A NEW ANALYTIC TECHNIQUE FOR THE STUDY OF DETERRENCE, ESCALATION CONTROL, AND WAR TERMINATION

Paul K. Davis

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The Rand Corporation, 1700 Main Street, P.O. Box 2138, Santa Monica, CA 90406-2138
ABOUT THE AUTHOR

Dr. Paul Davis is the director of the Rand Corporation's Strategy Assessment Center. He holds a BS from the University of Michigan and a PhD in Chemical Physics from the Massachusetts Institute of Technology. Before joining Rand he was a senior executive in the Office of the Secretary of Defense, specializing in both nuclear and nonnuclear strategic planning. He had previously held positions in the U.S. Arms Control and Disarmament Agency and the Institute for Defense Analyses. Dr. Davis' research at Rand involves a combination of policy analysis, military strategy, and a large-scale effort to combine knowledge-based modeling and traditional simulation modeling in a global game-structured system for strategy analysis. Dr. Davis is also on the faculty of the Rand Graduate School of Policy Studies, and currently teaches a course entitled "Technology and Policy Analysis."
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I. INTRODUCTION

The study of deterrence, escalation control, and war termination (DEWT, for short) is important because the resulting concepts and mindsets affect the way nations think and operate—i.e., the way they formulate and analyze defense programs and political-military strategies in peacetime, and the way they develop and contemplate choices in time of crisis or conflict. This paper* is concerned with methods for improving the quality of thought and discussion on such matters. It describes a new analytic approach that uses modern techniques of artificial intelligence to reflect in computer programs many of the principal insights about decisionmaking developed over the last twenty years.

The principles involved in this approach should apply equally well to other policy-analysis problems in which it is important for analytic work to deal explicitly with the complications that so burden the lives of decisionmakers—complications such as conflicting principles and objectives, ill-defined alternatives, complexity, and pervasive uncertainty. If the approach is successful, which will depend on students of political science and other social science disciplines learning to work increasingly with interactive computer models, the implications could be far-reaching.

The discussion in this paper is structured as follows: The second section touches briefly on past DEWT studies and identifies some of their shortcomings. The third section describes some of the requirements that arise when one decides to build an analytic model to treat DEWT issues. The fourth section describes a modeling approach using examples from prototype computer programs. The fifth section then illustrates how the approach can change one's thinking and form of argument. Finally, the sixth section offers suggestions for workers interested in applying analogous techniques to other policy problems.

II. BACKGROUND

There exists a rich literature on deterrence and escalation control (less on war termination), and this paper assumes general familiarity with the classic efforts by Brodie, Schelling, Kahn, and Wohlstetter.¹

This literature has had a profound effect, so much so that many of its concepts have become part of the West's general culture and language. Examples here include: (1) escalation ladders; (2) escalation control as a form of bargaining with explicit or tacit thresholds; (3) the role of mathematical game theory in understanding dilemmas in crisis; (4) the role of scenarios in exploring alternative futures; and (5) mathematical models of crisis stability. All of these trace back to the late 1950s and 1960s.

As brilliant as the early efforts were, they have not proven to be as comprehensive or balanced as many had believed. Some of the more important shortcomings were:

- A failure adequately to treat asymmetries of mindset between West and East;²
- A failure to recognize adequately the extraordinary confusion faced by real-world decisionmakers who work within a maze of organizations to cope with problems that are only poorly understood--i.e., a failure to deal significantly with bounded rationality;³

¹See Brodie (1959), Schelling (1960), Schelling (1966), Kahn (1968), and Wohlstetter (1959). Iklé (1971) is a rare and thoughtful study of war termination problems. See also Smoke (1977), which reviews much of the literature before turning to case histories of escalation.
²Ermarth (1978) summarizes distinctions between Soviet and Western strategic concepts. Davis and Stan (1984) compares Soviet and Western concepts of escalation while attempting to walk the tightrope between overstatement and understatement. See also Trulock and Goure (1984) and, as an example of the Soviet literature discussing issues primarily by critiquing Western concepts, Arbatov (1980). Jervis (1976) discusses the role of perceptions in escalation processes.
³Standard references include Simon (1980), Simon (1982), Allison (1971), and Steinbruner (1974).
• An almost exclusive focus on offense-dominated strategic nuclear force postures; and, to varying degrees,
• The tendency to encourage trivialization in search of mathematically tractable or otherwise simplified problems, and the tendency to leave "rigorous" analysis to quantitatively oriented workers with inadequate sensitivity to issues of political science, psychology, and decisionmaking theory.

None of this should be construed as criticism of the original work. Indeed, it can be argued that the simplifications and idealizations made in that work were highly appropriate for setting universal structures and fundamental principles. The point, really, is that we are now in the 1980s rather than the 1960s, and any DEWT theory of the 1980s should deal with the above matters in some depth.

All of the shortcomings mentioned above have been recognized and discussed over the last fifteen years. In the author's view, however, much less has come of this work than might have been expected in view of its importance. Instead, it seems to the author that we find ourselves in a world of competing but nonconvergent essays. That is, we have no dearth of essays discussing strategic theory generally, asymmetries, organization theory, the implications of the strategic defense initiative, and so on, but what we do not have is an analytic framework for comparing views rigorously and moving toward conclusions—especially when the comparisons must cross the boundaries of different disciplines.

A basic problem here is the inadequacy of prose for comparative analysis of complex issues—the nature of the medium encourages authors to work with stereotypes or to lapse into heavily caveated and balanced discussions ("On the one hand...but on the other hand..."), which are often stimulating but which seldom lead to sharp conclusions or guidance on what to do. Essay-style arguments seldom leave the reader clear on

*In addition to the references mentioned above, see Adomeit (1982), which includes an interesting critique of various classical and neoclassical DEWT concepts before moving into an excellent empirical and theoretical discussion of Soviet risk-taking. Miller (1984) is a useful volume of reprinted 1970s articles on strategic theory.*
the realm of the arguments' validity, and it is not uncommon to find oneself frustrated by apparent agreement with two essays that are supposed to be in direct conflict with one another, but that to some extent pass each other in the night. By contrast, the power of the early work by Schelling, Kahn, and Wohlstetter was in no small measure due to its analytic character and associated specificity.

The standard prescription for improving rigor in complex problems is to develop analytic models—not vague models or taxonomies, but operational models with inputs and outputs, models that can help analysts reach conclusions for a particular context. A major thesis of this paper is that it is now possible to develop analytic DEWT models that can take into account the complications addressed above and that can also be used for convergent thinking—albeit, thinking plagued by unavoidable uncertainties and conflicts of principle. What follows, then, describes work by the author and colleagues in the Rand Strategy Assessment Center to develop such models.
III. CHALLENGES IN DESIGNING DEWT MODELS

GENERAL COMMENTS

Our development of DEWT models at Rand has focused largely on escalation (and on nonescalation due to deterrence). The remainder of the paper will be similarly focused, although much of what follows would apply equally well to war-termination studies.

At the outset of our work in 1982 we addressed the following questions: (1) What general type of model did we seek? (2) On what variables should the model depend? (3) What specific issues should the model be able to reflect? and (4) What technological approach should we take? Let us discuss each in turn.

MODEL TYPE

For a variety of reasons including the context of the larger research program of which this work was part,¹ we decided early that the models we sought would be rather unusual. Specifically:

- They would be computerized strategic-level decision models attempting to reflect the same type of thinking exhibited by policy-oriented players in serious human political-military war games.
- There would be separate models for Red and Blue, models that would attempt to reflect differences in mindset between the Soviet Union and the United States (there would be additional models representing various nonsuperpower countries).
- The decision models would exist as part of a larger game-structured simulation of global crisis and conflict, but could also be used autonomously so long as the analyst provided the same information that the models would have if they were imbedded in the full simulation.

¹See Davis and Winnefeld (1983) and Davis (1986) for descriptions of work in the Rand Strategy Assessment Center, much of it motivated and sponsored by the Director of Net Assessment in the Office of the Secretary of Defense.
• The decision models would be basically deterministic so that we could keep track of cause-effect relationships and perform sensitivity analyses.

This approach, then, would permit rigorous analysis, would deal explicitly with the problem of asymmetries, and would discourage trivialization by placing the escalation decision models in the midst of a political-military war-game structure. It also meant entering uncharted waters.

MODEL VARIABLES

The next question was to specify on what the decision models should base their "thinking." It is useful here to distinguish among the variables that a rational-analytic model might use under circumstances of perfect information, the variables that it might use under circumstances of imperfect information, and the additional variables that might affect real-world decisionmakers unable to be altogether "rational and analytic." Examples of each might be, respectively: the military advantage of escalating as calculated in a best-estimate assessment accounting for the opponent's likely response; the likelihood of an "unreasonable" response by the opponent; and the visceral fear of allowing the opponent to escalate first, independent of the objective consequences of having that happen.

It was with such distinctions in mind that we developed a list of factors that should be reflected in our models, factors that make it difficult to maintain conflict at a given level: 2

• Desire to win the war or at least achieve an acceptable outcome;
• Desire of leaders to avoid losing the war and, very likely, their legitimacy and place in history;

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2This discussion adapts and expands upon Glaser and Davis (1983).
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- The increase in perceived stakes as crisis or conflict continues;
- Objective instabilities at the level of force structure (i.e., instabilities that exist when it is strongly advantageous militarily to escalate first rather than to respond to the opponent's escalation, and instabilities that exist when one side can escalate to a level where the other side does not have an "appropriate" response);
- Misunderstandings and misperceptions—whether preconceived or the result of time pressures, stress, and/or inadequate information about tacit limits, the state of the world, or the opponent's will and intentions;
- Fatalism coupled with the view that fine-tuned rational analysis is inappropriate given the uncertainties and the assumed malevolence of the opponent;\(^3\)
- Physical communication problems exacerbating fears about one's own capabilities and making difficult any bargaining with the opponent; and
- Problems in maintaining control of one's own forces.\(^4\)

Although this list is by no means complete, it reminds us of the range of factors that must be considered and the impropriety of slipping into the easier mode of dealing only with neatly quantifiable technical issues.

\(^3\)There is a common reluctance to single out this factor—perhaps because of its arguably nonrational character—but it seems to capture the phenomenon in which a protagonist fights for all he is worth, without regard to limits and without necessarily believing that he will prevail, because "it is the thing to do."

\(^4\)See Bracken (1983) for a provocative discussion of many real and potential command-control problems, Steinbruner (1984) for discussion of how a launch-under-attack posture could lead to pressures for first strikes, and Slocome (1982) for an organized and insightful survey of strategic command-control issues by an ex-"insider."
SPECIFIC ISSUES AND CONSIDERATIONS TO BE ADDRESSED

Having developed a list of escalation-related factors with one style of thinking, we next attempted to supplement our "requirements list" by conducting human war games and more extensive mental games in which we would think through some relatively detailed scenarios. At the same time, we conducted a critical study of Soviet, U.S., and Western European concepts of escalation. This work led to additional conclusions affecting our model building.\(^5\)

- Decision rules must reflect essential qualitative features of context because escalatory behavior would probably depend upon aspects of history and the degree to which "other" events worldwide had created a truly threatening environment.
- Decision rules based solely on doctrinal behavior as inferred from military writings and exercise practices would be a poor basis for analysis, as would rules based solely on Western concepts and mirror-image thinking. Which would be worse would depend on the qualitative context.
- The model must recognize fundamental uncertainties--eschewing the approach of "best-estimate analysis" for an approach that highlights the plausibility of very different behavior patterns.
- The models must allow for at least two different sources of escalation: that in which the villain is circumstance, with matters "getting out of hand" by virtue of command and control problems, misunderstandings and the like; and that in which escalation occurs by virtue of a cold decision. It is noteworthy that history contains few examples of accidental wars.

TECHNOLOGICAL APPROACH

Ordinarily, one does not think of technological issues when deciding how to build a model. In the present case, however, technological approach affects the very nature of the models. We considered a variety of technical options but the author was particularly impressed by the possibilities suggested by then-recent Rand work on heuristic models of third-country decisionmaking using an English-like artificial intelligence language called ROSIE™. The heuristic rules constituting the model could be read and understood by people other than programmers, and it was possible to change the rules interactively. This seemed extremely important because the decision rules for any DEWT models would be both inherently uncertain and controversial.

Upon further thought, the author concluded that the DEWT models would have to be considerably more complex than the third-country models, that the logic of those models should be analytically structured, and that the programming language should make it easy to use structures akin to decision tables. All of these influenced the overall technological approach, which can best be appreciated by seeing examples from the operational program later in this paper. Although the approach has many features in common with other artificial intelligence work, including some expert systems, there are some important differences, including the merger of AI techniques with traditional simulation.7

6The first Rand work on third-country decisionmaking models was that of Dewar, Schwabe, and McNaugher (1982). Schwabe and Jamison (1982) and Shlapak et al. (1985) describe the second and third generations of that work.

7Davis (1986) describes the relationship of work in the Rand Strategy Assessment Center to other research on artificial intelligence models. It was written primarily for computer scientists. See also other papers in Elzas (1986).
IV. PROTOTYPE MODELS OF NATIONAL COMMAND LEVEL DECISIONMAKING

GENERAL COMMENTS

With this background of requirements, actual design of National Command Level models (NCL models) began in 1983 and extended into 1984. The principal design issues were: (1) establishing the generic character of the models; (2) developing a strategic framework within which to organize decision rules for situation assessment; (3) characterizing alternative NCL models representing different behavior patterns and strategies; and (4) implementing the ideas as a computer program with the technological characteristics described above. Each of these issues merits some discussion here. 1

DEFINING THE GENERIC CHARACTER OF NCL MODELS

Background Considerations

The purpose of the NCL models is to decide a general course of action--i.e., roughly, to pick a "strategy." Some of the possible approaches to strategy selection were (1) decision-analytic models seeking "optimal" solutions in the sense of maximizing a formal utility function; 2 (2) game-theoretic models combining the utility-function approach with mathematical game theory; 3 (3) bureaucratic politics models; 4 (4) organizational or so-called cybernetic models describing decisions of large organizations as relatively local adaptations to achieve predetermined goals; 5 (5) rule-based heuristic models consisting of plausible "If...Then" rules prescribing actions for diverse

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1 For details, see Davis, Bankes, and Kahan (1986).
2 See Raiffa (1970) and Keeney and Raiffa (1976).
3 See especially the recent Brams (1985), which contains many references to the classic game-theory literature as well as new work specifically relevant to DFWT issues.
4 See Allison (1971) and Steinbruner (1974).
situations; and (6) cognitive models focused on how decisionmakers receive and process information, and how they cope with the problems of bounded rationality.\(^7\)

Realistically, of course, there was significant overlap among these potential approaches and the approach we chose took elements from most of them. To develop our approach we first defined an ideal strategic decisionmaker, drawing on ideas found in the literature cited above as well as our own ideas on command and control issues.\(^8\) Figure 1 describes that idealized extrapolation of what real-world decisionmakers attempt to do. The depiction emphasizes the importance of having a broad view, looking for specially relevant information, and following up on initial decisions to assure implementation and to allow for feedback and adaptation.

The image conveyed by Fig. 1 is not the image of "goal-directed search" in the sense that phrase is used in the technical literature of artificial intelligence. That is, Fig. 1's ideal decisionmaker does not start out by saying: "This is what I want to do, this is how I will measure results, now go out and find me the optimal approach!" To the contrary, even an idealized decisionmaker often does not know what his choices are at the outset, much less his goals. Indeed, when he gets to the stage of making evaluations, he is beset by conflicting goals and values that he must somehow balance off against each other.

Having sketched out an ideal it was also important to bear in mind the human frailties we should be able to reflect in decision models. Figure 2 summarizes some of the typical shortcomings encountered in actual decisionmaking.\(^9\)

\(^6\)See Carbonell (1978), Schwabe and Jamison (1982), and the expert-system literature such as Hayes-Roth, Waterman, and Lenat (1983).

\(^7\)See Simon (1980), Simon (1982), Janis and Mann (1977), and Kahneman, Slovic, and Tversky (1982).

\(^8\)See Davis, Stan, and Bennett (1983). There has been considerable subsequent work on command-control issues by the author's colleague, Peter J.E. Stan.

\(^9\)See also Janis and Mann (1977) and George (1980).
Fig. 1 -- Depiction of an idealized human decisionmaker

The Basic Process Model for NCL Decisionmaking

With this background of idealized decisionmaking and representative flawed decisionmaking, Fig. 3 now describes the model we have actually adopted. Let us first discuss it on its own terms, after which we will discuss its relationships to Figs. 1 and 2.
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- Fail to delegate adequately or act quickly enough, thereby remaining "behind the power curve."
- React constantly to perceived threats or competition rather than insist on seeking the initiative (allow the opponent to make first use of chemical and nuclear weapons).
- Attempt incremental adaptation, even when the probable need for more drastic changes is recognized (continue with a failing strategy or even a failing war, constantly upping the ante).
- See the situation in terms of past personal experience or a particular historical event, even when the analogy is strained. (Exaggerate the likelihood of the opponent launching a first strike on the homeland because of sensitivity to the effects of surprise in the past wars.)
- Insist on masses of information of dubious quality and relevance; suffer effects of saturation.
- Overestimate (or underestimate) the significance of particular risks (preemptively surrender because of exaggerated fear that opponent will use nuclear weapons; or, engage in conventional aggression because of exaggerated confidence that opponent will not use nuclear weapons).
- Reject or ignore complex analyses that cannot be boiled down to a few key arguments.
- Ignore important subtleties of complex analyses.

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Fig. 2 -- Typical generic shortcomings in actual decisionmaking

The first point here is that we build alternative NCL models for both the Soviet Union and the United States, which we call Ivans and Sams. Each Ivan or Sam consists of rules organized as a decision process as Fig. 3 indicates. Each Ivan or Sam has its own temperament and grand strategy, although they use the same decision process with three main elements: situation assessment (establishing context, in the figure), tentative plan selection by heuristics, and plan testing. It is worth discussing each in turn.
The situation assessment consists of several subprocesses. First, the model examines the current situation and surrogates for a memory of history (e.g., knowledge of how the crisis began); it then uses the experience so far in the crisis or conflict to "learn"—i.e., to adjust its assumptions about the opponent, third countries, and the laws of war (e.g., best-estimate rates of advance for ground armies). It then uses the revised assumptions to make a projection of what will probably happen if the current course of action is continued.\textsuperscript{10}

\textsuperscript{10}The general problem of "learning" is extremely difficult, as is well recognized in the artificial intelligence literature. The learning we represent is the type made possible when someone knows what to look for and how to use the new information.
The notion of projections is interesting. In the real world, decisionmakers have staffs who think out the implications of possible courses of action suggested by the decisionmakers. In our work we have a look-ahead consisting of a game within a game in which a given NCL model projects the future using its own models of reality, which can well be wrong. These look-ahead projections, which require use of the full game-structured simulation, are a mechanism for detecting problems that would not be uncovered by first-order heuristic rules—although, in retrospect after a look-ahead simulation reveals problems, one can usually construct better heuristic rules that depend only on the current state. The look-aheads also enforce the need for a net assessment of the proposed action.

The selection of strategies proceeds through a sequence of intermediate decisions once the situation assessment is complete. In the full game-structured simulation, the permissible options ("analytic war plans") are inputs and the NCL model's problem is to pick one. This has the great advantage of allowing us to make complex and sensible strategies available to the NCL models rather than attempting to have them concoct realistic strategies from whole cloth—something far beyond the current state of the art in artificial intelligence except in simple problems.

As Fig. 3 indicates, the choice of plans is limited first by decisions about escalation, then about operational objectives, and finally about operational strategy. Once the NCL model has chosen an operational strategy, it has essentially chosen an analytic war plan. What remains is for it to tune the plan by setting controls—e.g., controls on rules of engagement, delegation, and use of nuclear weapons.

At this point, then, the NCL model has picked and refined a tentative plan. It then conducts look-ahead tests to see whether a plan chosen with heuristics will hold up under greater scrutiny. If not, the NCL will consider another plan instead. Note that the failure of a plan in a look-ahead test provides feedback, as the arrows in Fig. 3 suggest. The NCL model uses feedback information and examines alternative strategies, objectives, and escalation guidance (in that order) until it finds a plan that succeeds on look-ahead. How many
different strategies are tested before considering different objectives, and how many and which objectives are tested before considering different escalation levels, depend on the Ivan or Sam.

Relationships with Idealized and Less Competent Decisionmakers

At first glance, the NCL model differs strongly from the idealized decisionmaker of Fig. 1. The differences, however, relate to the technical issues of building an operational model and computer program rather than to the underlying concepts. We make explicit some actions that are implicit in Fig. 1 (e.g., situation assessment). And, for the reasons mentioned above, we develop the NCL model's options (analytic war plans) separately so that in the running of our model they are inputs rather than outputs. Nonetheless, although our representations of decisionmaking are different, the NCL models incorporate features of the idealized decisionmaker such as consideration of multiple options, search for new information, reassessment, and use of heuristic rules in coping with conflicting goals. At the same time, a particular Ivan or Sam can represent an altogether incompetent decisionmaker: the heuristic rules can be simple or sophisticated, the plans taken seriously by the model can be few or large in number, the plans themselves can vary greatly, and the tests used on tentatively chosen plans can be simple or complex (indeed, tests can be made on alternative plans before the choice is made). And, finally, the quality of the information available to the NCL models can be high or low.

SITUATION ASSESSMENT

Consistent with the desire to have the NCL model think like an enlightened strategic-level decisionmaker, our approach emphasizes a hierarchical situation assessment built around natural qualitative characterizations.

The image motivating our prototype models has the NCL focusing on three fundamental aspects of the situation: status, prospects, and risk. The image is of a decisionmaker who, having been deluged with information in the form of briefings, memoranda, personal advisories, and so on, sums matters up as follows:
Fig. 4 -- Hierarchical determinants of status

By and large, we have not found it useful to work with stereotyped models of Soviet and U.S. behavior but have instead attempted to develop characterizations that are relatively complex. To develop a characterization we use a six-step methodology to sharpen and refine our image of a particular Ivan or Sam before writing the first decision rule. The steps are as follows:

1. **Limit the problem domain** to some class of scenarios, however large;
2. Develop a **prose description** of the Ivan or Sam;
3. Fill out a **temperament check list** that characterizes Ivan or Sam in terms of formal attributes of the agent's political, attitudinal, and perceptual personality;
Well, gentlemen, if I understand what you have been telling me these last few hours--and if I try to patch together some of the pieces that came out one at a time in our meeting--then it seems that our current status is pretty good--we have achieved our principal objectives, although not everything we had hoped for. We could push on, but prospects for further progress appear only marginal and there are big risks. If that is all correct, then I conclude we should begin to consolidate our gains and wind down our actions. Do you agree?

The high-level concepts such as status can be quite complex. For example, they can involve not only objective factors such as military gains, but also subjective factors such as political perceptions of victory. Figure 4 illustrates how "status" can be determined by a hierarchy of lower-level variables defined as follows (similar hierarchies would apply to prospects and risks): (1) Main-theater status summarizes overall progress in the main theaters of action; (2) Other status is a composite assessment of how things stand "elsewhere" than in the main theaters (e.g., are they worse than expected?); (3) Opportunity is a measure of whether one should raise objectives (is there a vacuum somewhere, or have the correlations of force changed dramatically?); and (4) Warning means what it suggests. The variables on the far right of this figure are the ones that can be observed objectively in the simulation or in the real world; those to the left are increasingly abstractions that depend upon values, judgments, and perceptions.

Although many Ivans and Sams could use the same hierarchical decomposition of variables, they would evaluate the variables differently.

CHARACTERIZING ALTERNATIVE NCL MODELS

Our approach to NCL modeling depends on the notion of alternative models of the United States and Soviet Union (Sams and Ivans, respectively), models embodying different grand strategies, value structures, and behavior patterns generally. This requires us to develop meaningful characterizations to create a coherent image in the mind of the rule-writing analyst and serve as the basis for explaining a given NCL model's behavior.
4. Construct a series of notional grand-strategy decision trees representing graphically how the Ivan or Sam might look at the current strategic situation and his likely downstream decision points (different trees must be constructed for a variety of plausible circumstances);

5. Fill out a transition matrix indicating the most likely escalations and de-escalations that would be entertained by the given Ivan or Sam; and

6. Establish some summary guiding principles.

It is inappropriate to go through all of these in the present paper, but some flavor for the results can be provided here by quoting the prose description for what we call "Ivan K":

Ivan K is neither simplemindedly doctrinal nor softheadedly optimistic. He tends to be somewhat aggressive, risk-taking, and contemptuous of the United States, but is ambivalent about the latter, believing that the United States and NATO, if provoked to war, would tend to become aggressive and irrational. Ivan K is "very Russian" in his belief that basic Soviet military doctrine is essentially correct, although not always applicable. He is strongly averse to nuclear war. While he would be loathe to instigate a general nuclear war, he believes that any war with the West might well escalate and that the Soviet Union could survive and, in some sense, "prevail."

[The description proceeds for several paragraphs, which touch upon Ivan K's attitudes toward expansionism in Southwest Asia, war in Europe, and avoidance of nuclear war.]

Finally, although Ivan K does not seek general nuclear war, he would not shrink from one once he believed it inevitable. Should he find himself in a war that he believed the West to have started in an attempt to dissolve the Soviet empire, or if he found himself in a war in which the West seemed to have taken on such ambitions, he might well set a grand strategy with the objective of the effective destruction of the United States as a world power. In such a case, he might be willing to escalate even to general nuclear war and, if he made that decision, he would seek opportunities for surprise and decisive initial action.
The astute reader may have noted that while he was picking up the flavor of Ivan K's temperament, the prose description was a long way from specific decision rules; hence, the need for the other steps mentioned above.

PROTOTYPE COMPUTER PROGRAMS

We have used the methodology discussed above to develop prototype NCL programs and are now working on more advanced versions. Figure 5 provides a flow chart of the prototype program structure, one independent of Ivan or Sam. The left-hand column identifies major program modules required by the basic process model given in Fig. 3. Note also that situation assessment depends on a series of processes corresponding to the first two levels of variables in Fig. 4. Processes such as Assess Warning on the right side decompose, as Fig. 4 suggests, into subordinate processes dealing separately with tactical warning of various types, strategic warning of various types, and so on.

To gain some insight into what it is like to work with these programs, let us consider briefly two illustrative sets of rules. Except for the titles, what follows is computer code written in the Rand-Abel programing language:¹¹

Assessing Risks

If Current-situation >= Eur-gen-tac-nuc
Then
{
  If Warning-of-escalation > Eur-nuc and
  (the report from price-of-going-second-IC > 50.0[%] or
  Disarming-capability is high)
  Then Let Risks be high.
  Else ...[omitted for brevity]
}

¹¹See Shapiro, Hall, Anderson, and LaCasse, 1985a and 1985b.
Fig. 5 -- Flow chart for prototype NCL programs
As the reader may guess from the first line, an escalation ladder of conflict levels is used to make first-order characterizations; within a given level of conflict, however, the assessment of Risks depends on a number of considerations. The phrase "report from price-of-going-second-IC" indicates that the program is performing a subordinate calculation measuring how much worse the consequences of a nuclear exchange would be if the opponent goes first. That is, imbedded within a complex rule-based model dependent primarily on qualitative considerations (e.g., Is there warning of escalation?), we find a traditional quantitative calculation of the sort dear to the hearts of strategic analysts.

The next example of program code illustrates an important and unique feature of the Rand-Abel language. Although what follows looks like what one might work out on a scratch pad as a decision table, it is executable computer code. To understand it one needs to know a few conventions of Rand-Abel: (1) items between brackets [...] are "comments" in the computer code; (2) hyphenated phrases are, in fact, variable names; (3) the symbol "/" separates the independent and dependent variables of the decision table; and "--" as an entry in the table means "don't care." This table, then, applies to a model called Ivan K that is re-evaluating his opponent on the basis of current information in the conflict. He has six different characterizations (Blue 1, ...Blue 6). The first line of the table is equivalent to the rule: IF the Current-situation is Eur-gen-conv (i.e., general conventional war in Europe), and IF there is no warning of escalation, and IF it has been a long time since D Day (the comment tells us that "long" means more than ten days), THEN--independent of the previous assumptions about the opponent--Ivan K will do best-estimate look-aheads assuming a Blue 1 behavior pattern for his opponent.

The decision table feature of Rand-Abel is especially valuable for rule-based programs because the rules can be reviewed and modified easily, even by someone who is at best a weak programmer--if he is a subject-area specialist familiar with the concepts and abbreviations.
Decision Table

<table>
<thead>
<tr>
<th>Current-situation</th>
<th>Warning-of-escalation</th>
<th>Time-since-D(Eur)</th>
<th>Presumed-opponent</th>
<th>Presumed-opponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eur-gen-conv</td>
<td>None</td>
<td>long</td>
<td>--</td>
<td>Blue 1</td>
</tr>
<tr>
<td>Eur-gen-conv</td>
<td>None</td>
<td>short</td>
<td>--</td>
<td>Presumed-opponent</td>
</tr>
<tr>
<td>Eur-gen-conv</td>
<td>Eur-nuc</td>
<td>--</td>
<td>Blue 1</td>
<td>Blue 3</td>
</tr>
<tr>
<td>Eur-gen-conv</td>
<td>Eur-nuc</td>
<td>--</td>
<td>&gt;Blue 1</td>
<td>Presumed-opponent</td>
</tr>
</tbody>
</table>

[long means greater than 10 days]

[the last rule reflects the nonpragmatic aspect of the case; hence, Blue is not Blue 5 and Ivan K now assumes the worst-case Blue 6]

The format makes it easy to follow the logic flow and to check that all the logical combinations are present. And, for the rule-writer, the pressure to use decision tables encourages tighter thinking: What are the key variables? How many do I really need? and so on. Readers familiar with typical artificial intelligence programs in LISP or other languages will appreciate these features.

Although "explanation facilities" are beyond the scope of this paper, it is worth noting that the table structure makes it especially easy to have the program automatically generate a first-order explanation of its logic. In a given run of the program, only a single line of the table will "fire," and the program can then write out a long-form version of that rule: If ...and...and...and... Then... We can also append what appear to be footnotes to each line of the table; these are comments about the analyst's rationale, which can also be automatically generated.
Consistent with the desire to make the NCL models an appendage of the analyst—i.e., a mechanism for extending and refining his thinking during a concentration cycle—the models can be operated in a standalone mode in which the information that would ordinarily be coming from the other elements of the full game-structured simulation are instead provided interactively by the analyst as data. The analyst can create a world state, run the model, see what the NCL model decided to do, look at the model's explanation of its own reasoning, change the world state, and repeat the process. He can also review the rules, and in most instances he can make corrections by mere editing if the first-draft version of the rules was basically sound. All of this can be accomplished rather efficiently even now (April 1986), but it will become much more efficient soon because Rand-Abel is being given interpretive features. When that occurs, an entire cycle of testing, review, editing, and testing may be possible within a few minutes—including "thinking time"—something that will make model development a true example of man-machine interactions comparable to spread-sheet programming in its cognitive effectiveness.

In summary, then, prototype NCL models exist and operate. Although they would not withstand unfriendly detailed scrutiny, they do successfully implement the various ideas sketched out in this paper. Moreover, even at the present stage of development the variables they consider are, to a large extent, the variables that policy-oriented humans concern themselves with in human war games focused on issues of escalation. Furthermore, the models perform reasonably over a rather large class of scenarios, provide explanation capabilities, and can be readily reviewed and modified. Developing them has been very instructive.
V. IMPLICATIONS FOR THINKING ABOUT DEWT ISSUES

This is not the place to analyze specific strategic issues, but it is appropriate to provide some sense for what can be learned from building and using NCL models of the sort discussed here. To accomplish this, let us consider briefly two issues and the effects that methodology can have on one's approach to them.

PREDICTING SOVIET ESCALATORY BEHAVIOR IN A EUROPEAN CONFLICT

In the 1970s Americans came to have a much better appreciation than previously of Soviet military doctrine. Much of the education was sobering, to say the least, because that doctrine was so starkly different from our own. One summary of Soviet doctrinal tenets goes as follows:¹

(1) The best deterrent is an effective warfighting capability, (2) victory is possible (or at least to be pursued vigorously even if the "winner" will suffer horrible losses), (3) it pays to strike first, (4) restraint is foolhardy, and (5) numbers matter.

By contrast, it can be argued that the prevailing view of the Western allies regarding escalation goes something like this:

(1) Ultimately, the best deterrent of large-scale Soviet aggression against Western Europe or the United States is the threat of a massive strategic nuclear attack (with flexible-response options dealing with lower-level threats, improving credibility, and providing opportunities to reestablish the ultimate deterrent should conflict begin), (2) the concepts of military campaigns and victory are meaningless in general nuclear war, (3) even preparing the capability for an offensive campaign (even counteroffensives) would be destabilizing and is therefore to be avoided, (4) restraint in a NATO-Pact war would be essential (i.e., escalate incrementally if at all) because the alternative to restraint

¹This draws on Lambeth (1981). For a more extensive discussion of Soviet, American, and Western-European views of escalation, see Davis and Stan (1984). See also Ermarth (1978).
should deterrence begin to fail would be the assurance of
total war, and (5) numbers are far less important in the
nuclear era than they once were--so long as assured
retaliation is indeed assured and we are able to preclude an
easy Soviet conventional victory.

In this image, then, NATO forces conducting a defense of Western
Europe would be inclined to begin conventionally, to use a small number
of nuclear weapons in a demonstrative strike should the conventional
defenses begin to fail, and to raise the "demonstration level" further
as necessary to reestablish deterrence. Obviously, those subscribing to
this classic NATO doctrine cannot possibly believe that the Soviets will
behave in accordance with the doctrinal tenets mentioned above. Who is
right?

No one can know with certainty how the superpowers would behave in
a large-scale war. However, in developing formal NCL models of the sort
described in this paper, one discovers that some of the apparent
contradictions disappear by virtue of the models' specificity about
context. For example, a single model of the Soviet Union can exhibit
the following behaviors:

• In contexts in which NATO has invaded the Warsaw Pact and the
  Soviet Union sees itself in the ultimate showdown between the
  socialist and capitalist worlds (the scenario underlying most
  Soviet doctrinal writing), the Ivan will follow doctrinal
  tenets--and will even initiate nuclear war if that seems
  necessary.
• However, in contexts in which, for example, the war began with
  a Soviet conventional invasion after secret negotiations
  between the two Germanys, and in which the Soviet invasion was
  predicated upon an analysis that occupation of Western Germany
  could be accomplished quickly, conventionally, and with little
  risk of U.S. nuclear use, the same Ivan might revert to a
  "bargaining behavior" in preference to a pure "warfighting
  behavior" should NATO prove cohesive and successful in
  thwarting the conventional campaign.
More generally, the Ivan's decisions about nuclear use in a European conflict would be sensitive to: (1) the origins of war, (2) tactical warning of NATO preparations for nuclear use, (3) assessment of U.S., UK, and French willingness to use nuclear weapons, (4) the net effect militarily in the theater of both sides using nuclear weapons, and (5) the likelihood of general nuclear war involving the homelands if nuclear war begins in Europe. It would not be especially sensitive to the detailed outcome of general nuclear war because this Ivan considers it obvious that any such war would be so catastrophic that calculations are unnecessary. On the other hand, should such a war appear virtually certain, then preemption would be essential.

Interestingly enough, many specialists who stress the Soviets' warfighting emphasis discount utterly the likelihood of any European war in which the Soviets had not concluded that the final showdown were at hand. They argue that the Soviets simply would not invade Europe unless the stakes were extremely high. If they are correct, then much of the analysis is moot since the likelihood and feasibility of a NATO invasion of the Warsaw Pact is virtually zero. The point, however, is that those arguing about what the Soviets would or would not do are often arguing implicitly about scenario, and the methodology of NCL modeling brings this out clearly. One need not choose between accepting or rejecting the doctrinal tenets of Soviet military thinking; instead, one can say that "it depends on context."

CRISIS STABILITY

For more than fifteen years one of the most popular subjects for nuclear strategists has been the ICBM exchange calculation in which it is assumed that the Soviet Union attacks the vulnerable portions of the U.S. strategic forces (ICBMs and nonalert bombers and submarines) and the United States responds in kind,\(^2\) or vice versa. This calculation is

\(^2\)See, for example, Nitze (1976), the influential article in which Nitze argued that the United States might not be able or willing to retaliate after a Soviet counterforce strike.
often asserted to be a measure of crisis stability. According to this view, if one side performs the calculations and notes that there is a high price for going second instead of first—e.g., if the postexchange ratio of nuclear weapons would be much worse after going second rather than first—then it might feel compelled to go first.

Let us next ask what might be expected from human players in political-military war games, and from NCL models attempting to mimic such behavior. Although a range of behaviors is plausible, necessitating alternative models, a few conclusions tend to emerge as soon as one attempts to develop serious models:

The decision to launch a first strike should not be uniquely sensitive to the "price of going second" as defined above, but should instead be sensitive to: (1) tactical warning of an opponent's first strike, (2) the absolute level of capability each side would have after the various attacks or exchanges—i.e., the absolute capability to execute various short-term and continuing operations against the other side's forces (and urban-industrial complex), (3) the assessment of the opponent's will and intentions, and (4) a number of command-control issues such as the capability to launch under attack, the assured survival of key leadership, the assured survival of communications necessary for retaliation, and the ability to maintain control over forces generally.

Once again, then, the discipline of having to identify key variables and the freedom to deal with qualitative issues as well as those amenable to numerical calculations leads one down a very different path than the canonical path of strategic nuclear analysis. While none of these considerations are new or unique, the framework of an NCL model highlights them and makes it difficult to sweep them under the proverbial rug once they have been mentioned. It certainly can change the priority one attaches to various enhancements of strategic capability. All this, it seems to the author, is highly salutary.
VI. SUGGESTIONS AND SPECULATIONS

The principal thesis of this paper has been that the process of building decisionmaking models sensitive to the same variables as real-world policymakers has much to recommend it in principle, and is now feasible by virtue of technological and conceptual advancements of the last decade. The act of building models provides a rigorous mechanism for honing arguments that otherwise would remain fuzzy and ambiguous. By analyzing alternative models it should be possible for people of different persuasions to narrow the realm of disagreement because the process of defining context eliminates many disagreements. Also, by developing alternative models, it should be possible to capture and recover as needed some of the best human reasoning available. This could obviously be valuable for educational purposes.

For workers contemplating the use in other policy domains of models analogous to those discussed here, there are some suggestions resulting from our work to date. First, the author would urge workers to approach problems on their own terms rather than as opportunities to use the new tools of computer science. One of the principal lessons from past applications of artificial intelligence, especially expert-system work, is that one should not expect to find general solutions--instead, successful problem solving depends on exploiting the special characteristics of the particular problem domain. That means that the key to success is the subject-area specialist, not a roving computer scientist with only passing interest in the problem.

A second recommendation is that workers take seriously the image of close man-machine operations in model development. This is especially appropriate on problems involving rule-based models rather than pure algorithmic techniques where it is feasible to separate the role of the analyst and programmer. There is real value in having the specialist be able to review and amend the program itself, something possible in most cases only if the program is highly structured in terms appropriate to the subject area and expressed in a transparent programming language. Rand-Abel has advantages in this regard, but there are many other options available as well.
Finally, the author would strongly recommend more widespread efforts to combine knowledge-based modeling with traditional simulation, and to employ game-structured techniques whenever action-reaction phenomena are especially important, as they often are in policy work. It is possible that such analytic systems will come to have a profound effect on education, staffing, and even the design of decision aids for policymakers and their staffs in the years to come.
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