LA-UR- 98-3938

Title:

**FREEDOM TO MIX VULNERABLE AND
DEFENSIVE FORCES**

RECEIVED

MAY 03 1999

OSTI

Author(s):

Gregory H. Canavan, P-DO

MASTER

Submitted to:

For discussions outside the Laboratory

Date: 1 September 1998 DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Form No. 836 R5
ST 2629 10/91

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

FREEDOM TO MIX VULNERABLE OFFENSIVE AND DEFENSIVE FORCES

Gregory H. Canavan

The "freedom to mix" offense and defense to expand without diminishing either side's second strike capability is shown to be counterproductive at large numbers of missiles; effective at intermediate numbers; and progressively less effective at modest numbers. Solutions are less stable for large second strikes.

It has been proposed to establish a "freedom to mix" offense and defense "so as to expand NMD (national missile defense) without diminishing either side's second strike capability."¹ This note examines the requirements for and consequences of that freedom. It studies mixing at constant stability and second strike levels. For modest second strike levels and stability indices, at large numbers of missiles, mixing defenses is counterproductive; at intermediate numbers of missiles, mixing requires a moderate number of defenses; and at modest numbers, mixing is useful but decreasingly effective. For larger second strikes, solutions are less stable and exist only for isolated numbers of missiles.

Exchange Model. For illustration, the analysis initially uses an simplified version of an aggregated, probabilistic treatment of the interaction between two equal, vulnerable missile forces in which outcomes are evaluated in terms of the first and second strikes each side could deliver.² Each side has $M = 250-500$ vulnerable missiles with $m = 2$ weapons each, for a total of $W = mM$ weapons, and D ideal random subtractive underlay defenses. A first strike consists of mM weapons, of which $mM - D$ survive the defenses. A fraction f of it is directed towards the other side's M vulnerable missiles, which gives a counter force attack of

$$r = f(mM - D)/M, \quad (1)$$

The remaining weapons constitute a first strike on value targets of magnitude

$$F = (1 - f)(mM - D), \quad (2)$$

The average survival probability of a vulnerable missile is $Q \approx q^F$, where $p = 1 - q$ is the missile single shot probability of kill. Thus, the penetrating second strike is

$$S \approx QmM - D. \quad (3)$$

Costs and indices. First and second strikes are converted into strike costs through exponential approximations to the fractions of military value targets destroyed. The calculations below assume each side has $1/k \approx 1000$ value targets. The cost of damage to self, $1 - \exp(-kS)$, and incomplete damage to other, $\exp(-kF)$, are combined with a weighting parameter L , which measures the attacker's relative preference for causing damage to the other and preventing damage to self,³ which produces normalized first and second strike costs

$$(1 + L)C_1 \approx [1 - \exp(-kS) + L\exp(-kF)]/(1 + L), \quad (4)$$

$$(1 + L)C_2 \approx [1 - \exp(-kF) + L\exp(-kS)]/(1 + L). \quad (5)$$

The ratio of first and second strike costs,

$$I = C_1/C_2, \quad (6)$$

is used as a stability index.

Strikes. If each sides' stability index is fixed at I , Eqs. (4) and (5) can be solved for

$$F = \ln[(L + I)/[I - 1 + (1 + IL)\exp(-kS)]]/k, \quad (7)$$

which depends on I and S as shown in Fig. 1 for $I = 0.5, 0.7$, and 0.9 , insensitive to D . For $I = 0.5$, F increases almost linearly from ≈ 300 at $S = 0$ to 570 at $S = 160$, i.e., as larger second strikes are required, first strikes are shifted from missiles to value. As I increases, the same variation with S is seen at progressively lower levels of F .

Defenses. Equations (1)-(7) can be solved iteratively to determine the number of defenders D required to maintain a required second strike and stability index I as the number of missiles is changes. Figure 2 shows the variation of weapon allocation f and survival Q with the number of missiles for $S = 75$ and $I = 0.7$. For $M = 480$, f approaches 75% of weapons allocated to vulnerable missiles, which produces a survival of ≈ 0.1 . As M falls, f falls and Q increases, reaching ≈ 0.33 at $M = 240$ where only about 40% of weapons are directed towards missiles. The rest are directed at value to achieve the penetrating second strike required.

Figure 3 shows the resulting first F and second S strikes and the number of defenses D required to support S . D is ≈ 90 at $M = 240$, but falls to ≈ 10 by $M \approx 380$. For larger M , D increases again. Figure 4 shows the rate of exchange of missiles per defender, dM/dD , from Fig. 2. The exchange rate is small and negative for $M = 240$, becoming more negative as M increases. By $M = 360$, $dM/dD \approx -90$, and a single defender would replace 90 missiles.

Figure 3 shows that is because $M = 360$ approaches the minimum of the curve of D vs M , where few defenses are needed, and their effect is magnified. For larger M , dM/dD is positive, which means that if defenses were added, more missiles would have to be added as well. Thus, in building down from 480 two-weapon missiles, the number of defenses would have to be reduced from $D \approx 12$ at $M = 480$ to ≈ 9 at 390. For smaller M , the number of defenses would increase as M decreased until $M \approx 240$, where they largely lose their effectiveness.

The inverse exchange ratio, dD/dM , is shown in Fig. 5. for $M = 240$, it is ≈ -2 , which means two defenses would be needed to offset the reduction of one missile. For smaller M , more defenses would be needed. The magnitude of the exchange falls rapidly for larger M , reaching zero at $M \approx 370$. For larger values the exchange is small and positive for the above reasons.

Second strike sensitivity. The calculations above are for a modest second strike of $S = 75$ weapons. For larger S , they are marginally stable, as shown by Fig. 6 which shows f and Q for $S = 200$. Both show oscillations between $f \approx 0.3$ and 0.4 and $Q \approx 0.3$ and 0.6 as M increases

above 340. The solutions are bistable, and small perturbations can cause them to tend towards one or the other. Figure 7 shows the results of the solution, in which D is the input and D_{appr} is the output of the iteration. Since they agree only for $M = 350, 380, \text{ and } 400$, only the solutions for f small and Q large in Fig. 6 are valid, the others are only approximate.

Summary and conclusions. This note examines the "freedom to mix" offense and defense "to expand NMD without diminishing either side's second strike capability." It derives the requirements for mixing at constant stability and second strike levels and the consequences of that freedom. For modest second strike levels and stability indices, mixing requires a moderate number of defenses at intermediate numbers of missiles. At large numbers of missiles, mixing defenses is counterproductive. At modest numbers, mixing is useful but decreasingly effective. For large second strikes, the solutions are less stable and produce true solutions for isolated numbers of missiles, which could impede a gradual reduction.

References

¹. D. Smith, "Missile Defense, Strategic Stability, and Arms Control," L. Krueger Ed, Proceedings of the World Federation of Scientists Working Group on Missile Proliferation and Defense, 5-8 April 1998, Erice Italy (The World Federation of Scientists, Lausanne, August 1998), pp. 102-106.

². G. Canavan, "Stability of Unsymmetric Forces," Los Alamos report LA-UR-97-1133, March 1977.

³. G. Kent and R. DeValk, "Strategic Defenses and the Transition to Assured Survival," RAND Report R-3369-AF, October, 1986.

Fig. 1. First strike F vs second strike S for various stability index I

Fig. 2. f & Q vs defense D for S = 75, l = 0.7

Fig. 3. F, S, & D vs M for $l = 0.7$

4 dM b dD

Fig. 4. dM/dD vs M for S=75, I=0.7

Fig. 5. dD/dM vs M for $I = 0.7$

Fig. 6. f & Q vs D for $S = 200$, $I = 0.7$

Fig. 7. D vs M for S = 200