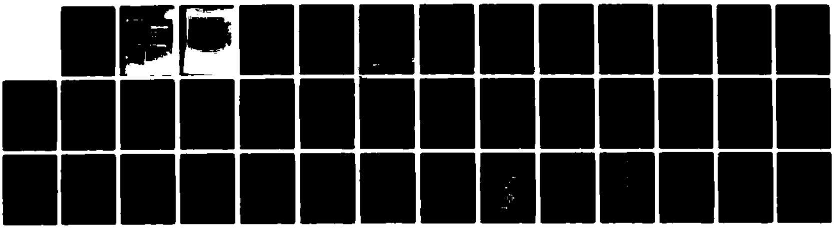
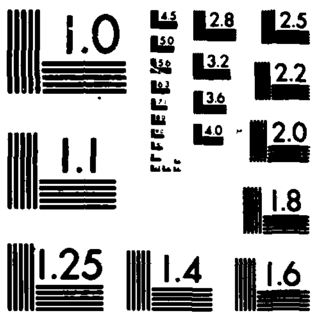
AD-A137 563 AUTOMATED WAR GAMING AS A TECHNIQUE FOR EXPLORING STRATEGIC COMMAND AND CONTROL ISSUES(U) RAND CORP SANTA MONICA CA P K DAVIS ET AL. NOV 83 RAND/ N-2044-NA 1/1

UNCLASSIFIED DNA001-80-C-0298 F/G 17/2 NL



END
DATE
FILMED
3-84
DTIC


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER: N-2044-NA | 2. GOVT ACCESSION NO.: AD-A137563 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle): Automated War Gaming as a Technique for Exploring Strategic Command and Control Issues | 5. TYPE OF REPORT & PERIOD COVERED: Interim |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s): Paul K. Davis, Peter J.E. Stan, Bruce Bennett | 8. CONTRACT OR GRANT NUMBER(s): DNA001-80-C-0298 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: The Rand Corporation, 1700 Main Street, Santa Monica, CA. 90406 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: Director of Net Assessment, Office of the Secretary of Defense, Washington, D.C. 20301 | 12. REPORT DATE: November 1983 |
| | 13. NUMBER OF PAGES: 28 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 15. SECURITY CLASS. (of this report): UNCLASSIFIED |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

No restrictions

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

War Games
Command and Control Systems
C3I

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

This ~~Note~~ [document] describes a preliminary concept for including strategic command and control effects within the automated war gaming of Rand's Strategy Assessment Center (RSAC). The concept features: a top-down functionally oriented approach relevant to the interests of civilian and military leaders; a hierarchical and otherwise multilevel gaming structure; and heuristic rule-based models using a variety of artificial intelligence techniques. The approach will be sensitive to key features of war plans and control procedures. It will make a start on reflecting such phenomena as nonunitary decisionmaking, deception, and confusion. It will take into account some of the asymmetries distinguishing the U.S. and Soviet approach to ~~C3I~~ [command control communications and intelligence]. Initial versions of the implemented concept should be useful and interesting but will be relatively simple; with time, it should be possible to evolve gracefully and use some of the detailed models available on pieces of the overall C3I problems.

Accession For
NTIS GRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification

By
Distribution/
Availability Codes

| Dist | Avail and/or Special |
|---|---|
| A/1 | |

# A RAND NOTE

AUTOMATED WAR GAMING AS A TECHNIQUE FOR EXPLORING STRATEGIC COMMAND AND CONTROL ISSUES

Paul K. Davis, Peter J. E. Stan,
Bruce W. Bennett

November 1983

N-2044-NA

Prepared for

The Director of Net Assessment,
Office of the Secretary of Defense



35th Year

Rand
SANTA MONICA, CA. 90406

## PREFACE

This Note presents an elaboration of a speech given at a Massachusetts Institute of Technology/Office of Naval Research symposium at which the authors discussed a preliminary concept for exploring command and control issues with automated war gaming. It draws on work being conducted for the Director of Net Assessment, in the Office of the Secretary of Defense, through Defense Nuclear Agency Contract No. DNA001-80-C-0298. Comments are welcome to any of the authors, including Paul K. Davis, Director of the Rand Strategy Assessment Center.

## SUMMARY

This Note describes a preliminary concept for including strategic command and control effects within the automated war gaming of Rand's Strategy Assessment Center (RSAC). The concept features: a top-down functionally oriented approach relevant to the interests of civilian and military leaders; a hierarchical and otherwise multilevel gaming structure; and heuristic rule-based models using a variety of artificial intelligence techniques. The approach will be sensitive to key features of war plans and control procedures. It will make a *start* on reflecting such phenomena as nonunitary decisionmaking, deception, and confusion. It will take into account some of the asymmetries distinguishing the U.S. and Soviet approaches to $C^3I$. Initial versions of the implemented concept should be useful and interesting but will be relatively simple; with time, it should be possible to evolve gracefully and use some of the detailed models available on pieces of the overall $C^3I$ problem. Even the early work, however, will represent a major break with past strategic analysis in which $C^3I$ issues have been largely ignored but for limited treatment of communications.

## ACKNOWLEDGMENTS

The authors wish to express appreciation for the consultation of Joachim E. Scholz on many aspects of the strategic command and control problem, as well as for a thoughtful review by Carl H. Builder.

# CONTENTS

## FIGURES

@@ @@ A137563 (U) FIELD/GROUP @@@@@@

UNCLASSIFIED TITLE

AUTOMATED WAR GAMING AS A TECHNIQUE FOR EXPLORING STRATEGIC COMMAND AND CONTROL ISSUES.

ABSTRACT

(U) THIS DOCUMENT DESCRIBES A PRELIMINARY CONCEPT FOR INCLUDING STRATEGIC COMMAND AND CONTROL EFFECTS WITHIN THE AUTOMATED WAR GAMING OF RAND'S STRATEGY ASSESSMENT CENTER. THE CONCEPT FEATURES: A TOP-DOWN FUNCTIONALLY ORIENTED APROACH RELEVANT TO THE INTERESTS OF CIVILIAN AND MILITARY LEADERS; A HIERARCHICAL AND OTHERWISE MULTILEVEL GAMING STRUCTURE; AND HEURISTIC RULE-BASED MODELS USING A VARIETY OF ARTIFICIAL INTELLIGENCE TECHNIQUES. THE APPROACH WILL BE SENSITIVE TO KEY FEATURES OF WAR PLANS AND CONTROL PROCEDURES. IT WILL MAKE A START ON REFLECTING SUCH PHENOMENA AS NONUNITARY DECISIONMAKING, DECEPTION, AND CONFUSION. IT WILL TAKE INTO ACCOUNT SOME OF THE ASYMMETRIES DISTINGUISHING THE U.S. AND THE SOVIET APPROACH TO COMMAND CONTROL AND COMMUNICATIONS (C3I). INITIAL VERSIONS OF THE IMPLEMENTED CONCEPT SHOULD BE USEFUL AND INTERESTING BUT WILL BE RELATIVELY SIMPLE; WITH TIME, IT SHOULD BE POSSIBLE TO EVOLVE GRACEFULLY AND USE SOME OF THE DETAILED MODELS AVAILABLE ON PIECES OF THE OVERALL C3I PROBLEMS. (AUTHOR)

POSTING TERMS ASSIGNED

ARTIFICIAL INTELLIGENCE TECHNIQUES
  USE ARTIFICIAL INTELLIGENCE

AUTOMATED WAR GAMING
  USE AUTOMATION
      WAR GAMES

COMMAND CONTROL
  USE COMMAND AND CONTROL SYSTEMS

DECEPTION
  USE DECEPTION

SOVIET APPROACH
  USE APPROACH
      USSR

STRATEGY ASSESSMENT CENTER
  USE STRATEGY

ASYMMETRIES
  USE ASYMMETRY

CIVILIAN AND MILITARY LEADERS
  USE CIVILIAN PERSONNEL
      LEADERSHIP
      MILITARY PERSONNEL

CONTROL PROCEDURES
  USE CONTROL

GAMING STRUCTURE
  USE GAME THEORY
      STRUCTURAL PROPERTIES

STRATEGIC COMMAND AND CONTROL
  USE COMMAND AND CONTROL SYSTEMS

      STRATEGIC COMMUNICATIONS

WAR PLANS
  USE COMBAT EFFECTIVENESS
      PLANNING

PHRASES NOT FOUND DURING LEXICAL DICTIONARY MATCH PROCESS

## TABLES

# I. INTRODUCTION

This Note describes a concept for incorporating effects of command, control, communications, intelligence, and warning (hereafter abbreviated as $C^3I$ or as "command and control") in the emerging technique of automated war gaming. The concern here is largely with the *architecture* of the concept, rather than with its implementation, much of which remains to be worked out. Constructing a formal architecture is essential because we seek to incorporate command and control effects in a way that is broad and useful, even in its earliest manifestations, and that can evolve smoothly over time to address a substantial portion of the strategic command and control issues of principal concern to national leaders. These include: continuity of government; timeliness of command decisions involving both intercontinental and theater nuclear forces; continuing control over those forces; and prosecution of conflict (which, depending on circumstances, might call for decisive military action, controlled escalation, or de-escalation). In future work we plan to implement the architecture and use the Rand Strategy Assessment Center (RSAC) as a tool for exploring this and other command and control problems. Further, we plan to go beyond our current emphasis on strategic nuclear weapons by extending the architecture to cover strategic aspects of global conflict generally.

The Note's outline is as follows. First, we describe succinctly the principal features of the RSAC automated gaming system. We then discuss our view of what the strategic $C^3I$ problem really is--or should be considered to be in our work. Finally, we describe the philosophy of our approach and sketch our intended plan for implementing it.

## II. BACKGROUND

The RSAC is developing a new approach to strategic analysis that attempts to combine the contextual richness and operational complexity of war gaming with the rigor and transparency of analytic modeling. On the one hand, we are building a large-scale simulation model with the *structure* of a political-military war game. In this simulation, models represent the various national players, making decisions of both a political and military nature. The simulation can be fully automated. On the other hand, much of the RSAC's work will be highly interactive, with human teams playing against computerized adversaries or changing assumptions about such matters as combat outcomes to see the strategic reaction of the automated players.

At the technical level, the RSAC is extending several modern techniques in artificial intelligence (AI) as well as using more standard modeling and analysis techniques.[1,2] We shall not discuss the techniques here. Instead, let it suffice to say: (1) that we make extensive use of heuristic rule-based modeling in an English-like programming language; (2) that our decision models use such devices as pattern-matching and search (with lookaheads accounting for likely opponent behavior); and, very importantly, (3) that contact with military realism is achieved in part by relating a (greatly extended) version of AI scripts to analytic constructs akin to war plans.[1-3] From the viewpoint of AI research our effort is notable because it is a rare application to *realistic* high-level military issues and because the application's scope has caused us to develop concepts for managing complexity in rule-based models that should have more general value.[4]

Figure 1 provides an overview of the RSAC system emphasizing its hierarchical structure, something that will prove important in treating $C^3I$. The first column shows the nominal move sequence in the overall game. The automated players are: (1) Red Agent representing the Soviet Union; (2) Blue Agent representing the United States; (3) Scenario Agent representing to first order all nonsuperpower countries on a country-by-country basis; and (4) Force Agent. The latter model is not really a

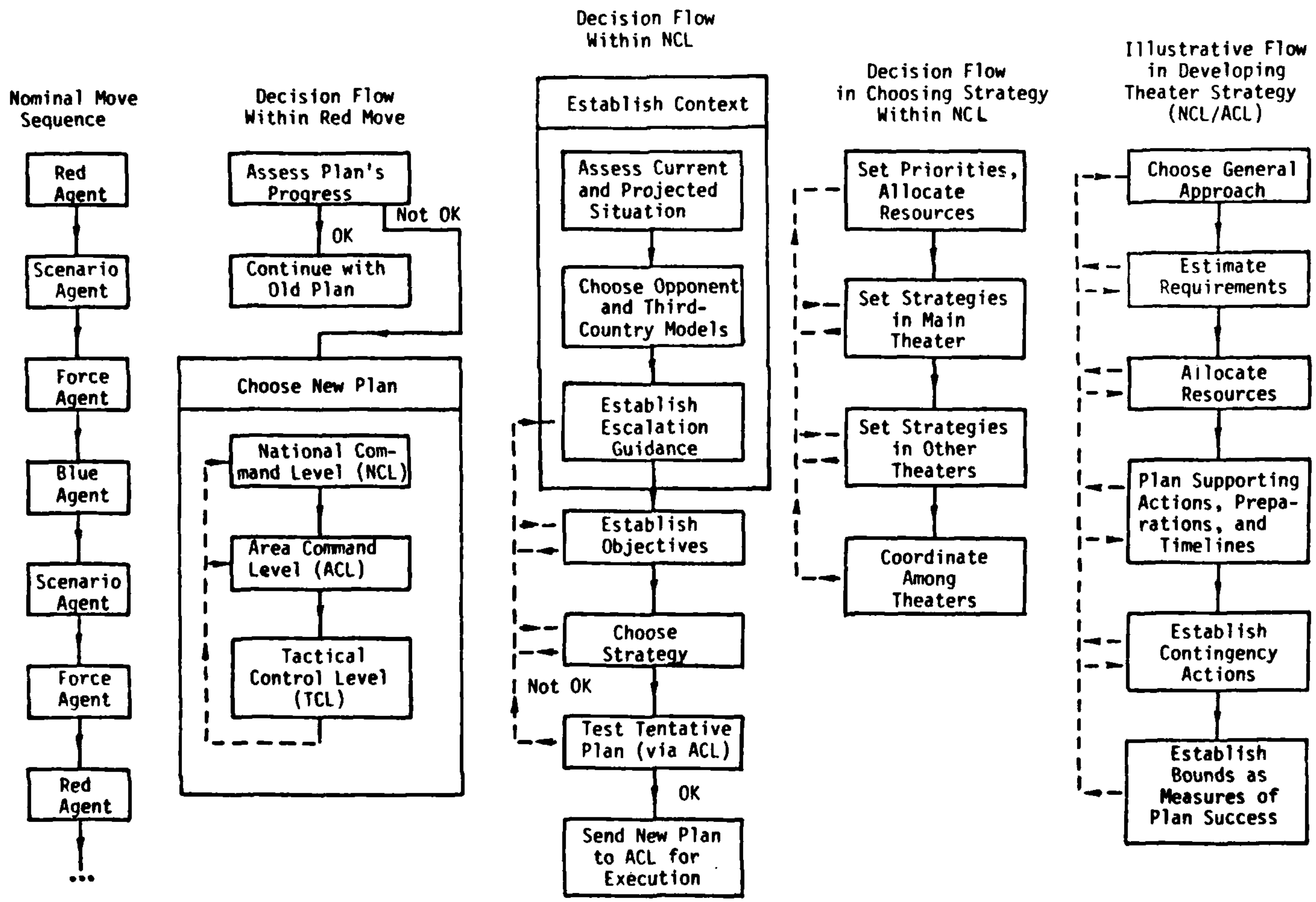



Fig. 1—A Hierarchical View of Processes in RSAC Automated War Gaming

player--rather, it keeps track of forces worldwide and computes the results of battle and other military operations such as movement. Its individual submodels are typically simple and aggregated, but because of the simulation's breadth and the requirements to interrelate phenomena across theaters, force types, and levels of conflict, Force Agent is quite complicated overall. There is also another model called Systems Monitor, which guides game development by scheduling moves and managing interfaces with automated recordkeeping, displays, and human players.

The second column provides a closer view of what happens in a single major-agent (Red or Blue) move. The move begins with the agent assessing his success with a previously chosen plan. If all is going well, he merely continues on that plan--which is represented in code by RSAC extensions of AI scripts.[2] All plans (or scripts) have bounds, however, and if any of the bounds have been broken (e.g., by excessive attrition or delay, or by the opponent's escalation), then the agent must reconsider.* This process begins with a rule set associated with functions of the national command level (NCL). The NCL chooses a tentative and incomplete war plan to be filled out and tested by the area command level (ACL), which corresponds loosely with the functions of area commanders such as U.S. CINCs or Soviet TVD commanders. The plan testing includes a lookahead implemented through the tactical control level (TCL), which controls the interfaces with Force Agent and (together with Force Agent's submodels) determines many of the detailed decisions about orders of battle, allocation of resources, etc. (decisions that should not be highlighted in a strategic-level game). The lookahead is a game within a game using the agent's assumptions about other players' actions and the likely results of combat. If the plan passes the test, it is then implemented, again through the TCL level. Otherwise, the ACL may adjust the plan and try again, or report back to the NCL that some strategic-level decisions must be changed.**

---

* The techniques for building such plans and scripts are under development by William Jones, Norman Shapiro, and Richard Wise.

** The sophisticated reader will recognize that Fig. 1 is an idealization with imperfect fidelity to the actual computer programs. In the code, distinctions among NCL, ACL, TCL, and decision rules in Force Agent are sometimes fuzzy and the functions alluded to in the boxes of Fig. 1 are sometimes accomplished by rules distributed throughout the program.

Continuing to unpeel the onion, the third column provides more detail on what happens in the NCL. The notable feature here is the process model guiding the structure of rule sets. In practice, we must rigidly define the permitted forms of escalation guidance, objectives, and strategies, and then write unambiguous rules leading from game observables (e.g., combatants, location of conflict, and status of forces) to unique permitted forms. We shall not discuss such matters here even though they are consuming a major amount of effort and time.

The fourth column expands upon the Choose Strategy process by noting that strategies must be chosen for each of the several military theaters, including the intercontinental and space theaters, and then coordinated. Finally, the last column expands upon this by suggesting some of the many steps required to define theater-strategy components that would be decided (or at least reviewed) at the NCL. These would include: (1) consistency of actions with overall escalation guidance and objectives; (2) cross-theater coordination; and (3) resource allocation across theaters.

Given this quick overview of RSAC system architecture, let us note some particular items relevant to what follows:

- *Variable behavior patterns*. The behavior patterns of Red, Blue, and Scenario Agents are variable to reflect fundamental uncertainties about the true patterns to be expected. Hence, we speak of alternative "Ivans," "Sams," and third-country "temperaments."
- *Parametric force models*. Similarly, Force Agent's component models are highly parametric with the parameters chosen for strategic-level analysis (e.g., a few simple equations that calculate bomber prelaunch survivability rather than a complex model considering details such as the propulsion characteristics of a Soviet SLBM that might be used to attack bomber bases).
- *Use of scripts*. The decision models do not generally extend below important operational-level issues. Instead, the agents choose among discrete war plans in the form of scripts, each of

which contains a number of microscopic (and sometimes arbitrary) action instructions (which may contain slots for parameters to be filled in by some ACL or Force Agent subroutine at the appropriate time).

- *Unmodelable Phenomena.* RSAC games allow certain phenomena to occur by fiat if the analyst so chooses--e.g., in some fraction of game runs the analyst may want to have riots occur in Poland if certain other events occur. Although the origin and nature of those riots are not simulated, Red's rules may be sensitive to whether the riots occur. The riot flag is, of course, a surrogate for whole classes of important real-world events contributing to fog-of-war effects (and escalation).* Such devices are familiar in manual gaming but may seem unnatural to traditional modelers.

Finally, let us summarize the RSAC system's essential elements, distinguishing between variables, hard-wired items, etc. This is actually not so simple because the RSAC system is designed for flexibility with a variety of users who have different notions about what should be hard-wired. However, Table 1 shows an illustrative breakdown appropriate for an application comparing nuclear-employment concepts in a range of scenarios. Although only illustrative, it demonstrates that there are many pieces to the overall system--all of which must be considered when attempting to treat command and control.

---

* See Refs. 5 and 6 for the RSAC's conceptual approach to escalation modeling.

Table 1

ELEMENTS OF THE RSAC SYSTEM AS VIEWED WHEN ASSESSING ALTERNATIVE STRATEGIES

| Fixed Structure | Fixed Characteristics[a] | Variable Characteristics | Principal Variables |
|---|---|---|---|
| o Game structure built around two (not N) primary players | o War plans/ scripts | o Sams, Ivans, national temperaments | o Employment strategies |
| o Rules for determining move sequence | o Force models<br>o Individual Scenario Agent rules | o Initiating scenario | |
| o Sequence of some NCL decisions | | o Some key parameters and rules in Force, Scenario, and scripts | |
| o Treatment of command levels | | | |

[a] In other applications these would be considered variable.

# III. DEFINING THE STRATEGIC $C^3I$ PROBLEM

Before deciding on an approach to the $C^3I$ problem, we must first know what it is. This requirement is more easily stated than fulfilled, however, since analysts have sought to define the essence of "command and control" for many years, often in highly emotional terms. For purposes of the present Note, we believe that we can avoid the better part of this fray by defining strategic $C^3I$ as the ingredients of the strategic $C^3I$ system, along with their interactions.* These ingredients are: (1) decisionmaking bodies and their procedures; (2) command centers to integrate information for the decisionmakers; (3) control procedures to assure that decisions will be implemented if transmitted; (4) intelligence systems to provide strategic and tactical warnings of attack and other information on enemy forces; and (5) communications to provide information on one's own forces, to permit transmission of decisions, and to permit report-back on the results of execution. In future work we will build on this approach to advance our views of "the $C^3I$ problem"; namely, that a realistic representation of command-and-control-related phenomena can be obtained by examining the complex emergent interactions of the comparatively well-understood $C^3I$ components given above, taking account both of multiple $C^3I$ effects that tend to reinforce one another, as well as of effects that cancel each other out.

In line with these remarks, it is important to remind ourselves that $C^3I$ does not depend on physical communication systems alone--it involves analysis by the NCA and his staff, as well as lower command levels, decisionmaking *procedures*, doctrine (which is a key element in control and planning), and many other items. Indeed, the breadth and

---

* This approach is fairly close to that taken in JCS Pub. 1, which defines "command and control" as: *the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of his mission.*

complexity of command and control are such that definitions and flow diagrams are often too abstract to communicate what the down-to-earth problems people worry about (or should worry about) actually are. It is therefore useful to list some of those illustrative concerns, drawing on the public literature as well as our own knowledge.* In listing these questions, we have not attempted to order them by their actual or perceived importance. Further, although these questions have caught the common fancy as "important" examples of potential $C^3I$ failures, we cannot exclude the possibility that prospective problems are more imagined than real in some cases.

## Illustrative Questions

1. What if the Soviets attack Washington on Inauguration Day? Would we be "decapitated"? What does "decapitation" mean on an operational level?
2. What if the Secretary of Education becomes the National Command Authority (NCA)? Will he know enough to make timely strategic decisions?
3. What are the implications of delegation, predelegation for contingencies, and unilateral lower-level assumption of authority?
4. What are the implications of normal decentralization of authority for control of events relevant to escalation? In other words, will the separate commands (CINCs and Soviet TVD commanders) be taking what they regard as standard measures that might on the one hand raise the likelihood of escalation or on the other hand fail adequately to anticipate the requirements of nuclear conflict or make nuclear strikes more lucrative? (Examples: ASW operations threatening SSBNs or dispersal of nuclear weapons in conventional conflict, or--

---

* The unclassified literature on strategic C I varies widely in accuracy and quality. For an apocalyptic and influential essay, see Ref. 7; for an interesting (but not always accurate) survey, see Ref. 8; for guarded discussion by knowledgeable experts, see Ref. 9. See also Refs. 10 and 11.

on the other end--massing of forces to achieve improved force ratios in conventional operations.)

5. What operational constraints narrow the NCA's employment options (e.g., concerns for SSBN vulnerability, weapon range, retargeting inflexibility, option purity, limitations in assessment capability)? What doctrinal constraints similarly narrow his options (e.g., failure to train crews for massive retargeting)?
6. What Soviet actions should we anticipate early in conflict by virtue of Soviet doctrine's emphasis on preparing for the nuclear phase? How should we prepare to observe, understand, protect against, and react to such measures?
7. What if we lose some or all communications (one-way or two-way) to the ICBMs, SSBNs, bombers, and/or CINCs...? Could we lose the capability for assured retaliation, limited responses,...? Is the EMP threat real and potentially devastating? What if we lose communications to the Soviets? Will that preclude termination short of unrestrained general nuclear war?
8. What if we lose early warning satellites from antisatellite attacks, sabotage on the ground, system failures, or unknown reasons?
9. Assuming the potential NCA desire to make limited responses to nuclear attacks, what capabilities at what level will be necessary to make appropriate limited responses possible--not only at the outset of conflict, but as a function of time thereafter?
10. What if the results of initial conflict are sharply different from those anticipated--because of system failures, surprise tactics, or whatever? What capabilities are needed to permit at least modest replanning?
11. What if communications are adequate initially but rapidly degrading? What are the effects on crisis stability and future ability to prosecute the conflict?

12. To what extent is a counterforce war made infeasible by fragility in the command and control system? What are the implications of one or both sides having command and control inadequate to prosecute an extended conflict?*
13. To what extent does the nature of actual war plans circumscribe the feasibility of limiting the scope of nuclear war, once it begins? Are they so inflexible as to preclude controlled responses or are they in fact adequately flexible given the limited number of plausible options, the relative predictability of certain aspects of strategic nuclear war, and the difficulty or cost of achieving enduring command and control to support more fine-tuned responses?

The list reinforces the conclusion that "addressing the strategic $C^3I$ problem" means addressing an enormous range of issues involving everything from standard operating procedures at the operational level to the implications of satellite vulnerability. Upon a moment's reflection it is also evident that the answers to the questions posed depend upon such diverse variables as: (1) nature of the superpower leaderships in conflict; (2) succession and devolution arrangements; (3) locations and levels of conflict; (4) prior history (initiating scenarios); (5) status of forces by type and theater; (6) range, quality, and flexibility of preplanned options; (7) the enemy's overall strategy; (8) technical issues such as the survivability of many systems (or functions); and (9) reconstitution capability for each component of $C^3IW$. We shall begin to address them in Sec. IV.

---

* Interestingly enough, it is sometimes argued that enduring $C^3I$ capability would be *destabilizing*, a view that would shock most defense professionals. See, for example, Ref. 10.

# IV. CONCEPTUAL ARCHITECTURE FOR AN APPROACH

## BASIC CONSIDERATIONS GOVERNING APPROACH

Section III demonstrates that *handling* $C^3I$ *within the structure of an ordinary modeling approach is simply not feasible*--too many of the issues are less quantitative and naturally analytic than operational or behavioral, and it would be fruitless to try reducing the problem at hand to a very small number of simple variables. By contrast, the emerging capabilities of automated war gaming will be an ideal vehicle for exploring many of the issues systematically. Indeed, recognition that gaming was probably essential in treating effects such as command and control underlay much of the initial government interest in the RSAC project.[12] The RSAC project is now far enough along so that making this idea a reality is a high-priority item.

The most important premise governing our approach to strategic command and control is that such issues should be reflected in the very *fabric* of the RSAC system--to view $C^3I$ as merely one more effect for which a program "module" needs to be developed would be to misunderstand utterly the nature of the problem. Indeed, it would be closer to the mark were we to say that the various and sundry RSAC models should be imbedded within the fabric of a command and control construct than vice versa.

All this implies that we need a conceptual *architecture* for our approach to including $C^3I$, rather than a mere grab bag of physical models and artificial intelligence techniques. We shall now sketch out what we see as design requirements for our effort and then provide the outline of our intended approach.

### Design Requirements

Upon reviewing the state of the art in strategic analysis, the major strategic issues of the day, as we see them, the nature of the RSAC charter from DoD,[1] and the conclusions of some past DoD work,[13] we have developed the following principles as guidance:

1. As mentioned above, the command and control issue should be reflected throughout the fabric of the simulation and not merely in some "module."
2. By virtue of our strategy-level focus, the approach should be top-down rather than bottom-up. This implies we should be focusing on $C^3I$ *functions* rather than individual systems; moreover, it means that the key game variables and displays should be aggregated and in a form natural to strategic-level discussion.
3. The character of the system must account for the existence of multiple levels, and locations within levels, of command and control authority. Moreover, it should reflect hierarchical phenomena.*
4. Even our early efforts to reflect command and control should be useful and realistic. It is better to reflect some of the real command and control issues early than to treat command and control comprehensively for a "toy problem" of no direct value.
5. However, the approach should be evolutionary and should allow linkup to some of the detailed work being conducted within the defense community on such matters as communications connectivity.
6. Although an evolutionary approach is appropriate, it should be broad-based from the outset--touching insightfully upon both U.S. and Soviet command, control, communications, intelligence, and warning rather than dwelling exclusively on, for example, U.S. capability to communicate an Emergency Action Message.

---

* The hierarchical principle of complex systems is what underlies the frequently mentioned analogy between living systems and command and control. Each level of a hierarchy has a recognizable separate existence and a set of internal processes. It communicates up and down the hierarchy, but the communications--however important--represent only a small fraction of the activities and are of little concern to most components of that level. Moreover, communications can be delayed, imperfect, inappropriate, misunderstood, etc. Manifestations of hierarchical effects are familiar to students of organizational theory, large business and government operations, biologists, and certain philosophers such as Arthur Koestler who see hierarchical principles as having broad applicability. We should note that it is one thing to build nested multilevel models, which are by no means unusual, and quite another to reflect hierarchical principles adequately.

7. The approach must permit the analyst (or game director when human teams are involved) to introduce phenomena representative of the *fog of war*--phenomena such as may arise from causes as diverse as unconventional warfare, flukes of nature, or catastrophic weapon-system failure.*

## Elements of an Architecture

To move from requirements to an architecture we must first think about what would constitute an architecture. How would we know if we had one? Remember here that we are not dealing merely with the design of a communications system. Rather, we are dealing with an approach to the design and application of an interactive war-game-based simulation. Upon reflection, and upon looking back at Table 1, which itemized the elements of the RSAC automated gaming system, it seems we must provide four different items:

- A suitable *structure* for the simulation (one that will provide the appropriate perspective on a multifaceted problem).
- *Variables (and corresponding data structures)* suitable for reflecting command and control factors simply and transparently in rules and algorithms.
- *Algorithms and rules* for manipulating variables and data structures to model desired effects.
- A management *roadmap* for assuring that $C^3I$ issues are introduced consistently throughout the complex RSAC system.

---

* We wish to achieve here some important features of manual gaming in which the Control Team can force teams to focus on events that are systematically left out of typical model-generated scenarios. For example, a Control Team can decree to the Blue Team that its early-warning capability has vanished, and thereby force the Blue Team to think out what it would do in such a situation. The Control Team does not have to explain in detail how the catastrophe occurred (although good game practice would entail a plausible explanation). Similarly, we want phenomena to be representable in the RSAC's automated war games even if there does not exist a good model to simulate their origin. See Ref. 3.

We shall now discuss our intended approach and touch upon each of these items in turn.

## OUTLINE OF A CONCEPTUAL APPROACH

### Simulation Structure

We shall not discuss the issue of simulation structure in much detail here because it should be reasonably clear from Fig. 1 and the attendant discussion that we anticipated most of the structural issues from early-on in the program. In particular, the RSAC's basic system design is well-suited to treatment of hierarchical and otherwise multilevel effects; moreover, it is flexible, modular, and designed with the expectation of evolutionary development from simple rule-based models to more sophisticated models using results of detailed work on such problems. Although it will be some time before we make extensive use of the capability, the system design also permits us to maintain separate data bases for Red, Blue, and "Real World." That is, our data structures permit us to have Red, Blue, and Force Agent to see different data bases on, for example, the status of Blue's forces. Handling such effects is painful for the analyst but will be essential for looking into matters such as deception and the fog of war.

### Variables and Data Structures

Discussions of rule-based models sometimes seem to suggest that rule-writing is easy and that structure is unnecessary--all that is necessary is to find an "expert." In fact, however, there are many instances in which experts able to provide a complete and incisive set of rules simply do not exist. In that case, which generally applies to command and control issues, it is necessary for analysts to do a great deal of background work to help experts think clearly and cover all the bases.[4] This implies anticipating (to the extent possible) what the experts will eventually find to be the most natural way to express rules simply and understandably from a strategic-level perspective. That is, we must anticipate the appropriate variables, related data structures, and logic flows.

Analytically, a major problem here is that the "natural variables" for those building the individual pieces of the RSAC simulation are often not the natural variables in which to express particular rules. For example, the RSAC has a world data base with information on worldwide forces, national orientations, etc. The data are collected initially in forms driven by the models that track locations and status of individual forces and the like. However, this form is too disaggregated and disorganized relative to what we need either to write simple decision rules involving command and control, or to write simple rules or models describing command and control effects in the execution of options.

With these considerations in mind, we are currently working out on a classified basis the details of an approach outlined in Table 2. Some of the basic notions here are as follows:

- It is useful to construct three time-dependent state vectors in addition to **O**, which characterizes the "world data base" as it is evolving in RSAC work. The three vectors, **C** (with subvectors for the $C^3I$ and W components of $C^3I$), and **S**, and **N**, pertain to the states of $C^3I$, functional support for the NCA, and NCA capabilities, respectively. Transformations between these vectors should be thought of as transforming raw data on system observables into forms more convenient for rule writing.
- Each of the state-vector components and their time trends should be definable, for our purposes, in highly qualitative terms. For example, we may characterize the quality of the first component of $\mathbf{C}_3$, communications to ICBMs in a given geographic region, as: poor, moderate, or good.
- We would expect to write nearly all rules involving the command and control influence on option *selection* in terms of the vector **N** (and $\mathbf{C}_1$, which determines the major agent's character); other rules, however (e.g., Force Agent rules on option *execution*), may depend on **S**, **C**, or--in rare instances--information found only in the world data base.

Table 2

ORGANIZING DATA FOR SIMPLIFIED RULE-WRITING SENSITIVE TO COMMAND AND CONTROL

| O → C → S → N | | | | | | |
|---|---|---|---|---|---|---|
| State of Basic RSAC System Observables | → | State of Command and Control | → | State of NCA Support (Functional Capabilities) | → | State of NCA Capability |

**O(t)** = {unstructured data on: status of forces and nations' war plans (scripts) being implemented, attrition rates, rates of movement,...}

**C(t)** = $\{C_1, C_2, C_3, I, W\}$

$C_1(t)$ = {Nature of NCA; Extent of Delegation; Extent of Contingency Predelegation; Nature of NCA Staff; Degree of Information Saturation}

$C_2(t)$ = {Lower-Level Capability to Respond (to higher-level orders), Lower-Level Willingness to Respond (to higher-level commands)}

$C_3(t)$ = {Communications (by geographic region) to: ICBMS, SSBNs; Bombers; SLCM Launch Platforms; Satellites; ASAT Systems; Other Strategic Defensive Forces (SAMs, ABMs, interceptors); Nonstrategic CINCs}

**I(t)** = {Intelligence on: Nature of Enemy NCA; Nature of Enemy NCA Support; Enemy ICBMs, SSBNs, SLCM Launch Platforms, Bombers, Satellites, ASAT Systems, and Other Strategic Defensive Forces (SAMs, ABMs, interceptors; and enemy forces in theaters)}

**W(t)** = {Warning of Attack by: Ballistic Missiles; Air Breathers}

**S(t)** = {*Ability of the NCA* to obtain finished assessments of: Status of his forces, Force operations, and Alliances; Status of the enemy NCA, NCA support, forces, and alliances. *Ability of the NCA support staff* to use, develop, and evaluate Options, both before and after execution. *Ability of the NCA's forces* to execute options.}

**N(t)** = {*NCA ability to*: assess option feasibiity; Modify or originate options; Compare and choose among options; and Communicate the chosen option.}

- In defining the state vectors, their components, and the values of their components, we must be cautious to maintain resolution distinguishing among the following, even in early work:

    -- *Theaters*: intercontinental, space, others (Europe, SWA,...), and simultaneous multitheater operations.

    -- *Strategic Forces*: ICBMs, SLBMs, bombers, SLCMs, space forces, and ASAT forces.

    -- *Time*: crisis; extreme crisis and possible theater war; period of U.S. first strike; period of Soviet first strike; period of immediate U.S. response, if any; initial aftermath; and extended aftermath (see Fig. 2, but note also the possibility of more complex stop-and-start wars).

    -- *Option Class*: e.g., limited versus massive counterforce options with modest or major coordination problems (including theater missions for strategic forces) limited and massive countervalue options, and mixed options, in each case executed as a first-strike, launch under attack, prompt second-strike, delayed second-strike, or follow-on strike.

    -- *Employment Concept*: distinctions among options calling for the same results to be achieved with different missions for the individual force types (e.g., striking the same targets with bombers as opposed to ICBMs).

    -- *Class of Effect*: effects on ability to choose, quality of choice, and speed of choice.

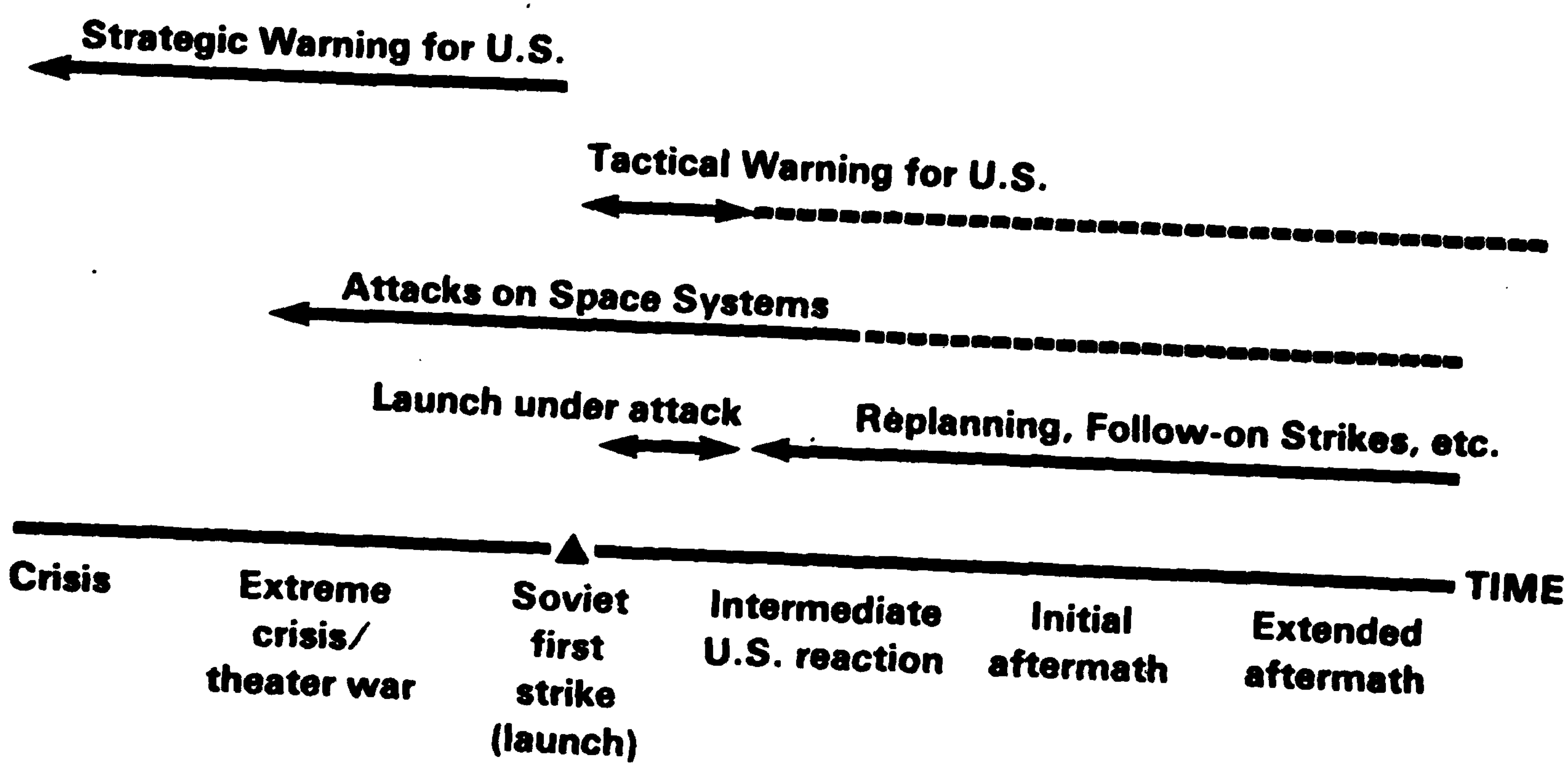



Fig. 2--Illustrative Time Periods and Events

- The NCA's ability to perform the functions listed in **N(t)** will depend strongly on the types of options under consideration. Although options can theoretically be indexed by all components of the preceding bullet, we thus far believe that Time and Option Class are the most important characteristics for option indexing. Thus, the NCA's ability to assess option feasibility, for example, should be understood to be with respect to each Option Class component within each Time component. For each such combination we are now in the process of defining high, medium, and low labels for the components of **N(t)**.

Even further distinctions will clearly be necessary when we begin to delve more into theater-level issues, but the above list is already intimidating.

Although the many distinctions itemized above may seem to imply that aggregation cannot work, in fact there appear to be many possible simplifications. For example, in characterizing the capability of the NCA to develop new options *during the "Period of Immediate Response,"* we might use Low, Low-Medium, High-Medium, and High as the principal descriptors with these definitions:

Low: No capability except for execution of preplanned options in class X (X to be defined in terms consistent with the war plans/scripts available). No retargeting. No capability to change theater war plans.

Low-Medium: Preplanned options of classes X and Y with retargeting of force elements A and B feasible (where A and B are the force elements for which retargeting is most plausible). No capability to change theater war plans from the NCA level.

High-Medium: As above, except full retargeting across force types within preplanned options.

High: Full nominal capabilities as of some future date, including in particular the ability to retarget against newly acquired targets in ad hoc options.

These definitions allow a few simple "values" to cover a number of issues. We would also need separately to characterize the components in terms of timeliness of decision (e.g., normal or slow).

Obviously, the approach involves an article of faith to the effect that the strategic command and control problem can be reduced to describing capabilities and phenomena in a large but highly finite number of crudely defined discrete states, preferably states that can be summarized briefly in intuitive terms. Considering that most strategic nuclear analysis implicitly assumes the state of perfect command and control (except for zero strategic warning), we need hardly apologize for an approach that will distinguish among tens (or perhaps hundreds) of states. How much disaggregation will be necessary remains to be seen.

**Roadmap to Integration**

Assuming that the structure we have outlined provides an appropriate view of the problem, and that its states are defined for rule-writing and model-building by using the natural variables of the command and control problem, the next challenge is to manage the implementation. Unfortunately, this is inherently difficult because, as repeatedly stated, $C^3I$ permeates everything and must therefore affect the work of numerous people working on different parts of the RSAC project. There are at least three aspects to managing the work in such a case: (1) rule writers and model builders must have checklists of items to consider, thereby reducing the likelihood that Red will write rules sensitive to some command and control issue that Blue will ignore, except in those cases where underlying strategic asymmetries dictate valid differential sensitivities; (2) there must be a mechanism of integration in which the various contributors systematically read each other's material, compare notes, and look for incompatibility; and (3) there must be formal "walkthroughs" of the overall simulation on every command and control issue expected to be important.

We cannot discuss these matters in much more detail here, but we can point out a few items of interest. For example, upon reflection we find it useful to distinguish clearly between command and control effects on decisions, and command and control effects on force operations. Figure 3 makes this distinction and points out that all of the RSAC agents are affected. Note that:

- The state of strategic command and control (and the projected state!) must affect Red and Blue *decision rules* by: (a) affecting Red or Blue character, warfighting ability, and efficiency; (b) limiting Red or Blue options; and (c) shading the perceived attractiveness of alternative available options. Similarly, Scenario Agent's decision rules must be sensitive to the nature of the superpowers' national command authorities and the overall effectiveness of those superpowers.
- The Force Agent must reflect command and control effects on force operations (and of projections thereof) by means of: (a) delays and related mismatches between decisions and current world states; (b) errors such as those caused by poor intelligence or communications; (c) degraded capabilities such as loss of certain types of warning or intelligence; and (d) coordination problems.
- The analytic *war plans/scripts* must reflect to some degree the partially independent operations of individual theater commanders and the potentially parochial decision rules governing those operations.* They should reflect doctrinal behavior at the operational level except where there are good reasons to assume otherwise.**

---

* Ultimately, we hope to reflect independent operations by commanders at levels lower than the theater. In the relative near term, however, we will omit such considerations.

** This has management implications because it suggests that we should invest in having separate teams develop the war plans for the individual theaters rather than building the plans from a purely top-down perspective that would tend to make the analytic plans used in the computer model come out far more coordinated and mutually reinforcing

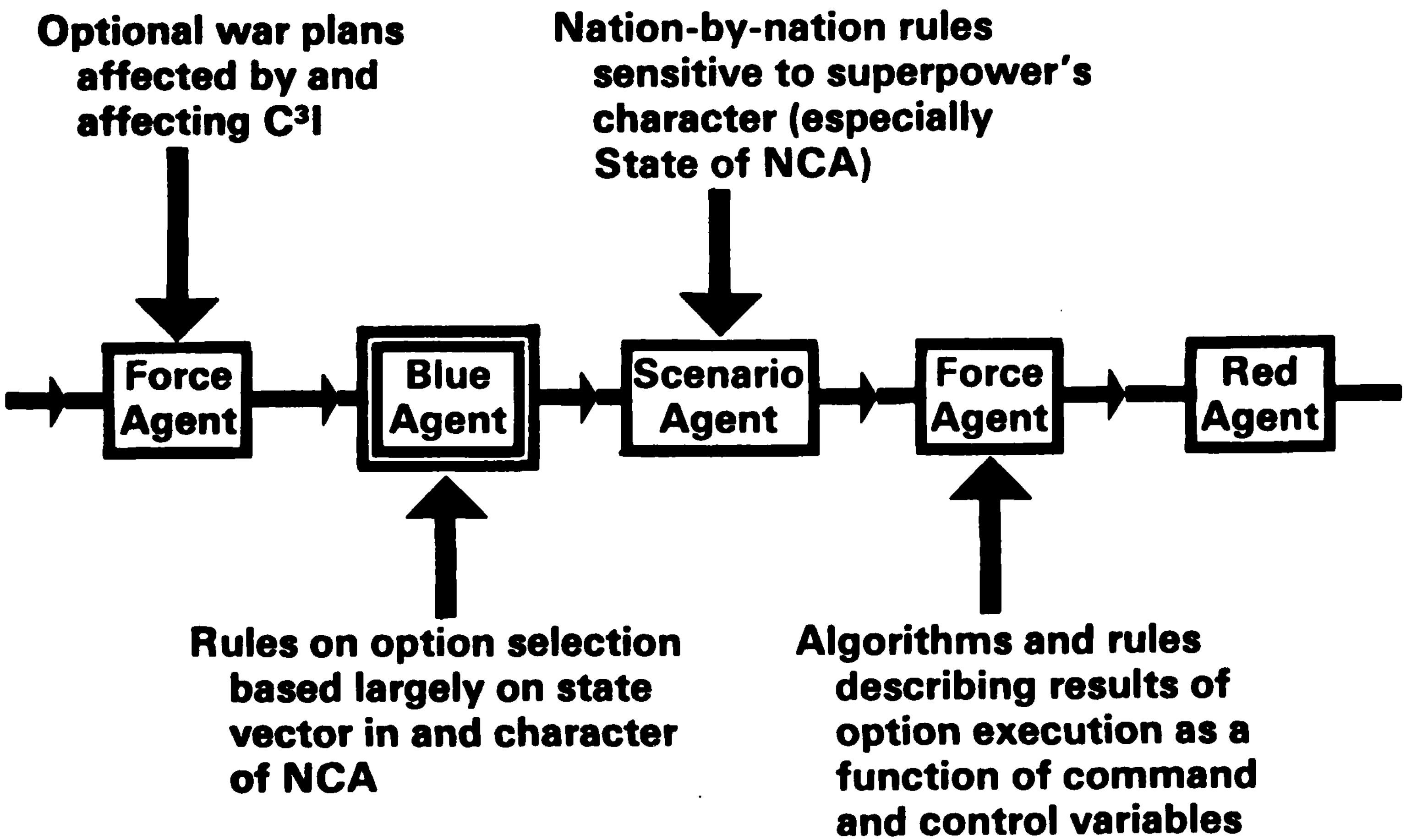



Fig. 3--Command and Control Effects on Blue Move and Results Thereof

- The analyst using the RSAC system must be able to insert "fog-of-war" effects and other related phenomena easily, something that has implications for Systems Monitor in particular, but also for the other agents (i.e., there must be variables created to serve as surrogates for the effects in question; the variables must be represented in all of the separate agents).

All of this is rather abstract, so it is useful to provide at least a partial image of what is involved in implementing the concept. Thus, let us discuss what might be involved in reflecting just one particular issue, Red's assessment of Blue's LUA capability. Such an assessment might be important in Red's detailed attack planning *if* the implications of a U.S. LUA were major. Figure 4 suggests a somewhat oversimplified logic.

To implement this logic in the RSAC system one would have to do the following:

1. Create Red war plan components that would, if successful, destroy Blue's warning satellites and radars.
2. Build Force Agent models to estimate the effectiveness of such Red options under a variety of circumstances (e.g., the status of Red's antisatellite systems and space-tracking network, the number and vulnerability of U.S. satellites, the locations of Red's SSBNs capable of attacking U.S. warning radars).
3. Build Red decision rules sensitive to Red's assessment of Blue's LUA capability (e.g., rules affecting Red's willingness to launch a first strike or rules affecting the size and nature of a first strike; also, rules relating Red's desire to prevent U.S. LUA to other Red actions that would provide the United States with strategic warning).
4. Build Red rules assessing Blue's LUA capability (as in Fig. 4) and relating the items in the figure to the war plan components

---

than is realistic. Unfortunately, developing such separate plans is manpower and expert intensive, especially because of the effort required to train teams of analysts.

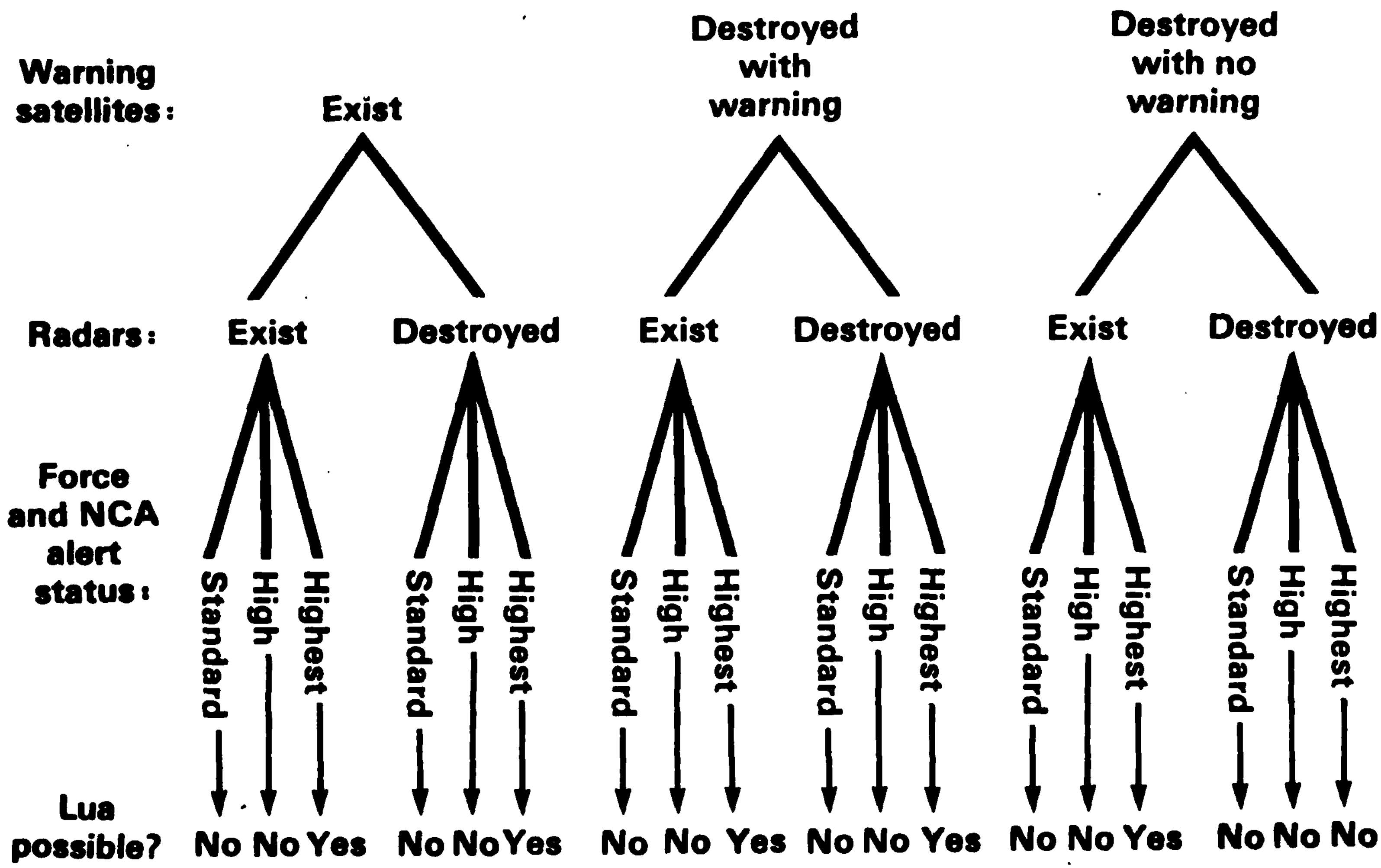



Fig. 4—A Simplified Logic Tree for Red's Assessment of Blue's Ability to Launch Under Attack

mentioned in (1) and Blue's probable response to other Red war plan components as mentioned in (5).

5. Build Blue rules sensitive to indication that warning satellites are under attack (e.g., go on highest alert) and rules establishing whether Blue would actually try to launch under attack under some circumstances (a function of policy and capabilities, which might be quite different from those assumed by the Soviet Union, whose strategic doctrine has stressed LUA for years).

Although this is only a narrative sketch, it is sufficient to demonstrate once again that incorporating command and control effects is an inherently complex business demanding that attention be paid to details of scenario, strategy, the two-sided nature of the game, etc.

Where, then, do we stand at this point in our development program? Is this all conceptual, or are we actually implementing the ideas? At the moment, we are within a few months of automating the most recent version of the basic RSAC system, having conducted semiautomated experiments last summer.[14] Once the basic system is operational, we plan to incorporate selected command and control effects on a simplified basis using heuristic rules tied to grossly defined world states (e.g., have the Soviets already attacked warning satellites?). We then expect to implement a more ambitious but still first-generation version of the overall architecture, probably in November or December, 1983. Finally, we expect to build more sophistication into the system over the period of several years--including explicit tie-ins to the results of detailed models such as those used to estimate connectivity to bombers as a function of weapon lay-down and scenario. We plan to use structured human gaming as a source of insight and rules. Our expectation is that applications will be possible early next year, well before we have much sophistication--primarily because a major contribution of the effort will be a war game framework requiring consistency from move to move and requiring the human or automated players to take first-order $C^3I$ effects into account when developing their overall strategies.

## REFERENCES


1. Davis, Paul K., and James A. Winnefeld, *The Rand Strategy Assessment Center: An Overview and Interim Conclusions About Utility and Development Options*, The Rand Corporation, R-2945-DNA, March 1983.

2. Steeb, Randall, and James Gillogly, *Design for an Advanced Red Agent for the Rand Strategy Assessment Center*, The Rand Corporation, R-2977-DNA, May 1983.

3. Davis, Paul K., *Concepts for Improving the Military Content of Automated War Games*, The Rand Corporation, P-6830, November 1982.

4. Davis, Paul K., "Concepts for Managing Complexity in Realistic Applications of Artificial Intelligence to Problems of Strategy and Operations," The Rand Corporation, forthcoming.

5. Glaser, Charles, and Paul K. Davis, *Treatment of Escalation in the Rand Strategy Assessment Center*, The Rand Corporation, N-1969-DNA, April 1983.

6. Stan, Peter, and Paul K. Davis, "Escalation in Automated War Games," The Rand Corporation, R-2012-NA, forthcoming.

7. Steinbruner, John D., "Nuclear Decapitation," *Foreign Policy* 45, Winter 1981-82.

8. Ball, Desmond, "Can Nuclear War Be Controlled?" *Adelphi Papers* 169, International Institute for Strategic Studies, London, 1981.

9. MITRE Corporation, *National Security Issues 1981 Symposium*, MITRE Document M82-30, 1982 (reporting on a symposium held by the Air Force Electronic Systems Division and MITRE during October 13-14, 1981, on the subject of "Strategic Nuclear Policy, Weapons and the $C^3I$ Connection").

10. Tucker, Jonathan, "Strategic Command-and-Control Vulnerabilities: Dangers and Remedies," *Orbis* 26, No. 4, Winter 1982.

11. Van Creveld, Martin, "Command," Unpublished report for the Director of Net Assessment, Office of the Secretary of Defense (n.d.).

12. Marshall, Andrew, "A Program to Improve Analytic Methods Related to Strategic Forces," *Policy Sciences*, Vol. 15, No. 1, November 1982. See also Appendix 1 of Ref. 1.

13. Harris, Donald, Andrew Marshall, Eugene Durbin, and Fred Giessler, *Final Report of the OSD Research on Military Command Control*, 1979, Office of the Director, Net Assessment, Department of Defense, 1979.

14. Winnefeld, James A., *Illustrative Experiments with an Interim Version of Rand's Strategy Assessment Center*, The Rand Corporation, N-1917-DNA, November 1982, For Official Use Only.

3 –