COWLES FOUNDATION FOR RESEARCH IN ECONOMICS

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COWLES FOUNDATION DISCUSSION PAPER NO. 606

GAME THEORY: THE LANGUAGE OF STRATEGY?

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October 1, 1981

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by

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1. THE SOCIAL PROCESS AND SCIENCE OF WAR

> We say therefore War belongs not to the province of Arts and Sciences, but to the province of social life. It is a conflict of great interests which is settled by bloodshed, and only in that is it different from others. It would be better, instead of comparing it with any Art, to liken it to business competition, which is also a conflict of human interests and activities; and it is still more like State policy, which again, on its part, may be looked upon as a kind of business competition on a great scale. Besides, State policy is the womb in which War is developed, in which its outlines lie hidden in a rudimentary state, like the qualities of living creatures in their germs.
>
> Whether such a conflict of the living, as takes place and is settled in War, is subject to general laws, and whether these are capable of indicating a useful line of action, will be partly investigated in this book; but so much is evident in itself, that this, like every other subject which does not surpass our powers of understanding, may be lighted up, and be made more or less plain in its inner relations by an inquiring mind, and that alone is sufficient to realize the idea of a theory.
>
> —Clausewitz

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*This work relates to Department of the Navy Contract N00014-77-C-0518 issued by the Office of Naval Research under Contract Authority NR 047-006. However, the content does not necessarily reflect the position or the policy of the Department of the Navy or the Government, and no official endorsement should be inferred.

1.1. The Social Process of War

The social process of arming a nation, preparing for the possibility of conflict; threatening and negotiating using the potential of military power to achieve political goals while avoiding direct conflict; is far from the same as the study of war or diplomacy or the giving of operational or moral advice.

The analogy of Clausewitz can be extended. The business of war stands in the same relationship with the science of war as does the business of the economy with the science of economics.

Many individuals in a complex social network are embroiled in the business of war. Politicians, diplomats, generals, scientists, industrialists, advisors, budget bureaucrats, lawyers all are engaged in a complex social process involving advocacy, cooperation, adversary struggles, science, intuition, goal formation, moral introspection and value formation.

Perception, responsibility, fact, volition, belief, power and desire are blended by the many forces at work to produce an overall perception and policy. This policy, to many individuals be they senators, generals or scientists or the public, may be far from their own beliefs, yet is partially the result of their inputs into the process.

All individuals, even remotely associated with the act of war have a moral involvement and responsibility at large. The politicians and statesmen and other political, social, religious and intellectual leaders of a society have a responsibility for the overall timbre of policy. The generals and the military establishment as a whole have the prime responsibility for executing policy in an efficient manner and for pointing out whatever weaknesses or flaws which exist in policy in terms of the feasibility and efficiency of execution. The historians, physical scientists, social scientists, engineers, operations researchers and other advisors have a scientific and metascientific responsibility. At the least they must verify facts and muster more or less objective opinions about a host of questions. But beyond the bare minima, they must also challenge the relevance and the precision (or lack of it) in the specification of the questions being asked. The ability to deepen understanding and clarify insight depends upon the knowledge, analysis and artistic insight which characterize scientific enquiry.

Knowledge, responsibility, strength of purpose and social perception are not all required for good scientific understanding. They are, however called for in framing good overall policy. The adviser [Goldhamer (1978)] plays many roles, but taking direct responsibility for blending administrative, political, social and scientific inputs is not among them.

The historian, social scientist and other advisers are cast in an anomolous role. They are expected to provide objective judgment yet to advise and counsel on social process. If for no other reason than to establish better communication between those responsible for evolving and executing policy and those responsible for understanding the scientific implications, the development of a language of strategy is called for.

1.2. The Art and Science of Studying War

It is suggested here that the study of war is a social science, much like economics or political science. Like all of the other social sciences it has been subjected to a considerable debate concerning the role of mathematics. Furthermore in all of the social sciences there has been a tendency to equate the mathematical formulation with the scientific content. To a great extent this has come about by a failure to recognize three rather than two important distinctions in the utilization of science in the processes of war. Specifically there are (1) those responsible for policy and execution, (2) those responsible for modeling and setting up problems to be analyzed and (3) those responsible for analysis.

Perception and cognition are not the same as analysis. The mathematical model may be precise and deep. The mathematical analysis may be elegant and difficult. But no amount of mathematics in and of itself spells out good science in general, or military science in particular. The good scientist requires the ability to perceive and formulate the relevant problem prior to the analysis. The good scientist when operating in an environment where he has to both communicate with his colleagues and bear witness to the social worth of their studies must transcend many boundaries in an effort to promote precision of thought and good analysis on problems of scientific honesty and worth.

At this point the different roles *per se* in the development of the art and science of war are discussed no further. Attention is focused upon one specific aspect. That is the need for a language to aid in model building, analysis and communication in the study of conflict. It is suggested here that the theory of games may provide this language.

2. THE LANGUAGES OF GAME THEORY

The very title of game theory from its inception was a misnomer. It was a misnomer caused, in essence, by the clash of the mathematical and non-mathematical cultures. Von Neumann can be credited with the title game theory derived basically by analogies with chess and poker which were the sources he used in the development of the notation and many of the underlying concepts of the theory of two person constant sum games.

The well defined formal structure of games such as chess was an obvious starting point from which a precise descriptive language, concise enough to facilitate analysis could be invented.

Unfortunately, language in scientific usage may easily clash with language in social use. To the diplomat or general the word "game" may be synonymous with "fun and games," with entertainment and frivolity. By attaching the word game to a military exercise or analysis the social communication may easily be made harder. The work of the two Von Reisswitzs, father and son, were first regarded as games, all be it war games. Their adoption and utilization were by no means guaranteed until the chief of staff of the Prussian army, Von Mueffling, exclaimed, "It's not a game at all, it's a training for war; I shall recommend it most emphatically to the whole army."

It is my contention that in actuality there is no theory of games, but there are several different topics the most important of which is a powerful, formal language for the description and analysis of strategic and tactical situations. There are also several theories of behavior which contain normative prescriptions as to how one should behave or behavioral descriptions of individual action in strategic or tactical encounters.

The language of game theory is more than a game; it provides a way to outline the anatomy of cross purpose optimization. In other words, it provides a precise description for situations in which there are many actors with independent goals and only partial control over their environment.

In this section the structure of the description of strategic situations is given in a more or less formal manner. In Section 3 the various concepts of solution are discussed. In Section 4 both the formal language and the solution concepts are recast both in terms of military strategy and diplomacy. Stress is laid upon the problems of modelling, perception, and interpretation. Study and analysis is different from sponsorship and utilization. It is precisely this difference that spells out the distinctions between the science and art of war and war as a social process.

2.1. Scope, Detail, and the Rules of the Game

The formal methods of Von Neumann and Morgenstern utilized to describe strategic situations provided three different descriptions of multi-person cross purposes optimization, each based upon different levels of scope and detail and different purposes for the use of the models. The three descriptions are known as: 1) the extensive form of a game; 2) the normal or strategic form of a game; and 3) the coalitional or characteristic function form. The first deals primarily with process, information, and details of behavior; the second is designed for the analysis of strategic policy; and the third is to aid in negotiation and diplomacy and in other situations in which there is the possibility of cooperative behavior resulting in mutual benefit. Most international dealings (and for that matter most dealings among individuals) can be characterized as giving rise to mixed motivations. There are both elements of potential conflict and cooperation. Each may want as large a slice of the cake as he can claim, but by cooperation the cake itself can be made larger. Situations involving pure opposition of interests are relatively rare and occur, for the most part, at the level of tactics.

2.2. Process and the Extensive Form of a Game

In the art of modelling the fight between precision and interpretation and perception of meaning is always there. Simple examples like two-by-two matrices may be combined with verbal discussions to illustrate points in brinksmanship, deterrence, and so forth. But simple analogies can be as dangerous as they are valuable. In chess and poker we all know what constitutes a move; there are well defined rules which tell us what a move is. In diplomacy much of the fun comes in inventing moves which had not been perceived as feasible.

As the interpretation of what formal models might mean and the discussion of the perceptual difficulties in modelling is delayed until Section 4; here we concentrate on the exposition of a purely formal model and we put off the various interpretations of the model until Section 4.

Let us imagine a formal game with well defined rules where at the start each player has to make a choice among two alternatives. We call the selection of an alternative, a move. Each player's move is decided upon simultaneously. Let us give the players names; we call the first one A or blue and the second B or red. They each commit themselves to their respective moves without knowing what the other has done. After both have commited themselves to their moves they are informed of what has transpired. They are then called upon to each simultaneously select another alternative. Call their original alternatives 1 and 2. If the move of each had been to select his first alternative then in the second stage of this game we assume that they face a choice among two alternatives each. If anything else had been selected as the first set of moves we assume that each player must make his selection among three alternatives. After each has decided upon his second move the game is over and a payoff or reward is given to each player.

The primitive concepts involved in the description above are player, alternatives, choice, moves, information, and payoffs.

We can represent the detailed anatomy of this complete game by a simple diagram called a game tree. Figure 1 illustrates this. The node labeled zero indicates where the game starts. Each node may be regarded as a choice point. Each branch radiating downward from every node (except the terminal nodes) represents an alternative at a particular choice point. Each point is labeled with the name of the player who is called upon to choose at that position during the game. Thus, here we have ascribed the first choice to player A whose name is indicated by the symbol P_A .

The next two nodes are labeled with P_B and are enclosed by a curve illustrating that they belong to the same information set. An information set (or more properly a "lack of information set") is a set of choice points which cannot be distinguished from each other by the player who is called upon to select his move. Operationally in this setup it does not matter if A or B went first, if neither find out what the other has done before both are committed.

The fact that both are completely informed after each has selected his first move is indicated by the four one-element information sets at the second level (or ply) down the tree. Each of these choice points are labeled with P_A indicating that player A is called upon to select his second move and at that point he knows precisely how the game has developed. In particular, if the selection of moves has been (1,1) then player A is confronted with two alternatives. If the selection of the first moves had been anything else, then player A is confronted

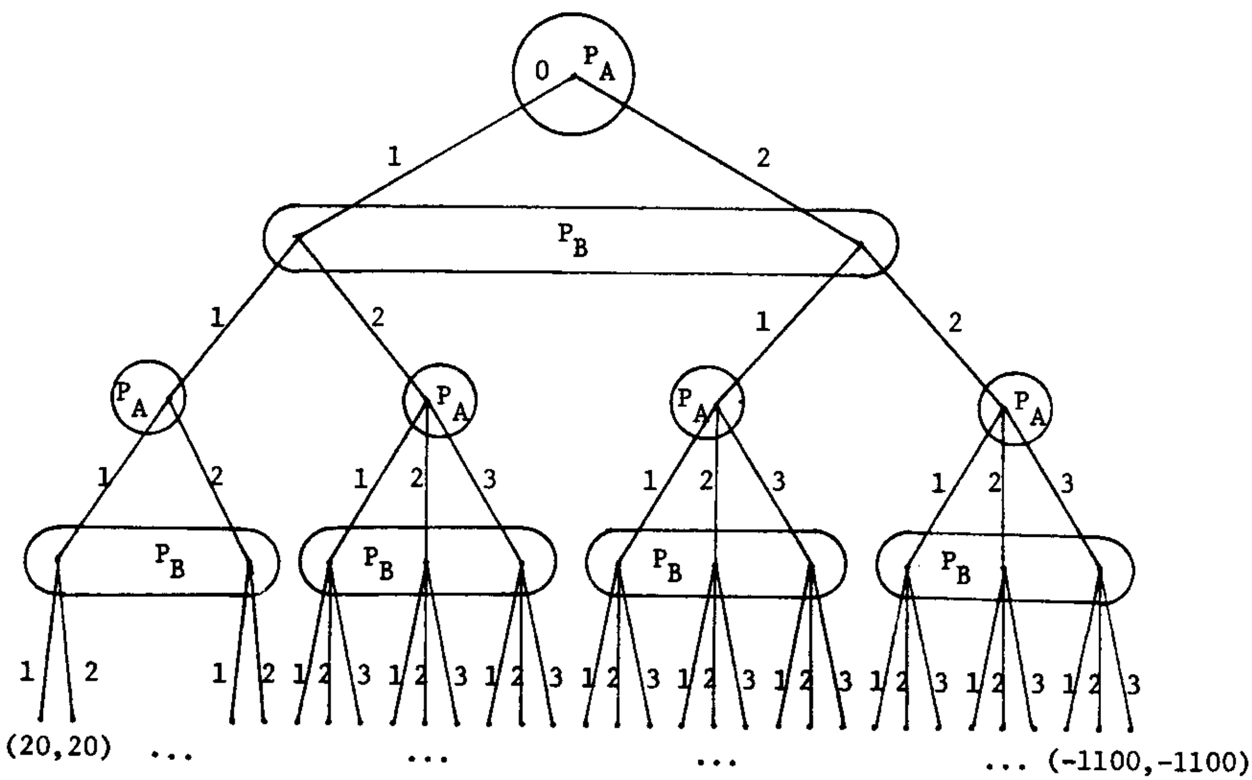

FIGURE 1

with three alternatives. An immediate analog with chess can be seen; depending upon the variations in the opening positions at any point in time the number of alternatives among which a player must select his move will vary.

Once more, in order to indicate informational simultaneity in the moves we break the information sets of player B into four sets. Each set indicates that player B does not know what was the second move selected by player A but knows all history previous to that point. After B has selected his move the game terminates and both players receive their final payoffs. In Figure 1 if on each occasion each player had selected his first alternative, the final payoffs would have been (20,20) . This symbolizes 20 to the first player and 20 to the second player. We have not specified the units. They could be utiles, brownie points, billions of dollars, or many other items. The specification of goals and the measurement of payoffs is clearly a critical problem.

If at each choice the players had initially selected their second alternative and followed that with their third alternative, then the payoff indicated is (-1100,-1100) . There should be a pair of numbers at every terminal node. For brevity we have only indicated two payoff values out of the thirty-one needed.

A complete path down a game tree starting at the origin and ending at one of the terminal nodes can be called the play of a game. It is a complete history in full detail of how the action developed from the beginning to the end.

Although it is not done in Figure 1, we can also introduce the possibility of external random events. Even ones where the probabilities will depend upon what the players have done. For example, we can invent a player called P_N who moves at any relevant point during the game with preassigned probabilities. An interpretation of this, for instance, might be that the actions of the two players are to start a theater nuclear war but a random event such as the wind or weather conditions in general might considerably influence the outcome of the first engagement. When probabilities have to be taken into account then the payoffs must be considered in terms of expectations or some evaluation which takes into account the effect of the randomness.

2.3. Strategy and the Normal or Strategic Form

The extensive form outlined in 2.2 displays in detail the sequencing of the moves and the information conditions. For some purposes this detail may not be required. In particular, the game theoretic concept of strategy can be used to remove much of this detail and represent the same situation for different analytical purposes by a payoff matrix stressing only strategies and payoffs. The payoff matrix for the game illustrated in Figure 1 is given in Table 1.

The game theory definition of strategy is not the same as the military definition and the distinction between the two will be explored in Section 4.

In essence, the game theoretic concept of strategy is a complete plan of action covering all contingencies. Another way of looking at it is as follows: imagine that there were a group of agents employed by player A and player B . Suppose that each player has one agent at every information set he has; thus, in the example in Figure 1 player A will have five agents and player B will have five agents. A strategy is a book of instructions which can be given to every agent and which contains information for him as to how to act when called upon to select among his alternatives.

Even in this extremely simple two-stage game there are fifteen strategies or different books of instructions which could be left to the agents.

The extensive form illustrated in Figure 1 gives rise to the 15×15 matrix representation of the game in normal or strategic form. The 15 (nonredundant) strategies for player A are follows:

Strategy 1 "I select alternative 1 for my first move; if (1,1) then I select alternative 1 for my second move. If (1,2) then I select alternative 1 for my second move."

This can be abbreviated as:

"(1,1) then 1; (1,2) then 1."

We call this strategy 1. A full listing of the fifteen strategies is given below:

1. (1,1) then 1; (1,2) then 1
2. (1,1) then 1; (1,2) then 2
3. (1,1) then 1; (1,2) then 3
4. (1,1) then 2; (1,2) then 1
5. (1,1) then 2; (1,2) then 2
6. (1,1) then 2; (1,2) then 3
7. (2,1) then 1; (2,2) then 1
8. (2,1) then 1; (2,2) then 2
9. (2,1) then 1; (2,2) then 3
10. (2,1) then 2; (2,2) then 1
11. (2,1) then 2; (2,2) then 2
12. (2,1) then 2; (2,2) then 3

13. (2,1) then 3; (2,2) then 1

14. (2,1) then 3; (2,2) then 2

15. (2,1) then 3; (2,2) then 3

Clearly, if the agents were in fact commanders at a lower level in the hierarchy they would have more degrees of freedom, initiative, and individual action than merely to follow a book of instructions. But at this point our purpose is to make precise one way of conceptualizing strategic analysis. This way clearly will call for modification when considering the influences of perception, aggregation, and organization.

As the game selected here for illustration is symmetric (the false assumption of symmetry is always a danger in modelling; sometimes simplicity comes at too high a price) each side has fifteen strategies. We can number the strategies from one to fifteen where the numbers have no other significance than names. They may be regarded as a listing of the volumes. Volume one contains a certain plan; volume two contains a somewhat different plan and so forth.

Looking at Figure 1 we see that there can be thirty-one different plays of this game. A play is a path from the initial node to a terminal node. There are thirty-one terminal nodes and the path leading to each is unique. There can, however, be 225 combinations of strategies used. Any one of the fifteen strategies of player A can be used against any one of the fifteen of player B . This is shown in Table 1. The numbers in the column at the side are strategies of player A and the numbers across the top are the strategies of player B . The two numbers in each cell represent the payoff to player A , followed by the payoff to player B . For example, suppose that each employs his first strategy. This calls for each to select his first alternative as his first move. But given that the first pair of moves is (1,1) then each will select his first alternative for his second move. Thus, thc play of the game will trace a path down to the terminal node on the far left of Figure 1, where we observe the payoffs are 20,20 .

How are these payoffs to be calculated for all instances? In order to envision fully the sensitivity of responses we need all 450 numbers in Table 1. Only 34 are indicated, but we show a way for generating all of the others.

Empirically it could be that partial payoffs are obtained at the end of period 1 which are then added to the partial payoffs obtained at the end of period 2 to form the final payoffs. Supposing that this were the case, then a simple way to calculate the payoffs for this table is as follows. If in the first period the moves were:

(1,1) the partial payoffs are (10,10)

(1,2) the partial payoffs are (-100,100)

(2,1) the partial payoffs are (100,-100)

(2,2) the partial payoffs are (-100,-100)

If in the second period the moves were:

(1,1) the partial payoffs are (10,10)

(1,2) the partial payoffs are (-100,100)

(1,3) the partial payoffs are (-1000,1000)

(2,1) the partial payoffs are (100,-100)

(2,2) the partial payoffs are (-100,-100)

(2,3) the partial payoffs are (-1000,900)

(3,1) the partial payoffs are (1000,-1000)

(3,2) the partial payoffs are (900,-1000)

(3,3) the partial payoffs are (-1000,-1000)

TABLE 1

P_A \ P_B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	20 / 20														
2		20 / 20					0 / 0								
3			20 / 20												
4				−90 / −90											
5					−90 / −90										
6						−90 / −90									
7		0 / 0					−90 / −90								
8								−200 / −200							
9									−1100 / −1100						
10										−90 / −90					
11											−200 / −200				
12												−1100 / −1100			
13													−90 / −90		
14														−200 / −200	
15															−1100 / −1100

Thus the payoffs from strategy 1 used by each are (10,10) + (10,10) or (20,20) . The payoffs from strategy 2 used by player A and strategy 7 used by player B are (-100,100) + (100,-100) = (0,0) .

It is obvious that for a game with many moves and a fair amount of information the proliferation of potential contingent plans becomes astronomical. The number of strategies for a game such as chess is beyond the bounds of reasonable computation. This does not detract from the precision of the concept of strategy; it merely calls our attention to the fact that when humans attempt to implement a concept such as contingent planning the proliferation of alternatives is so enormous that at best they can only seek a judicious selection of contingent plans based upon perception and aggregation as well as computation.

We have derived the strategic form of the game given in extensive form in Figure 1. When we look at Table 1 we observe that all detail concerning moves and information sets has been removed; whereas merely by the display in Table 1 emphasis is placed on strategies and payoffs.

One can derive the game in strategic form from the game in extensive form because in essence one is throwing away detail. There is no unique way to work backwards. In other words, one cannot uniquely divine the extensive form of the game knowing only the strategic form.

Tactics or Strategy?

At this point the reader interested in application must be warned about a confusion that could arise. Although it is true that the strategic form of a game can be derived from its extensive form, as a matter of modelling it may well be that the modeler wishes to take the strategic representation of the game as his primitive concept. This is a matter of modelling choice and in actual application to military problems many tactical situations are easily modelled and analyzed in some variation of the strategic form of a game without ever considering the extensive form. These applications include the study of duels (see Kimeldorf in this volume); the study of games of pursuit and surveillance (see Ho and Oldser in this volume); and problems in force allocation. A simple example of the last is given below. A mythical Colonel Blotto has three divisions which must be used to defend two forts. An enemy has two divisions to attack the forts. There are four ways in which Blotto can divide his divisions and three ways in which the enemy can divide his. A superior force will capture a fort, but in an engagement of equal size the defenders will win. Suppose that the value of each fort is 100 to the winner and -100 to the loser. The payoff matrix to this simple game is illustrated in Table 2.

	(2,0)	(1,1)	(0,2)
(3,0)	200	0	0
(2,1)	200	200	0
(1,2)	0	200	200
(0,3)	0	0	200

TABLE 2

The four strategies for Colonel Blotto are indicated by the different troop assignments. Thus (3,0) stands for assigning three divisions to the first fort and no divisions to the second fort.

The entries in Table 2 show the payoffs to Colonel Blotto. The payoffs to the other side are the negatives of these amounts as this is a game of pure opposition.

An inspection of the payoff matrix leads immediately to some suggestions. In particular, Colonel Blotto must split his forces and the attacker cannot afford to split his forces. We return to this point when we consider solution concepts in Section 3.

2.4. The Coalitional Form and Negotiation

The cooperative form is utilized when considering the possibilities for negotiation. The concern is focused upon what various groups can claim as their individual "justified demands." In some instances a reasonable way to calculate minimum individual claims is to use a worst case analysis. In this instance refering to Figure 1 and Table 1 neither player A nor B can guarantee more than -1100, whereas together they can obtain 40.

We may symbolize the description of the coalition possibilities by using a set function which assigns a value to each coalition. For n players there will be $2^n - 1$ values. Thus, for the two players we have:

$$v(A) = -1100 \ , \quad v(B) = -1100 \ , \quad v(A,B) = 40 \ .$$

When there are only two players almost all of the information that counts is contained in the evaluation of the individual claims and joint benefits. For three or more players the combinations become important. Thus for even five countries in a pact there are already 31 subgroupings which may need to be considered. In Section 3, when solutions are discussed, two three-person games will illustrate how an analysis of the potential gains of coalitions alone can offer some insights into the stability of alliances.

Once more it can be seen that in the progression from the extensive form to the strategic form to the coalitional form of a game, detail is thrown away. There is (as already indicated) a natural way of going from the extensive form to the strategic form and it is unique. There is no "natural way" to go from the strategic form to the coalitional form of a game unless you believe that "worst case" analysis is the correct way to analyze what a coalition can claim. But this may well lead to a virtually paranoid assessment with the implicit or explicit assumption that the rest of the world is out to get you.

In this article no attempt is made to enter into the full details and intricacies of modelling and formal game theory. The reader interested in an extensive overview of models, theory and general applications is referred elsewhere [Shubik (1975, 1982)]. Here only a minimal exposition of the basic concepts is given in order to consider them in terms of usefulness and relevance to military and diplomatic, strategic, or tactical analysis.

3. THE SOLUTION CONCEPTS OF GAME THEORY

3.1. Normative or Behavioral Solutions?

The specification of the rules of the game or the complete description of a strategic situation in extensive, strategic, or coalitional form is in and of itself a pre-solution. In other words, an enormous number of assumptions and a considerable amount of analysis has to be made in order to obtain a description of the strategic situation being studied. By the time this has been done already a considerable narrowing of our scope of attention has taken place.

In any form of strategic planning the selection of the model and the specification of its scope is a major task and many of the bureaucratic biases may already be built in at this level. Old diplomats, seasoned generals and politicians all have different perceptual stories to tell in contrast with those of a newly minted Ph.D. in quantitative methods for strategic analysis.

The construction of strategic models is, at best, an artistic and scientific activity heavily constrained by social process. The activities of sponsors, scientists, and advocates are all interwoven.

The construction of strategic models for analysis encompasses the host of empirical work done in index construction, listing of relevant variables, construction of tables of inventories, and preliminary assessment studies.

A reasonable model serves as a data organizing device where perceptions about causality provide guidance for the procurement of information and decisions on level of detail.

The work, however, is not over when one has described the model. If there is any lesson of importance that game theory has to teach, it is the lesson that our usual concepts of individual, rational behavior do not extend to situations involving more than one individual. In other words, even if it were possible to ignore all social psychological and bureaucratic features of behavior with safety there still is no nice natural way to extend our concept of individual rationality to situations involving an intermix of community and conflict of interests. Thus, even if we have a full description of "the game" we have to make an inductive leap based upon our social perceptions as to what we wish to consider to be a solution. Full net assessment requires not only that we know what the numbers are, but what the numbers mean. In order to know what the numbers mean we need not only an assessment of capabilities but also an assessment of intentions. The concept of solution broadly speaking involves the deducing of probable behavior from assumptions not only about capabilities but also about intentions. The value of this exercise will clearly be highly dependent upon the quality of the perceptions.

Underlying much of the work in the social sciences and especially the work in economics, operations research, and military analysis has been the development of two parallel views of theory development. One view concentrates on behavioral description of societies and individuals, while the other lays stress upon normative theories. The first tries to offer an explanation as to why people do what they do, while the other offers advice as to what one should do in certain situations.

There is one philosophical school of thought whose proponents feel that there should be a unique normatively most desirable way for individuals and nations to behave. There should be some universally acceptable way of resolving the conflicting goal problem which takes into account both the realities of power and the concepts of equity and efficiency. Eventually this philosopher's stone may be found but in the current state of strategic analysis and of game theory there appears not to be a unique agreed upon set of assumptions concerning intent or behavior, but there are many different solution concepts and a patchwork of partial theories which have been more or less justified in certain usages. In the remainder of this section three solution concepts are noted. Two are in essence normative and the third is usually defended on behavioral grounds.

3.2. Pure Opposition and the Maximin Solution

A two-person zero sum game is a game in which what one side wins the other side loses. It is the very definition of what is meant by opposition. In Table 2 the Colonel Blotto game provides an example of a two-person zero sum game representing a tactical situation.

It was argued by Von Neumann that without having to swallow too many extra assumptions concerning individual intent or behavior the idea of individual rationality can be extended to a situation with pure opposition and the normative suggestion is that a rational individual should select a strategy which maximizes the expected value of the minimum payoff he will receive by using that strategy. This is simply predicated upon the proposition that an intelligent enemy whose goals are diametrically opposed to the player will be trying to minimize the player's payoff,as in that manner he maximizes his own payoff.

In terms of the Colonel Blotto example, the maximin solution for Colonel Blotto involves deciding with equal probabilities to either use his second or his third strategy, i.e. to use two divisions in the first fort and one in the second fort, or vice versa. He must take great care not to signal his intentions to the enemy. The enemy's choice is to concentrate all of his forces and with equal probabilities either hit the first fort or the second fort. He, too, must take great care not to disclose his intentions. If there is an information leak on either side, the game is strategically considerably different.

In the study of dueling and weapons evaluation the maximin solution appears to make good sense. It is a reasonably safe assumption to not count upon your enemy being a fool or more grossly incompetent than you in attempting to evaluate the relative merit of opposing weapons or the chances of detection or evasion in a search game.

In certain situations it may be well known that the morale of one side is low, that their training is poor, or that they are plain fools. But before such an assumption is made it is important to remember that the art of deception is being crazy like a fox.

3.3. Noncooperative Equilibrium

Although it may be reasonable to model certain tactical situations as zero sum games with total opposition, in general most strategic situations and certainly situations involving grand strategy and diplomacy do not have a pure opposition of interests. The game used for illustrative purposes in Figure 1 and Table 1 serves as an example. The fates of the individuals are not related in pure opposition.

What should we consider to be a solution to such a strategic situation? Were we to moralize, we might suggest that in the best of all possible worlds the individuals should jointly maximize, thus in Table 1 the strategy pair (1,1) should be selected or possibly the strategy pairs (2,2) or (3,3).

Tables 3a and 3b provide two simple examples of two-person nonconstant sum games where each individual has just two strategies. If we were to subscribe to the proposition that the parties should jointly maximize in each case they would select their first strategy. But the games are considerably different. In the first game there clearly is a "sucker's bait" incentive for each to move away from the joint maximum. If I know that you are committed to your first strategy then you are a sitting duck for me to move to my second strategy gaining twenty for myself and inflicting a loss of fifteen on you. But the reasoning is circular and if we both do it we may go down the tubes together and end with zero each. The experimental evidence in laboratories is overwhelming that this is what individuals, in fact, do in one shot experimental games of this variety.

	1	2
1	5 / 5	-15 / 20
2	20 / -15	0 / 0

a

	1	2
1	5 / 5	-15 / -20
2	-20 / -15	0 / 0

b

TABLE 3

This analysis does not hold for the second game. If both have selected their first strategies then any deviation can only make it worse for both. Here we encounter a paradox. By making certain parts of the environment bad enough for both sides the stability of a jointly desirable outcome may be improved. This is one of the key concepts in discussions of deterrence and in the design of self-policing systems.

Unfortunately, even the simple example shown in Table 3b raises another problem. Suppose for historical or other reasons that both players had been trapped into utilizing their second strategies, unless they can simultaneously decide to switch to their first strategies an independent move could cause damage to both. The moral of this example is that there are instances in which the self-policing of the system becomes so good that it conceivably could lock the system into an undesirable as well as a desirable state.

Table 4 shows yet another type of situation. Here strategies (1,1) and strategies (2,2) are both favorable. The first pair are more favorable to the first player and the second pair more favorable to the second player.

	1	2
1	20,10	0,0
2	0,0	10,20

TABLE 4

The problem is clearly one both of coordination and conflict.

The concept of a noncooperative equilibrium point has been in economic literature since the writings of Cournot in 1836. In a more general form it has been in game theoretic and strategic analysis since the work of Nash in the 1950's.

A noncooperative equilibrium point has the property that it is self-policing against any individual violation. Thus, for example, in the game illustrated in Table 3a if I know that you are committed to strategy 2 it is my self interest to play strategy 2 and vice versa. Thus the strategy pair (2,2) resulting in the payoffs of zero to each is in equilibrium.

This solution concept offers some plausible explanation of the stability of some outcomes but it does not provide any dynamics nor does it offer unique predictions.

It does not have the normative property that outcomes will necessarily be optimal to all or even any of the participants. Perhaps the most attractive aspect of the noncooperative equilibrium solution theory is that it does not presuppose cooperative behavior and that in certain situations there seems to be some evidence that it offers a better explanation than other solutions concepts. But possibly even more important, the noncooperative strategic analysis of even relatively small games which provide analogies to strategic and bargaining situations illustrate in a forceable manner many problems in strategic analysis involving escalation, deterrence, preemptive strikes, precommitment, doomsday machines, the deliberate introduction of the probability of failure or uncertainty into certain systems, and other items.

Modelling and mathematical attempts to extend the noncooperative equilibrium analysis to multistage problems have resulted in a closer appreciation of the close relationship between any sort of dynamics and behavioral and organizational problems. One immediately has to take into account not merely information, memory, and learning but also signaling, communicating, teaching, and deceiving.

A detailed discussion of the various aspects and modifications of noncooperative equilibrium theory is given elsewhere [Shubik (1982), chs. 8, 9, 10].

3.4. Cooperative Solutions

Cooperative solutions are primarily based upon the coalitional form of the game and frequently use the characteristic function to provide the initial description of individual and joint claims.

There are many competing solution theories at this time; most of them normative, but some behavioral. Among the better known solution concepts are the core, the value, the bargaining set, and the stable set. The first two are usually given normative interpretations, whereas the last two have been offered as explanations of the outcomes of bargaining behavior or of social stability.

A full description of these competing solution concepts together with examples is given elsewhere [Shubik (1982), chs. 7, 8,11]. In this exposition only the core is discussed and illustrated with two simple three-person examples. Even at this level of simplicity these examples and this solution concept serves to indicate a fundamental problem in alliance stability and a paradox concerning the gains to be had from cooperation and the sum of individual claims to these gains.

Tables 5 and 6 show two three-person games in coalitional or characteristic function form. The interpretation of Table 5 is given in detail, the interpretation for Table 6 is similar.

$$v(1) = v(2) = v(3) = 0$$

$$v(12) = 1\ ,\quad v(13) = 2\ ,\quad v(23) = 3$$

$$v(123) = 4$$

TABLE 5

$$v(1) = v(2) = v(3) = 0$$

$$v(12) = 2\ ,\quad v(13) = 3\ ,\quad v(23) = 3\tfrac{1}{2}$$

$$v(123) = 4$$

TABLE 6

The three players are called 1, 2, and 3. The first three values of the characteristic function indicate that an individual acting alone can obtain zero (the zero should be interpreted not necessarily as nothing but as his status quo point or even the payoff from a worse case analysis). If players 1 and 2 can form a coalition without 3, they will obtain 1. If 1 and 3 form a coalition without 2, they obtain 2. If 2 and 3 form a coalition without 1, they obtain 3. If all players together decide to cooperate then jointly 1, 2, and 3 can obtain 4.

Given cooperative behavior then the three players will have to decide as to how to split the prize of 4 between them. The core solution to a game suggests that the players should cooperate in order to maximize joint gains and then they should split the gain in such a way that the claims of all subgroups are satisfied. In other words, no subgroup gets less than it could have obtained by breaking the alliance.

For an n-person game we call a set of n non-negative numbers an imputation if it adds up to the total gain obtainable by all n players. An outcome of a bargaining agreement will be in the core if it is an imputation and gives all groups as much or more than their "go it alone" claims. For the general three person game an imputation will be in the core if it satisfies the following set of conditions:

$$\alpha_1 + \alpha_2 + \alpha_3 = v(123)$$

$$\alpha_i \geq v(i) \quad \text{for} \quad i = 1, 2, 3$$

$$\alpha_1 + \alpha_2 \geq v(12)$$

$$\alpha_1 + \alpha_3 \geq v(13)$$

$$\alpha_2 + \alpha_3 \geq v(23)$$

Checking these conditions for the game shown in Table 5 we can see that the imputation (2/3, 4/3, 6/3) lies in the core. Altogether they obtain 4; individuals all get more than zero; 1 and 2 obtain 2; 1 and 3 obtain 2-2/3; and 2 and 3 obtain 3-1/3. It is relatively straightforward to check that there are many other agreements or ways of cutting the cake which are in the core.

A quick check of Table 6 shows that the suggested division of (2/3, 4/3, 6/3) is not in the core. In fact it is possible to show that there is absolutely no way whatsoever in which the alliance of all three can split their joint gains in such a way that every pair will obtain at least what it claims to be able to get by going it alone.

The existence of a non-empty core tells the analyst that there are possibilities for agreement where all subgroup claims can be met. When the core is empty this cannot be done and the motivation for defection of groups who perceive that they can do better by going it alone is high.

Much of the value in utilizing games in coalitional form comes in the estimation of the values for the characteristic function. That exercise alone requires a careful assessment of the different joint interests of members of an alliance. For example, Germany, Holland, and Belgium or Norway and Denmark might have group assessments which should be specially recognized when evaluating an alliance including all of them, others, and the United States.

3.5. External Symmetry and Strategic Analysis

> The natural qualities of a warlike people play just this part: bravery, aptitude, powers of endurance, and enthusiasm.
>
> —Clausewitz, p. 256

War is a complicated matter and in the analysis of war or any human process it is extremely easy to leave out of consideration critical variables. Morale, bravery, national will, terrain, weather, and a host of other factors all may appear to be important.

The constant fight in the construction of operational models is between confusing oneself with irrelevant detail which adds to the appearances of reality but subtracts both from analysis and understanding, and the leaving out of critical factors.

In strategic analysis and in weapons evaluation or doctrine development there are some natural divisions of the variables and other factors which can and should be made. In particular most human factors are taken as given and unless otherwise stated explicitly the factors are assumed to be the same for all. Thus, for example, in describing a tank fight between a South and North Korean tank unless otherwise stated the implicit assumption is that the competence, morale, and intelligence of the tank crews are the same.

In all of the formal modelling of game theory the assumption of external symmetry is present as a key modelling convention. It can be phrased as follows: unless explicitly stated otherwise all influencing factors are assumed to be the same for all sides. If we do not explicitly introduce differences in fighting ability or morale; if we fail to explicitly note that equipment failure and repair characteristics are noticeably different, then our analysis will proceed on the basis that the differences do not matter.

If the differences do matter, then we should blame ourselves not for bad analysis but for bad initial perceptions and poor modelling.

Methodology is not a substitute for perception. If used with care, it may, however, provide a supplement to perception. If one knows how to model fast and analyze clearly, an analysis which reaches ridiculous conclusions may serve as a warning that one's initial perceptions were poor and this in turn can lead to a re-conceptualization of the problem at hand.

4. MODELLING, THE STRATEGIC AUDIT, AND ANALYSIS

4.1. Systems Modelling and Modelling Systems

The art and science of systems modelling, analysis, and net assessment take place within a bureaucratic context. The mere fact that we are dealing with operations removes the process from the sole domain of the research institutions and academies.

The bureaucratic environment provides much of the motivation or volition and many of the biases to perception which go into the model building process.

Although this article is not directly concerned with the study of the organizational aspects of strategic decision making, three references are suggested for those who wish to consider in more detail the social processes influencing strategic planning. The references are the article "Optimal Ways to Confuse Ourselves" by Albert Wohlstetter (1975), The Adviser by Herbert Goldhamer (1978), and Group Think by Janis (1972).

Concerning the debate on strategic arms Wohlstetter offers advice on how to save a dogma, how to keep from noticing that your predictions have been wrong, how to ignore the decline in strategic spending, and other advice as to how to bend perception during debate.

The lengthy scholarly essay of Goldhamer deals with the role of advisers in political systems, the forms in which advice is given, the background of the advisers, the risks involved in being an adviser, and the relationship between advice giving and decision making.

The work of Janis helps to characterize the basic way committees and groups constituted for decision making are able to bias their joint decisions. He suggests that among the more important aspects to be guarded against are: 1) a sense of invulnerability; 2) shared stereotypes;

3) agreed upon rationalizations; 4) a comforting group shared illusion of morality; 5) self-censorship; 6) an illusion of unanimity in decision making; and 7) a level of mind guarding that guarantees that off-beat ideas will not be considered.

In a highly amusing and instructive article entitled "A Guide for the Perplexed" Amrom Katz (1967) offers eight maxims to help guide tourists through a classified bureaucracy. The first four maxims appear to be particularly relevant both to the science and process of strategic planning.

Maxim 1: where are the calculations that go with the calculated risk?

Maxim 2: inventing is easy for staff outfits. Stating a problem is much harder. Instead of stating problems, people like to pass out half accurate statements together with half available solutions which they can't finish and which they want you to finish.

Maxim 3: every organization is self-perpetuating. Don't ever ask an outfit to justify itself, or you'll be covered with fact, figures and fancy. The criterion should rather be, "what will happen if the outfit stops doing what it's doing?" The value of an organization is easier determined this way.

Maxim 4: try to find out who's doing the work, not who's writing about it, controlling it or summarizing it.

4.2. On Modelling

In the remaining sections we concentrate on the art and science of modelling applied to strategic problems rather than to the political process.

There are at least five aspects of model building which must be considered at any level of analysis. They are:

1. Abstraction and analogy
2. Omission
3. Aggregation
4. Symmetry
5. Simplification and approximation

Clausewitz offers an analogy between war and economic competition. Recent work in political science has been devoted to analogies between party contests and economic competition. How fruitful and how general are the analogies? When confronting a new situation it is highly desirable to look around to see if a precedent has already been established. Was there a piece of history which comes close to where we are now? Is there a different subject where the phenomenon has been studied under a different name? Will a re-labeling of the major variables indicate a kinship in causal structure to a different problem?

Perhaps one of the hardest tasks in modelling is to be able to have a conscious justification for at least a few major factors left out of current consideration. For example, we are only going to consider the Democrats versus the Republicans even though there is a third party candidate running because traditionally third party candidates never matter. Or we only need to consider the posture of the Soviet bloc against the Western bloc because it is ridiculous to conceive that a third party trying to provoke a war would sink the Nimitz. Or previous general staffs were foolish to have ignored the tank and aircraft as interesting toys but of little military significance, but Laser technology is not like those examples it really is in the releam of science fiction and can be safely ignored for at least several decades.

Although high speed digital computers can manipulate many variables, human beings and organizations use extensive aggregation in their conceptualization of problems. Thus, the behavior of quarter of a billion individuals is summarized into the behavior of a macro player called the Soviet Union. The aggregate noun "they" is invariably used to describe the battle between the individual and the surrounding bureaucracy. The selection of the appropriate level of aggregation involves both the choosing of the appropriate macro players and the aggregation of economic, political, social, and other factors. Clausewitz, for example, tended to more or less ignore or to aggregate the logistical features of war.

Throughout all of the social sciences, throughout philosophy, and mathematics the assumption of symmetry is beguilingly attractive. Problems which have different forms of intrinsic symmetry are frequently easier to analyze than those which do not. There are, unfortunately, two major dangers with assumptions concerning symmetry. First, the assumptions are frequently wrong and are made from either an implicit or an explicit wish to simplify without empirical justification. The second problem is somewhat more subtle. Even if the problem is intrinsically symmetric it is possible that there are solutions which are not symmetric. Yet, one's mind set will tend to be such that non-symmetric solutions to symmetric problems may be overlooked.

Simplification and approximation are called for in all operational analysis. Especially where our insights are shaky and the structure of the environment is both complex and uncertain. Linear, quadratic, and other simple approximations will tend to abound. Simple indices will be constructed. Not because we have undying faith in their portrayal of the world but because we should be able to justify that they are better than nothing and are about all we can handle.

4.3. A Simple Escalation Model

In Figure 1 a relatively simple example of an abstract game in extensive form was presented. There are two players, two periods, and depending upon what took place during the first period there were two or three alternatives during the second period. The game description and notation was purposely kept completely abstract to serve as an example of a precise notation. A key act in modelling is to map from real problems onto abstract structures to be analyzed. A concrete interpretation of this model is offered together with a critique of some of the difficulties encountered in modelling.

This can be regarded as an extremely simple stripped down version of a Soviet bloc-Western bloc confrontation with danger for escalation to theater and possibly strategic warfare. We may assume that player A is the Soviet bloc and player B is the Western bloc. This assumption involves an enormous aggregation and simplification which may or may not be reasonable depending upon the question to be answered.

The two alternatives faced by each player during the first period can be interpreted as 1) maintain the status quo peacefully, and 2) attempt to extend one's influence by means of a theater war. The implicit assumption or omission here is that there would be no inclination for either side to go directly to a strategic war without going through the intermediate stage of having a theater war start.

During period two if no war has started the alternatives remain peace or theater warfare. If a theater war has already been insighted then the alternatives are peace, the continuation of the theater war, or an escalation to strategic war. In this model it is assumed that the game ends at this point. In reality extreme care has to be exercised in specifying terminal conditions. The perceptive work of Iklé (1971) on Every War Must End is of critical reference at this point.

The information conditions assumed are such that each side is expected to be able to maintain information security concerning its intentions at about the same level.

This simple model is laced with symmetry assumptions. It is probable that this may be the point of greatest lack of realism. Is it pious thinking or empirical fact that leads us to assume that the Eastern and Western bloc players have equal capabilities and equal views and values on the possibility of war?

Another critical difficulty that can be seen in the inspection of this model is that in the second round a clear perceptual distinction has been made between the choice of theater war and strategic war. It may well be that one of our gravest difficulties is to know at what point a theater war has become strategic.

In Section 2.3 a method for calculating the payoffs resulting from the employment of any pair of strategies was given. It was done by calculating the period payoffs for all states of the system during period one and then again during period two. In making the analogy between this game and an escalation situation we have to ask is it even a reasonable first approximation to hang numbers onto these payoffs, let alone to add them? Where do these numbers come from, who is responsible for generating them, what empirical inputs can be used, and what moral decisions must be made when the calculations implicitly or explicitly involve the evaluation of mega-deaths or other forms of mass destruction?

When the players are gross aggregates it is extremely hard to attach simple single numbers to their goals. There are many other more complex preference structures which can be considered [Shubik (1982), ch. 4]. But the problem here is not purely scientific. It is precisely here where the moral aspects of war call for a social as well as scientific assessment of how high a price is being paid.

Applying the concept of the noncooperative equilibrium solution to this model one such equilibrium has both sides risking a theater nuclear war which then is escalated into a strategic nuclear war. The model is limited and the strategic reasoning is somewhat simplistic but if only as a parable it has a story to tell which needs to be considered. In this model as formulated the guards required for an adequate self-policing system are not there. Is it merely a fault of simplistic modelling or is it a fact of life?

The argument here is that the very exercise of formal modelling if done with emphasis more on meaning, concepts, and causality provides an important tool for improving the perceptions and making more precise the questions.

The model, its analysis, and its answers are not an end in and of themselves. They are part of a process leading to better questions, better understanding, and communication between analysts and those with operational responsibility, which in turn leads to more sophisticated and better models and analysis.

4.4. The Strategic Audit

An elementary consideration of the problems involved in modelling human affairs is enough to suggest that the peculiarly rationalistic and relatively precise concepts of strategic analysis and game theory must be modified and interpreted with great care when modelling actual tactical, strategical, or grand strategical situations. It is suggested here that the conceptual organization provided by the languages of game theory combined with the less precise but more historical and socially oriented language of military strategy and diplomacy enable us to construct a checklist which serves the purposes of structuring a strategic audit. This provides a structure and a checklist for observing and relating the key factors which must be taken into account when constructing models for strategic analysis.

The major headings for such a checklist are:

1. Scope
2. Time frame
3. Players or strategic actors
4. Rules of the game and choice sets
5. Payoffs and goals
6. Behavioral assumptions

These headings, in terms of the discussion presented in Section 2 provide the modelling outline for translating one's understanding of the nature and scope of the problem at hand into the formal rules of the game.

A more detailed breakdown of these six distinctions is given.

1. Scope
    a. Grand strategic; military diplomatic
    b. Theater strategic
    c. Tactical
2. Time Frame
    a. Date of study
    b. Length of period studied
    c. Event oriented, fixed clock or both
    d. Initial conditions assumed
    e. Terminal conditions assumed
3. Players or Strategic Actors
    a. Level of aggregation
    b. Number of strategic players
    c. External symmetry assumptions
    d. Verification of "strategic dummies"
4. Rules of the Game and Choice Sets
    a. Relevant political detail (own and others)
    b. Relevant bureaucratic detail (own and others)
    c. Relevant technological knowledge (own and others)
    d. Information and communication conditions
    e. Scope of feasible actions
5. Payoffs and Goals
    a. Short and long term
    b. Defined on a finite or indefinite horizon
    c. Ordered, partially ordered or other
    d. Quantifiable (risk measures)
    e. Team or individual goals

f. Principal agent or fiduciary goals

g. Zero sum or nonconstant sum environments

6. Behavioral Assumptions

a. Rationality

b. Risk behavior under time pressure and/or stress

c. Instinctive or programmed behavior

d. Problems of perception and interpretation

Under scope, the three broad distinctions made by Jomini are adopted. They are, in essence, grand strategic where military, diplomatic, and national goals and actions are all intermixed. Strategic and theater strategic where national and diplomatic goals can be held constant while our consideration turns to overall military planning; and tactical where we are limited to a specific direct engagement of less than global scope.

Although the need to specify the date of the study and the length of the period to be studied is fairly obvious, nevertheless it needs to be stressed that assumptions concerning what items can be ignored or treated as parameters depend delicately upon the length of time selected and to some extent the specific date. For example, seasonal factors may be important.

There is no magic overall rule which distinguishes the short term from the long term. But an _ad hoc_ decision must be made for any model concerning the influence of time.

Another important distinction is between event oriented and fixed clock oriented models. The game tree does not have a time metric imposed upon it in general, but illustrates the sequence of decisions. Many routines are oriented towards clock time whereas many important decisions are oriented towards specific changes in the environment which can take place at any point and which must serve as cues for action.

Virtually all planning models cut out a slice of time from an ongoing process. A true understanding of the dynamics implicit in even the most limited one shot model requires careful specification of both initial and terminal conditions. The initial conditions postulated in and of themselves summarize the modeler's view about the relevance of history.

The terminal conditions postulated recognize the possibility that there may be a tomorrow.

A technical trick often used by mathematicians to produce paradoxical results is the backward induction. One starts at the end of time when there is only one choice left for each side, figures out what the best action should be under those circumstances and works backwards to figure out what you should do now. This device has some merit in forcing explicit thought in long range planning about the future but it depends delicately upon being able to specify plausible terminal conditions which model the fact that there will probably be a future history which is being reflected in the assumptions made about the terminal period.

One of the fundamental weaknesses in the simple escalation model presented in Section 4.3 is the assumption that there are only two time periods. Whenever there is a tomorrow there is a chance that you may be punished for what happened today. In military conduct the hoards of Genghis Khan appeared to be highly conscious of the possibilities of tomorrow. They tended to kill traitors and informers on the basis that if they could be false to one master now they could be false to them later. They also tended to massacre deserting armies on the basis that a desertion at one time could be followed by a desertion at another time.

The institutional difficulties in extricating oneself from an adventure commenced without contemplating its alternative ends are enormous. The difficulties in coping with how to end wars have already been noted. In economic matters it is probably true that getting out of bad businesses or bad investments is harder than getting in to good ones.

Much of strategic analysis whether military, economic, or political has been based upon models of purposive behavior. In order to stretch the domain of definition of purposive behavior most of us anthropomorphize organizational behavior. Thus we talk about the French morale is low, England expects, the Soviet Union demands, and so forth. As the size of the aggregation grows the problems with defining goals and purpose of the aggregate player increase considerably.

Our attention span is relatively limited. It is easier to think about matters if we can aggregate the players highly and limit the number of players. Frequently the most attractive limit is two. "Us and they." Most tactical analysis is done with two players and is cast into a zero sum or confrontation mode. It is tempting but almost always false to do the same with strategic analysis. This becomes especially dangerous when studying the grey zone between strategic nuclear warfare and theater warfare. In spite of its horrendous implications much of the first and second strike analysis has been carried out at virtually a tactical level mode of thought. Yet, the odds are overwhelming that the commencement of a strategic war would be preceded by a theater war. In this case in the selection of relevant players extreme care must be exercised in removing even Albania or Argentina from the list.

In Section 3.5 sufficient discussion has been given concerning external symmetry conditions. No further comment is made here.

The verification of strategic dummies is a technical problem frequently confronted in game theoretic analysis which is of importance in strategic analysis in general. In situations involving more than two parties it is exceedingly difficult to pre-judge when a particular third party will have no influence of significance on the outcome. It may be safer to include the third party into the analysis even at the cost of more work and then by the analysis be able to demonstrate that the third party is irrelevant and can be left out of further analysis with safety.

Depending upon the level of analysis political, bureaucratic, and technological detail will be more or less important. Especially when planning at the level of grand strategy the assumptions concerning these factors will tend to be made by different groups and depending upon their professional biases the analysis will tend to be biased accordingly.

The old adage from Bridge that "a peek is worth two finesses" holds true for both war and business. In Section 2 it has been indicated that the language of game theory as used in describing the extensive form is particularly adapted to displaying information conditions. It must be stressed, however, that the meaning of information both in game theory and information theory is devoid of semantic content. The statement that you have more information is equivalent to the statement that you can perceive more states of the system not that you understand what these states mean.

How to model both information and communication conditions in the description of strategic situations is still one of the most difficult tasks which face the strategic analyst. Many of the skills of bargaining and negotiation depend upon making distinctions fuzzy and dissolving perceptions of opposition. The more tactical the situation is, the easier it becomes to characterize information. Whether a certain bridge has been blown up or not can be described with reasonable precision.

The description of the scope of feasible actions is in terms of formal game theory the equivalent of specifying the strategy sets for all players. At best the description must be highly aggregate. The astronomical proliferation of strategies in the formal game theoretic sense, i.e. totally encompassing contingency plans, make it quite clear that the choice of alternative plans to analyze must be highly limited.

Those who use numbers and mathematical analysis in strategic planning tend to like one number descriptions of payoffs. In all of the examples given in Section 2 the formal game theoretic models had one number representing the payoff to each player or in the case of the games in coalitional form one number was used to represent the size of a joint gain which a group of allies could divide between them.

There are many different technical ways in which complex goal structures may be described when presenting a strategic analysis. The techniques are there, but the difficulties are primarily conceptual and empirical. What is a good representation of the goals of an organization? How does risk behavior where the individual is risking his own life or assets differ from risk behavior where he may be sending others to their death or ruin? No formal methodology is going to answer these questions. On the other hand it can and does assist in asking them.

The last set of conditions we must consider in modelling are our behavioral assumptions. A complete description of the strategic environment does not tell us how our competitors or opponent will behave. Whether we like or not the process of strategic analysis involves implicitly or explicitly the piling of assumption upon assumption. At this point most strategic studies make some form of assumption about individual rationality and the analytical abilities of the other sides. Unfortunately this is not enough to be able to determine behavior. In Section 3 above it has been noted that there are many solution concepts to nonconstant sum games of strategy. Phrasing this less technically it amounts to observing that there is no unique generalization from the commonly accepted concepts of individual rationality to multi-person rational behavior. The paradoxes encountered in some game theoretic models tell us that tunnel vision individual rational behavior by all parties may in fact spell joint disaster.

In general the very act of strategic planning is purposive. The overall context in which it takes place is behavioral. Throughout strategic analysis there is an element of goal oriented normative planning buried in a sea of instinctive or programmed behavior. The good planner has to make do with assumptions that are at best more or less precise. He needs to make behavioral assumptions about large segments of his own system and the organizations of others but he cannot afford the luxury of ignoring the element of purposivity and calculation that lies in his own decisions and the decisions of others.

4.5. Tactics, Strategy, and Negotiation

> Tactics is the theory of the use of military forces in combat. Strategy is the theory of the use of combats for the objects of the war.
>
> In a word it is easier to make a theory for tactics than for strategy.
>
> —Clausewitz, pp. 173 and 190

> Diplomacy is to do and say the nastiest thing in the nicest way.
>
> —Isaac Goldberg, The Reflex

The three quotations above are supplied as a preamble to some closing remarks on modelling at the three different levels of tactics, strategy, and negotiation.

The formal methods of game theory do not distinguish between strategy and tactics. This distinction is made at the level of modelling.

In essence the limitations of scope, and time; the specification of the two players and their goals all make the two-person zero sum formal game model of tactical warfare a reasonably good representation of the problem at hand. Be it situations involving dueling, weapons evaluation, search, or force structure there are many reasonably tight models which can be formulated. The excellent article by Weiss (1953) on "The Requirements for a Theory of Combat" presents an exposition which applies equally well to Lanchester equation, game theory, and other models of combat.

With the advent of nuclear warfare and intercontinental ballistic missiles a new category of analysis has appeared. For want of a better description following a distinction made by Jomini at the level of strategy we distinguish grand tactics from tactics. It is suggested that first and second strike analysis or the "salvo study of nuclear war" can best be regarded as tactical analysis on the grand scale. The difference between conventional tactical analysis and this is that the game is not zero sum, the payoff functions are vague in the extreme, and the terminal conditions are difficult to conceptualize let alone describe. A highly simple form of this analysis is given by Dalkey (1965) in his paper "Soluble Nuclear War Models." The modelling of the command and control system for the first twenty minutes after a verified red alert and the subsequent twenty-four hours is an activity that hardly exists in the open literature. Yet its implications and importance are enormous.

As we proceed from strategic through to grand strategic analysis the time span increases, the perception of the key variables become vaguer, the moral imponderables become greater, and the setting of values and goals become more and more a part of a social process than an empirical given of the problem.

As diplomatic considerations begin to intermix with the more purely military aspects of the situation, the need for accurate inventories of weapons and what they can do still remains but the conceptual framework must include bargaining and negotiation as well as force. The analysis of coalitional structures is valuable in indicating as a first approximation what there is to bargain about. At this point three psychically different approaches can be distinguished. The first is that the study of bargaining and diplomacy should be left to non-quantitative students of political science, diplomacy, and history. The second is exemplified by a growing literature on formal models of bargaining processes. A brief volume by Roth provides a coverage of axiomatic models of bargaining.

The third approach presents an intermix of history, political science, game theory, social psychology, law, and mathematical analysis. This is typified by the work of Ikle (1964) on how nations negotiate, Schelling's (1959) Strategy of Conflict, and Fisher's (1970) little handbook on how to negotiate.

In all of these the mixture between the analytical and behavioral approaches can be seen. Frequently tied in with the rational actor view of strategic negotiation is the normative proposition that principled problem solving should be able to resolve even international strategic conflict.

Perhaps there may be a rational analytical way for solving international conflict, but if there is it will depend upon the development of international law which in turn depends upon the expansion of our mutual understanding of the strategic choices we face.

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