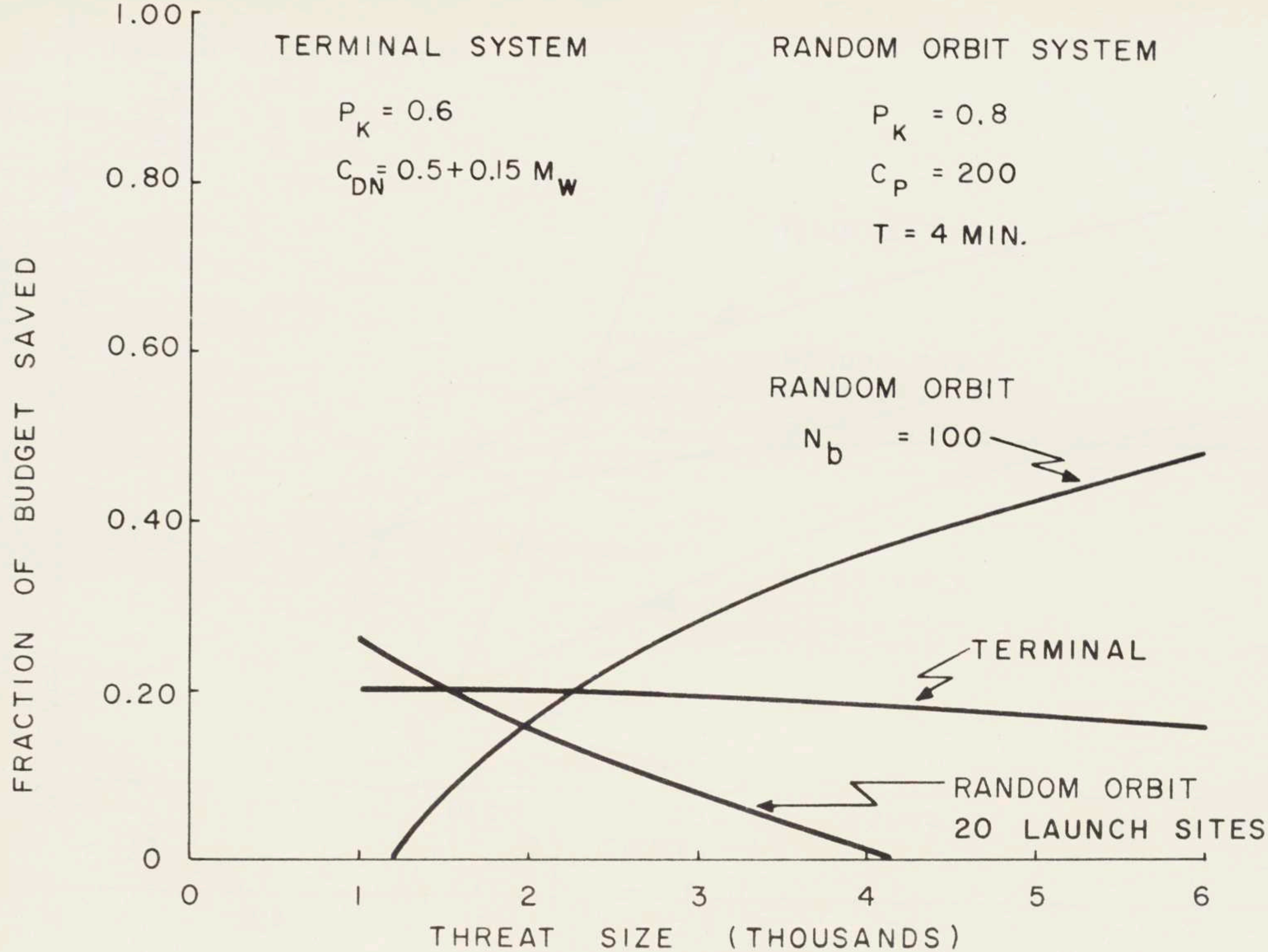

FIG. III - 8

FRACTION OF BUDGET SAVED vs THREAT

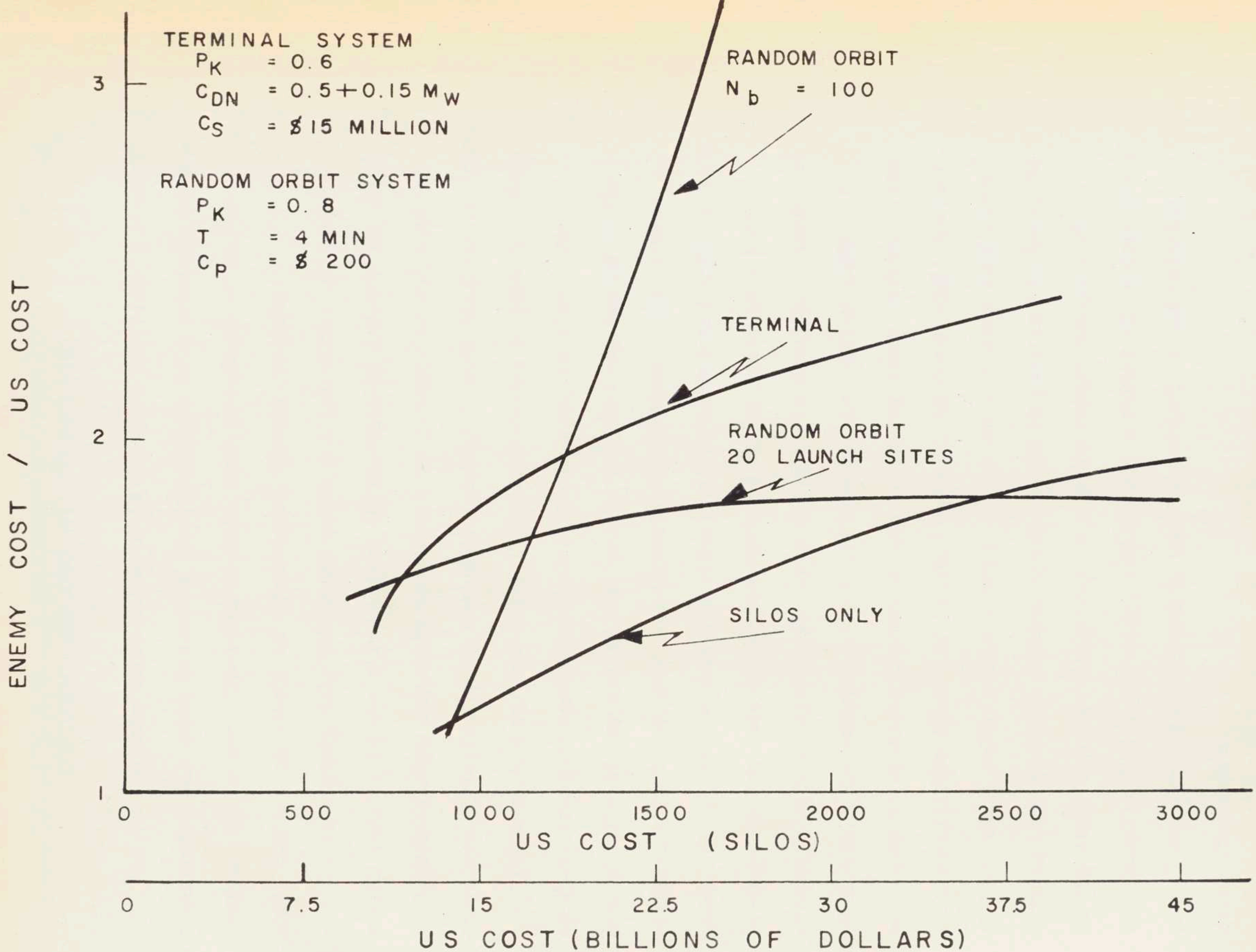

FIG. III - 9

RELATIVE COST vs US COST

CHAPTER IV

CONCLUSION AND AREAS FOR FURTHER STUDY

One of the main conclusions of this report has been to present a general model which describes the parameters of a terminal defense system. The other effort has been to show an example of how one might apply such models to investigate defense problems.

In this study only the basic model and the effect of parameters such as threat size, target vulnerability, AICBM size, AICBM kill probability, and decoy to warhead ratio were investigated as an essential beginning to the understanding of more complex problems.

However, the defense model is general enough to permit a study of wide ranges of possible situations which may develop. The desirability of any system that may be proposed may depend on the relative effort required to overwhelm the defense. The defense model can be used to show the effectiveness of certain enemy countermeasures in the face of certain defense deployments, or a very effective defense system may force an enemy to develop another type of threat. For example, a low altitude defense system might force the enemy to consider thermal attacks covering large surface areas by high altitude bursts of begaton weapons; an enemy might consider a short range Polaris-type missile attack to eliminate sufficient warning time that the defense system needs to perform its task, or if the enemy had the capability to perform target analysis after each missile firing, he might investigate a series of "shoot-look-shoot" attacks, again depending upon the effect it had relative to other strategies.

The other area of interest was to present a particular application of the model by specifying the requirements of a defense system. The requirements were related to a single task of developing a second strike capability.

Considering the total military strategy of this country, the "sub-study" is only one part from a larger number of interlocking areas of interest. The development of a military strategy model to include studies of other "segments" can produce meaningful results. However, the first essential step is to develop the model for each of the various sectors.

The total defense concept might be formulated as follows. What is the minimum size budget for the United States which will produce sufficient military capability to "win"[1] a military engagement with Russia. Next, what is the best allocation of this minimum budget between population defense and retaliatory force systems? Finally, considering the retaliatory force block, what is the optimum combination among various retaliatory systems?

The particular results of this study were to illustrate a method of approach which might be applicable to the other sub-sectors, and to a total study. Figure 10-1 is an example of one possible system study.[2]

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[1]A win is defined as a pre-established loss of population and industry below a given minimum, while inflicting a given maximum damage above a certain value on the enemy.

[2]The area defense system in the figure is one that attrites ICBM's that are dangerous to an area. However, it cannot determine ICBM target points within the area.

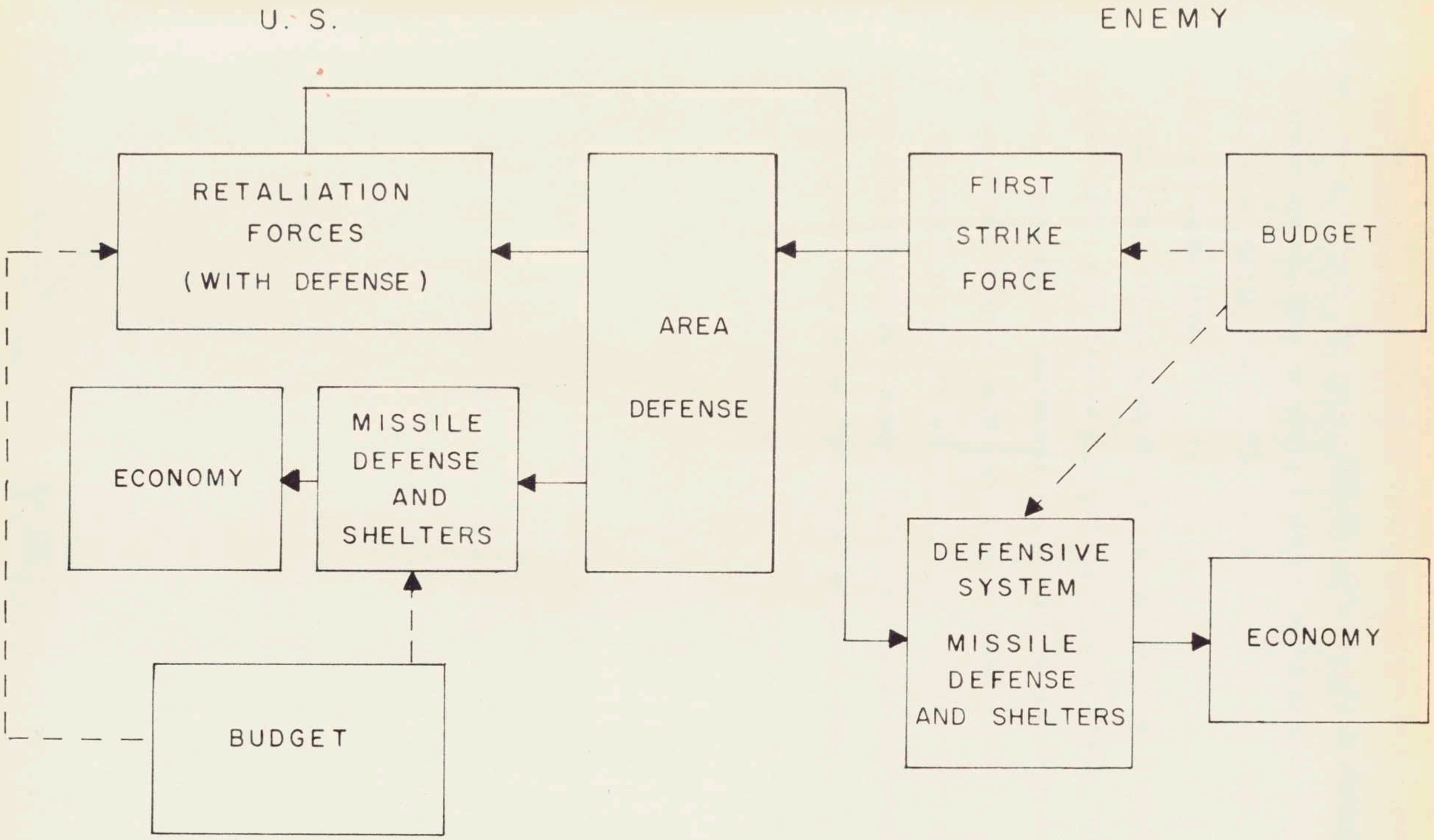

FIG. IV - 1

BLOCK DIAGRAM OF SYSTEM STUDY

The Russian allocation of funds will have a major effect upon the distribution of the U. S. budget. For example, if Russia builds a defense system, this country may need to spend more on offense. If the U. S. builds more ICBM's, Russia has to divert ICBM's from cities to attack them.

The inputs from a total defense concept study would be the Russian threat size, and the expected survivability which is required. Inter-sector influences would be the effect of fallout on the population after an attack upon the retaliatory forces.

The result of this effort has not been to present a solution to the defense problem. Rather, cost-performance requirements may aid the system designer develop needed defense weapons.

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