THE RATIONAL TIMING OF SURPRISE

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SURPRISE is frequently possible only by risking the revelation of the means of surprise. Thus, anyone who has the means to surprise his opponent faces the problem of when his resource for surprise should be exploited, and when it should be conserved for a time when the stakes are higher and the surprise would be more valuable. Using the resource for surprise at the first opportunity would mean getting less from it than would be possible if a more suitable event were to come along immediately after the resource for deception had been expended. On the other hand, it is frequently necessary to pay significant costs to maintain a resource for surprise. And, as in all calculations about getting things at one time or another, it is better to get a given payoff sooner rather than later.

The problem that I address in this paper is *when* a resource for surprise should be exploited. In the first part of the paper, I will show how broad this type of problem is in the area of international relations in general, and in political-military affairs in particular. In the second part of the paper, I will develop a rational-choice model to treat this sort of problem. In the third section, I will examine the ways in which actual actors are likely to differ from fully rational actors; by means of these differences I will then develop some important implications of the model.

I. Resources for Surprise

A fascinating example of a resource for surprise is a spy who has been discovered and has had his loyalties changed. This is a double agent. A double agent is a resource for surprise because he is under the control of the government he is supposed to be spying upon. Therefore, this government can use the double agent to send back false information and thereby deceive the government that originally sent the spy.

A striking case of the use of double agents on a grand scale was the achievement by the United Kingdom in World War II of capturing

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every single one of the German agents operating in Britain and using many of them against Germany.[1] The British achieved this feat by the beginning of 1941, but acted cautiously until they were certain that their control of the German espionage system in Britain was complete. Although they were sure by 1942, they decided to continue their caution in order to be able to exploit their resource to the fullest in one grand deception. The occasion was to be the Allied invasion of Europe. The British realized that they would incur a cost in the meantime—a cost measured in terms of valid information that would have to be supplied to Germany through these agents in order to maintain their credibility. But the stakes involved in D day were so high that it was worthwhile to conserve these controlled agents at least until then. This patience was amply rewarded: the Germans fell for the grand deception and kept a large number of troops at Pas de Calais—even several days after the real attack at Normandy.

Today, spies and double spies have been surpassed in importance by technical means of collecting information, such as reconnaissance satellites.[2] These technical means allow a great deal to be observed. They also allow powerful inferences to be made about the significance of observed patterns of behavior.

But even if the observations are accurate, the inferences can be deceptive. In fact, one way to deceive someone who is watching closely is to use a pattern of behavior which allows certain inferences to be drawn and verified.[3] Then, once this pattern is well established, changes can be made in such a way that the inferences are no longer correct. It is now widely recognized that a government's standard operating procedures allow an opponent to make inferences about the first government's behavior.[4] What is not so widely recognized is that, if the observed side can discover *its own* standard operating procedures, it has a resource to deceive the enemy. The same trick may of course

[1] J. C. Masterman, *The Double-Cross System in the War of 1939 to 1945* (New Haven: Yale University Press 1972).

[2] Richard M. Bissell, Jr., "The Bissell Philosophy: Minutes of the 1968 'Bissell Meeting' at the Council on Foreign Affairs as Reprinted by the Africa Research Group," reprinted as Appendix to Victor Marchetti and John D. Marks, *The CIA and the Cult of Intelligence* (New York: Knopf 1974), 381-98; Herbert Scoville, Jr., "Is Espionage Necessary for Our Society?" *Foreign Affairs*, Vol. 54 (April 1976), 482-95.

[3] For a discussion of indices of behavior, see Robert Jervis, *The Logic of Images in International Relations* (Princeton: Princeton University Press 1970), 18 and 41-65. See also Erving Goffman, *Strategic Interaction* (Philadelphia: University of Pennsylvania Press 1969).

[4] Graham Allison, *Essence of Decision* (Boston: Little, Brown 1971).

not work twice; therefore the question arises as to when this resource should be exploited.[5]

Double agents and standard operating procedures are both resources for achieving surprise through deception. They are means of providing believable but misleading information. However, if the other side is sufficiently confident that the information channel is under your deliberate control, there is no resource for surprise, or at best a resource of attenuated value. Therefore, in discussing resources that achieve surprise through deception, an important point to keep in mind is that I will deal only with information channels that are accepted by the other side even when the stakes are high.[6]

Some resources for achieving surprise do not depend on deception. One important category is an enemy code that has been broken. For example, when the Allies broke the German U-boat code in World War II, they were able to spot and sink German submarines with unusual frequency. After a short time, the Germans guessed that their code had been cracked; therefore, once this resource had been exploited, the codes were changed immediately. Allen Dulles, former head of the CIA, has presented the problem of when to exploit this type of knowledge as follows: "One can risk terminating the usefulness of the source in order to obtain an immediate military or diplomatic gain, or one can hold back and continue to accumulate an ever-broadening knowledge of the enemy's movements and actions in order eventually to inflict the greatest possible damage."[7]

A particularly good example of this dilemma occurred in the North African campaign of World War II. The British had developed a method of cracking the major German codes. The method was called Ultra. In order to preserve the security of Ultra, they decided not to

[5] The morality of deception is worth at least a footnote. Most of us find deception distasteful. In everyday relations we regard deception as immoral. We don't deceive others around us and we feel we have a right to expect that they won't deceive us. But not all relationships are of this basically cooperative, trusting type. Wars certainly are not. Whenever a relationship is based on violence, it seems hardly immoral to add some deception. Indeed, it would have been immoral for the British and Americans not to try to deceive Hitler about the location of the D-day attack, for example. Thus, whether deception is moral or not depends upon the nature of the relationship between the two sides. (I would like to thank Alan Donagan for this formulation.) When the relationship has less than total conflict, there is an additional consideration. The very practice of deception tends to make the relationship less trusting and more hostile.

[6] Goffman (fn. 3), 69, states that when the stakes become high enough, "nothing (it can be thought) ought to be trusted at all." I think that even when the stakes are high, something has to be trusted.

[7] Dulles, *The Craft of Intelligence* (New York: Harper & Row 1963), 75.

attack an enemy ship on the basis of Ultra alone.[8] Instead, an aircraft had to be sent to the ship to make a visual report so that the enemy would believe that aerial reconnaissance rather than code breaking was responsible for sinking the ship. However, during a critical period in the North African campaign, on October 26-27, 1942, fog protected an Axis convoy from aerial reconnaissance. The British were therefore faced with the dilemma of allowing Rommel's supplies to get through or risking the disclosure of Ultra. Churchill was consulted. "Churchill hesitated for an appreciable period as he weighed the alternatives, then he ordered that the ships were to be attacked and sunk. This time Churchill was willing to risk Ultra."[9]

A fourth category of resources that can be exploited for surprise is information obtained through a spy. As with information obtained through a code that is broken, the use of such information risks the ending of its usefulness. A striking example from the 1960's is provided by the Israeli agent Eli Cohen, who managed to infiltrate the leadership of the Syrian Baath Party. The Israelis exploited their information for propaganda purposes by broadcasting a number of secret Syrian cabinet decisions. This apparently alerted the Syrians to the possibility of a highly placed spy. When, in November 1964, the Israelis exploited this information even further by showing astonishing accuracy in attacking long-range artillery emplacements in Syria, Cohen's radio signal was detected and located by Syria within two months.[10] He was captured and executed.

Another example of how superior knowledge can be exploited is the introduction of a new weapon. The first use of a new weapon or new capability gives great advantages. These advantages are of at least two types. First, the other side has not yet had a chance to adapt to its use and therefore will have a suboptimal response. Typically, this advantage is lost shortly thereafter, as the other side learns how to

[8] Anthony Cave Brown, *Bodyguard of Lies* (New York: Harper & Row 1969), 128. See also Patrick Beesly, *Very Special Intelligence* (London: Hamish Hamilton 1977), 90f.

[9] Cave Brown (fn. 8), 128. Was the success of the German air raid on Coventry a result of the British reaching the opposite decision—namely to protect Ultra by deliberately not taking advantage of the information it provided? Brown, p. 40, says yes. Michael Howard, in "The Ultra Variations," *Times Literary Supplement* (May 28, 1976), 641-42, and David Kahn, in "The Significance of Codebreaking and Intelligence in Allied Strategy and Tactics," summarized in *Newsletter of the American Committee on the History of the Second World War*, No. 17 (May 1977), 3-4, dispute this and argue that Coventry was not a deliberately martyred city.

[10] Zwy Aldouby and Jerrold Ballinger, *The Shattered Silence: The Eli Cohen Affair* (New York: Coward 1971), 226, 325f.

adapt to the weapon and perhaps even to use it.[11] There is also a psychological effect. A Soviet military study puts it this way: "The experience of past wars teaches us that the unexpected employment of new weapons has always had a powerful moral-psychological effect on the enemy."[12] Since both the nonadaptive and the psychological effects are reduced after the first use of the weapon, the familiar problem arises as to whether the weapon should be introduced at a given time or saved for a later and perhaps better occasion.

A good example of how it can pay to wait is presented by the Syrian decision not to use its new SAM air defense system in September 1973. Knowing that they would be attacking Israel less than a month later, the Syrians withheld the use of their new SAM system when a major air battle started over Syrian skies and then extended over the Mediterranean. Withholding the use of the SAMs cost Syria twelve planes to Israel's one, but it preserved the secrecy of the effectiveness of the system. The effectiveness of the SAMs in Egypt as well as in Syria was one of the major surprises the Israelis encountered in the opening days of the 1973 war.

All these examples present the same structural problem in determining whether to wait or whether to exploit the resource immediately. In all of them, the stakes vary over time: there may be an even more important situation later than there is now. Likewise, in all of them, there is a cost in maintaining the resource. Also, in all of the cases, the use of the resource risks its future value. Finally, in all cases, there are several reasons why one would prefer a given payoff at once rather than wait until a future opportunity. These structural similarities suggest that a mathematical model will be helpful in understanding the rational timing of surprise.

In order to develop such a model, it is necessary to look at the structure of the problem more closely.

1. *The stakes vary.* In each case the stakes vary over time, so that however great they are now they may be greater later. For example, the Syrians knew that an air battle had significant stakes, but they also knew that the stakes would be even higher in the following month when their major attack would be undertaken. Typically, future stakes are not known precisely, but some estimate can be made with greater or lesser confidence.[13] Thus, when Churchill decided

[11] James C. Aller, "Electronic Warfare Concept," *Naval War College Review*, XXII (May 1970), 75-79.

[12] A. S. Milovidov and V. G. Kozlov, *The Philosophical Heritage of V. I. Lenin and Problems of Contemporary War* (Moscow: Military Publishing House 1972; trans. ed., Washington, D.C.: U.S. Government Printing Office), 198.

[13] We are assuming that the determination of the stakes is independent of the choice

to risk Ultra for the sake of sinking some supply ships to Rommel, he had to decide whether the latter was worth it; one of the considerations would have been the stakes in future situations when Ultra might be even more valuable.

In general, the gains from exploiting a resource are proportional to the stakes. The costs of maintaining a resource are also proportional to the stakes, although the proportionality factor is typically lower. For example, the bigger the air battle over Syria, the greater the stakes; hence, the greater would be the gain if the SAM system were used, but also the greater would be the price of not using it. Naturally, the stakes must be considered in terms of the resource at hand. Thus the use of the SAM system had stakes that were determined by the magnitude of the air battle and its relationship to broader policy considerations. Obviously, the concept of stakes has to be viewed broadly in order to take into account all of the gains and losses that are relevant to the decision.

2. *There are costs to maintaining a resource.* If a resource is not used today, a cost must typically be borne to preserve it for tomorrow. For example, if a controlled agent is to continue to be credible, he must provide some valid information. In the same way, if a standard operating procedure is going to be used for deception later, it must be maintained in the meantime. While it is being maintained, there are real costs to allowing an opponent to make valid inferences about one's own behavior. In the case of waiting to exploit a code that is broken, or a spy who is in place, or a new weapon that can be introduced, the costs are necessary in order to minimize the chance that the opponent will learn that such resources are available for use.

3. *Exploitation risks exposure.* If it were not for the fact that exploitation of the resource risks its exposure, there would be no need to calculate at all. For example, in achieving surprise through the exploitation of a standard operating procedure, the risk of exposure is likely to be very great. To try to deceive in the same way again means that the deception itself becomes stereotyped. A Soviet military text makes this point well: "Stereotype contradicts the very essence of surprise. If one has succeeded in deceiving the enemy once, then he will not allow himself to be deceived a second time by the very same technique."[14]

The same text notes that the introduction of a new weapon cannot

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whether to use a resource for surprise. Put another way, the stakes are exogenous to the model.

[14] V. Ye. Savin, *The Basic Principles of Operational Art and Tactics* (Moscow: Military Publishing House 1972; trans. ed., Washington, D.C.: U.S. Government Printing Office), 235.

remain secret for very long. "Therefore sooner or later the monopoly on the new weapon is lost and the level of technical outfitting begins to even out."[15] Similarly, once a controlled agent has been exploited, he may be disbelieved in the future.

4. *Value is discounted over time*. In all cases, it is reasonable to suppose that if the value were the same for exploiting a resource today or waiting until tomorrow, the choice would be made to exploit it today. There are at least two important reasons why there is a substantial discount rate in decisions concerning international politics and military affairs. The first is that the resource may disappear even if not used. Even without being exploited, a controlled agent may be blown, a cracked code may be changed, or a secret weapon may be uncovered. A second reason is that a gain today may accumulate in its impact on future events. Thus, a relatively small advantage over Rommel in 1942 could be leveraged into greater and greater advantages through one battle after another.

There is one important factor that tends to reduce the discount rate: a resource which is not used may actually grow or ripen. Thus, a double agent who is not exploited may be evaluated as more reliable, precisely because he provides a run of valid information. A standard operating procedure that builds a track record in terms of verifiable inferences is more likely to be trusted when the time for exploitation actually arrives. In the case of a new weapon, waiting until it can be introduced on a large scale can bring substantially greater rewards than rushing it into use as soon as possible.

To simplify the discussion, let us temporarily make two assumptions which will be dropped later. The first is that when the resource is exploited, it is certain to be discovered; therefore it can only be used once. The second is that the factors making for a positive discount rate and the factors making for a negative discount rate cancel each other out, and we therefore do not have to worry about the discount rate. With these simplifying assumptions, we can represent the problem of when to exploit a resource for surprise in terms of a simple gambling situation involving a single six-sided die. The point is to show that even under the simplest assumptions, the calculations are not the kind that can be done easily by intuition; yet, they can be done quite readily with a little simple algebra. Thus, even the simplest situation displays some of the advantages that a mathematical model can offer in the understanding of these types of problems.

[15] *Ibid.*, 236.

Suppose we are offered the following game. A die is rolled and we have two choices. The first choice is to pay the face value of the die in dollars and continue. The other choice is to collect twice the face value of the die and end the game. For example, if the first roll of the die were a five, we could end the game and collect $10, or we could continue the game by paying $5 and rolling again. This could go on as long as we were willing to pay to roll again.

What is the best strategy when faced with such a game? That is to say, when should we exploit our resource and when should we be willing to pay to maintain it into the future? Clearly, whenever a six comes up, we should cash in because there is no point in paying to go on; we could never do better anyway. On the other hand, if a one is rolled, it is probably worth paying the $1 necessary to continue the game in the hope that we will get something more worthwhile soon.

Let us take the analysis a little further: if we do cash in on the first roll of the die no matter what it is, the expected gain is simply twice the average of the die roll. The average die roll is 3.5, and thus the expected gain of stopping on a die roll, no matter how small, is twice 3.5, or $7. Thus, if we followed the strategy of stopping no matter what came up, we would get an expected value of $7 from the game. This shows that the game would be worth an expected value of at least $7, and perhaps more if we could find a better strategy.

If we follow the strategy of stopping when a two or more comes up on the die roll, then we will be paying for all the one's, and collecting on the first two, three, four, five, or six. Thus, our average gain when we do cash in will be twice the average of all the numbers between two and six; this means that on the turn when we cash in, we will get —on average—twice four, or $8. However, we will also have to pay if a one turns up before any higher number. A third strategy is to wait until a three or better shows up before cashing in. In general, since the die rolls are independent, the best strategy will take the form of waiting for a sufficiently large number and paying what is necessary to continue the game until this sufficiently large number comes up on the die.[16]

The question, then, is where to set our threshold so that when we do cash in, we will be receiving a large payoff, but will not have to pay too much to wait for that time to arrive. The reader is invited to guess

[16] This strategy assumes that what we are trying to maximize is expected value—i.e., average dollar winnings. It ignores risk aversion and the possibility that we will run out of money to maintain our position while waiting for a good roll.

what the best strategy is: that is to say, how large a die roll should we wait for before cashing in? The answer is given below.[17]

II. The Model

SPECIFICATION OF THE BASIC MODEL

The gambling game illustrates the basic problem in the rational timing of surprise. At each point in time there is a conflict between the desire to exploit the resource immediately for its potential gain, and a competing desire to pay the necessary cost to maintain the resource in the hope that an even better occasion for its use will come along soon.

An algebraic representation will help to gain a deeper understanding of this type of problem. It would represent the expected payoffs that can be achieved if the decision is made to exploit the resource whenever the stakes are at least as great as some given threshold level. The problem then is to find the best threshold.[18] It should be high enough so that the resource is exploited only in a worthwhile circumstance, but not so high that great investments have to be made to wait, while the stakes remain lower than the threshold.

First, consider what happens if the stakes are at least as great as the threshold. In that case, the resource is used, giving a value that is proportional to the stakes. In the die game, this constant of proportionality was two, but in general it can be any positive number. This number will be called the enhancement factor, E. Thus, if the stakes are at least as great as the threshold, the value received is the enhancement factor times the current stakes. Under our temporary simplifying assumptions, the resource can only be used once, so when this value is collected, the calculations will end. Thus, if the stakes are at least as great as the threshold, the expected value of the current situation is $E\bar{S}$, where E is the enhancement factor and $\bar{S}$ the average stakes, given that the stakes are at least as great as the threshold.

On the other hand, if the current stakes are less than the threshold

[17] The highest expected value is achieved by waiting for a three or more. This would give an expected value of \$8.25 to the game. If we stopped at one or above, we would get on average \$7; at two or above, \$7.80; at three or above, \$8.25; at four or above, \$8; at five or above, \$6; and at six, a *loss* of \$3.

[18] It can be shown that a threshold decision rule is optimal for the type of model being described in the body of the paper. It can also be shown that for a broader class of model, embodying Markov processes, the optimal decision rule need not be a threshold rule. The proofs are available in the appendix of Axelrod, "The Rational Timing of Surprise," IPPS Discussion Paper No. 113, available from the author or the Institute of Public Policy Studies, University of Michigan, Ann Arbor, MI 48109.

level, the decision will be to pay the price of maintaining the resource. In that case, there will be an immediate loss that is proportional to the stakes, and the same decision problem will arise with the next stakes. Without loss of generality, we can take *this* constant of proportionality equal to one, as we did in the die game. Thus, if the stakes are less than the threshold, the expected value of the current situation is $-\underline{S} + V$, where $\underline{S}$ represents the average stakes, given that they are below the threshold factor, and V represents the expected value of going on to the next event.

For a given threshold, the probability of collecting and stopping is determined by the probability that the stakes will be at least as large as the threshold. If we let this probability of using the resource at a given time be P, the probability the threshold will not be met or exceeded is $1 - P$. Putting all this together allows a calculation of the expected value of the given threshold in terms of a weighted average of the payoffs of stopping and continuing, where the weights are the probabilities of these two choices. Thus, the value of using a given threshold is:

$$V = PE\bar{S} + (1 - P)(-\underline{S} + V).$$

The enhancement factor, E, is known. Also known is the probability distribution of the stakes. Therefore the choice of threshold determines three numbers: the probability that the threshold will be exceeded, P; the average stakes if it is equalled or exceeded, $\bar{S}$; and the average stakes if it is not equalled or exceeded, $\underline{S}$. Thus, the problem is to select the threshold that gives the highest value of V.

We are here assuming that the discount rate is zero and the stakes are independently determined from one event to the next. This means that if the threshold is not exceeded on a given trial, then the necessary cost of $\underline{S}$ is paid, and the situation merely repeats itself. That is why there is a V on both sides of the equation.

Solving for the value of the game, V, gives:

$$\begin{aligned}(1 - (1 - P))\,V &= PE\bar{S} + (1 - P)(-\underline{S})\\ PV &= PE\bar{S} + (1 - P)(-\underline{S})\end{aligned}$$

and finally

$$V = E\bar{S} - \frac{1 - P}{P}(\underline{S}).$$

The problem of when to exploit the resource is now reduced to the problem of finding the threshold that results in the largest value of V.

For example, in the illustration of the die game, there are six possible thresholds; the one that gives the highest value is three. When the game is stopped at three or more, the average value of the stakes when the threshold is equalled or exceeded is $\overline{S} = 4.5$. The average value of the stakes when the threshold is not equalled or exceeded is the average of one and two, which is $\underline{S} = 1.5$. The probability that a three or more will be rolled on a single turn is $P = 2/3$. Using an enhancement factor of $E = 2$, we have $V = 2(4.5) - \left(\frac{1/3}{2/3}\right)(1.5) = 9 - .75 = 8.25$. Since no other threshold gives a value as great as \$8.25, the best decision rule is to maintain the resource until the stakes are three or larger. Using this decision rule, one can expect an average gain of \$8.25. Since the decision rule calls for stopping on a three or greater, the odds of stopping on a given roll are $P = 2/3$.

In actual practice, not all stakes are equally likely to occur. In international relations and military affairs, the more typical expectation is that low-stake situations are much more likely than high-stake situations. Moreover, there is often a great range of stakes, from low-stake events that are fairly common up to events that are quite rare but have stakes that are very great. The old question then arises in even more intense form: how big should the stakes be before the resource is exploited? Very large stakes will come along once in a great while and will be worth waiting for. But their very rarity makes it expensive to wait for them.

A concrete example is the historical distribution of wars over a long period of time. Richardson's statistics are a convenient source.[19] In the period between 1820 and 1945, there were 282 wars which caused 300 or more deaths. Dividing these into logarithmic intervals, the distribution of wars by magnitude is as follows:

Size of War		*Number of Wars*
About	1,000	188
About	10,000	63
About	100,000	24
About	1,000,000	5
About	10,000,000	2
		282

[19] Lewis F. Richardson, *Statistics of Deadly Quarrels* (Pittsburgh: Boxwood Press; Chicago: Quadrangle Press 1960).

If we suppose that the stakes are proportional to the size of the war and can be expected to be distributed in the same manner as these wars were distributed, what is the best decision rule to use? Our earlier calculation shows that it pays to wait for the largest kind of war, even though it is less than one percent of all wars. This is so with an enhancement factor of two—when the gain from exploiting a resource is twice the cost of maintaining it for any given stakes. Even if the enhancement factor is only one, it still pays to wait for the largest category of war.

Notice how much the situation has changed when the distribution of stakes becomes so skewed. In the die game, the best thing to do was to wait for a three or more, which meant that the probability of using the resource on any given turn was two-thirds. In the case of the distribution of wars, where there are only a few medium-size wars and even fewer very large wars, the best thing to do is to wait until the largest category of war. This means that the probability of using the resource on any given turn is less than one percent.

Typical decisions about the exploitation of resources for surprise are generally not made on the basis of wars, but on the basis of some smaller unit of analysis, such as a battle. However, the expected distribution of stakes is usually similar to the distribution of wars: many events of small stakes, a few events of large stakes, and a very few of very large stakes. For any given belief about future stakes, and any given estimate of the enhancement factor, it is thus possible to calculate whether the current stakes are sufficient to merit the exploitation of the resource, or whether it is best to pay the price of maintaining the resource and to wait.

EXTENSIONS OF THE MODEL

It is easy to extend the model to take account of the fact that when a resource for surprise is used, it still has some chance of surviving. For example, a double agent who is used to mislead an opponent may not be discredited the first time he gives false information.

The British use of double agents to mislead the Germans about the location of the D-day attack is a brilliant example. In fact, not a single double agent was compromised by this massive deception.[20] The reason appears to be that the information provided by the agents served to confirm the cover story. As real troop formations reached France, they

[20] Masterman (fn. 1), 168.

were always units that had already been identified by the agents. Thus the information that could be verified by the Germans turned out to be accurate, and this led them to trust the other reports as well. The Germans apparently held to the belief that if the invasion at Normandy had not been so successful, the major attack would in fact have occurred at Pas de Calais.[21]

If a resource for surprise is thought to have a chance of Q for survival when used (where Q is greater than zero), then its use is less costly than if it were certain to be lost upon its first use. The optimal decision rule can be calculated as before, but with the modification that the value of using the resource is no longer $E\bar{S}$, but instead is $E\bar{S} + QV$.

At the same time, we can go one step further and introduce the idea of a discount rate greater than zero. Earlier, we assumed that the discount rate was zero, meaning that the reasons for wanting an immediate payoff counterbalanced the reasons for expecting the value of a given exploitation to grow. As previously stated, there are at least two important reasons why the discount rate is significantly greater than zero. One is that the resource may disappear even if not used; the second is that a gain today may accumulate in its impact on future events. These two factors often dominate the offsetting factor that the resource's value for surprise may grow over the time that it is maintained.

Introducing a discount rate means that the value next time is $(1 - D)$ percent of the value this time. For example, if the discount is 10 percent per event, a given payoff received in the next event is only worth 90 percent of what it would be worth today. With a significant discount rate, we would tend to exploit the resource earlier, and thus would be satisfied with a somewhat lower payoff, provided it came soon. Thus, as the discount rate goes up, the optimal threshold goes down.[22]

To calculate the optimal threshold when a discount factor exists, we note that whenever the resource survives, the value that is attained for its survival is no longer V, but $(1 - D)V$.

Taking both the survival odds of Q and the discount rate of D into account, the value of using a given threshold is then:

$$V = P(E\bar{S} + Q(1 - D)V) + (1 - P)(-\underline{S} + (1 - D)V).$$

As before, the term that is multiplied by P represents the payoff for getting or exceeding the threshold. In that case, the resource is exploited, and a payoff of $E\bar{S}$ is received immediately. Moreover, there is

[21] *Ibid.*, 157f.

[22] This is true regardless of the distribution of stakes and the value of the other parameters.

now a Q chance that the resource will survive to be used again. If it does survive, it is worth, on average, $(1 - D)V$, which is the value of using the same decision rule the next time, discounted to take account of the necessary wait for the next event. Similarly, the term that is multiplied by $(1 - P)$ represents the payoff if the stakes are less than the threshold. In that case, the decision rule calls for paying $\underline{S}$ to maintain the resource, and the expected value of waiting is again $(1 - D)V$.

As before, the calculations can proceed by solving for V. The result is an elementary but not very pretty formula:

$$V = \frac{EP\bar{S} - (1 - P)\underline{S}}{D + (1 - D)\,(1 - Q)P}$$

This formula is consistent with the basic formulation in the previous section when $Q = O$ and $D = O$.

To take a concrete case, let us suppose that there is a 50 percent chance that the resource will survive even if used. Let us also suppose that the discount rate is 10 percent per event, which takes into account the reduced value of a given payoff if it has to be waited for, the chance that the resource will be lost even if not used, and (in the opposite direction) the potential growth in the exploitation value of the resource if it does survive.

Now what is the best thing to do? Let us assume that the stakes are distributed just as the wars have been—with many relatively small events and a few very large ones—and that the enhancement factor is still two. We should recall that when there was no chance that a resource would survive if used, and that, when there was no harm in waiting (except for the cost to maintain the resource), the optimal decision rule was to wait for the largest class of events even though fewer than 1 percent of the events were this large.

With a 50 percent chance of survival of the resource every time it is used (instead of no chance) and with a 10 percent discount rate (instead of a zero rate), there are now two good reasons to be more willing to use the resource than before. In fact, increasing the survival rate if the resource is used, and/or increasing the discount rate, will always lower the optimal threshold.[23] But what is more interesting is that the optimal threshold does not go down very much when the stakes are

[23] See Axelrod (fn. 18) for the proof. If the risk to the resource is constant per year rather than per event, then the discount rate per event will be greater in peacetime, when events are few and far between compared to wartime. With a high discount rate per event in peacetime and the expectation of protracted peace, there would be an incentive in peacetime to exploit the resource to achieve such things as affecting the other side's defense investments and force postures. I am grateful to William R. Harris for this point.

as skewed as they have been in the distribution of wars. Even with these survival and discount rates it is best to wait for an event at least as large as the next-to-largest category. Such events constitute less than 3 percent of all events, but they are large enough to be worth waiting for—even though using the resource might not destroy it, and even though waiting reduces the future payoffs by 10 percent for each of the many events that are likely to pass in waiting for such a high-stake event.

III. Policy Implications

The most important relationship illuminated by the model is that there is a common structure to problems involving the use of resources for surprise. Double agents, standard operating procedures, cracked codes, spies, and new weapons can all be regarded as resources that have the potential to create surprise in the opponent. In each case the same problem arises: when the resource should be risked and when it should be maintained for a later, potentially more important event. This problem appears in historical accounts of many of the examples cited, but no one seems to have appreciated just how general it actually is, nor how it can be analyzed with a formal model. If quite diverse phenomena are seen to be structurally related, an understanding of each separate phenomenon can expand the understanding of each of the others.

Even beyond this, a formal model can suggest new ways of looking at the whole range of phenomena in question. In the case of the model developed in this paper, this means that the model itself can be used to suggest policy implications for the rational timing of surprise. There are implications both for the exploitation of such a resource and for protection against its exploitation.

Before looking at these implications, it is worth repeating that the model deals only with certain types of situations. In particular, when dealing with resources for surprise that work through deception, the model only treats those information channels which the other side will believe even when the stakes are high. The model also deals only with situations in which the determination of the stakes is independent of the decision concerning the exploitation of a resource for surprise. With these restrictions in mind, we can turn to the policy implications of the model.

Of course, these implications can be developed in a quantitative fashion only if the parameters of the model can be measured quantitatively.

In practice, quantitative measurements of variables, such as the chance that the resource will survive if used, are difficult to estimate with any great degree of confidence. Fortunately, a quantitative estimate is not always needed. There are a number of important policy implications that rely only on the qualitative assessment of the parameters. An example is the result that the lower the survival rate when the resource is used, the higher should be the threshold, and thus, the less readily should the resource be exploited. This result is what might be expected, so let us now turn to some less obvious policy implications.

1. Patience is a virtue. When rare events have very high stakes, the best strategy may be to wait for these rare events before exploiting a resource for surprise. As we have seen, even if the resource has a good chance of survival when used, and even if there is some chance that it will be destroyed when not used, the distribution of stakes may be such that it still pays to wait for a very rare but important event.[24] It is widely asserted that democracies are less patient than more centralized forms of government. If so, and if the distribution of stakes is as skewed as the distribution of wars has been, then a good deal could be gained from resisting the temptation to exploit resources on occasions where the stakes are only moderate.

2. Since the optimal strategy will often require quite long waits, the bureaucratic incentives may not actually reflect the national interest. A bureaucrat or president may not have a very great probability of being in the same job when a sufficiently important event comes along. Therefore, he has an incentive to exploit the resource prematurely, since he is likely to care more about how his own performance looks than about how his successor or his successor's successor looks. The implication is that those who have control over the use of resources for a surprise should be rewarded for passing on a good inventory of undestroyed resources, as well as for the successful use of such resources.

3. Another implication of the need to be patient is that it is to be expected that many resources will "wither on the vine," as reflected in the discount rate over the many events that pass before a sufficiently important event occurs. The agony of waiting is well expressed by the man who helped run the double-cross system in Britain in World War II:

> It must be remembered that we had always looked forward to the day when we should take part in the great final deception which would pay ten times over for everything we had given out earlier. But no one can

[24] The way in which the distribution of stakes affects the optimal threshold is shown in Axelrod (fn. 18).

> maintain a bluff indefinitely; sooner or later a blunder or sheer mischance will inevitably give it away. How should we feel if the whole of the double-cross system collapsed before it had been put to the test in a grand deception?[25]

The willingness to accept this risk and to preserve the resources intact until D day was one of the reasons that the double-cross system was so successful.

4. Turning the perspective around, one can see that it would be a mistake to evaluate the opponent's resources for surprise by what you have seen when the stakes were low or moderate. He may be rationally waiting for an event with sufficiently large stakes to justify the exploitation of whatever resource for surprise he has. This point has very broad application. For example, in judging the reliability of a spy who may be controlled by the other side, it is not sufficient to note that the reports of the spy have been "usually reliable." Instead, it would be wise to take into account explicitly the relative stakes at each point in time. Thus, if the agent provided verifiable reports in situations with higher stakes than the current ones, this would be greater evidence for reliability than would a longer string of verifiable information in situations of uniformly low stakes.[26] The same principle applies to other resources for deception. For example, a rule of inference about the other side's behavior which has worked in a series of low-stake situations may not work when the stakes are greater, precisely because the other side may have been waiting to exploit a standard operating procedure as a resource for surprise.

5. This leads to the fundamental principle that when stakes get very large, a great deal of surprise can be expected. Indeed, this may be one of the primary reasons why nations so often are overconfident about their ability to predict the actions of their potential opponents. They simply do not fully take into account the fact that being able to predict when the stakes are low does not provide a good reason to believe that prediction will be good when the stakes are high. Thus, knowing that the other side is predictable when the stakes are low should not be very comforting. In order to avoid paranoia, one should have an estimate of how many resources for surprise the other side might plausibly have. The availability of resources for surprise aids an attacker, but it can also work against him. Knowing that when the stakes are large, his

[25] Masterman (fn. 1), 127.

[26] Once again it should be emphasized that stakes really need to be evaluated not only in terms of the overall importance of the current event, but also in terms of the relevance of the resource to the event. For example, the stakes for a resource involving tank operations will be low if the current event mainly involves aerial combat rather than armored combat.

opponent may also exploit his resources for surprise may have the net effect of increasing uncertainty. If so, it could help strengthen the stability of deterrence.

6. Just as one may expect surprise more when the stakes are high, there are occasions when one may expect surprise less. One is when the stakes are low—especially if they are low relative to anticipated future stakes. Another type of situation in which little surprise would be expected is after an event of very high stakes, such as the outbreak of a major war. Many resources for surprise may have been used, and those with a low survival rate cannot be used again. Therefore, less surprise from these would be expected after a very high-stake situation.[27]

7. The model constructed for the rational timing of surprise also has implications for the use of current information in the updating of prior beliefs. That is the task of Bayesian inference. A weatherman can use Bayesian statistics to update his estimates of how his indicators can be used to predict tomorrow's weather. A government can do the same in trying to predict the behavior of another government. However, in doing so, it would be wise to keep in mind that the patterns that provide the best predictions of behavior when the stakes are low do not necessarily provide the best predictions when the stakes are high—especially when the opponent is deliberately shaping his behavior in such a way as to mislead, and when high-stake situations are relatively rare. In principle, Bayesian estimation can take these factors into account. It is important that they be treated explicitly since, if they are not, the quality of predictions will be unexpectedly poor just when the stakes become relatively high. A recent report by a CIA analyst on the CIA's use of Bayesian inference for the assessment of political events provides no indication that this point is appreciated.[28]

8. Another implication is that, in making predictions when the stakes are high, one should try to use data that are unlikely to be a resource for surprise by the other side. Such data can take any of the following forms: (a) things that the other side cannot control, (b) things that the other side can control only with great expense, (c) things that the other side does not know are being observed, or (d) things

[27] An important but somewhat tangential point is that, in writing treaties, it is sometimes possible to shape the stages of the implementation so that the stakes are relatively uniform. There would then be no occasion in which one side would have an incentive to surprise the other by breaking the treaty. Treaties dealing with staged withdrawals are of this form, as are some types of staged arms-control agreements. The object in both cases is to design the sequence of events so that at no time do the stakes make it rational to exploit one's resources for surprise.

[28] Nicholas Schweitzer, "Bayesian Analysis for Intelligence: Some Focus on the Middle East." Paper presented at the International Studies Association Annual Convention, Toronto, February 1976.

that the other side is unlikely to realize can be used as indicators of its future behavior.

9. For those situations in which speed is of utmost importance—such as air defense—rules for the exploitation of surprise can be developed in advance. A good example is provided by the case of the Syrian SAM missiles which were ready to operate before the attack on Israel in October 1973. As we have seen, the Syrians did not use these SAMs during an air battle in September, thereby preserving an important resource for surprise. But what would the Syrians have done if the Israelis had launched a pre-emptive air strike against Syria hours before the Syrian attack was scheduled to begin? (A pre-emptive air strike was actually suggested to the Israeli Cabinet by the Chief of Staff, General Elazar, but was rejected.)[29] Such an attack might have come so quickly that it would have been impossible for the Syrians to change standing orders. Therefore, an optimal Syrian policy would have been to calculate the magnitude of an air attack that would justify the exploitation of their SAM missile system for the first time. This type of contingent rule could be calculated at leisure in peacetime and applied immediately when an event occurs that is specified by the decision rule.

10. A final, sobering policy implication is that, as observational technology improves, the potential for surprise and deception does not necessarily become less. If the rational timing of surprise is not well understood by the target of a deception, then the better the target can observe the other side's activities, the more readily it can be deceived when standard operating procedures are used as a resource for surprise. The more an unsophisticated side can observe, the more readily it can be deceived. The reason is simply that the more a side can observe, the more things can be presented as patterns of behavior in order to build up a false sense of confidence in the ability to predict. Thus, the presence of ever more sophisticated photographic and electronic reconnaissance devices may simply allow the observed side to obtain more and more resources for surprise. The resolution of this dilemma is not so much in the further improvement of observational technology as it is in the more sophisticated understanding of the proper way to draw inferences from observations. This understanding includes an appreciation of the ways in which resources for surprise can be exploited as a function of the stakes of the situation.

[29] Chaim Herzog, *The War of Atonement* (London: Weidenfeld and Nicolson 1975), 52f; Michael I. Handel, "Perception, Deception and Surprise: The Case of the Yom Kippur War," Hebrew University of Jerusalem, Jerusalem Papers on Peace Problems, No. 19 (1976), 38.