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**FIRST STRIKE STABILITY AT LOW
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FIRST STRIKE STABILITY AT LOW WEAPON LEVELS

Gregory H. Canavan

Proportional force reductions could reduce stability by giving the side with fewer vulnerable significant benefit in preemption by allowing the use of his full force in damage limitation at intermediate force levels. That benefit would be reduced if both sides shifted towards larger fractions of survivable forces.

First strike stability at START II force levels and below can be studied parametrically. The optimal attack allocations can be found analytically and are similar to those at larger forces, although the first and second strikes are smaller. The first and second strike costs remain significant for all levels and favor the side with the fewer vulnerable forces. Proportional force reductions could reduce stability by giving the side with fewer vulnerable significant benefit in preemption by allowing the use of his full force in damage limitation. That benefit would be reduced if both sides shifted towards larger fractions of survivable forces in the reduction.

The model used is described in a companion paper on the "Effect of Unsymmetric Force Reductions."¹ This note extends that treatment to proportional force reductions from START I levels, using the models for force exchanges, damage, costs, and stability indices derived in earlier notes.^{2,3} Attack allocations are determined analytically. Numerical calculations show that at these force levels, the impact of non linearity on attack allocation is 10-20% and on costs and stability indices is only a few percent.

Forces. The two sides are denoted as in the earlier notes by "unprime" and "prime," corresponding to the symbols used to denote their forces and parameters. The forces are reduced proportionally and shifted towards greater proportions of survivable forces. However, unprime starts with a large fraction of survivable forces, while prime starts with a preponderance of vulnerable forces, so it is assumed that prime's shift is only partial for through this stage.

Figure 1 shows the forces used in the evaluation, which roughly start from START I missile force levels and compositions. The forces are assumed to be reduced proportionally, so unprime's weapons per vulnerable missile, m , can be used to index the reduction of all parameters. Unprime's non-survivable missiles M starts at 500 and falls to 20, i.e., it falls by 60 missiles each time m falls by 0.4. Unprime's survivable missiles N starts at 400 and falls to 40, i.e., it falls 45 missiles each time m falls by 0.4. The number of weapons on each remains at $n = 10$, as it is only the total number nN that impacts the stability analysis. By the time m falls to 1, the number of unprime weapons is $W = 1 \times 20 + 10 \times 40 = 20 + 400 = 420$.

Prime's non-survivable missiles M' starts at 500 and falls to 100, i.e., by 50 each time m falls by 0.4. The number of weapons per prime missiles falls 2.5 times faster than m . Prime's

survivable missiles N' starts at 100 and falls to 20, i.e., it falls 10 missiles each time m falls by 0.4. The number of weapons on each missile remains at $n' = 10$. When m falls to 1, the number of prime weapons is $W' = 2 \times 100 + 10 \times 20 = 200 + 200 = 400$. This gives a rough parity in total weapons, although prime's force is 50% vulnerable, while unprime's force is only 5% vulnerable. The effects of this asymmetry are discussed below.

Attack allocation. Figure 2 shows the two sides' allocations of their first strikes as functions of m . The two sides are assumed to have equal attack preferences $L = L' = 0.5$, kill probabilities of 0.6, and equal value target sets, so the ratio of their optimal allocations to missiles is⁴ $f/f' = (M'/W) \ln(-L/m \ln q) / (M/W) \ln(-L'/m \ln q)$. At $m = 4$, $M'/W = 500/6000 = M/W$, so $f/f' = \ln(-0.5/10 \times \ln 0.5) / (-0.5/4 \times \ln 0.5) = 1.53$, as seen in Fig. 2. Those allocations are relatively stable until m reaches about 1.5-2. Then prime's allocation drops rapidly because $f' \sim M \sim 0$. Conversely, unprime's allocation increases because $f \sim M'/W$, and W decreases more rapidly than M' . Vulnerable forces remain a significant, and increasing, fraction of the attack even for low numbers of weapons.

Strikes. Figure 3 shows the resulting first and second strikes. The first strikes are comparable, as is unprime's second strike, due to the large fraction of survivable missiles. Prime's second strike is strongly reduced because even at $m = 1$ there are about 1.4 weapons per silo, which gives a probability of survival of about 0.27, so the 100 vulnerable missiles only contribute about $2 \times 27 = 54$ weapons to the 200 from survivable missiles to the total second strike of $S' = 254$ weapons.

Costs. Figure 4 shows the first and second strike for each side as a function of m . The top curve is prime's second strike cost C_2' , which is large because S' is small for $m > 1$. Prime's first strike cost C_1' is large and relatively constant due to the large fraction of unprime's survivable missiles. Unprime's second strike cost C_2 starts $= C_1'$, but falls rapidly with m . Unprime's first strike cost C_1 is the smallest of the four and relatively constant. Note that C_1' and C_2' approach each other by about $m = 2$, but C_1 and C_2 do not approach each other until about $m = 1$.

Stability indices. Figure 5 shows the stability indices as functions of m . The top curve is for prime, whose increasing stability results from the fact that the curves for C_1' and C_2' on Fig. 4 remain at a roughly constant distance until $m = 2.5$ and then come approach one another. Thus, prime's stability index $I' = C_1'/C_2'$ starts at about $0.66 / 0.75 \approx 0.9$ and increases to unity by $m = 1$, reflecting the fact that the side with many vulnerable forces sees little benefit in preemption in facing one with fewer. Unprime's index $I = C_1/C_2$ starts at about 0.7 and then decreases until $m \approx 2$ because the curves for C_1 and C_2 on Fig. 4 separate until $m \approx 2$ before starting to come back together. The side with few vulnerable forces facing one with more sees significant benefit in preemption because it allows the use of his full force in limiting damage to his value targets. This

variation of I and I' produces a reduction in the composite index $I \times I'$ for m from 4 to ≈ 2.5 . For smaller m the index begins to increase, reaching about unity at $m = 1$.

Summary and conclusions. First strike stability at START II force levels and below can be studied parametrically. Optimal attack allocations can be found analytically and are similar to those at larger forces. First and second strikes are smaller. First and second strike costs remain significant for all levels and favor the side with the fewer vulnerable forces. For that reason, proportional force reductions could reduce stability by giving the side with fewer vulnerable significant benefit in preemption by allowing the use of his full force in damage limitation. However, that benefit would be reduced if both sides shifted towards larger fractions of survivable forces in the reduction.

References

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1. G. Canavan, "Effect of Unsymmetric Force Reductions," Los Alamos National Laboratory report LA-UR-97-2194, March 1997.
 2. G. Canavan, "Stability of Unsymmetric Forces," Los Alamos National Laboratory report LA-UR-97-1133, March 1997.
 3. G. Canavan, "Attack Optimization for Unequal Moderate Forces," Los Alamos National Laboratory report LA-UR-97-2195, June 1997.
 4. G. Canavan, "Attack Optimization for Unequal Moderate Forces," Eq. 9.

forces vs m

Fig. 1. Prime and unprime forces.

f vs m

Fig. 2. Attack allocations versus m.

F & S vs m

Fig. 3. First and second strikes versus m.

C1 & C2 vs m

Fig. 4. First and second strike costs versus m .

indices vs m

Fig. 5. Stability indices versus m .