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ISSUES ARISING IN MANAGEMENT AND CONTROL OF NAVAL FORCES

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Many issues arise in the analysis of the technical problems of the command and control of naval forces that illuminate the importance of matching these problems with some basic questions concerning the political use and control of modern military forces. Since modern naval forces are among the more complex institutions in existence and play a central role in deterrence it is important that the naval role be considered in terms of the organizational, naval and political control problems which must be treated simultaneously.

Naval developments themselves must be considered in the context of the basic questions whose answers lie in the grey zone among organizational, technological naval doctrinal and national political considerations.The theories of deterrence as formulated by Herman Kahn, Thomas Schelling, and Albert Wohlstetter among others, and closely related doctrines of foreign policy and international relations as described in the writings of Henry Kissinger provide a context which must be explicitly accepted,rejected or modified in evaluating naval developments. Our interest therefore is on the influence of seapower on deterrence.

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The above question can be approached in two separate parts. Part I would examine evolutionary trends in the political and military command and control of navies. This is not dealt with here. Part II takes the context of political and military command as given and considers the fundamental question raised above, that is, of how a modern navy fits in with the usual conception of nuclear deterrence between the United States and the Soviet Union. We here summarize the major issues, questions, and conclusions from this research as they serve to provide the context for our observations on the relevance of and potential for operations research and decision sciences contributions to providing understanding and analysis for these critical and highly qualitative problems.

1. Forward Positioning

The need for credibility in crisis management situations often translates into naval deployments that emphasize a presence and visibility mission. U.S. Naval surface forces are often flooded into a particular geographic area with orders that effectively constrain their speed and dispersal abilities in order to emphasize their presence and visibility. However, deployments such as these can entail substantial risk, because they increase the vulnerability to attack, giving an enemy good intelligence on position and target density.

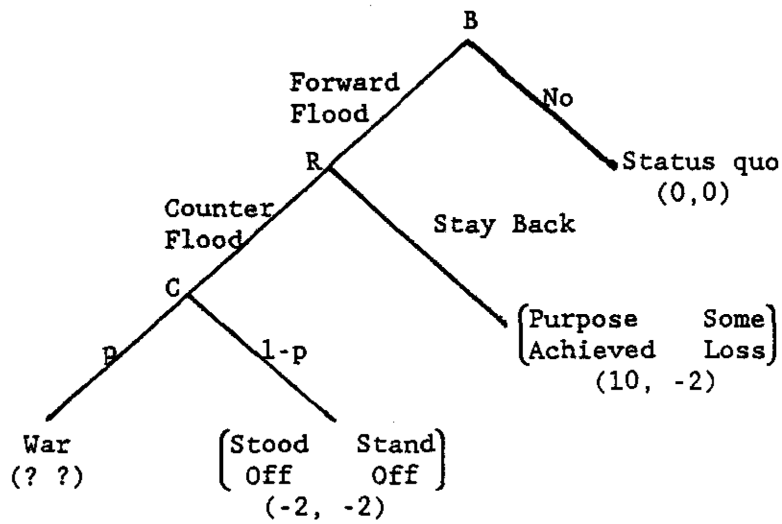
Apparently, political faith in deterrence is so great that this military risk is accepted in the belief that the danger it creates is dampened by political factors. Namely, the U.S. expectation is that the Soviet government would not easily release its own naval and air forces to attack the U.S. Navy when it is in such a vulnerable deployment. In effect, the judgement is made that although the military risks may be relatively high, the broader risks of escalation avoidance offset the military advantages of attack. There is also apparent belief that in a crisis situation the Soviet and American leadership will have tight control over their naval forces to forestall inadvertent actions that might precipitate a shooting exchange.

Modern wartime deployments of the superpower navies would emphasize dispersal of surface forces, and would involve greater stand-off ranges from enemy targets and danger zones on land. Instead of flooding surface platforms into a limited geographic area, forces would be separated and operated at high speed to escape detection. Moreover, command and control countermeasures would be taken, such as blinding of enemy ocean reconnaissance satellites and jamming of his COMINT and radar capabilities in order to prevent ascertaining of position information and coordination/relay of this between his sensors and weapons.

While the actions need not involve the firing of weapons (the usual definition of an act of war) many would increase the intensity of a crisis, thereby reinforcing the political power to coerce an enemy.

The elimination of a U.S. carrier battle group is not an easy task, for it does not represent a single target. A typical two carrier battle group formation might occupy some 56,000 square miles. With 9 AAW ships and two carriers this works out to a density of approximately one ship per 5000 square miles of ocean (Watkins,1986). When this force employs electronic emission control or jamming to negate enemy sensors, it increases the chance that missile strikes, at least with conventional weapons, will not find their targets accurately enough to destroy them. These parameters illustrate one of the significant changes that modern command and control developments have produced: naval forces may now operate in a highly dispersed manner compared to World Wars I and II. Geographic separation can be overcome through communication, coordination, and distributed information processing.

The structure of the forward positioning problem is such that it can be usefully cast as a two person nonzero sum game at its crudest level, the 2 by 2 matrix where Blue's two strategies are to either use a forward flooding as a display of force and intent or to refrain and Red has the choice to heed or ignore the demonstration. The specification of the payoffs is critical to the analysis. Yet even at the highest level of aggregation this is not clear as a simple example illustrates.



C stands for a move by chance.

Forward Flood, Counter Flood

Figure 1

Figure 1 shows a simple decision tree with Blue deciding first whether or not to forward flood. The terminal branches have two labels, one in words the other numerical. This is done to stress the fundamental difficulties that are faced in assessment and in attempts to go from context rich situations to abstract calculations based upon "playing the odds." Unfortunately decisions often must be made on evaluations of the odds; but the key problem is how these odds are evaluated and believed, much less the calculations made from them.

Referring to Figure 1. Suppose Blue decides not to forward flood. The end of the branch is labeled "status quo" and a numerical evaluation underneath suggests (0,0) or no gain to each side. But this has to be based on the context of what had happened before Blue had to decide whether or not to "show strength." If matters were at a level of business as usual, the label "status quo" and its evaluation as (0,0) might both be highly descriptive and valid in terms of costs and gains incurred. If, however Red had previously made an aggressive move elsewhere, the failure to show strength somewhere considered in the context of a Red display of force leaves neither an evaluation of (0,0) nor the status quo.

Suppose Blue has resorted to forward flooding and Red stays back. The situation may end with Blue viewing that its purpose has been achieved and the message has been delivered to Red. How do we "score" this outcome. The numbers (10,-2) have been hung on the payoffs to stand for Red loses a little in comparison to our failure to react and we gain somewhat. What are the units that these payoffs are measured in? They could be money, a menu of lost or tied up specific resources (two carrier groups, so many submarines etc...), brownie points, megadeaths, or a vague but highly meaningful multidimensional nonquantifiable bargained consensus emerging from interactions among the politicians, diplomats, the civilian and naval command and control ashore and the situation reports from those at sea.

Suppose that instead of staying back, Red had decided to counter flood. It is at this point that the analysis becomes murkier and the human aspects of command and control face new dimensions of difficulty. The next two branches in the game tree in Figure 1 are labelled as random events. They stand for the possibility that with two sets of forces engaged in showing the flag, a form of brinkmanship which might have suited the reaction times and potential lethality of unleashing the naval technology of 1886, does not necessarily apply to the risks and costs of 1986. Only the two extreme branches are suggested here. In one instance there is some probability p that the joint display of force produces a state of tension and error which escalates into unintended war. In the other instance there is a chance of (1-p) that the status quo is restored. This has been labelled as "standoff" and a payoff of (-2,-2) has been suggested to indicate that resources have been used by both sides in their efforts to signal firm resolve and counter resolve short of war. Under the scenario leading to war, instead of noting numbers two question marks appear. It is clearly here that the problem of assessment is at its most critical and least satisfactory.

Is there a lesson to be learned concerning the use of analytical methods for the type of problem described? We suggest yes. But although there is a need to continue to develop specific mathematical models and algorithms, there is an even greater need to concentrate on how to link the formal mathematics, game theory, control theory and network analysis with the realities of human expertise, experience and error which are manifested at the various levels of assessment driving the system. The problems faced by the United States scientific community appear to be simultaneously better and worse than those in the Soviet Union. As can be seen from books such as Concept, Algorithm, Decision (Druzhinin & Kontorov, 1972) and the activity in Soviet research in Cybernetics and Game Theory, considerable emphasis is laid upon the use of relatively abstract mathematical models for military purposes. But invariably missing from Soviet literature is a discussion of the fundamental evaluation problems which occur when a political commissar is seated next to each military commander.

In the United States there is apparently less open support for basic research on mathematical methods,[2] but a greater chance to raise fundamental questions concerning the dangers that exist in command and control systems when technological, naval, bureaucratic and political sources of influence and error must be considered simultaneously.

2. Problems in Lateral Coordination

The relatively greater difficulty of lateral coordination among naval forces in different functional groupings (e.g. submarines with surface forces) is likely to show up to an even greater degree in coordination of naval with land and air forces, and perhaps between naval forces and strategic forces.

In the 1973 Middle East War, for example, U.S. Naval forces were out of phase with the political and strategic aspects of the crisis. Of the tools open to political leaders, air, land, sea, and strategic forces have different rhythms and time constants. Naval forces west of Italy could not

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[2] For example the Soviet Union has a book on game theory for naval officers, (Suzdal, 1976), the U.S. has no equivalent service publication.

get to the Middle East in time to send a "signal" to Soviet leaders, consequently an alert of nuclear forces was undertaken that would generate signals that would certainly be picked up. The tendency in naval writings has been to concentrate on the naval aspects of the situation without regards for their interrelationship with other forces. Historically, this has been justified because there has usually been little possibility of closely integrating naval operations with land operations for example.[3] The use of couriers and telegraph lines could bring information on the land situation more rapidly than was possible in reporting ship movements to a central commander. However, greatly increased electromagnetic bandwidth between land and seas has changed this, so that intelligence agencies now watch naval movements for signs of political as well as military intent. Both Soviet and American navies have been reorganized in the post war period to be part of an overall national military command structure, although in the United States the Chief of Naval Operations still has important crisis management functions because of certain unique and complex aspects of operations at sea.

The Cuban missile crisis was managed out of the CNO's command facility, Flagplot. It seems plausible also that since naval forces so greatly depend on hiding their general locations from the enemy that information on sensitive fleet movements would be concentrated in naval command centers like Flagplot, with sharing to other groups on a need to know basis. Location of SSBNs is the best example of the need for maintenance of position uncertainty for security reasons, and so it is likely that this information is highly compartmented. The trend here is merely an illustration of the fundamental difference between land and sea forces: land forces are tied to a particular geographic location to a far greater extent than naval forces. The Seventh Army is confined to known sections of Germany, but the Seventh Fleet travels with its bases over thousands of miles of the Pacific.

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[3].Amphibious operations are a counterexample to this statement.

Some of the vexing problems involving both the technological and political aspects of vertical command and control have been illustrated in fiction form in the surprisingly widely popular novel The Hunt for Red October (Clancy,1984). Although this is fiction it raises a clear and fundamental question concerning the political and behavioral aspects of command and control and deterrence. It is hard to conceive of a Soviet ballistic submarine going to sea without a political officer on board. At least to the minds of some United States naval analysts the gain in deterrence in sending U.S. ballistic missile carrying submarines to sea without PALs or "political officers" more than offsets the dangers of the decentralization of command and control power of the firing of nuclear weapons.

At one level the problems of political loyalty and psychological stability appear to be far from mathematical analysis. Yet there are clearly several deep analytical problems involving decision networks of a few dozen individuals which are closely related both to reliability and the design of error correcting codes. If one assumes a given level of political unreliability (Lamport et al., 1982) or danger of breakdown or even error in perception by an individual then it is possible to well define the appropriate mathematical problems in the design of networks that can detect errors up to some specified level of probability.

It must be stressed that there are three types of reliability and error checking required in a human decision system as contrasted with the reliability of a machine. The first involves the straight failure or malfunction of a part of the system. For humans this can include laziness, foolishness, errors in perception and cognition and blunders in execution of a task. Each of these raises detailed problems in measurement and description. But even if it is possible to obtain an adequate probabilistic description of these sources of error a major logical and mathematical systems design problem remains highly related to the reliability design problems already noted as well as the investigation in distributed detection in C^3I systems (see for example, Lauer, Teneketzis, Castanon and Sandell 1982).

Human systems have two other sources of difficulty. Error may be generated internally by a dissident or traitor or by an individual who decides that his goals or perception of mission should override higher command. After the fact it may have been desirable that Nelson put his blind eye to the telescope, but before the event the desirability of a failure in command and communication is less clear.

The third source of error is the deliberate provision of misinformation or sabotage of lines of communication by an enemy. Both of these sources of error pose dynamic problems in game theoretic inference even if the psychological difficulties are left out. The subject of Agency Theory is devoted to considering incentive systems in situations where although there may be a considerable overlap in the goal orientation of most of the agents, the identity of interests is not complete. In particular a problem which is present not only in the naval and other military hierarchies but in virtually all large organizations with hierarchical structures is how to make sure that the incentive structure does not encourage too much risk aversion or place too high a penalty on nonconformist behavior. (Arrow, 1984 provides a survey.)

3. Ship to Shore Control

The movement of navies would be virtually unconstrained by external factors were it not for the growing dependence of navies on shore based information processing to locate the position and status of enemy forces, and for the need to be tied to the political leadership for response orders in a crisis situation.

Naval commanders are aware that their actions at sea could have an impact on the worldwide strategic situation, and they must be tied to their capitals for rules of engagement. In extreme, all naval platforms carrying nuclear weapons must be tied to shore for the release order for retaliation which can only originate in political centers. The growing ties to shore have come about in the last fifty years at an accelerating rate and represent a major departure from historical experience. They can hardly be expected to work smoothly in a fast moving naval engagement. The result is that tactical military efficiencies may be considerably dampened in combat, as one side waits for release orders or guidance that is either ambiguous, untimely, or never arrives at all.

Inefficiencies are relative in a competitive situation. Outcomes determined by weapons systems effectiveness may be greatly exaggerated by inefficiencies in exploiting advantages on account of tardy political release. Alternatively, great advantages might accrue to the fleet that is put on more of its own initiative by political leaders. These issues are further complicated by the expectations that build up over the years. Far from exploiting local opportunities to their fullest by military officers on the scene, as some caricatures of the military would lead one to believe, the military might be bred to be so risk averse that they would do nothing. During the Falklands War (See Hastings and Jenkins, 1983) the British submarine Conqueror that sank the Argentine battleship Belgrano may have procrastinated on orders from political leaders in London to torpedo that vessel. Apparently, they felt there must be a mistaken radio transmission to sink a lightly defended surface ship outside of the total exclusion zone (TEZ). They, of course, were unaware of the complicated strategic game being played out between London and in Buenos Aires, a game of escalation in which a major jump in the level of violence was seen in London as a necessary precondition for convincing the United States and others that this was a war, not a comic opera.

Until World War II it was more or less up to the captain of the ship or at most the admiral present in the fleet to assess the meaning and symbolism to be attached to carrying out a threat. A higher level of abstraction is now called for. And with the growth of better communication comes a lowering of the level of comprehension and understanding by the ship's immediate command. "Their's is not to reason why, Theirs is but to do and die."

Although the more formal and mathematical work is in its early stages and is by no means satisfactory, attempts have been made to study both the formation and plausibility of threats (Shubik 1959, 1964, Selten, 1974, Schelling, 1960, Roth, 1979) and the closely related problem of the formation of reputation (Wilson, 1984). The experimental work by Axelrod(1979) on the playing of the Prisoner's Dilemma and the effectiveness of the tit-for-tat strategy, as well as the Israeli's open policy of an eye for an eye, a tooth for a tooth in reprisals against terrorism point the way to the proposition that there may be some underlying principles governing the plausibility of threat which have not yet been fully formulated.

An important problem in hierarchical control, in game theory, social psychology and ethics concerns the concept of need to know. Without dealing with the more intangible social science and psychological aspects Shubik (1985) has suggested that there may be a fruitful area of mathematical application in formalizing the concept of perceptive commanders in control of less perceptive or at least less informed subordinates. A way to start to represent this is to consider that the payoff functions perceived by the subordinates contain fewer distinctive values than do those perceived by their commanders.

4. Transient Cascading Failures

The tight coupling introduced within a carrier battle group, a fleet, or an entire navy by having the whole wired together with real time global information systems could amplify the consequences of a local failure or mistake. Incorrect data, "facts,", or orders would no longer be confined to the local area where they originated, but would be transmitted fleet wide. Mistaken firing orders, or rules of engagement would cascade throughout the net, and would be difficult to check before the consequences were felt.

This problem must be addressed at several levels. They are forming a correct assessment of the nature and probability of human error and then taking this as a given and designing an operating system which minimizes the dangers caused by this error. From an applied mathematical point of view given the assessment of human fallibility and communications failure as data, the control of the fleet or the decision to change the alert level pose similar problems. They are network design problems calling for the appropriate redundancy to achieve a sufficiently high level of error correction.

The big "if" in the observation above comes in the adequate understanding and modeling of the interactions of specific man-machine systems failures (such as a carrier task force here and now) rather than from the elaboration of control theory or error correcting codes. Examples of some of the qualitative difficulties in interpretation at higher levels of command are provided by Bracken (1983) and Sagan (1985).

5. Maneuvering for Optimal First Strike Position

The peacetime/crisis transition involves prepositioning of naval assets, because the major technological consequence of modern weapons is that battle begins long before the first shot is fired. A jockeying for the optimal fleet disposition is much of what peacetime maneuvering is about, at least in terms of naval strategy. Submarines must be sent to chokepoints and to stand off of major enemy ports. Surface vessels must deploy to the GIUK gap area, minefields must be laid in critical zones, ships in port evacuated, etc. These operations are routinely practiced, at least in piecemeal fashion, as part of the standard operating procedures of wartime preparation. Preengagement positioning is an obscure and arcane subject for most political leaders.

The overall consequences for the United States of allowing our submarines to advance into the Barents and North Sea area and the Sea of Okhotsk, may be viewed by the public, not in terms of naval balance analysis but in terms of generating political signals. This may result in considerable exposure of naval assets if shooting does ultimately occur. For example, sending attack submarines into the sensitive waters near enemy areas must often be done at the outset of a crisis, or even continuously in peacetime. The reason is that enemy ASW forces will be laid down to block such advances. Mines may be sown, approach zones closely patrolled, and defensive forces fully generated. One outcome of this process is that attack submarines may be trapped in enemy waters, unable to easily exit once they have entered. This possibility could of course effect the political aspects of a crisis, especially if it turned out that the enemy had much better ASW abilities than were estimated in peacetime.

Two aspects of the structure of naval information systems seem especially important in this preengagement positioning. First, communication nets to some naval forces are periodic rather than continuous. Undersea forces especially achieve their effectiveness by reason of stealth. They listen to fleet broadcasts only periodically in order to avoid detection. If conditions warrant, they may skip even these prespecified listening periods. Only rarely will they originate transmissions. Even surface fleets may engage in prolonged periods of emission control (EMCON) to avoid detection by the enemy. This makes determination of location by shore based commands difficult. Naval communications are by their nature variable geometry networks. Nodes appear and disappear on some rough overall schedule, but oftentimes they stay invisible at random or for very long periods of time (as in the case of on station SSBNs). Secondly, the time compression of on board decisionmaking is so severe for cruise missile and other kinds of attack, especially when forces are hugging each other in a crisis deployment situation, that resort is made to automatic or near automatic command and control systems to engage enemy attacks.

Both the U.S. Navy Aegis and Close in Weapon System (CIWS) can be operated in fully automatic mode. The commander merely turns on the system and computers do the rest. Especially in close-in crisis deployments what this does is turn a sequential move game into a simultaneous move game. In other words, from the point of view of political control of an intense crisis that involves interacting naval forces (such as the 1973 Middle East War), the political command's "move" really amounts to advance specification of engagement rules. This has been seen in several instances. In the 1982 deployment of the 6th Fleet offshore from Lebanon the Defense Department expanded the perimeter around ships that were free fire zones. "If a Backfire comes within x miles of a unit, defensive fire is allowed." There is some latitude in individual interpretation of such guidelines.

Expectations matter greatly in crisis situations, and therefore a fundamental institutional transformation takes place between the peace/crisis and the crisis/war transition. In crisis there is central political control from the top, using the crisis management command system that bypasses much of the middle management within the Defense Department and the Navy. In war, decentralized control is the rule because it is impossible to run a naval campaign from Washington. Delays in release are fatal, the situation changes rapidly, and the volume of information from multi-fleet and multi theater contacts overloads even the expanded vertical integration channels built over the past several decades.

In the peace/crisis situation expectations are that the fear of escalation will restrain the enemy from launching the first strike against the fleet. However if the crisis escalates expectations arise that the forces will really have to go to war. At sea, there will be demands to break contact in order to gain distance from enemy missile boats, begin electronic interference with his communications circuits, neutralize his satellites, and closely hug his submarines so that when the shooting starts we will get in the first blow.

Notice some features of this situation. We are postulating a basic transformation that is as much institutional as it is psychological. Peace/Crisis to Crisis/War: Tight Central Control from Top is replaced by Decentralized Control. At the start information flows top down but this may turn to information coming from the Bottom Up. In the Peace/Crisis mode we may expect that the Military Commanders are highly Risk Averse. In the stage Crisis/War the Military Commanders will tend to be Mission Oriented.

In the early crisis military commanders will be biased toward actions that do not upset the delicate balance preserving the constraints on firing. This permits tight control from political commanders at the top. Indeed, there is likely to be even more risk aversion and conservatism displayed than is usual in peacetime. When war appears imminent however, a bias toward mission accomplishment, self preservation, and independent initiative must prevail unless it is known that timely orders from the top will be forthcoming.

Information flows will be bottom up, because military forces will report upward that they are being tracked by enemy fire control radars, that their communications are being jammed or interfered with, and that the enemy is undergoing unusually ominous changes in his pattern of electromagnetic emissions. The reason the German government in 1915 and 1916 had difficulty enforcing complicated rules of engagement on their submarine forces to avoid firing on American vessels was because the wartime environment served to decentralize command to the platform level. The interpretation of the multitude of parallel bottom-up information flows at various data fusion centers and intelligence posts may easily shape a malevolent interpretation of the situation, leading to worsened expectations up and down the chain of command. Increasingly aggressive preengagement positioning prepares each side for an improved strike posture. This is dampened by a tight political control that believes war between the two superpowers is unthinkable, so "unthinkable" in fact that it becomes safe to manipulate these risks and to accept increased exposures on a worldwide scale in order to impress the opponent that one is credible in one's deterrent strategy.

It is emphatically not the role of the systems analyst, control theorist or naval strategist to evaluate the political worth of various arrays of forward positioning. It is however of critical concern that the implications for systems control and battle control are spelled out so that those who evaluate political worth may be adequately briefed on the costs, not merely in terms of resources but naval exposure.

In systems terms the development of modern command and control, with distributed information processing and communication, permits a carrier battle group to increase its effectiveness as intergroup coordination and communication leads to the whole becoming far more than the individual sum of the platforms in the group. The notion of superadditive payoff describes this, where S and T represent a subset collection of ships in the group.

$$v(S) + v(T) < v(S \cup T)$$

Improved command and control also allows operation of the battle group in dispersed fashion, minimizing its vulnerability by increasing the difficulty for the enemy of making accurate up to date position fixes on the ships. Control technology is only one factor shaping fleet operation however. Political factors, such as the need to operate forward with presence and visibility, but without permission to jam and interfere with enemy sensors and communications, could operate to reconcentrate the carrier battle group, overriding the tactical desire to minimize vulnerability. Furthermore, advances in enemy weapon lethality increase fleet vulnerability, a vulnerability that is offset tactically by dispersion, jamming, and speed. The naval attrition function appears to have gone from a Lanchester square law in World Wars I and II to a form of pulse attack in which the first striker has advantages even larger than described in the Lanchester square law case (Hughes, 1985). Shubik and Weber (1979) offer a variant of the well known Colonel Blotto games in order to study the naval attrition or other network value problems.

The net consequence of the above trends can be summarized as follows. First strikes at sea with missiles and airplanes are becoming deadlier than ever before, even compared to the carrier battles at Midway. This vulnerability is decreased either by preemption (firing first), or by dispersion of targets and interference with enemy position/location sensors. Political control rules may rule out both options, either on the belief that the enemy will never strike first for fear of escalation, and/or that dispersion and interference defeat the mission of presence in a nonprovacative manner.

We view this problem to be simultaneously of considerable importance and one to which formal quantitative methods can be applied, but only with extreme circumspection. The use of mathematical, operations research, game theory or control theory methods is probably best served by utilizing the few senior professionals who have both qualitative understanding as well as professional ability as advisors to ad hoc assessment studies.

6. Nonserializable Control

Different military forces have different time constants associated with them. Flushing a fleet was faster than reinforcing ground forces. While different arms can be timed for coordination in an initial use (Axelrod, 1979) preserving intertemporal coordination of forces several steps into a crisis is likely to be far more difficult (witness the 1973 experience when the U.S. pulled the 6th Fleet too far West). The reporting delays of different systems, aperiodicity of submarines and surface vessels, and information processing delays will give a distorted picture of the world, mixing current and stale information in unknown degrees on a tracking screen at the national military command center that reports in turn to the political command center. Strategic uncertainties will reinforce the breakdown in phasing, as a nation's ability to predict enemy moves several steps ahead is demonstrably small. All of this means that the political top will not be able to place in serial chronological order what the enemy did, and what it is doing. Consider the Cuban crisis of 1962, when the Russians sent two notes to Kennedy, and both were out of synchronization with Soviet military activities. We still do not know the exact temporal ordering of the notes, nor which one was indeed valid. Our ability to comprehend events decreases when event orderings are mixed up by variable reporting and information processing delays. We may consider playing a repeated prisoner's dilemma in which the report of enemy moves had a random shuffle to the order of his moves. His cooperation was reported with a two move delay, or his defection was reported immediately only with certain (unknown) probabilities. The most familiar nonserializable system is one's bank checking account. Checks clear with different and unknown time delays, yet one must be careful to preserve liquidity and avoid the penalty of overdrafting. Military command and control reporting is similarly nonserializable for information sent to the top, something arising from the structure of the military institution. Attempts to interpret misordered information are only partly problems of cognition, because no degree of psychological prescience could overcome the misordering. A recent paper makes the convincing point that one consequence of increased reliance on distributed control systems is greater difficulty in imposing a temporal order on reported events (Lamport,L. 1978). Distributed control requires distributed data bases, and it is difficult to continually update multiple data bases.

Experience with simple experimental games indicates that even slight random events concerning the misreporting of moves appear to have a considerable influence on behavior. Shubik (1975) proposed experimentation on a 10x10 game to show how coordination could be disrupted by misreporting. Lags would introduce the same effects. A well known bureaucratic ploy is to allow on purpose a time lag to develop in answering correspondence, it can have considerable destabilizing influence.

Concluding Remarks

Where to from here? Dreyfus and Dreyfus (1986) in their perceptive book entitled Mind over Machine discuss the difficulties and the limitations of artifical intelligence. The expert systems are not quite as expert as their proponents believed they would be by this time. This does not mean that we should give up on increasing levels of computerization or interlinked networks of automated communication. It means that fruitful further research and development has to face up to overcoming the problems caused by the different perspectives of those concerned with the design of hardware, the machine aspects of a command and control system and those concerned with the man machine interfaces and with the understanding of human conflict.

We suggest that there is a fundamental role to be played by formal modeling, systems analysis, expert systems, operations research and the general imaginative use of applied mathematics. But the fundamental gaps between the models and reality must be appreciated with both the heart and head. Expert systems and game theoretic models are a long way from dominating experts and experience. Their role is to aid experts, to warn and to challenge the mindset that comes with experience, not to replace decision-making and risk evaluation which is always context relevant, by algorithms which are context free.

If we have an specific suggestion at all it is that we believe that formal context free models can be of great help only if all parties can use, interpret and discuss them in a context relevant discourse. This calls for a level of discussion and reflection that frequently exists among retired admirals and active scholars and researchers, but rarely exists among active flag rank officers and the modelers.

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