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"Open Skies" for the 21st Century[1]: A New Approach to Missile Defense and The Global Public Good

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ABSTRACT

To deserve serious consideration a missile defense system must pass three tests:

(1) It must be *technically feasible*. It must be physically possible simultaneously to acquire large numbers of stealthy in-flight missiles, distinguish them from decoys, and to reliably shoot down practically all of them with our missiles/beams/bullets/electronics etc..

(2) Once in place, at any point in time it must not overturn or reverse the no-attack stability of mutual deterrence. This is *war initiation stability*. A missile defense which induces instability is unacceptable.

(3) It cannot be *relatively* too expensive. If an adversary can overwhelm a missile defense deployment by building more missiles over time, and if this response costs much much less than the missile defense itself, then deployment leads to *arms race instability*. Such missile defense just invokes its own defeat-by-saturation and is unacceptable.

Historically, proposed missile defenses, ABM, or BMD deployments have failed all three tests. This is why they have always been rejected. Here I argue that technical and international political changes of the past decade have made missile defense viable. But a crucial new ingredient in its viability is the opportunity that BMD be implemented as a global public good, collaboratively designed, financed, and provided by/among otherwise adversarial countries. The technical changes relate to the new possibilities for boost-phase intercept of ballistic missiles, while the political changes follow from the end of the Cold War.

Rather than national (or alliance) oriented BMD to advance individual national interests, collaborative, international, universal missile defense to limit damage globally can pass all three tests. Our technical and political R&D should focus on this path to substitute for Mutual Assured Destruction. And the current debates over missile defense should not lead to decisions which overlook this opportunity.

[1]"Open Skies" was the name given to President Eisenhower's proposal for exchange of intelligence access to status of deterrent forces by the US and USSR.

INTRODUCTION

For five decades our security against nuclear annihilation has depended on Mutual Assured Destruction or "MAD," our abilities to deter, to pose unacceptable risks of unacceptable retaliatory damage to any potential attacker. Among the critical if paradoxical features of MAD: it is in *our* security interests, that adversaries be secure in maintaining the invulnerable survivability and retaliatory capabilities of *their* strategic offensive forces.[2]

The fact that such has been our (blessedly successful) strategy, however, doesn't mean we have to like it. And to the ordinary citizen, an ability to protect himself and his family by defeating attack and preventing damage if it is possible, *ceteris paribus* obviously dominates an ability to deter attack by promising punishment. An ability to protect by defense eliminates one's dependence on the rationality of calculation by an attacker, and simply feels more secure.[3] I believe that this evident commonsensical superiority of defense over deterrence as desirable goals goes a long way toward explaining our political leaders' persistent flirtation with strategic missile defense.[4] Beginning with Nike Ajax in the 1950's, ABM of the 1960's and 70's, SDI-Star Wars of the 1970's and 80's, there has been a longing for Mutual Assured Survival "MAS"--- and a frustration also as understanding has grown that disarmament cannot substitute for defense, because very low inventories of strategic offensive forces generate inherently unstable incentives to avoid being second in a missile exchange (Intriligator, 1975).

Once again a missile defense debate is upon us now, provoking a familiar clash of rhetoric: between elites who oppose from their perch of technical expertise, to down-home moralists who demand defense as an ethical imperative.[5] This paper suggests that the time has come to reevaluate these disagreements in the light of a new opportunity given to us by technical and political possibilities undreamed of at the time of the ABM Treaty. This

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[2]Included is the desirability that we know he knows he is secure, he knows we know etc. See Schelling (1960).

[3]The more conversant one becomes with the game theoretic subtleties and paradoxes of maintaining a credible deterrent, the greater is one's appreciation for the burden of demands on calculating rationality which MAD imposes or assumes, and the greater should be the relief if a viable substitute could be found.

[4] No doubt there are other ingredients in the explanation: including (1) special interest seeking by the military industrial complex (2) aggressive hegemonism of some military and civilian elites, (3) naivete and ignorance.

[5]Not to mention shameless self-interest mongering and cockamamie wishful thinking.

is the opportunity for "public good" type collaboration between otherwise-adversaries to make MAS this generation's stable, affordable, substitute for MAD: time to replace the current reliance on MAD, not with deployment of nation-centered ABM, but rather with its renunciation, and instead its replacement with global-oriented defense, time for a pact among the major powers, universally to limit potential damage using BMD, not as a measure of partisan domination, but for the global public benefit which it would create.

Under what conditions could we prudently replace MAD, at least in part, with MAS in the foreseeable future? There are basically three criteria to bring to bear on this question:

- C Technical: Is it physically possible to shoot down or otherwise defend against large salvos of fast, stealthy, deceptive missiles? Most importantly can missile defense be implemented without reliance on nuclear weapons?
- C Strategic: Can a large scale missile defense preserve stability in the bilateral/multilateral decision calculus of the delicate balance of terror (Wohlstetter, 1959)?
- C Financial: In a missile/defense arms race duel, can an attacker nullify the opposing defenses at a much lesser cost than the cost of the defense itself?

As a paper in economics this will consider the structure of incentives along each of these margins. Written without access to classified information my conclusions are necessarily conjectural.

But to anticipate the conclusion, consider the vast increases in intelligence acquisition and smart weapons technology of the past two decades, especially as applied to boost phase intercept and attacker neutralization. These we argue can sustain missile defense as superior, *especially if it is based on strategic agreements between adversaries* and treated as an international Public Good. Treatment as a global public good implies a "Global Missile Launch Surveillance and Warning Authority," coupled with a "Multinational Missile Intercept Command," which would destroy attacking ballistic/cruise missiles once launched *irrespective of their origin*. To treat missile defense truly as a multi-country collective good, not a weapon for one nation's dominance or advantage, of course implies a gigantic change in political perspective. But this may now be feasible because of changes in the international political system over the past decade. Moreover, as we shall see, internationalizing missile defense as a global public good may be the best or even only answer to the otherwise destabilizing

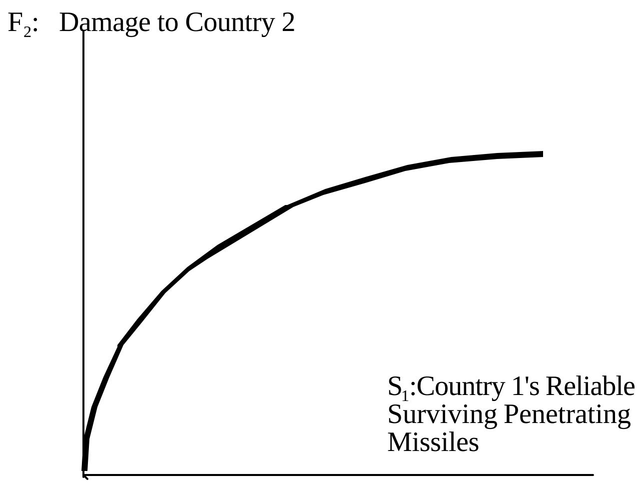

Figure 1

properties of BMD in an asymmetric world of unequal adversaries.

What "Missile Defense" Is and Is Not

I want to present the underlying, comparative static, cost benefit analysis of deterrence versus defense for a world of great powers --- strategically and economically great --- who threaten each other with major thermonuclear exchange and war. Missile defense to protect against rogue states, or midget powers is not what I have in mind.[6] Countries such as Russia, China, the U.S., might at present or in the proximate foreseeable future, reliably deliver scores to thousands of counter value warheads, causing destruction in the scores to hundreds of millions of persons. In years to come one would include India and if it ever so decided Japan. Missile defense confers an ability to *limit damage* in this context, but not to entirely eliminate it. It must be physically possible to protect a country in an environment where if unprotected, casualties in nuclear exchange could number 30% to 80% of its population? (See Figure 1 for the assumed relationship between one country's retaliating weapons S_1 and the target country's damage, F_2). By "protect" I mean reduce damage to a lesser percentage, 2%, 5% or 10%, not completely or perfectly eliminate it. I am of course fully aware that 5% casualties in the U.S. population would be an unimaginable calamity, but I assume that the goal of "successful" defense would be to reduce damage to such level from a much larger fraction. Reducing damages to levels of 1% or 0.1 % (themselves catastrophic) is in all probability simply not achievable. Nor I do not concern myself here with the rather quixotic issue of whether any protection is even desirable. "Will the survivors envy the dead?" Read Herman Kahn's *On Thermonuclear War* (1960) Chapter for one answer.

PRECONDITIONS FOR SUCCESSFUL BMD

[6]Actually, missile defense against bit players is an out of the gate loser in a world of smuggling and surreptitious state sponsored nuclear terrorism.

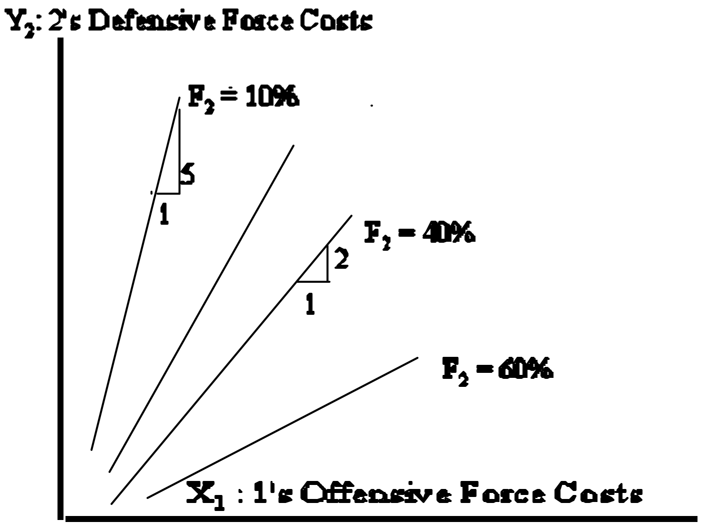

Figure 2a : Costs Favor Offense

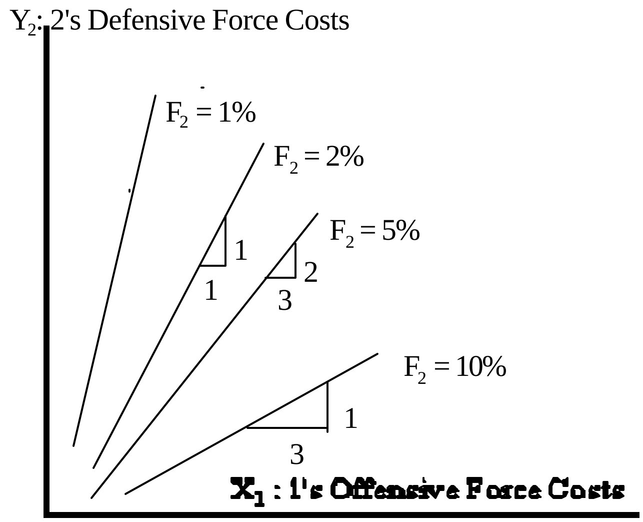

Figure 2b: Costs Favor Defense

Technical Feasibility

Successful BMD must pass through three analytic sieves as mentioned. The first sieve is technical. This paper assumes technical feasibility, or relates to a future time period when the technical capacity exists to do all the tasks needed: to determine that missiles have been launched, distinguish them from decoys, acquire them as targets in the distinctive phases of their trajectories, and destroy/disable them, and of course included in such tasks

is the ability to defeat countermeasures which could interfere with missile defense itself.

Arms Race Stability

Secondly more than simply feasible technically, for serious consideration BMD must be sustainable financially --- the more so especially as between countries which are approximately economic and technical equals. To show what is meant by financial sustainability consider a plot of the system cost of imposing a level of punishment or damage on another country *versus the cost of defeating* such damage capability by BMD. Figure 2a/b shows how at any point in time under a particular technical regime offensive and defensive expenditures will compete, just offsetting each other at various levels of damage. It pictures the relative effectiveness of deterrence vs. defense expenditures, by making explicit how much missile defense outlay is required to cancel out, negate, or override a $1 of expenditure on deterrence. It shows not only the absolute ratio, it shows marginal ratios as the slopes of the F_1, and F_2 contours (damages to Countries 1 and 2). Most importantly, Figure 2 also shows that this ratio --- the "Offense/Defense Neutralization Ratio" will depend significantly on the level of damage in question.

The marginal cost advantage for attack, in general, will increase with lower damage levels. Figure 2a as an example assumes that when the damage level is 40%, the offense can negate an increase of $1 in defense expenditure (Y) by increasing offense (X) by 50¢. Moreover, when damage level is 10%, the offense can offset an incremental defense expenditure of $1 with an increase in X of only 20¢. So the diagram plainly shows how in the competition between offense and defense there may be a techno-economic advantage to offense and this may grow (from 2:1 to 5:1 in our example), the higher the level of safety or protection for the defender.[7] In a techno-economic environment like this, missile defense can only "limit" damage to say 40% casualties, a performance so pitiful it may not be worthy of the name "defense" at all, and probably not worth undertaking.

Figure 2b then shows a contrary configuration. There, the marginal offsetting cost Neutralization Ratio favors defense, such that for a damage level of 10% offense must match defensive outlays 3 to 1, while at a damage level of 2% this falls to 1 to 1. The appendix shows the implications of systematic cost advantage/disadvantages in more detail. For the moment, we just recognize that an economic structure reflected in Figure 2a implies that missile defense is unsustainable. It is so cheaply defeated that it will invoke a self-defeating response from the adversary: a futile offense-defense arms race arms race. On the other hand, a structure such as Figure 2b basically makes it possible to pursue defense over offense. Of course the relative wealth and technical capabilities between adversaries are highly relevant as well. If there are marked asymmetries between adversaries, this may offset some disadvantages of one security posture over another. But aside from this last

[7]These summary "iso-damage contours" and "Neutralization Ratios" will in practice be based on detailed elaborate sub-optimizations in force compositions and targeting programs but numerous studies (a classic being Kent, 1964) show the general relationship pictured in Figure 2.

factor, a sustainable BMD basically requires a cost structure more like Figure 2b's over that of Figure 2a

Thus, another precondition for BMD: only if the new missile defense technologies now being advanced incorporate an economic advantage for defense something along the lines of Figure 2b is it reasonable to consider deployment. One reason for rejection of ABM/BMD in the 1960's and 1970's was just such a cost disadvantage.

Strategic Second Strike Stability

The third sieve BMD would have to survive to merit consideration is one of strategic and political dynamics. Here consider two cases: symmetric and asymmetric. First assuming a rough symmetry between adversaries, can a *mutual bilateral* cost-effective BMD be implemented which maintains the undesirability of striking first, the dominance of a "wait-don't-shoot" strategy *for both* in a crisis between nuclear powers? To illustrate consider table I. It shows % of "national value lost" in a nuclear exchange, for two countries, A and B, when one or the other initiates a war and the other retaliates. Three different cases are shown; in all three, the two countries, the presence or absence of BMD, and war outcomes between them are symmetric. The numbers are merely illustrative.

Table 1. Example of Deterrent Stability
Equally Matched Countries

I: Deterrent Stability Without Missile Defense
II: A Bilateral Missile Defense Which Destroys Deterrent Stability
III: A Bilateral Missile Defense Which Enhances Deterrent Stability

	Loss to A	**Loss to B**
A Initiates: B Retaliates	**I: 20%** **II: 1%** **III: 10%**	**I: 60%** **II: 41%** **III: 5%**
B Initiates: A Retaliates	**I: 60%** **II: 41%** **III: 5%**	**I: 20%** **II: 1%** **III: 10%**

Row I illustrates the stability of Mutual Assured Destruction which has served for 50 years. Although initiating attack results in a lot lower loss than retaliating, still it is so costly to the initiator that in a crisis he prefers to wait, taking a chance that the adversary will not initiate.[8] And since both sides make the same calculation, both wait and war is avoided.

Next consider Row II: it illustrates a bad, destabilizing BMD which capsizes MAD and demolishes stability of deterrence. Row II assumes that BMD reduces damage to initiator or retaliator *more or less equally* whether one strikes first or second. Evidently a "bad" BMD system! It raises the incentive to strike first in a crisis. Even though 1% damage is an unprecedented catastrophe, 41% is so much more incomparably worse, both parties may find the incentive to choose the lesser bad irresistible.

Finally row III of the table shows a "good" missile defense, one which enhances stability by eliminating the differential advantage of shooting first. In fact Row III makes "wait-don't-soot" an absolutely superior decision rule[9] so that waiting is better even if the opponent decides not to wait!

Table 2. Example of Deterrent Stability
Asymmetric Countries and Forces

I: Deterrent Stability Without Missile Defense
II: A's Unilateral Missile Defense Destroys Deterrent Stability

	Loss to A	**Loss to B**
A Initiates: B Retaliates	**I: 5%** **II: 1%**	**I: 40%** **II: 40%**
B Initiates: A Retaliates	**I: 20%** **II: 5%**	**I: 30%** **II: 30%**

Now consider a case where the outcomes are not symmetric --- a more realistic case which might concern the Russians, or the Chinese even more. In Table 2 Country A represents the US, and Country B China or possibly Russia. Row I of the table indicates how MAD keeps working even under asymmetry. Only Country A

[8] A good analysis of the detailed structure of this stability, based on Ellsberg's (1958) "critical risk" can be found in Brams (1985) or Brams and Kilgour (1988).

[9] If the side which initiates must expend more missiles to disarm the target than it kills (account being taken of BMD on both sides) then striking first may amount to unilateral disarmament (partial) and produce such results.

deploys a missile defense in Row II; this raises A's incentive to strike first in a crisis. Moreover, a unilateral BMD deployed by the stronger country, gives it far more latitude to be aggressive/ provocative short of nuclear threat in pursuit of its foreign objectives, a situation which Chinese and Russians alike must dread. (They may not know for sure how intolerable a 1% loss would be to the US.)

Limits of Comparative Static Analysis

In addition to being incomplete, our models suffer from the defect that they are comparative static. But even if the case for missile defense turned out to be clear and unimpeachable, a crucial danger could lie in the transition from deterrence based MAD strategy to defense-based MAS strategy--- *the danger that deterrence would fail before defense became effective*. I have nothing to say about this peril, except that it becomes of special concern when defense is unilateral, non-cooperative, and uncoordinated. If to the contrary BMD were effected by multinational agreement, this dynamic risk would be lessened.

COLD WAR VS. 21ST CENTURY

Cold War BMD Technology

Figure 2a conveys a rough idea as to why historically the case for ABM, BMD, SDI etc. etc. has been so unpersuasive. Even if the missile intercept systems could actually be made to work, and even if advocates reconciled themselves to the porousness of a defense, and to its ineffectiveness against rogue/terrorist attacks, and even if the threat to deterrence stability which initiation of BMD entailed were all accepted, still the underlying cost structure has made it unacceptable. A "defense" which can be defeated or circumvented at 10%-50% its own cost, is just basically untrustworthy. For the US knowingly to expend, say, $500 Billion on a defense which could be defeated at a cost of $50-$100 Billion simply makes no sense. Thus, throughout the Cold War and since, we have been trapped at something like the Nash equilibrium of *excess* MAD. (See Figure xx in the Appendix to illustrate the Nash equilibrium, showing it to be "excess" in the sense of more than Pareto optimal.).

21st Century BMD Technology

Has anything relevant to alter this argument happened over the past generation? To an outside observer it seems several techno-economic, strategic, and political developments of the past two decades suggest a positive answer. Principal among these developments are the following:

- C First, sufficient political changes seem to have occurred to allow military collaboration, including cooperative, multinational, missile intercept forces. The fact that one country's technology and intelligence dominates, simplifies coordination problems. The fact that cold war rivalries have diminished makes trusting exchanges of information more feasible. Cooperation is now attainable which was unthinkable 20 years ago.
- C Second, new developments in boost phase target acquisition and intercept mean that missile defense is much cheaper relative to offense than at the time the ABM treaty was signed. Huge improvements have been made in target acquisition, engagement and management. Smart weapons accuracy means that missile defense without use of nuclear warheads is possible. Rather than shooting down a speeding bullet at its least vulnerable position (which is traveling 15,000 mph carrying multiple decoys and chaff) with another bullet, boost-phase intercept destroys when the attacker is most vulnerable. Because surveillance and boost phase intercept defeats "attacking" ICBM's or SLBM's at their most vulnerable, it should change the cost structure, so that against large scale salvos it becomes *cheaper to defend than to attack* and the example of Figure 2b applies rather than Figure 2a. (Defense against, surreptitious, terrorist-like, individual weapons is not what I mean).

  Note especially how these technical developments interact with the political. More specifically, consider how much cheaper boost-phase intercept should become with the *collaboration* of otherwise adversarial countries. The marginal costs of individual missile kills should decline dramatically, while counter measures aimed at raising the costs of defense can be restricted further limiting costs of defense. Of course, the degree of collaboration can be instituted step by step, beginning with shared real time information about missile launch status, to reciprocal territorial patrols, all the way to joint multinational force missile intercept

- C Third collaborative defense would mean that global missile defense can be *financed as a public good* with costs shared among rivals/collaborators. Thus the costs of defense to any one party become only a fraction of total costs, while the benefits are shared in a non-rival, non-exclusionary manner characteristic of public goods. (Initially the US, no doubt, would pay the greatest share of the costs, but over time as in the NATO experience, the US share might decline).
- C Fourth, global missile defense can be configured so that it *enhances stability of deterrence* rather than undermines it. In fact this protection/advantage is inherent in global missile defense, just as instability is inherent in national missile defense. The reason: any multinational missile defense will be subject to resource constraints. Therefore, there will have to be a limit to the number of missile killing intercepts it can effect --- say N in number. A global BMD force can assign those N intercepts to the *first N* missile away targets it acquires. If it does this, it will be the initiator's attack force which is reduced by BMD and not the retaliator's. And this will *either diminish the advantage of striking first or even reverse it.*

Meeting Gorbachev in Iceland in 1985, Ronald Reagan spontaneously offered to share missile defense technology with the USSR, a move which it is said alarmed his advisors. Twenty years later, in view of political, technical and economic developments since then, the time to follow through on his proposal may have arrived.

To give an idea of how a change in relative costs of defense vs. Attack can change the Nash equilibrium between deterrer and deterred, suppose we concentrate on one country's damage at risk. Consider Country 2's damage if nuclear exchange happens, i.e., F_2. This is desired as a positive good by Country 1 and suffered as a"bad" by Country 2. Let us ignore the interactions between F_2 and F_1, just for illustrating a Nash equilibrium. (The Appendix includes these interaction in Figures 6 and 7, postulating preferences and indifference curves between F_2 and F_1).

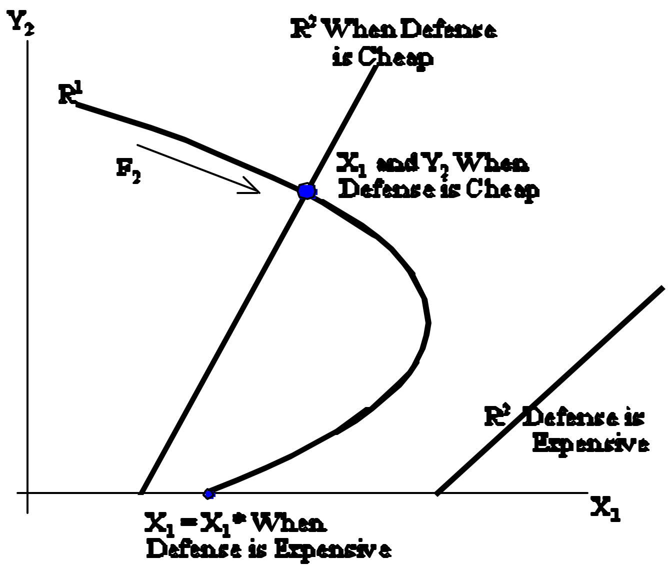

Figure 3:
Nash Equilibrium Depends on Cost of Defense

Figure 3 -- derived from the more detailed analysis in the Appendix --- then gives an idea of the implications of a new low cost BMD compared to earlier high cost versions. In Figure 3 the Cournot reaction curve of the attacking (i.e., counter value retaliating) country (Country 1) is shown as R^1. Using notation developed in the appendix the space is offensive force (X_1) vs. defensive force (Y_2). Damage to Country 2 is increasing in the direction of the arrow F_2. (R^1 curves backward because of ordinary income and price effects; see the Appendix for more.). When missile defense is relatively expensive, the defending country's, (Country 2's) reaction curve R^2 (also derived in the Appendix) is as shown out to the right. Nash equilibrium occurs at $Y_2 = 0$, and $X_1 = X_1$*. In other words there is no missile defense.

Now let cost of defense *decline*. R^2 shifts in, and a new equilibrium results with lesser damage to 2, greater defensive effort ($Y_2 > 0$) and more or less offense, X_1 >=< X_1*. Given ordinary price and income effects, the change in Nash equilibrium may actually entail an increase in competitive deterrent expenditure, but the level of damage in the event of war will assuredly decline.

Appendix
Economic Structure of Deterrence vs. Defense:

In the interests of focusing on essentials I will make a number of heroic simplifications about strategic forces of two adversaries, identified as countries 1 and 2. This collapse of deterrence and defensive forces into a small number of variables effectively assumes rather detailed, elaborate sub-optimizations going on in the background[10] but it gets at the basic economic structure of deterrence vs. defense.

F_j : Damage to country j from a counter value first or second strike by country k in a stylized nuclear war measured in %. Country j's and k's stylized war scenarios may be impossible to generate as simultaneous since both, for example, may assume that the other strikes first.

S_k : Number of reliable surviving penetrating missiles[11] which country k could use as counter value weapons to retaliate against j.

$F_j = F_j(S_k)$: An assumed unique[12] monotonic "damage function" asymptotic to 100%. $F_j' > 0$, and $F_j'' < 0$. See Figure 1.

X_j : Country j's efficient provision of offensive missile forces[13] for purpose of deterrence.

Y_k : Country k's provision of damage limiting defense against j's counter-value missile attack forces.

p: Relative price of defense.

C_k: Consumption of all other goods in Country k.

M_k : Total resources available in Country k: $X_k + pY_k + C_k = M_k$

Now the offense-defense force interaction or force conflict function becomes:

$$S_k = ö^k(X_k, Y_j);$$

and we assume

$$ö^k_k > 0;\ ö^k_j < 0;\ ö^k_{kk} < 0;^{14} \qquad ö^k_{jj} > 0; \qquad ö^k_{kj} >=< 0.$$

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[10]For example, an optimal mix between submarine based and surface based, air launched offensive weapons is assumed. Similarly we assume an optimal mix between pre-boost phase, boost phase, ballistic trajectory, and terminal re-entry phase defenses. And I ignore problems in such optimizations due to scenerio dependency (e.g. warning time)

[11]Reliable, surviving, penetrating numbers of missiles may not be the best measure of a retaliator's power. Reliable surviving RV's or Ó(Megatons) or $Ó(\text{Megatons})^{b}$ or $Ó(\text{Megatons})^{1/2}$ may be better indices. The term "missile" includes them all.

[12]Here again scenerio dependence is ignored.

[13]The same missile can be both offensive/deterrent and defensive/damage-limiting weapon, but we shall overlook this possibility. These expenditures are "efficient" in that they reflect an optimal mix of alternative systems for each outlay level.

[14]This may be a dubious assumption since there are increasing returns to expenditures on missile survivability against an enemy missile attack of fixed strength. I assume this is overcome by diminishing returns in the damage function, $F_j(S_k)$

Within this notation we can contain the basic strategic problem faced by each of two adversaries in a diagram, and more importantly depict the crucial importance of the intrinsic advantage of offense over defense (or vice versa) as contained in the conflict of forces functions ö$^{k}(X_k, Y_j)$ and ö$^{j}(X_j, Y_k)$[15].

Figure 5 shows the conflict between countries 1 and 2 over the value of S_1 = ö$^{1}(X_1, Y_2)$ and, therefore, of $F_2(S_1)$. Again S_1 is, Country 1's secure, retaliatory, deterrence/punishment force (or equivalently Country 2's defensive vulnerability.) For each combination of value of offensive and defensive outlay (X_1, Y_2) a particular value of S_1 or of $F_2(S_1)$ is identified.[16] The offensive and defense effectiveness curves on the two sides of the figure are

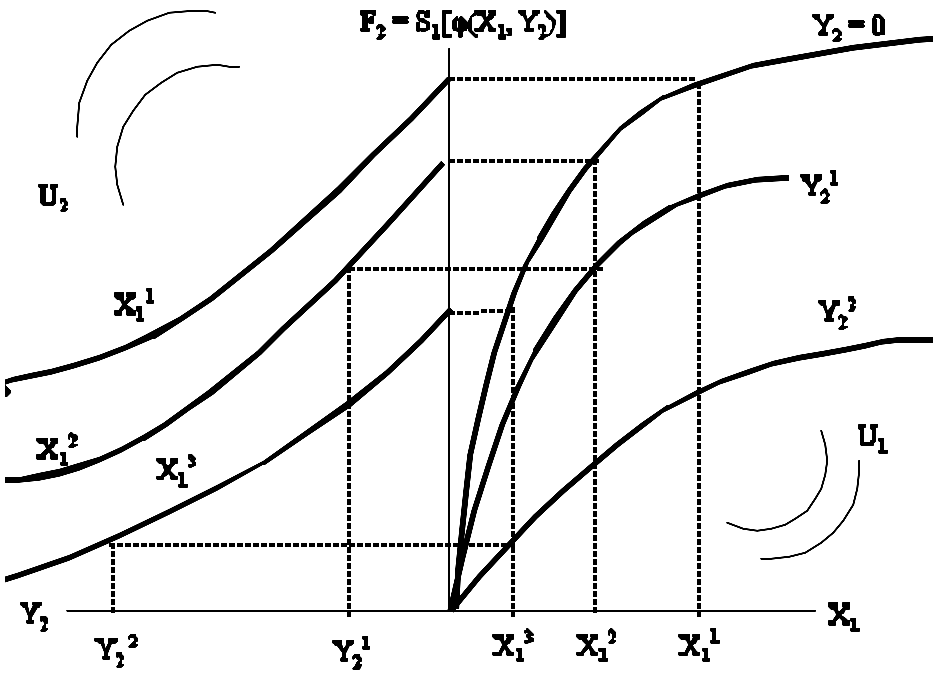

Figure 4: Offense-Defense Competition

interrelated as shown and typical indifference curves are added. Figure 4 is of special import to economists because it implies a distinctive characteristic between offensive and defensive expenditure (respectively on X and on Y) prominent in economic analysis --- namely the distinction between income and substitution effects. Inspection of Figure 4 as it is drawn confirms that offensive expenditures (X_1) by Country 1 have direct *negative income effects* on Country 2 and also produce *positive price effects*, which *increase*, the marginal productivity of defensive outlays

[15]A detailed construction of such functions from missile exchange/ defense processes is developed in McGuire (1967)

[16]The curves drawn in Figure 4 on the assume that both defense and offensive targeting and target acquisition are optimized. This usually leads to a linearization of the damage curves in the right panel, where the optimal defense establishes a “price” or constant unit effectiveness for the attackers payload for all value-targets attacked. This detail is not pictured.

Y_2 --- that is reducing the marginal price of defense.[17] The income effect of X_1 is obvious from the left panel of Figure 4; it increases F_2 and therefore pushes Country 2 in the left panel northward, which is a negative income effect. Since the defense effectiveness curves increase in slope along any vertical slice for given Y_2 the marginal product of Y_2 increases with greater X_1. Thus, for the defender, both price and income effects of the adversary's deterrent force reinforce each other to stimulate defense. In contrast, defensive outlays (Y_2) by Country 2 operate through their *negative income effects* by pushing Country 1 southward in the right panel and *negative price effects lowering* the marginal productivity of retaliatory power, as shown in the right panel of Figure 4 .

If we ignore other variables in their strategic interdependence (specifically ignore X_2 and Y_1), we can picture the two adversaries will choose values of (X_1, Y_2) and therefore (C_1, C_2) given total resources M_1 and M_2. Suppose for the sake of argument that this process is resolved as a two-country Nash equilibrium. Then, this equation depends on relative subjective, utility values of C_2 and F_2 in Country 2 (the defending country trying to reduce the size of the retaliatory punishment which it would absorb, less F_2 is better) and of C_1 and F_2 in Country 1 (the retaliating country desiring to maintain an unacceptable degree of retaliatory punishment, the more F_2 the better). Figure 3 showed this Nash equilibrium, derived in principle from Figure 4 after indifference curves (on the right for Country 1, on the left for Country 2, have been added to that first diagram) tangency points recorded etc..

Consistent with Figure 4, the derived reaction curves of Country 1 and 2 were shown in Figure 3. Because income and price effects work in the same direction for the defending country, I have drawn Country 2's reaction curve $Y_2 = R^2(X_1)$ with a positive slope throughout. But because income and price effects conflict for the deterring or offensive Country 1, I have shown a region of high defensive outlay (to the left of its vertical slope) where an increased price of deterrence lowers offensive expenditures. Equilibrium occurs where these two reaction functions intersect.[18] Simultaneously a Nash equilibrium supports a choice of $S_2 = ö^2(X_2, Y_1)$, and of $F_1(S_2)$. To show this result another pair of figures similar to 3 and 4 would have to be drawn. Each pair of graphs would indicate that at an equilibrium in the deterrence/defense game both countries have in effect accepted the damage levels they each risk. In other words, S_1, and S_2, or F_2, and F_1 are in effect public "public goods" or "public bads" that countries accept in equilibrium. These are properly called "public" as both F_1 and F_2 effect the welfare of both countries.

Another way to assemble the information contained in a pair of relationships as in Figs. 3 and 4 for both countries is shown in Figure 5. This has combined Figure 4 and an equivalent diagram for the competition over $F_1 = F_1(S_2)$, into one picture. The entire range of aggregate budgets, possible allocations between X and Y for each country, and resulting war outcomes measured by F_1 and F_2 is shown. Figure 5 pictures the relative effectiveness of deterrence vs. defense expenditures, by making explicit how much defense expense is required to cancel out,

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[17]This is quite a general phenomenon, although often buried in the tremendous detail of operations analysis of strategic budget and targeting.

[18]No doubt the complexities of international affairs makes the assumption of Nash equilibrium too naive to capture the actual interactions between strategic adversaries. This analysis can only be suggestive of an underlying structure at most.

negate, or override a $ of expenditure on deterrence. For example, the marginal cost advantage for the attack/offense increases for lower damage levels as explained earlier.

Now although these graphs picture the individual choice of both F_1 and F_2 in each country they do not show how an overall budget constraint forces countries to choose *between* the two. Adversaries do this in effect by allocating outlays between X and Y. We showed elements of this choice already in Fig. 3. Now can combine the two choices for both deterrence and defense together. For a given budget on both sides, i.e. M_1 and M_2 fixed, and for a given combination of each value of X_2 and Y_2, country 1 is free to choose between values of X_1 and Y_1 provided these sum to $X_1 + Y_1 = M_1$.

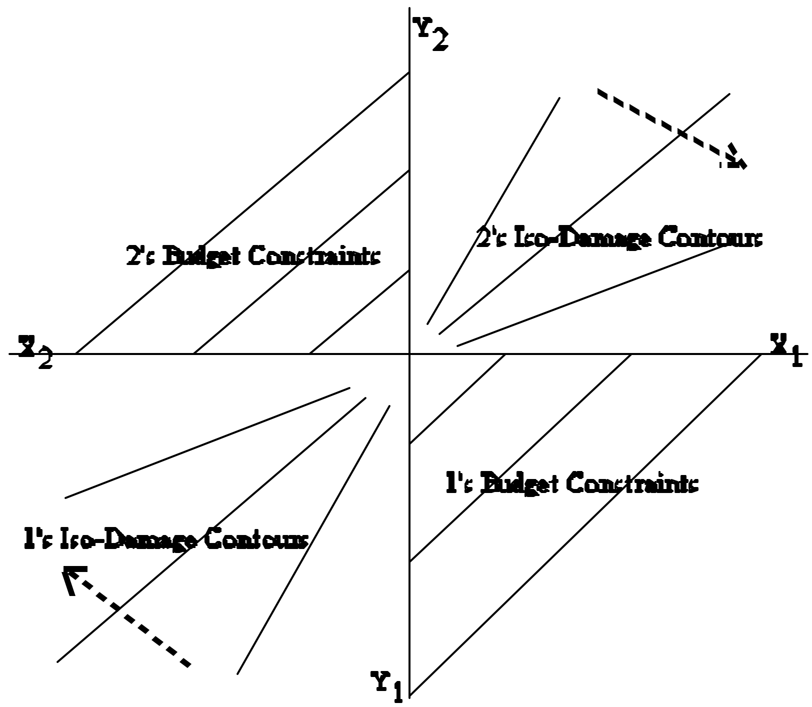

Figure 5: Dual Deterrence-Defense-Budget Possibilities

Imagine holding M_1 and M_2 constant. For one combination of fixed budgets on both sides, the set of choices open to country 1 is shown in Figure 6 as the flat opportunity set. If M_2, X_2, and Y_2 are all fixed, then by allocating M_1 between X_1 and Y_1 Country 1 can trade off F_1 and F_2. The resulting set of possibilities is shown by the flat line in Figure 6. The choices open to country 2 are shown in Figure 6 as the steep opportunity set. Supposing M_1, X_1, and Y_1 are all fixed then Country 2 can trade off F_1 and F_2. Such is the meaning of the steep line.

Each country in the anarchy of international politics must decide on how much to allocate to strategic offensive and defensive forces altogether, and how to divide this optimum budget between offense and defense. For a given $X_2^* + Y_2^* = M_2^*$, and a given M_1^* how does Country 1 decide on X_1^* and Y_1^*? To answer this we assume that country k places a positive value on the ability to threaten j's survival in the event of war or more generally to damage/punish/deter j, while it places a negative value on j's threatening/deterring capacity. Thus, k's utility or objective function can be written:

$$V^k = V^k(F_j, F_k, C_k),$$

where C_k denotes country k's non-defense consumption. Or given the monotonicity of F_j (S_k) etc., it can be equivalently written as:

$$V^k = V^k (S_k, S_j, C_k).$$

This is to be maximized over X_k and Y_k subject to the adversary's choices of $X_j^* + Y_j^*$ and k's overall resource constraint of $X_k + pY_k + C_k = M_k^*$. Here the price variable p has been added to allow for changes in absolute and relative costs of defense. Consistent with indifference curves with ordinary shape and diminishing MRS between S_k and S_j we assume (where V^k_k = MV^k/MS$_k$, V^k_j = MV^k/MS$_j$ and so on): $V^k_k > 0$; $V^k_j < 0$; $V^k_{kk} < 0$; $V^k_{jj} < 0$. (Where convenient for exposition we, may assume V^k and V^j are completely or partially separable in S_k, S_j, C_k. For example, $V^k = V^{kj}(F_j) + V^{kk}(F_k) + ëC_k$). The first order conditions for such a maximization, consistent with Nash behavior will be:

$$p\frac{V_k^{\ k}}{V_j^{\ k}} \ \text{'} \ \frac{ö_k^{j}}{ö_k^{k}}$$

Thus the choice of X_1* and Y_1* will be shown by a tangency of a V-contour with an opportunity set as in Figure 6, where we combined these together in a single diagram to show a Nash equilibrium (assuming the Nash equilibrium budgets to be chosen implicitly). The assumption behind Figure 6 was that attack or offensive technology confers a basic cost advantage over defensive technology. Note that in this case Nash behavior generates an equilibrium *with an over emphasis on offense*. By “over emphasis” here I mean that a Pareto improvement is available through mutual agreed and enforced reallocations (even within the same budget in both countries). Such Pareto improvement will follow away from reduction in offensive weapons and increases in defensive weaponry. So we have the conclusion that when technology and cost favors the attack, an arms race type duopolistic competition leads to an over provision of offensive weapons providing deterrence, and an under supply of defensive expenditures to reduce damage if deterrence fails. *Moreover, this tendency exists for both adversaries.*

Figure 6 illustrates such Nash-Cournot equilibrium where each country configures it strategic forces for a given budget to determine optimal enemy damage (a “good”) vs. own damage (a “bad”). Nash equilibrium is shown at the tangency of indifference curves and opportunity curves (point “a”). At this point both countries have over allocated to MAD

Now consider the outcome when BMD is relatively cheap. In this case reducing own damage costs less than increasing damage to an enemy. Now the opportunity sets (assuming symmetry) and Nash equilibrium is as shown in Figure 7, and in this case Nash equilibrium tends to under provide deterrence and over provide defense.

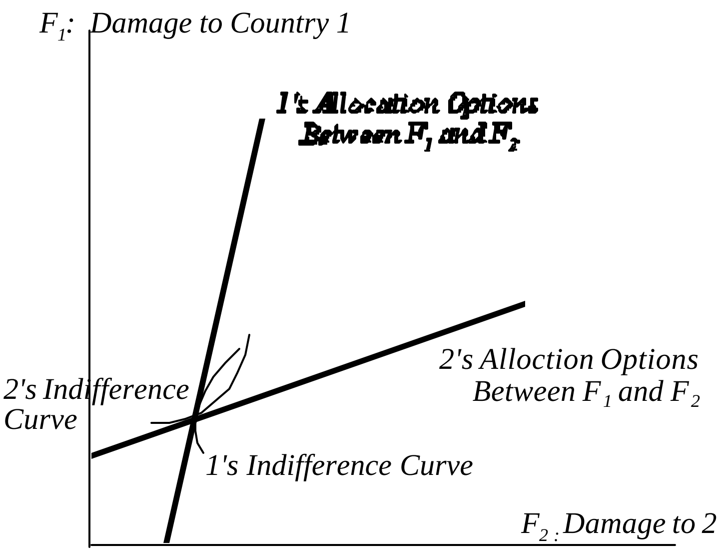

Figure 7: Nash Equilibrium
When Missile Defense is Cheap

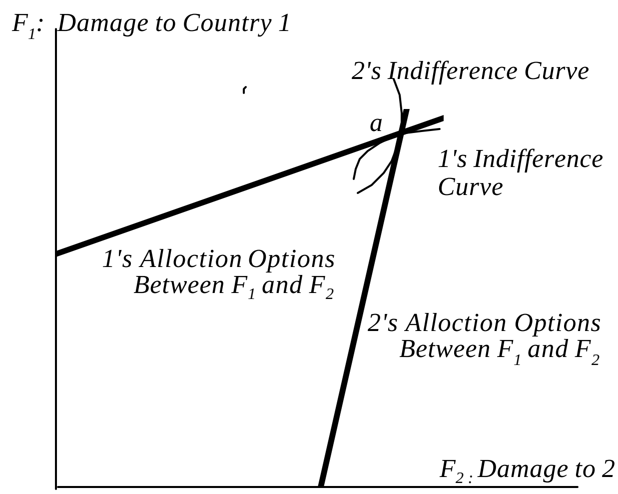

Figure 6: Nash Equilibrium
w/o Missile Defense

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