DDA 77-3802

1 JUL 1977

MEMORANDUM FOR: Deputy Director of Central Intelligence

FROM : John F. Blake
Deputy Director for Administration

SUBJECT : Status Report - Development of Regulations Relating to CIA Relationships with the Academic Community

1. In your memorandum of 29 January 1977 dealing with the IG Survey of the DDS&T, you stated that the DDA should establish a task force chaired by a DDA representative and composed of representatives of the concerned Agency components to deal with the subject of developing a consolidated CIA regulatory issuance governing the Agency's relationships with the academic community.

2. Such a task force was established under the chairmanship of [redacted] of my staff. This task force began meeting in February 1977 and dealt with the definitions and scope of activities which it would be proper for the proposed Agency regulation to cover. It was determined that even these areas proposed significant problems and that our progress toward developing a consolidated regulation would be slow.

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3. Subsequent meetings were held and limited progress was made up until the point when we were advised that Harvard University was proposing a set of formal guidelines to deal with the relationships between Harvard and CIA. At this point, many of the members of the original task force were asked to participate in dealing with the proposed Harvard guidelines. It was also generally agreed that the original task force should pause and await the outcome of the negotiations between Harvard and CIA regarding the guidelines so that we could incorporate into our basic Headquarters regulations any policies that were developed.

4. As you are aware, the Harvard guidelines affair took more time than was anticipated. As a result, the task force was delayed. Now that the Harvard matter has been dealt with, we are picking up the pace. The task force met during the week of 20 June and is scheduled to meet again on 6 July to discuss a proposed regulation which has been drafted. We have established 29 July as a goal to present to you a coordinated Agency regulation dealing with this matter. We are aware of the external pressures which relate to this matter and the need for timely response. Nonetheless, we feel that to shorten the deadline would increase the risk of an inadequate regulation being provided for your consideration.

/s/ John F. Blake

John F. Blake

STAT AI/DDA [redacted] ydc (1 July 1977)
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Approved For Release 2004/03/23 : CIA-RDP80M00165A000800080001-8

Notes from the Director No. 11

25 August 1977

CIA RELATIONS WITH ACADEMIC COMMUNITY

In May of this year, Harvard University published guidelines for relationships between the University and intelligence agencies. In brief, the guidelines state that:

- the existence of any CIA-university contacts must be public
- private consultation arrangements must be reported in writing to the dean and president
- CIA recruiters must be identified to dean, president, and placement office in writing
- Harvard community members may not volunteer names of other members without their permission
- Harvard community members should not undertake intelligence operations for the CIA.

In correspondence with President Bok of Harvard on this subject, I have made the following points:

"... American scholars who have been willing to share information and interpretations of developments in the international arena often have contributed valuably to intelligence support of the U.S. foreign policy-making process. Without the continuing assistance of the academic community, our ability to provide the President and other senior officials with objective and enlightened analysis and estimates would be hampered. I believe strongly that in this increasingly complex and competitive world it remains in the best interests of both the academic and intelligence communities to expand and refine their contacts in a spirit of mutual respect and understanding."

"... Current CIA policy covering our relations with American staff and faculty members of U.S. academic institutions is already, to a large degree, consistent with the Harvard guidelines. Present Agency policies may be summarized as follows:

> All of our contracts with academic institutions are entered into with the knowledge of appropriate senior management officials of the institution concerned.
>
> All recruiting for CIA staff employment on campus is overt.
>
> It is against our policy to obtain the unwitting services of American staff and faculty members of U.S. academic institutions."

"... I take exception to the provision in your guideline which requires your faculty members to report such arrangements in writing to the dean of their faculty.... I believe that attempts to regulate the private lives of our citizens in a manner discriminatory to any particular group, profession or segment of society poses serious risks. I believe that we would be far safer not to single out any group, despite what may be transient enthusiasm for so doing. In point of fact, it is our policy in these cases to suggest to individual scholars that they inform appropriate officials at their universities of their relationship with CIA. Frequently, however, scholars object to advising any third parties on the understandable grounds that to do so would violate their constitutional rights to privacy and free association and possibly expose them to harassment and damage to their professional careers.... Thus, the decision on whether to advise their institution of a relationship with CIA is left to the discretion of the individual. We intend to continue respecting the wishes of individuals in this regard."

This issue, of course, transcends the relationship with academics. All American citizens must continue to have the freedom to choose whether or not they want to cooperate with any government agency, and, if they choose to assist the CIA in its work, we must be able to ensure the confidentiality of that relationship.

PROPOSED INTERNAL REVENUE ACTION ON ALLOWANCES

I share the concern of our operating components and the employees overseas with respect to the possible repeal of Section 912 of the Internal Revenue Code, which would mean that allowances paid to employees at foreign posts would become taxable income to them. The matter of employees' entitlements has been discussed at the President's Cabinet meetings, and I assure you that the agencies and departments concerned are acutely aware of the implications and the impact it can have on morale. The Secretary of State and I have sent letters to the Secretary of the Treasury to urge that the provisions of Section 912 [illegible] Copies of these letters have been disseminated to the overseas posts and to the Headquarters components which support them, and I assure you that the Agency will do whatever it can to preserve the entitlements of our employees overseas.

STANSFIELD TURNER
Director

COMMENTS ON

THE GEOMETRY OF THE ARMS RACE

BY BRAMS, DAVIS AND STRAFFIN

The paper, "The Geometry of the Arms Race," by Brams, Davis and Straffin, is interesting and is indicative of an important subject. Unfortunately, it is of limited practical value as it stands. However, it does seem to be a useful vehicle to focus and stimulate interest that could ultimately lead to results of practical significance. The following discussion indicates the deficiencies in the results as presented in the paper.

Criticism of the paper falls naturally into three categories: mathematics, assumptions, and conclusions. The categories are discussed in that order. The mathematics in the paper is correct. With the single exception of the game theoretic payoff matrix presented in Figure 1, there are no errors in the mathematical concepts or the derivations. In Figure 1 there is an interchange of subscripts, and the correct matrix should be:

		B: Disarm	B: Arm
A	Disarm	A_2, B_2	A_4, B_1
A	Arm	A_1, B_4	A_3, B_3

In the body of the paper, the subscripts always appear correctly. Hence, the derivations are correct.

Certain assumptions are presented which link the physical reality of arms races to the mathematical formalism of Prisoners Dilemma game theory. Some of these assumptions are made for convenience, and can be easily modified without changing the fundamental results. Other assumptions are a necessary part of the main theme of the paper. The assumption that both parties have the same detection probability, p, is a matter of convenience. Unequal probabilities, p_A and p_B, could have been retained throughout with only an increase in complexity. The assumption that each is greater than 50%, however, is more fundamental to the paper and deserves some attention. While it is certainly the case that a flip of a coin will result in p = .5, it does not follow that this lower bounds the detection probability. A rational player will only flip a coin if he knows that his detection probability is less than 50%. In a covert armament program, however, player B might force player A's probability well below .5 while player A still believes it to be well above .5. Thus, the game becomes one not only of imperfect information but one of misinformation. This changes player A's views on the security level achieved by a policy decision.

Another assumption which is central to the paper is that each side is willing to accept an expected value criterion of the worth of a policy. While this assumption can be changed to, say, a minimax criterion, such a change makes the mathematical conclusions of the paper inapplicable.

Perhaps of most importance, however, is the main assumption of conditional cooperation of the two players, the "I will disarm if I do not detect a violation by my opponent" policy. In view of the way many analysts consider the arms race, and international conflict in general, this appears to be an unlikely assumption. Unfortunately, it is central to the paper and is thus intimately related to the results. While possibly a valid assumption, the results of the paper need to be considered within the context of this assumption. Discarding this assumption produces radically different conclusions from this methodology.

The conclusions of the paper, which tie the mathematical formalism back to the reality of arms races are less strong than the authors assert, as they rely heavily on the previous assumptions. Thus, while a pooling of verification intelligence or technology might be a good idea in its own right, that conclusion from this paper is conditioned on the assumption of conditional cooperation. Otherwise, it, itself, becomes an uncertainty which must also be monitored. This is directly related to the issue of a player's knowledge of his own misclassification probability.

In summary, this paper should be taken as an interesting attempt to bring some game theoretic ideas to the arms control verification problem. The interest of the paper lies in its methodology rather than its results. Game theoretic analogies to arms control are not new, rather it is the introduction of probabilisitc knowledge that renders the paper novel and is an important step. The fact that previous game theoretic models of arms control have not had a dramatic inpact on reality should indicate the difficulty of the problem, not the futility of the approach. Perhaps the ideas generated in this paper coupled with both the dynamical theories of arms races and results on detection capability in a noncooperative environment will be fruitful.

Subject: Comments on the Geometry of the Arms Race by Brams, Davis and Straffin

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Remarks:

3-4: The attached comments were drafted by [redacted] of the Analytical Methodology Research Division of the Office of Research and Development. She is less sanguine than Professor Brams about the likelihood that the US and USSR will adopt a policy of conditional cooperation in arms control--a critical assumption of Brams methodology.

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[redacted]

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Subject: Comments on the Geometry of the Arms Race by Brams, Davis and Straffin

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Remarks:

See DCI's note inside.

cc – [redacted]

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Remarks:

2-4: OSR and ORD are reviewing the Brams' article for possible applicability to our analysis of verification issues.

Sayre Stevens

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The Director of Central Intelligence

Washington, D.C. 20505

7-6-77

Dear Professor Brams:

Thank you for your draft article on "The Geometry of the Arms Race." I have sent it to several members of my staff for study.

The evaluation of new methodologies and their application to difficult problems are continuing priority tasks for our analysts. Your thoughtfulness in bringing your research to our attention as soon as practicable is appreciated. It strengthens my conviction that there are many academicians who recognize the importance of intelligence and are willing and anxious to contribute to our analytic effort.

Yours sincerely,

/S/

STANSFIELD TURNER

Professor Steven J. Brams
Professor of Politics
New York University
25 Waverly Place
New York, N. Y. 10003

SUBJECT: Response to Professor Steven J. Brams Letter

CONCUR:

STAT

[redacted]

Deputy Director for Intelligence — 1 JUL 1977 — Date

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D/OSR: [redacted] (1 July 1977)

MEMORANDUM FOR: D/OSR

Attention: [redacted]

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Please prepare by ~~COB, 8~~ Noon 6 July, an appropriate response from the Director back to Professor Brams. Perhaps it would be better if some knowledgeable individual could include some critical remarks in the response.

STAT

[redacted]

Date 6/29/77

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Executive Secretary
[illegible]
Date

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New York University
Department of Politics
25 Waverly Place
New York, N.Y. 10003
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DDI # 2539-77

June 23, 1977

The Honorable Frederick Turner
Director
Central Intelligence Agency
Washington, D.C. 20505

Dear Director Turner:

I have enclosed a copy of a paper entitled "The Geometry of the Arms Race" that I thought might interest you because of its focus on intelligence and verification capabilities.

Please note especially the section of our paper on "Policy Implications" and our major conclusion on p. 17: "It is in the interest of the United States not only to improve its own detection [verification] capabilities but also to abet those of the Soviet Union."

This conclusion seems to fly in the face of current policy, though recently some interest has been expressed in negotiations concerning a new SALT agreement that both sides develop a common data base. Our analysis strongly supports this development and also supports heavy investments in the research and development of expensive new weapons systems. We find less support for measures that make the benefits of an arms-control agreement more attractive.

These are, in my opinion, significant policy conclusions. To be sure, if the underlying assumption of our analysis--that both sides will cooperate if they are reasonably assured that the other side will follow suit--is untrue, then our analysis is no longer applicable. However, I think that both sides recognize that it is in their mutual interest to cooperate, at least on a conditional basis.

I hope you find our analysis helpful.

Sincerely,

Steven J. Brams

Steven J. Brams
Professor of Politics

enclosure

DRAFT--Not for Quotation

THE GEOMETRY OF THE ARMS RACE

Steven J. Brams
Professor of Politics
New York University
New York, N.Y. 10003

Morton D. Davis
Associate Professor of Mathematics
City College of New York
New York, N.Y. 10031

Philip D. Straffin Jr.
Associate Professor of Mathematics
Beloit College
Beloit, Wis. 53511

Approved For Release 2004/03/23 : CIA-RDP80M00165A000800080001-8

THE GEOMETRY OF THE ARMS RACE

Of all the significant problems that confront the world, the nuclear arms race between the United States and the Soviet Union has proved one of the most intractable. Its intractability, however, stems not from the awesome amounts both sides have expended on arms, nor even in the millions of lives at stake should the arms race culminate in a nuclear war. While these facts help to explain why the arms race looms so large in our lives, they do not explain why this race has proved so difficult to slow down.

To be sure, a variety of explanations for the persistence of the arms race has been advanced. The military-industrial complex in each country holds sway over major policy decisions (1). The economies of the United States, and perhaps the Soviet Union as well, require major military expenditures to avoid recessions or even depressions (2). The dynamic nature of an arms race requires that each side match or exceed the expenditures of the other side (3). Or, where moves toward disarmament are observed, they are no more than an elaborate fraud by which the superpowers deceive the rest of the world so that they can maintain their hegemony (4).

It is not our purpose to criticize these and other purported explanations of the arms race, though we believe all are seriously flawed. For the most part, they are ad hoc, single-factor explanations--sometimes colored by ideological considerations--that are not embedded in a general model that disciplines the weighing of benefits and costs to decision makers in the arms race.

Our purpose in this article is to construct a model of the arms race that rests primarily on rationalistic calculations. We do not mean to imply that national decision makers go exactly through the calculations we set forth or that they are unmoved by nonrational considerations. Rather, we believe that where the stakes are high, as they are in the nuclear arms race, decision makers, at least in a rough way, take account of benefits and costs in the manner postulated in our model.

These benefits and costs are dependent on what both sides do, and for this reason we believe that the proper representation of the arms race is as a game. The game we begin with, called Prisoners' Dilemma, is well-known in game theory and has been used by others as a model of the arms race (5). In our view, it shows up in a strikingly simple way why the arms race is as intractable as it is, which is the note on which we introduced this article.

But we are also concerned with possible solutions to the arms race, and for this purpose we posit a sequence of moves by the superpowers that we believe may lay the basis for future cooperation that leads to arms-control agreements. (There is already some evidence to support this sequence, as we indicate later.) Consequences of this sequence are investigated when each side (i) possesses an ability to detect what the other side is doing with a specified probability, and (ii) pursues a "tit-for-tat" policy--cooperates if the other side does, otherwise does not. Given the detection probabilities and the reciprocity norm, we show, geometrically, when cooperation between the superpowers is rational and, therefore, likely to occur.

Prisoners' Dilemma and the Arms Race

Prisoners' Dilemma is a two-person game that is illustrated in Fig. 1. We shall not describe the original story that gives Prisoners' Dilemma its name but shall instead interpret it in the context of the arms race between the superpowers, whom we call A and B.

The superpowers each have a choice between two strategies, "Disarm" and "Arm," as shown in Fig. 1. The choice of a strategy by both superpowers results in one of the four possible outcomes shown in the payoff matrix of Fig. 1. An outcome is defined by an ordered pair of numbers (A_i, B_j), where A_i is the payoff to A (row player), B_j the payoff to B (column player).

For player A we assume that A_1 is his best payoff, A_2 next best, A_3 next worst, and A_4 worst; a similar ordering obtains for B. Thus, for example, (A_2, B_2) is a better outcome for both players than (A_3, B_3).

The dilemma in this game is that both players have an unconditionally best, or dominant, strategy of Arm: whatever the other player does (Arm or Disarm), each player obtains a higher payoff if he chooses Arm. Yet, if both players choose Arm, the outcome is (A_3, B_3), which is worse than if both players choose Disarm and thereby obtain (A_2, B_2).

If this is the case, should not both players choose Disarm? The problem here is that (A_2, B_2) is not in equilibrium: given the choice of (A_2, B_2), each player has an incentive unilaterally to switch to Arm and thereby obtain his best payoff (A_1 or B_1), inflicting on the other player his worst payoff (B_4 or A_4). This temptation for each player to doublecross the other makes (A_2, B_2) unstable and, we

FIGURE 1

THE ARMS RACE AS A PRISONERS' DILEMMA GAME

		B: Disarm	B: Arm
A	Disarm	(A_2, B_2)	(A_1, B_4)
A	Arm	(A_4, B_1)	(A_3, B_3)

believe, points up the fragility of cooperation (when both players choose Disarm) in the arms race. It is precisely this temptation to doublecross that induces each player to "play it safe" and choose his dominant strategy of Arm, even though the resultant outcome, (A_3, B_3), is the next worst for both players.

The outcome (A_3, B_3), which is circled in Fig. 1, is in fact the unique equilibrium outcome in Prisoners' Dilemma--once chosen, neither player can do better by unilaterally switching to his Disarm strategy. The fact that both players prefer (A_2, B_2) leads us to ask how movement from (A_3, B_3) to (A_2, B_2)--as indicated by the arrow in Fig. 1--can be induced, given that (A_2, B_2), once reached, is unstable.

Introducing Detection Probabilities

Assume that A and B begin the game by both announcing a tit-for-tat policy of conditional cooperation: "I'll cooperate (i.e., choose Disarm) if I detect you do; otherwise, I won't." Then, to show their good intentions, assume both players initially cooperate and choose Disarm. This is the first stage of the game (6).

The second stage begins when each player makes a second strategy choice, depending on what he detected his opponent did in the first stage. Assume that A can detect with a certain probability the strategy choice of B; and B can likewise detect A's strategy choice. Specifically, let

p_A = probability that A can detect B's strategy choice in the first stage;

p_B = probability that B can detect A's strategy choice in the first stage.

We assume $0 \leq p_A, p_B \leq 1$.

Presumably, the better intelligence one player has of the other's capabilities and intentions, the higher his detection probability will be. Although we assume that p_A and p_B may vary between 0 and 1, practically speaking it seems reasonable to suppose that these probabilities will never assume values less than 1/2. Otherwise, a player can better guess his opponent's strategy choice by flipping a coin.

Consistent with a policy of conditional cooperation, assume that a player chooses Disarm if he detects that his opponent chose Disarm in the first stage; otherwise, he chooses Arm. The question is: does a policy of conditional cooperation benefit the players in the second--and perhaps later--stages of the game?

The <u>expected payoff</u> a player derives in the second stage is the sum of the payoffs he obtains from each of the four possible outcomes times the probability that each occurs. (The expected payoff in the first stage is A_2 for A and B_2 for B, because by assumption the "cooperative" outcome (A_2, B_2) is chosen with probability 1.) For A, his expected payoff in the second stage will be

$$E(A) = A_2 p_A p_B + A_1(1-p_A)p_B + A_4 p_A(1-p_B) + A_3(1-p_A)(1-p_B), \qquad (1)$$

assuming A and B make independent strategy choices based solely on their probabilities of detection. Thus, for example, the first term on the right-hand side of (1) says that A and B will correctly detect their mutual choices of Disarm in the first stage with probability $p_A p_B$, so A will obtain a payoff of A_2 with this probability.

Rearranging terms in (1), we obtain

$$E(A) = p_B[A_2 p_A + A_1(1-p_A)] + (1-p_B)[A_4 p_A + A_3(1-p_A)]. \quad (2)$$

Whatever the value of p_A, we know that the first term in brackets on the right-hand side of (2) is always greater that the second term in brackets since $A_2 > A_4$ and $A_1 > A_3$. Therefore, it is in A's interest that p_B be as high as possible (so B will correctly detect cooperation and thereby cooperate himself), and similarly for B with respect to p_A.

This is not a surprising conclusion. Rearranging terms in (1) again, we obtain a more curious result:

$$E(A) = p_A[A_2 p_B + A_4(1-p_B)] + (1-p_A)[A_1 p_B + A_3(1-p_B)]. \quad (3)$$

Now the second terms in brackets on the right-hand side of (3) is always greater than the first term in brackets, so it is in A's interest that $(1-p_A)$ be as high as possible, or p_A be as low as possible. This is because A, if he incorrectly detects that B chooses Arm in the first stage and thereby chooses Arm himself in the second stage, obtains a higher expected payoff than if he correctly detects cooperation on the part of B.

But surely B could anticipate this consequence if he knew p_A were low. Hence, B should not mechanically subscribe to a policy of conditional cooperation in the second stage unless he is assured that A can predict with a high probability his cooperative choice in the first stage and thereby respond accordingly. A similar conclusion applies to B. Therefore, it is in the interest of A and B that both p_A and p_B be as high as possible (7).

Equalizing the Detection Probabilities

How can both players ensure that p_A and p_B are as high as possible? One way, which has been proposed in recent negotiations on a new SALT agreement (8), is to pool their information so that they both operate from a common (and enlarged) data base. A common data base, presumably, would have the effect of setting the detection probabilities equal to each other. Alternatively, if "national technical means for verification"--in the terminology of current arms-limitation talks--of both players were equally good, their detection probabilities would also be equal.

To investigate the consequences of equal detection probabilities, assume that $p_A = p_B = p$. The expression for E(A) given by (1) then becomes

$$E(A) = A_2p^2 + (A_1+A_4)(1-p)p + A_3(1-p)^2. \quad (4)$$

An analogous expression can be obtained for B, but henceforth we shall make only calculations for A since the conclusions we derive apply to B as well.

Without loss of generality, we may assume that the payoffs associated with the best and worst outcomes are one and zero, respectively, i.e., $A_1 = 1$ and $A_4 = 0$. Given this assumption, (4) becomes

$$E(A) = A_2p^2 + (1-p)p + A_3(1-p)^2,$$
$$= (A_2+A_3-1)p^2 + (1-2A_3)p + A_3, \qquad (5)$$

which is a parabola in p.

What is of interest is the shape of the parabola in the four regions of the A_2-A_3 coordinate system shown in Fig. 2. This tells us how beneficial a policy of conditional cooperation is as a function of p, assuming (for now) that A_2 and A_3 are fixed.

Since by assumption $0 < A_3 < A_2 < 1$, we need not consider the area on or above the diagonal $A_2 = A_3$. If $(A_2+A_3-1) > 0$, which defines regions I and II, the parabola is concave up; if $(A_2+A_3-1) < 0$, which defines regions III and IV, the parabola is concave down.

In the interval $0 \leq p \leq 1$, graphs of E(A) as a function of p are shown in Fig. 2 for each of the four regions. The vertex of the parabola in all regions is at

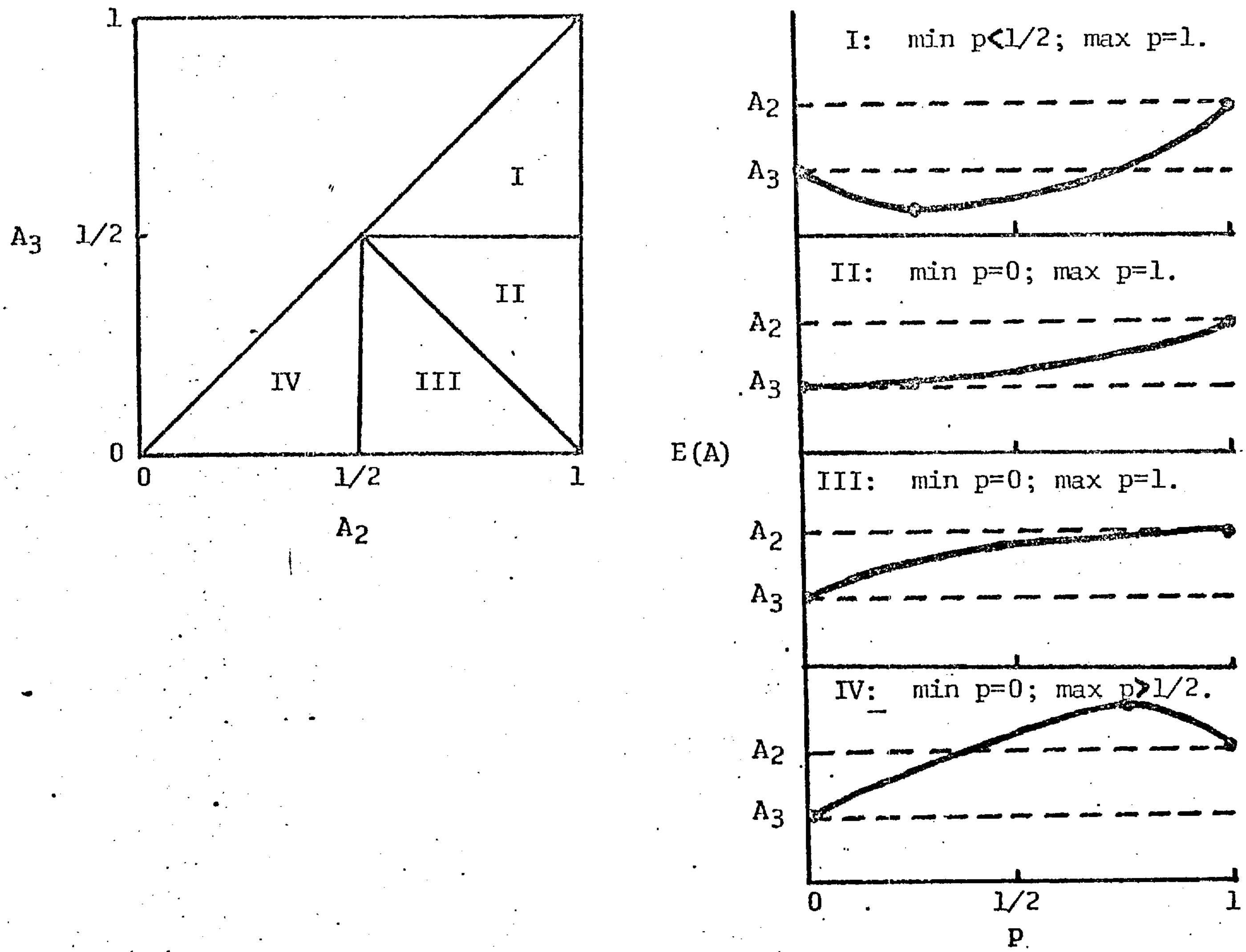
$$p = \frac{2A_3 - 1}{2(A_2 + A_3 - 1)},$$
$$= \frac{(A_3 - 1/2)}{(A_3 - 1/2) + (A_2 - 1/2)}. \qquad (6)$$

When substituted into (5), the vertex gives the minimum value of E(A) in regions I and II, the maximum value of E(A) in regions III and IV.

In regions I and II, where the denominator is positive, the minimum is at $p > 0$ if and only if the numerator is also positive,

FIGURE 2

EXPECTED PAYOFFS IN FOUR REGIONS



i.e., $A_3 > 1/2$. This occurs in region I; in region II the minimum occurs at $p < 0$, but in the interval $0 \leq p \leq 1$, the minimum of E(A) is at the boundary $p = 0$, as shown in Fig. 2.

In regions III and IV, both the numerator and denominator of (6) are negative, so the maximum is always at $p > 0$. Rewriting (6),

$$p = 1 - \frac{(A_2 - 1/2)}{(A_3 - 1/2) + (A_2 - 1/2)}, \tag{7}$$

we see that the maximum is at $p < 1$ if and only if the numerator in the second term on the right-hand side of (7) is negative, i.e., $A_2 < 1/2$. This occurs in region IV (9); in region III, the maximum occurs at $p > 1$, but in the interval $0 \leq p \leq 1$, the maximum of E(A) is at the boundary $p = 1$, as shown in Fig. 2.

When Is Conditional Cooperation Rational?

The graphs of E(A) in Fig. 2 show that $E(A) \geq A_3$ for all values of p in regions II, III, and IV. Thus, a policy of conditional cooperation in these regions ensures at least the security level of A--the minimum payoff he can ensure for himself, A_3, whatever B does. In fact, this policy will always yield an expected payoff greater than the security level A_3 except when $p = 0$, which occurs when A always detects the choice of Arm by B, the opposite of what B does.

No such assurance can be offered A if he is in region I. This is the region in which $A_2 > A_3 > 1/2$, i.e., where both the cooperative payoff A_2 and the noncooperative payoff A_3 are both closer to $A_1 = 1$

than $A_4 = 0$. In this case, the loss A suffers from being double-crossed is significantly below all his other payoffs.

For this reason, it may be advantageous for A to accept his security level A_3 rather than commit himself to a policy of conditional cooperation. After all, conditional cooperation could result in the payoff $A_4 = 0$, which is much worse than $A_3 > 1/2$ in region I.

In region I, the advantage of A_3 over E(A) is greatest when E(A) is at a minimum, which occurs when $p \leq 1/2$, as shown in Fig. 2. Even for $p \gtrsim 1/2$, however, E(A) may be less than A_3. To determine how high p must be in order that E(A) exceed A_3, we solve

$$E(A) = (A_2+A_3-1)p^2 + (1-2A_3)p + A_3 = A_3 \tag{8}$$

for p, and get

$$p = 0 \text{ or } p = (2A_3-1)/(A_2+A_3-1). \tag{9}$$

We already know $E(A) > A_3$ if $p > 0$ in regions II, III, and IV. In region I, $E(A) > A_3$ if

$$p > \frac{2A_3 - 1}{A_2 + A_3 - 1} = \frac{2(A_3 - 1/2)}{(A_3 - 1/2) + (A_2 - 1/2)}. \tag{10}$$

Algebraic manipulation gives

$$(A_3 - \frac{1}{2}) < \frac{p}{2-p}(A_2 - \frac{1}{2}).$$

Thus, in region I, a policy of conditional cooperation is better than security level A_3 if the point (A_2, A_3) lies below the line which passes through (1/2, 1/2) and has slope $m = p/(2-p)$. For several representative values of p between 0 and 1, these isolines are illustrated in Fig. 3 and show that as the detection probability approaches 1, the possibility that conditional cooperation yields less than one's security level vanishes.

Because the slope m of the isolines is convex in p $(d^2m/dp^2 > 0)$, raising p will make conditional cooperation more advantageous if p is already high (cf. representative values of p and m in Fig. 3). Moreover, since m is always less than 1 except when p = 1, raising A_2 [see (11)] is in general less effective in encouraging conditional cooperation than lowering A_3.

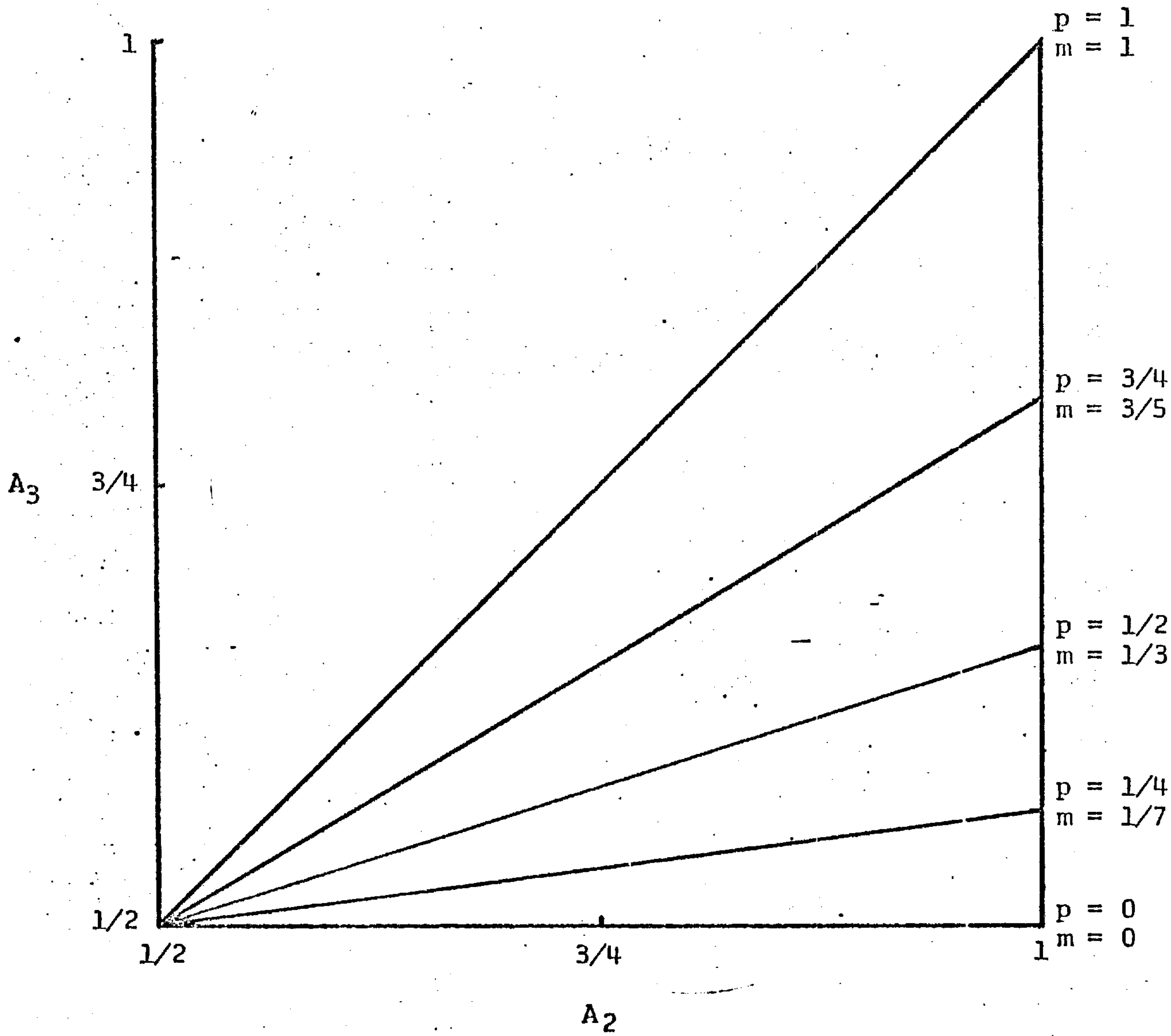
Policy Implications

We have shown that a policy of conditional cooperation always yields an expected payoff that is at least equal to, and generally exceeds, one's security level in three of the four regions that are feasible for Prisoners' Dilemma when both sides have the same detection probability. In these regions, therefore, this policy will generally work to the players' mutual advantage, even if the detection probability is low.

Unfortunately, the arms race between the two superpowers probably occurs in region I. Here the consequence of being double-

FIGURE 3

ISOLINES BELOW WHICH $E(A) \gg A_3$ IN REGION I



crossed ($A_4 = 0$) is very unsatisfactory compared to accepting one's security level ($A_3 > 1/2$). Yet, our analysis indicates that conditional cooperation even in region I may be beneficial, depending on the detection probability p of both sides. The area in this region where conditional cooperation leads to a higher expected payoff than one's security level increases as (i) p increases, (ii) A_2 increases, or (iii) A_3 decreases. Indeed, the effects of (i) seem already to have been felt in the limited agreements so far achieved in SALT I and SALT II (10).

If p continues to increase as technology improves, conditional cooperation should become even more attractive. This is because the slope m increases faster than p when

$$\frac{dm}{dp} > 1, \qquad (12)$$

or

$$\frac{2}{(2-p)^2} > 1,$$

$$p > 2 - \sqrt{2} \approx 0.586.$$

Thus, technological improvements that raise p above 0.586 will even more rapidly expand the area in which conditional cooperation is rational for both sides.

We indicated earlier that the effects of (iii) in encouraging conditional cooperation are greater than the effects of (ii). This means that developments that increase the costs of a continuing arms race (decrease A_3) do more to encourage conditional cooperation than developments that increase the benefits of an arms-control agreement (increase A_2).

Of course, raising the benefits of an agreement and raising the costs of no agreement are two sides of the same coin. But if there is a lesson to be derived from our model, it is that they have unequal trade-offs. Since the multiplier effect is on the cost side of the equation, behavior that raises the costs of an arms race provides the greater incentive for making reciprocal concessions.

Probably the best way to make an arms race more costly is to invest heavily in research and development. This investment increases the probability of technological breakthroughs that create the need for expensive new weapons systems. Paradoxically, perhaps, by making present weapons systems more vulnerable to technological breakthroughs, and hence less cost effective, we may better foster a future policy conducive to arms-control agreements.

Since the early 1960s, one of the most significant qualitative changes in the nuclear arms race has been the dramatic rise in the detection capabilities of both sides, which has been principally due to the use of reconnaissance satellites (11). Indeed, President Johnson once stated that space reconnaissance had saved enough in military expenditures to pay for the entire military and space programs (12).

If this detection capability of either side is destroyed or even threatened, then conditional cooperation in region I will once again be rendered unappealing and the prospects of a continuing arms race will be high. On the other hand, if each side's detection capabilities can be ensured or even strengthened--especially through the sharing of data that helps render $p_A = p_B = p$--then further agreements in SALT would appear not only desirable but also rational for both sides.

Just as stability in the arms race has depended up to now on the ability of each side to respond to a possible first strike by the other side, a diminution in the arms race now seems to depend on the ability of each side to detect cooperation on the part of the other side and to respond to it in kind. Unfortunately, "probably nothing the United States does is more closely held than the techniques and performance of its verification machinery" (13). To promote movement toward an arms-control agreement, we believe it is clearly in the interest of the United States not only to improve its own detection capabilities but also to abet those of the Soviet Union.

Summary

The arms race between the two superpowers was conceptualized as a Prisoners' Dilemma game, with the additional property that each player can detect initial cooperation or noncooperation on the part of the other player with a specified probability. Consequences of the following scenario were investigated: both players initially cooperate; each player knows the other player's detection probability and follows a policy of conditional cooperation--cooperates if he detects cooperation on the part of the other player, otherwise does not coope

For the case in which the detection probabilities of the two players are equal, conditional cooperation by both players yields the following conclusions:

i. Each player's expected payoff as a function of the detection probability is a parabola, which may assume four different forms depending on the payoff each player assigns to the cooperative versus noncooperative outcomes in Prisoners' Dilemma.

ii. The different payoffs can be represented geometrically by four different regions; in only one of the four regions does conditional cooperation not guarantee a player at least his security level.

iii. Even in this region, as the detection probability approaches one, the possibility that conditional cooperation yields less than one's security level vanishes.

Policy implications of this analysis for SALT are discussed, and a suggestion for the sharing of intelligence data is advanced.

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7. For further details, see S. J. Brams, J. Conflict Resolution, 19, 596 (1975). Cf. N. Howard, Behavioral Sci., 21, 524 (1976), for a general metagames analysis of Prisoners' Dilemma.

8. New York Times, April 27, 1977, p. A7. For an argument that data be collected and verified under United Nations auspices, see A. Myrdal, Sci. Amer., 231, 21 (1974).

9. Region IV is the only region in which F(A) is not at a maximum

when p = 1 (in the interval $0 \leq p \leq 1$). This is because

$$2A_2 < A_1 + A_4 = 1$$

in this region, so an alternation of the players between their strategies associated with outcomes (A_1, B_4) and (A_4, B_1) yields A a higher expected payoff than does outcome (A_2, B_2). For this reason, Prisoners' Dilemma is sometimes defined so as to preclude payoffs in region IV. See Rapoport and Chammah, pp. 34-35.

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14. S. J. Brams gratefully acknowledges the financial support of Mathematica, Inc.

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6 July 1977

Dear Professor Brams:

Thank you for your draft article on "The Geometry of the Arms Race." I have sent it to several members of my staff for study.

The evaluation of new methodologies and their application to difficult problems are continuing priority tasks for our analysts. Your thoughtfulness in bringing your research to our attention as soon as practicable is appreciated. It strengthens my conviction that there are many academicians who recognize the importance of intelligence and are willing and anxious to contribute to our analytic effort.

Yours sincerely,

STANSFIELD TURNER

Professor Steven J. Brams
Professor of Politics
New York University
25 Waverly Place
New York, N. Y. 10003

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Yours sincerely,

/s/ Stansfield Turner

STANSFIELD TURNER

Professor Steven J. Brams
Professor of Politics
New York University
25 Waverly Place
New York, N. Y. 10003

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