

Deterrence as a method of preserving peace is not new in the realm of diplomacy, but is relatively so as a subject for scientific analysis. The model of the interaction of opposing strategic forces described here provides a useful framework for such analysis.

A Strategic Force **DETERRENCE MODEL**

M. C. Waddell

The Western World's use of some concept of deterrence as an instrument of diplomacy and as a basis for developing policy has been the subject of much debate during recent years. However, agreement as to which concept of deterrence would be most desirable is not easily obtained. Deterrence, basically, is a method by which aggression is averted by instilling in the mind of the potential aggressor a prior and overwhelming fear of the consequences of his acts, even of his plans. The use of deterrence as a method of preserving peace is not new. It is a continuation of age-old concepts of retaliation, reprisals, hostages, sanctions, and mutual security systems.

To realize its desired effect, any deterrence policy is dependent upon the rational behavior of all nations involved. Since rational behavior is a factor of such critical importance, it must be clearly defined before analyzing the various deterrence concepts. Rational behavior, as used here, is defined as a world power's *deliberate avoidance of acts which inevitably invite national destruction*. Conversely, those acts which clearly lead to national destruction are considered irrational. The most easily understood instance of irrational behavior would be the

initiation of a surprise attack directed solely against an opponent's population and economy. Such an attack would be considered as irrational behavior because in executing it the attacking power would be inviting—if not insuring—its own destruction by retaliation and thereby actually committing national suicide.

The purpose of this paper is to present a model for use in the investigation of strategic nuclear force interaction in a rational world, and for examining various degrees and kinds of deterrence that can exist between two nuclear powers. This model was first conceived by Dr. Dalimil Kybal of the Lockheed Aircraft Co., and has been elaborated upon by members of the APL Assessment Division under the direction of C. F. Meyer.

The basic model of strategic force interactions considered here assumes the existence of two nuclear powers, each possessing at least one type of nuclear striking force. In addition to the striking forces, each power possesses a civil substance consisting of population, city structure, industrial potential, recuperative items, etc., which are considered vital to the continuance of the culture of that power. The vulnerability of any one power's strategic forces to the action of

the other will depend on the measures taken to reduce the effects of enemy action; these striking forces may be defended, hardened, or hidden to decrease their vulnerability to enemy action. Thus, each type of strategic force possesses a specific vulnerability to each type of counter force, which may be measured by the number of enemy forces of a particular kind required to destroy one unit of strategic force of the power under consideration. The vulnerability of each part of a nation's civil substance can be described in a similar manner.

A potential aggressor, before launching an all-out attack on an opposing nuclear power, will first assure himself that his forces are sufficient to:

1. Prevent intolerable civil damage to himself in retaliation, i.e., to reduce a victim's forces to a level incapable, in turn, of reducing one's own civil substance below a specified, tolerable level; and

2. Insure adequate residual forces for himself sufficient to inflict intolerable civil damage on his victim, deter other nations from entering the war, etc., i.e., to reduce the victim's forces to a level incapable, in turn, of reducing one's own residual forces below a specified adequate level.

Unless the victim's initial forces are negligible, a case of little interest, conditions (1) and (2) are to be interpreted as meaning that the victim's forces must be attacked and thereby reduced to some sufficiently low level.

The forces required to meet the above conditions for attack will, of course, depend on the size of the opposing forces; the minimum number of such forces required is defined as the *attack boundary*. In a force diagram (aggressor force level E versus victim force level F) the attack boundary divides the diagram into two regions; in one the attack conditions are met, and in the other they are not. The attack boundary may be written as

$$E = E_F + E_R,$$

where E_F = force level needed to destroy victim's forces F ;

and E_R = aggressor's required residual force level.

A nuclear power will consider that he has sufficient forces to deter an opponent from all-out attack if he is assured that a sufficient part of his forces would survive an initial attack by his opponent to enable him to inflict intolerable retaliatory civil damage on his opponent.

This requisite force level F again depends on the size of opposing force E of the potential aggressor, being made up of the forces needed for the retaliatory strike plus sufficient forces to absorb the initial attack. The minimum number of forces required is defined as the *deterrent boundary*, and may be written as

$$F = F_R + F_E,$$

where F_R = force level needed to destroy a specified part of an aggressor's civil substance;

and F_E = force level needed to absorb an initial attack by E .

In order to see more readily the fundamental implications of the model, consideration will here be limited to a two-power (Blue and Green) world. In it each power possesses a single type of strike weapon, i.e., all weapons of a power possess the same strike effectiveness and the same vulnerability to opposing weapons, and damage inflicted by forces attacking a set of like targets is proportional to the size of the attacking forces.

In deriving the attack and deterrence boundaries, the following notation will be used:

E = Blue's total forces,

F = Green's total forces,

e = damage to E per weapon of Green attacking E , and

f = damage to F per weapon of Blue attacking F .

Blue's attack boundary consists of the following forces:

$$E_F = \frac{F}{f}, \text{ the force level to destroy } F,$$

and E_R = residual post war forces;

therefore, the attack boundary is given by

$$E = -\frac{1}{f} F + E_R.$$

Blue's deterrent boundary (beyond which he is deterred) is determined by the following Green forces:

$F_R =$ force level to destroy a specified part of Blue's civil substance, and

$F_E = f E,$ the force level to absorb the initial attack by $E,$

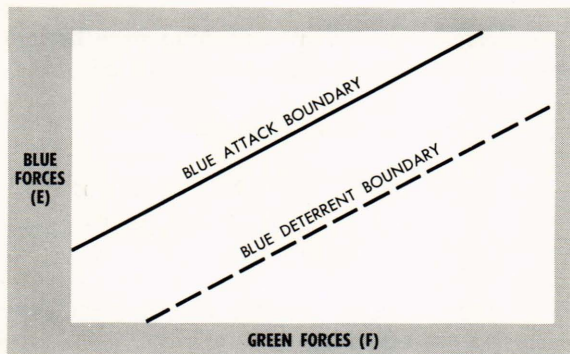
so the deterrent boundary is given by

$$F = F_R + f E,$$

or, on rewriting,

$$E = -\frac{1}{f} F - \frac{1}{f} F_R.$$

Note that the two boundaries, shown also in the first illustration, have the same slope and differ only in their intercepts. From any point *on or above* the attack boundary, Blue can destroy Green's forces and have enough left to hurt seriously Green's civil substance. On the other hand, from any point *on or below* the deterrent boundary, Blue will exhaust his force and still



Force diagram showing attack and deterrent boundaries of one power.

leave Green capable of retaliating effectively. The difference in intercepts is thus a measure of the civil damage each side can tolerate. If any civil damage, however small, were intolerable, then, neglecting post-war force needs, the two

boundaries would coincide.

Since the choices of levels of civil damage that would be intolerable are largely arbitrary, and since the civil damage per attacking weapon involves considerable uncertainty, the intercepts of the two boundaries are by no means certain; similarly, uncertainties as to damage inflicted on forces attacked introduce uncertainties in slopes of boundaries. In short, the boundaries cannot be sharply drawn in practice but must be somewhat diffuse. Such diffuseness, however, does not invalidate the model unless uncertainties are so great as to imply almost complete ignorance.

The relative positions of the boundaries of attack and deterrence have important implications regarding the interaction of the opposing forces. Two distinct situations arise, one in which the forces of each side are relatively vulnerable to the action of the other, and the other where the forces of each side are relatively invulnerable. The second diagram illustrates the case of relatively vulnerable forces on both sides.

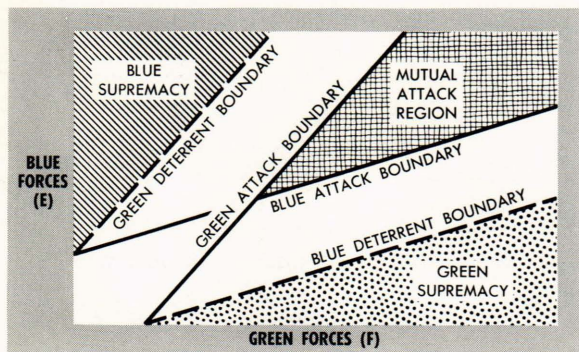
Here are drawn the boundaries of attack and of deterrence for each side. Consider first the region labeled "Blue Supremacy." In this region it is clear that if Blue attacks first he can destroy substantially all the forces of Green and still have sufficient forces remaining to do intolerable damage to Green's civil substance. If, on the other hand, Green attacks first, he will exhaust his forces, leaving himself at the mercy of Blue's remaining force. Thus, clearly, Blue is superior to Green and can, by threatening attack, theoretically impose his will on Green. Similarly Green is superior in the region labeled "Green Supremacy."

While supremacy might be comforting for the power that enjoys it, it is not a very stable state. Such superiority in arms cannot be easily maintained by the stronger power since competition in arms production favors the weaker opponent; for each weapon built by the weaker opponent, the stronger must build several to maintain his supremacy.

It will now be noted that in this situation the attack boundaries cross at some point. The region lying above Blue's attack boundary and to the right of Green's attack boundary, and beyond the cross-over point, is clearly a region in which each side can satisfy his attack conditions, and so the advantage is to the first attacker.

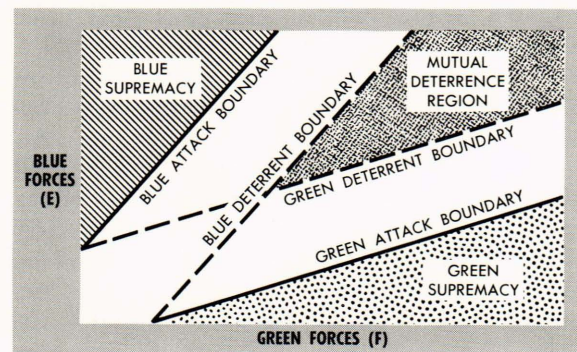
This region can appropriately be called the *mutual attack region* or the region of *negative deterrence*. If the initial force relationship falls in this region it is obvious that the situation is unstable in the sense that the advantage lies with

there is no premium for initiating military action of this type. Again, production competition, sparked by the desire of one side to achieve a position of supremacy, favors the other side; an arms race here is futile.



Force diagram of vulnerable opposing forces, showing the mutual attack region.

the attacker; motivation exists for both sides to initiate an attack. Increased arms production by one side, in an attempt to move out of the mutual attack region and toward his own supremacy region, can only lead to an accelerated arms race or to increased risk of attack by the opposing side, thereby aggravating an already perilous situation. And production competition again favors the opposing side.



Force diagram of invulnerable opposing forces, showing the mutual deterrence region.

The situation is quite different with respect to relatively invulnerable forces. Illustrated in the third diagram is the case of relatively invulnerable forces on each side. As in the case of vulnerable forces, there exist regions of supremacy which need no further discussion. It will now be noted that the attack boundaries do not cross but that the deterrent boundaries do cross at some point. The region above the Green deterrent boundary and to the right of the Blue deterrent boundary is a region of *mutual deterrence* or *positive deterrence*. It is clear that for an initial force relationship in this region, whichever side attacks first will lose his own forces and still leave the victim with sufficient capability to inflict intolerable civil damage on the aggressor, i.e., each side meets the condition for deterrence. Thus, a relatively stable condition exists since

Admittedly, the model described above is simple indeed. Many of the assumptions, both expressed and implied, upon which the model rests will rarely, if ever, be met. In order to remove objections to the model arising from these artificial assumptions, considerable effort is being expended to elaborate and modify the model in several ways: to include mixes of weapons having differing characteristics; to encompass interactions between more than two nuclear powers; to reflect the many uncertainties that obtain in describing force levels, target and weapon characteristics, and deterrence thresholds; and to permit assumptions, other than that of proportionality, concerning the relation between expected damage and size of attacking forces. In addition, the model or extensions of it have been employed in examining the effects of technological surprise on the stability of deterrence, on certain aspects of various arms controls proposals, and on the consequences of achieving weapon invulnerability by means of concealment as opposed to hardening or defense. These efforts have been informative and have demonstrated that the model provides a promising means for gaining greater insight into the difficult problems of deterrence and arms control.