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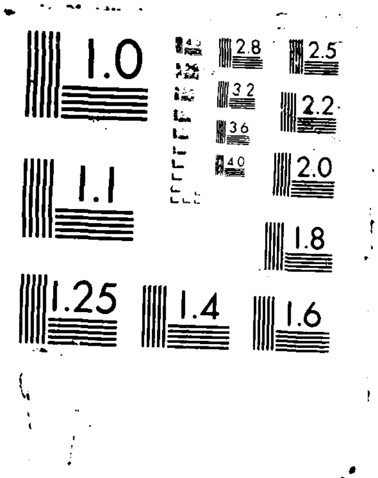
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AD-A190 573

STRUCTURE FOR A KNOWLEDGE-BASED SYSTEM

TO ESTIMATE SOVIET TACTICS

IN THE AIRLAND BATTLE

Anne Martin Fletcher
Captain, USAF

AFIT/GST/ENG/88M-2



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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research



Anne Martin Fletcher, B.S.

Captain, USAF

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## Preface

The purpose of this ~~research~~ was to build a prototype decision aid that can use knowledge about Soviet doctrine and tactics to infer when, where, and how the Soviet Army plans to attack NATO defenses given intelligence data about Soviet (Red) military units, terrain data, and the positions of the NATO (Blue) defenses. This study raises issues that must be resolved before such a decision aid, which is a part of the Rapid Application of Air Power concept, can become operational.

I would like to acknowledge the assistance of several people and organizations who supported my efforts and contributed to my understanding of the complex issues that must be resolved. Major Herb Harrison and Headquarters Air Force Intelligence placed me in contact with experts in Soviet doctrine, provided me with reference material, and funded a large part of my research. Dr. John Allen of LICA and Lt Col William P. Baxter (Ret.) of BDM each patiently answered my many questions and suggested convincing, creative approaches to the automated estimation of Soviet tactics. Captain Chartrand of the Air Force Directorate of Soviet Affairs provided me with copies of translations of many Soviet works on military tactics. Finally, Dustin Hunington of EXSYS provided me constant technical assistance during the development of the prototype, although we were unable to overcome the difficulties encountered.

On a more personal basis, I would like to thank my advisor, Lt Col Gregory Parnell, for his guidance and insight, and Maj Chuck Fletcher, who helped me leave AFIT with much more than a Masters Degree.

Anne Martin Fletcher

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## Abstract

This study first examines the need to shorten the $C^2I$ decision cycle in order for the ATOC staff to keep pace with the tempo of modern warfare. The Rapid Application of Air Power is a concept that includes automating various steps in the decision cycle to allow air power to be applied proactively to stop Soviet forces before they obtain critical objectives. This study presents a structure for automating the second step in the decision cycle, assessing and clarifying the situation, through a knowledge-based decision aid for interpreting intelligence data from the perspective of Soviet (Red) doctrine and estimating future Red tactical objectives and maneuvers.

This study found that a complex analysis with many data and labor intensive tasks must be performed in order to prepare an estimation of future Red objectives and tasks. A wide spectrum of knowledge that is dynamic, heuristic, symbolic, and numerical is required to perform these tasks.

While some of the task and knowledge characteristics are highly suitable to automation with a knowledge-based system, other characteristics are less suitable. A system design is presented that uses various techniques for adapting the less suitable tasks and knowledge requirements to a knowledge-based system.

A prototype Red "estimator" written in an expert system shell demonstrates most features of the system design, although it cannot

actually predict Red tactical objectives and manuevers. The prototype served its purpose as a tool for exploring the issues that must be resolved before an operational Red estimator can be built.

A large number of issues and the methods required for exploring these issues are enumerated. The key issues are security, the availability of signalling elements, and the need for an interdisciplinary approach to developing the Red estimator.

The benefits from this study are the enumeration of issues, the use of rules to evaluate the impact of unknown information, and a system design that is robust with respect to Red deception efforts. While the development of an operational Red estimator is technologically feasible, it will require the integration of multiple disciplines and many years of research.

STRUCTURE FOR A KNOWLEDGE-BASED SYSTEM

TO ESTIMATE SOVIET TACTICS IN THE AIRLAND BATTLE

# I. Introduction

## General Issue

Modern technology has increased the tempo of warfare beyond the rate that allows unaided battle staffs to interpret intelligence information from the perspective of enemy doctrine and use the information to interdict previously unforseen enemy actions. While technology has increased both the amount and timeliness of intelligence collection through satellites and high-speed communications, it has also developed responsive weapon systems, such as the F-16, capable of being vectored to interdict new targets in a matter of minutes. NATO depends on this high technology to successfully defend against Soviet divisions trained to advance three times faster than they could during the last year of WW II. The NATO battle staffs controlling modern weapon systems must therefore analyze more intelligence information and make decisions based on their analysis more rapidly than ever before.

According to Lieutenant General John W. Cushman, a former commander of the 101st Airborne Division, the U.S. Army Combined Arms Center, and I Corps (ROK/US) Group in Korea's Western sector:

> Information is pouring into the command post - too much for the staff to handle. They need help in sorting it out, in correlating this piece of data with that piece, in displaying the results of their thought (6:48).

A panel of experts gathered by the U.S. Army Research Institute specifically to investigate the deficiencies in the U.S. military's command and control system published a list of five command and control deficiencies. Four of the deficiencies questioned the ability of the $C^2$ staff to effectively assign targets, allocate resources, and generate plans in the "compressed time frame... of the Airland Battle" (12:ES-3).

The Allied Tactical Operations Centers (ATOC) are one link in the $C^2$ system that may not be able to fully utilize available intelligence when allocating resources during the compressed time frame. Currently, the Operational Intelligence Branch of the tactical air force's Combat Operations Intelligence Division (COID) considers enemy doctrine when developing estimates of enemy capabilities and intentions (20:19). A different branch of the COID considers these estimates when preparing daily target nominations for the Combat Plans Division. Yet another COID branch prepares reconnaissance nominations for use in the daily battle plan.

This daily planning cycle does not provide timely enemy assessments to current operations planners. Current Operations is responsible for assigning air resources to fulfill immediate requirements that might arise from deviations such as weather aborts, unsuccessful missions, or the discovery of targets of opportunity (20:27). Adjustments to the daily plan have to be made in a few hours, which is not enough time to receive a new enemy situation assessment from the Operational Intelligence Branch. Yet as deviations occur and military resources become more scarce, using all available information to ensure effective resource employment becomes more important.

In the future, it is likely that the daily cycle will not be rapid enough to keep pace with the tempo of warfare.

## Problem Statement

An automated means of applying Soviet doctrine to intelligence analysis is needed to help the commander's staff plan preemptive missions against Soviet operations by inferring such operations from the voluminous amount of intelligence information available. Such an automated aid is described in the Rapid Application of Air Power (RAAP) concept advocated by the former chiefs of the Headquarters Air Force Intelligence Planning Division and the Office of Doctrine and Concepts (26:165).

## Background

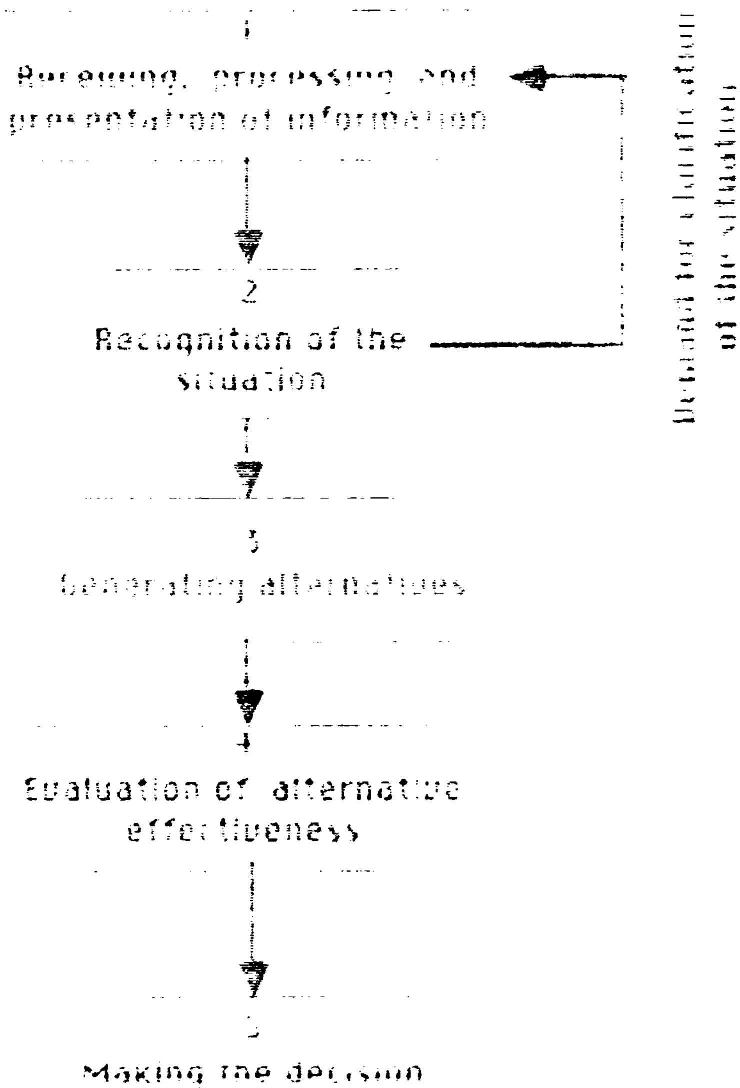
RAAP is a project for reducing the $C^3I$ decision cycle by using artificial intelligence and other advanced technologies. RAAP is exploring ways to let computers assimilate and draw inferences from intelligence data, allowing the staff and the commander to concentrate on tactics and decisions, thereby shortening the commander's decision cycle. General Cushman stresses the importance of a short decision cycle:

> Over the centuries, much has changed about war, but one thing has not changed: this cycle of sensing, understanding, deciding, and execution, and the reality that the side whose commanders perform the cycle faster and with better results has a decisive tactical advantage (6:48).

The Decision Cycle. The decision cycle refers to the cyclic procedure battle staffs follow to process information and choose which military actions to take based on that information (6:48,9:14,13). Figure 1 depicts the decision cycle.

The first step in the procedure is to sense and organize all incoming information, including radar returns, intelligence reports, and terrain features into a usable display. The next step is to use the displayed information to assess and, if necessary, clarify the combat situation. The third step is to generate alternative actions and, fourth, to evaluate these alternatives. The final step is to select and implement the best feasible alternative. Once the best alternative has been implemented the cycle returns to the first step to determine the selected action's impact on the combat situation, continuing the cycle. The procedure is also iterative because conclusions reached in one step of the procedure are used to re-evaluate the information used in reaching those conclusions.

The RAAP Concept. The purpose of RAAP, as presented by Colonel John Rothrock, then Chief of Plans, Headquarters Air Force Intelligence, is to shorten the Blue (NATO) decision cycle so that the Air Force can apply air power proactively to stop Soviet actions before the


1
Receiving, processing and presentation of information
2
Recognition of the situation
Demand for clarification of the situation
3
Generating alternatives
4
Evaluation of alternative effectiveness
5
Making the decision

Soviets obtain critical objectives (25). The RAAP concept, according to Colonel Rothrock and Colonel Timothy Kline, then Chief of Doctrine and Plans, Air Staff, includes creating computer-based decision aids to:

- Electronically receive all-source intelligence information.

- Compare the enemy operations profiles [doctrinally defined Soviet tactical manuevers]... to incoming intelligence data to determine the most likely schemes of [Soviet] manuever being employed (considering weather and terrain) with continuous sensitivity to possible enemy denial and deception efforts.

- Adapt predefined friendly attack employment packages to available attack assets, focusing on previously analyzed enemy practice and vulnerabilities.

- Recommend candidate times and places for execution to the decision maker (26:165).

Colonel Rothrock and Colonel Kline stress that the RAAP approach calls for using computers to do the things computers do best, mostly to quickly compare and sort large amounts of data (26:163), which will shorten the steps of the decision cycle involved with recognizing and clarifying the situation and generating alternative plans of action. By using computers to recommend actions to counter anticipated Soviet tactical manuevers, the human staffs and decision-makers can concentrate on exploiting NATO's strengths and countering unexpected Soviet manuevers (26:165).

The focus of this research was the second decision aid that Colonel Rothrock and Colonel Kline describe. It takes inputs from the first aid, the intelligence fusion device, and sorts the incoming intelligence data into indicators of various doctrinally defined Soviet manuevers. It then presents the decision-makers a picture of when and where to expect the most likely Soviet tactical operation. Tactics, as used in this research, refers to "...that part of military art directly concerned with preparing for and conducting combat at division level and below in all branches of the armed services" (2:28). This decision aid or Red (Soviet manuever) estimator would considerably reduce the time needed in the second step of the decision cycle, assessing and clarifying the situation.

## Research Objective

The purpose of this research was to build a prototype decision aid that can use knowledge about Soviet doctrine and tactics to infer when, where, and how the Soviet Army plans to attack NATO defenses given intelligence data pertaining to the location, size, movement, and type of Soviet (Red) military units, terrain data, and the positions of the NATO (Blue) defenses. This decision aid can be used to help critique the design of the Red manuever estimator contracted for under RAAP funds, by comparing required inputs, outputs, and demonstrated capabilities.

## Research Scope

The prototype Red estimator will consider a smaller problem than an operational system will be required to handle.

While there are at least 16 doctrinally defined Soviet tactical manuevers (10:9), the prototype Red estimator considers only six of them. Furthermore, the estimator considers only an European scenario of Soviet versus NATO troops.

Because the prototype focuses on demonstrating the overall structure of a Red maneuver estimator, it does not contain enough knowledge to assign a true probability of occurrence to each manuever. The prototype does assign a confidence level to each manuever but its reliability is not verified. To increase user acceptance, an operational system would be verified by comparison with records of Soviet exercises.

The Red estimator predicts only Soviet tactical manuevers; it does not recommend how to counter the manuevers. Recommending countermeasures is the goal of the third decision aid described by Colonel Rothrock and Colonel Kline (26:165).

Instead of directly interfacing with a data fusion device as called for in the RAAP concept, the Red estimator reads intelligence data from a prepared scenario data file. The limitation of not interfacing with the data fusion device will not affect the demonstrability of the Red estimator since the data fusion device is not yet developed.

The final limitation is an assumption that the user will screen the intelligence reports and not input data that is suspected of being deliberate misinformation. The Red estimator will assume that all information is true until it receives a conflicting data item or the user tells the machine to ignore a piece of information. On request, the Red estimator will list all of the information it is using for the user's review.

## Overview

The next chapter describes the tasks that the Red estimator must accomplish, as well as its required inputs and outputs. Chapter Three tells why a knowledge-base system is an appropriate structure to accomplish these tasks and discusses expert systems developed for similar applications. Chapter Four discusses which expert system development tool was chosen, while Chapter Five examines the prototype design. Chapter Six reviews the issues that arose during the system development and suggests methods for handling these issues in an operational Red estimator. Chapter Seven concludes this study by summarizing its achievements and evaluating the performance of the prototype.

## II. System Requirements

This chapter presents the tasks, knowledge requirements, and challenges for the Red estimator.

### Tasks

The Red estimator must use a variety of knowledge to accomplish several complex tasks. The tasks involved in estimating the Red forces' actions are summarized in Table I, which indicates how the tasks are being accomplished today in Allied Tactical Operations Centers (ATOCs), as well as how they are accomplished in the prototype. In addition, the matrix indicates how an operational Red manuever estimator would accomplish each task.

A difficult aspect of automating these tasks is that they are complex enough to require a large team of people (analysts from three offices) to perform them. Furthermore, tasks involving the assignment of confidence levels and the consideration of terrain when estimating Red actions (tasks 3,6, and 8) are not done today; consequently there is no example for modeling an automated method to accomplish these tasks. Table I also reviews the key challenges of each task.

The section following the task matrix describes the variety of knowledge that must be acquired to perform these tasks.

Table I. Task Matrix

| Level: Tasks: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|
| 1. Read and store fused all-source intelligence data | Enemy Situation Correlation Division (ENSCD) correlates, fuses, and plots data from organic collection sources (PHOTINT, RADINT, ELINT, and COMINT) and passes information to the Combat Operations Intelligence Division (COID) for additional analysis (20:12-14). | Prepared scenario database file. | Interface with intelligence data fusion system. | Data intensive, interdisciplinary |
| 2. Build situation map of reported Red unit and equipment positions. | Manually by intelligence analysts. | Automated. | Automated. | Data intensive, labor intensive |

| Level: / Tasks: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|
| 3. Compare situation map with terrain and weather data. | Not considered. (Done by wing level operations analysts and mission planners.) | Compared with limited terrain data base (weather is neglected). | Compared with extensive terrain data base and daily weather updates. | No manual methodology to model an automated system after |
| 4. Build situation map of predicted Red / Blue unit and equipment locations at the commander's time of interest based on reported unit speeds, doctrinally defined speeds, terrain, and weather. | TAF intelligence analysts manually prepare overlays showing enemy orders of battle, estimated operating areas, and weapon system ranges (20: 16,17). | Look-up table simulates program to predict locations. | Automated. | Data intensive, labor intensive |

| Level: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|

| Level: Tasks: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|
| 5. Using Red doctrine and the situation identified in step 4, identify possible Red manuevers being accomplished by Red armies, divisions, regiments, and battalions (7:2-6). | COID personnel manually generate hypotheses and then determine if the enemy has the capability to conduct the hypothesized maneuvers (20:19). This analysis is done for 24 hour and longer cycles (20:18). | Automated, but scope limited to six manuevers by regiments. | Automated. Identifies possible manuevers at battalion-level and above. | Complex analysis of situation is required. |
| 6. Assign confidence levels or probabilities to the possible manuevers. | Not done. | Automated. | Automated, with accuracy refined during testing against actual Soviet military exercises. | No manual methodology to model an automated system after |

| Level: / Tasks: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|
| 7. Create different hypotheses for each probable manuever, considering different avenues of approach, Red objectives, and times of attack. | Done manually during task 5 hypothesis analysis. | Not done. | Automated. | Complex analysis of situation is required. |
| 8. Assign confidence levels or probabilities to each hypothesis, assuming that a particular manuever will occur. | Not done. | Not done. | Automated. | No manual methodology to model an automated system after. |

| Level: / Tasks: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|
| 9. Predict location/times of Red targets for most effective Blue interdiction of each manuever. | Prioritized target nominations are developed by the COID (on a 24 hour cycle) (20:23-24). | Not done. | Automated using interface with Blue forces decision aid. | Complex analysis of situation is required. |
| 10. Generate suggested intelligence gathering requirements. | Reconnaissance nominations are developed by the COID on a 24 hour cycle (20:24). | Automated to improve confidence levels. | Automated to improve confidence levels and resolve conflicting hypotheses. | Data intensive, needs to be performed faster, interdisciplinary |
| 11. Explain reasoning and data used to perform all tasks. | Limited by human memory along with historical data. | Automated. | Automated. | Data and reasoning must be reproducible |

| Level: Tasks: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Task Features |
|---|---|---|---|---|
| 12. Be able to predict Red actions to "what if" situations posed by the commander. | Limited by time available for commander to make decisions. | Limited to situations concerning the six manuevers. | Limited to situations concerning doctrinally defined manuevers. | Needs to be performed faster and be reproducible. |
| 13. Display task results graphically and with text. | Manually. | Text outputs only. | Automated using high-resolution computer-generated maps. | Labor intensive |

## Knowledge Requirements

The knowledge required to estimate Red actions may be classified as static or dynamic and observed, doctrinal, or heuristic. Static knowledge refers to facts or descriptions which can be prepared and stored in advance, such as descriptions of Red doctrine or terrain. Dynamic knowledge, including the location or predicted actions of Red units, will change and must be updated with every situation. Observed knowledge is information that was reported by Blue sources, while doctrinal knowledge uses theoretical values based on Soviet writings. While most doctrinal knowledge is also heuristic, this study uses the latter term to refer specifically to the techniques used by skilled analysts in deciding which knowledge is most relevant for estimating Red actions.

Predicting Red actions is a data intensive process. Table II summarizes the inputs and outputs currently used during this process as well as those required for the Red estimator prototype and an operational Red estimator. The table also summarizes the challenges inherent in each type of data. The Red estimator's knowledge requirements include information on Red doctrine, terrain, Blue forces, and intelligence reports, as well as heuristics on how to use this information.

Red Doctrine is a static description of how the Red forces dictate that manuevers and tactics should be performed, including theoretical values for speeds of advance, correlation of forces, and firepower ratios.

Table II. Inputs and Outputs

Current ATOC inputs and outputs are taken from reference (20:B-4 to B-9).

| **Level:** / **Inputs:** | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Input Data Features |
|---|---|---|---|---|
| Static | Red doctrine | Red doctrine | Red doctrine | Symbolic, Heuristic, Multiple experts |
| | Enemy system capabilities and vulnerabilities analysis | Look-up table | Enemy system capabilities and vulnerabilities analysis | |
| | | Terrain | Weather effects on Terrain | |
| | | | Terrain | |
| Dynamic | Mission reports | Blue data | Blue data | Symbolic, Dynamic, Uncertain |
| | Intelligence estimate of the situation | | Previous situation maps | |
| | | | Enemy maneuver history | |

| Inputs: / Level: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Input Data features |
| --- | --- | --- | --- | --- |
| Dynamic | Multiple intelligence collection reports<br><br>Inflight reports<br><br>Reconnaissance reports<br><br>Photography<br><br>Intelligence objectives analysis<br><br>Intelligence reports<br><br>Downed aircraft reports | Fused intelligence incorporating all of the information into databases | Fused intelligence incorporating all of the information into databases and computer graphics. | Symbolic, Dynamic, Uncertain, Wide domain knowledge |
| | Enemy aircraft loss reports | BDA not considered. | BDA effects on terrain | |
| | Battle damage assessments (BDA)<br><br>Other considerations (human inspiration) | User may 'what if' by changing some pieces of information and comparing results. | User 'what if' interface | |

| **Level:**<br>**Outputs:** | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Input Data features |
|---|---|---|---|---|
| DISPLAYS.<br>Graphics | Operational Intelligence Situation Map<br><br>Targets Display Maps<br><br>Situation Correlation Plot Maps<br><br>Area of Operation maps and plotting boards<br><br>Overall military situation display<br><br>Order of Battle displays<br><br>Theatre situation displays<br><br>Forward Area display | None. | Reported and Predicted situation maps depicting military units using standard symbology and high resolution computer maps, generated upon request. | Graphical, Symbolic, Dynamic |

| Outputs: / Level: | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Input Data features |
|---|---|---|---|---|
| DISPLAYS: Knowledge | Intelligence estimate of the situation | Estimate of doctrinally defined enemy courses of action and the confidence level associated with each course of action. | Situation map showing observed (not predicted) locations of units. | Dynamic, Graphical, Symbolic, |
| | Estimate of Enemy Intentions | Intelligence data used. | Estimate of doctrinally defined enemy courses of action and the confidence level associated with each course of action | Heuristic, Uncertain, Multiple experts, |
| | Estimates of Enemy Threats | Reasoning explanation. | Estimate of enemy timing, avenues of approach, and objectives for the doctrinally defined maneuvers | Numerical, explanations required. |
| | Estimates of probable/ possible Enemy Courses of Action | | Intelligence data used | |
| | | | Reasoning explanation | |

| **Level:**<br>**Outputs:** | ATOC | Red Estimator (Prototype) | Operational Red Estimator | Challenging Input Data features |
|---|---|---|---|---|
| ACTIONS: | | | | |
| Explanations | Intelligence briefings | Complete trace of reasoning upon request | Complete trace of reasoning upon request | Explanations required, |
| Recommendations | Target and Reconnaissance nominations by COID (20:24) | Reconnaissance nominations | Target and reconnaissance nominations when installed with complete RAAP system | Heuristic, Dynamic, Wide knowledge domain required. |

Terrain is a static description of observed prominent land features, obstacles, possible routes of travel, and the traversability of the routes. Battle damage assessments and weather reports determine possible changes in the traversability of routes.

Blue force data is a dynamic account of the locations and capabilities of NATO forces.

Intelligence reports are fused, dynamic observations revealing Red unit types, locations, command relationships, equipment, speed and direction of movement, formations, objectives, and current and past maneuvers. The intelligence fusion aid updates these observations as the Blue forces receive better raw intelligence.

Not all of the information described above will be available at any one time. Therefore the Red estimator must use Red doctrine or heuristics to supply missing information and to create and pursue different possible hypotheses depending upon which information is missing. Similarly, it is possible that the Red estimator will receive information from fused intelligence reports that conflicts with previous observations or doctrinal knowledge. The estimator must be able to identify these cases to the user and pursue different hypotheses that are applicable.

A great deal of the difficulty encountered while developing a Red estimator is posed by the nature of the knowledge requirements. Much of the required knowledge is dynamic, classified, uncertain, inconsistent, incomplete, and "soft." The fused intelligence and the Blue forces reports will be constantly changing and must be handled securely. They may be based on information that is in error, as in the case of a misinterpreted radio signal. The knowledge inputs are likely to be inconsistent or incomplete; for example, some information may indicate that a Red unit is proceeding toward one objective, while other information may indicate that the Red unit is proceeding in the opposite direction, possibly because the unit is trying to deceive Blue sensors or just because it is lost. The final challenge is that there is no hard and fast method for estimating Red actions, just "soft" ideas and rules-of-thumb that vary from expert to expert.

Chapter Three suggests a methodology for dealing with the challenges posed by the knowledge and task requirements presented in this chapter.

## III. Methodology: Knowledge-Based System

The Red estimator was developed as a knowledge-based system, which is a subset of artificial intelligence (AI) technology. Knowledge-based systems, including expert systems, use AI techniques to represent and manipulate large amounts of knowledge.

> An expert system is a problem-solving program that achieves good performance in a specialized problem domain that generally requires specialized knowledge and skill. The systems process the knowledge of experts and attempt to mimic their thinking, skill, and intuition (13:21).

The Red estimator covers a broader spectrum of knowledge than is normally included in a single expert system, although it also includes heuristics used by expert intelligence analysts.

### Why an Expert/Knowledge System?

The problem of predicting Red actions is well-suited to the characteristics of an expert system. Rich states, "The most important characteristic of an expert system is that it relies on a large database of knowledge" (24:284). The expert panel mentioned in Chapter One that investigated command and control deficiencies recommended that:

> In order to project the battle ahead in time, the $C^2$ system would be required to assimilate vast quantities of friendly and aggressor combat information including number, armament, position, terrain, weather, etc. It also suggests that the $C^2$ system be guided by an expert system (high or low level) which would peruse and integrate these data in regard to decision rules distilled from many interviews with successful Army tacticians (12:2-6).

Predicting Red actions is a knowledge-driven process.

Another characteristic of expert systems is that they are oriented toward symbolic processing instead of toward mathematical processing as are most conventional programs (16:8). The Red estimator's inputs and outputs as described in Chapter Two are mostly symbolic. Much of the intelligence information is linked to other entities or pieces of information; for example, the command relationship for a particular Red unit may change, linking one small Red unit to a different, larger unit. This type of information is easier to address through a semantic net and symbolic processing than through numerical processing.

The Red estimator must also be able to reason with incomplete, conflicting, and uncertain information. An advantage of using an expert system is that rules of thumb may be written to tell the program which information to use and a best guess for missing values. Another way an expert system may develop values for missing information is to allow information to be 'inherited' from another entity. These approaches permit more flexibility than conventional programming allows toward imperfect information.

Perhaps the most important characteristic of expert and knowledge-based systems for this application is that they can explain their logic, even in the middle of a run (16:8). Conventional algorithmic programs are often difficult to explain and impossible to query while they are running. Because the Red estimator uses information that is susceptible to enemy deception to make recommendations to battle staffs controlling human lives, it must allow the human to review the estimator's logic and information sources. The Red estimator, by explaining how it arrives at a predicted enemy course of action, reduces the time necessary for the decision maker to recognize the situation, yet gives him the final ability to agree or disagree with the machine's conclusion.

Similar knowledge system applications have revealed the likely successes and problems involved with this approach. The next section discusses some of these analogous expert systems.

## Analogous Expert Systems

Even though no software has demonstrated the ability to perform the specified Red estimator tasks, the Navy has demonstrated several artificial intelligence systems that perform similar tasks. One system, the Multi-sensor Integration Evidential-Reasoning System (MSI), outputs the Soviet threat most likely to have emitted particular signalling elements (15:A-3). While MSI does not contain knowledge about Soviet combined arms doctrine, it does account for uncertainty in the intelligence information it receives as inputs (15:Abstract).

A study was done by the U.S. Army Electronics Research and Development Command to develop an airland battle management decision aid with software requirements similar to those of the Red estimator. One of its contractors, the MITRE Corporation, developed a prototype expert system called ANALYST, which depicted a situational display of enemy combat units from intelligence sensor sources (4:iii). This system, while lacking the scripts (predefined scenarios) identifying particular Soviet manuevers, demonstrated the feasibility of using software to identify and predict enemy actions.

Mitre is currently working on a follow-on system that combines the rule-based Analyst program with a script matcher called Scripted Analyst (SCAN) (3:3). The project is being sponsored by Rome Air Development Center and is called IPS, Integrating Plans and Scripts (3:1). According to a draft of the contractor's progress report, "An initial demonstration system containing all the parts shown [a sensor report generator, SCAN, and a plan generator and analyzer] ... has been built, but the full functionality ... is not yet available" (3:6,8). The report concludes that further developments are needed to compare and distinguish the scripts that indicate the true Soviet plans from the other possible scripts and to increase the "sensitivity and selectivity of SCAN" (3:15).

Another Army sponsored study, Combining Decision Analysis and AI Techniques: An Intelligent Aid for Estimating Enemy Courses of Action (AI/ENCOA), approaches the problem of recognizing and predicting Soviet manuevers by using decision analysis techniques to resolve conflicting hypotheses generated by rule-based artificial intelligence techniques (19:17). The system developed does not use intelligence reports but asks the user to answer key questions. Instead of identifying particular Soviet maneuvers AI/ENCOA only identifies four general Soviet actions and possible avenues of approach (19:33). AI/ENCOA lacks the doctrinal knowledge and sophistication necessary to identify detailed Soviet intentions or to use fused data reports. The study's concept of using decision analysis techniques to resolve conflicting hypotheses may, however, prove to be a valuable future enhancement to the Red inference engine.

While the IPS project comes closest to performing all of the tasks required of the Red estimator, none of these systems can do so at this time. Primarily, this is because their design did not include an extensive Red doctrine knowledge base. However, two sources did indicate that capturing Red doctrine in a knowledge base is feasible.

E-Systems, a contractor who specializes in the development of applied artificial intelligence programs, concluded that due to the rigid Soviet conduct of war at the tactical (as opposed to the operational or campaign) level and advances in information processing technology including artificial intelligence, a knowledge based decision support system to identify Soviet tactical manuevers is feasible. E-Systems visualized the parallel processing of 16 software packages: one to identify each manuever. The contractor recommended that a prototype system be built and evaluated in a European operations center against a Soviet training exercise (10:1,18,19).

Mr. James Papagni, the RAAP project manager at Rome Air Development Center, which is managing the development of the RAAP system's components, confirmed that an outline of the architecture for the Red inference engine exists and a contract is being written for a prototype system. According to Mr. Papagni, the architecture calls for an artificial intelligence system based in "C" compiler or FORTRAN computer language to use backward and forward chaining rules (rules to search through a knowledge or data base both from the answer to applicable questions and from the question to applicable answers) to identify "scripts" or patterns of intelligence items representing Soviet tactical maneuvers. A phase II demonstration of RAAP using a prototype inference engine is being planned to take place in an operational environment (22).

## Challenges for Knowledge based Systems

Some aspects of the Red estimator do present challenges to current knowledge-based system technology. Table III summarizes the key features of the Red estimator's problem domain and their suitability to knowledge-based systems. Many of the key features are highly suitable to a knowledge-based system and techniques are available for attempting to adapt the less suitable features to a knowledge-based system. Combined with the advances of expert systems being used in similar applications, this information indicates that the development of the Red estimator as a knowledge-based system is feasible.

Table III. Key Features of Red Estimator Problem Domain

| Problem Domain Features | Suitability to Knowledge-based System | Other Applicable Methods | Techniques to Adapt Task to Knowledge-based System |
|---|---|---|---|
| RELATED TO TASKS: | | | |
| Data-intensive tasks need to be performed faster and be reproducible. | High | | |
| Labor intensive | High | | |
| No manual methodology (some tasks not currently done) | Low | Simulation | Expert opinion on how task could be done. Adaptive design |
| Complex analysis of situation is required. | High | | |
| RELATED TO KNOWLEDGE CHARACTERISTICS: | | | |
| Symbolic. | High | | |
| Numerical (as in computing distances between military units). | Low | Conventional programming | External calls to conventional programs. |

| Problem Domain Features | Suitability to Knowledge-based System | Other Applicable Methods | Techniques to Adapt Task to Knowledge-based System |
|---|---|---|---|
| RELATED TO KNOWLEDGE CHARACTERISTICS: | | | |
| Uncertain. | Low | Simulation, decision analysis | Confidence factors obtained from experts' subjective opinions; trial and error adjustments using test cases (obtained from records of Soviet exercises). |
| Dynamic. | Low | DSS | Frame representations of time, frequent updating of fact (data) bases, non-monotonic reasoning. |
| Heuristic. | High | | |
| Wide domain, interdisciplinary. | Low | Conventional programming using subroutines | Segregated knowledge-bases developed by domain experts. |
| Multiple Experts | Low | Multiple individual methods | Segregated rule-bases containing heuristics from individual experts. |
| Explanations Required | High | | |
| Graphical Displays Useful | High | | |

# IV. Tool Requirements and Selection

An important step prior to developing the prototype Red estimator was the evaluation of available expert system shells (specialized artificial intelligence programs for creating expert systems) and the selection of the best shell for this application. One initial requirement was that the shell must be available for use on a computer secured for processing secret information. Expert system environments (artificial intelligence languages for creating expert systems that are generally more powerful and flexible than shells) are not available on a TEMPEST computer at AFIT and consequently were not considered for use in the prototype. This chapter specifies the tool requirements initially judged necessary for accomplishing the complex tasks listed in Chapter Two. It concludes with a re-assessment of the tool requirements and an evaluation of the selected tool with the benefit of hindsight.

## Tool Requirements

The selected expert system shell required twelve features for the prototype to perform the tasks listed in Chapter Two. Two additional features made development of the prototype easier. All features are discussed below.

1. The shell must run on AFIT's TEMPEST Z-150 computer.

2. The shell must be able to do both backward and forward chaining (reasoning from the answer to the appropriate question and from the question to the answer). This will permit the intelligence data to indicate candidate manuevers (forward chaining) and then let more specific rules fine-tune which manuever is most likely to be conducted (backward

chaining). Backward chaining is also used to find evidence supporting the user's 'what if...' hypotheses

3. The shell must be able to do integer, fixed-point, and trigonometric math. These functions are used to compute rates-of-movement and predict new unit locations.

4. The shell must be able to quickly search large amounts of data, either by using a database system, segregated knowledge bases, or an equivalent system.

5. The shell must be able to do looping (use some rules over and over again). For example, the estimator must be able to use the rules which predict new unit locations every time a new unit is identified.

6. In addition to rules, the shell must be able to represent relationships between different objects and facts with semantic nets, frames, or object-attribute-value triplets (data containing information about a particular attribute possessed by a particular object, such as the size of a Soviet military unit). Information such as command relationships is efficiently represented this way.

7. The shell must demonstrate inheritance when a new object would have the same characteristics (attribute values) as previous objects (for example, if intelligence reports identify an enemy unit as a regiment, then that unit will usually contain the characteristics of a typical enemy regiment). This will be used to supply missing values with the most likely or typical value.

8. The shell must have means to explain how its conclusions are reached and why it pursues particular lines of reasoning.

9. The shell must have a graphics capability or be compatible with external graphics packages. This will make the presentation of the estimator's conclusions clearer and is also the form of battlefield situation presentation that battle staffs presently use.

10. The shell must have readily-available user support and an easy-to-understand manual and tutorial.

11. The shell must use confidence values, certainty factors, or probabilities to compute the likelihood of Red actions. An inexperienced user could misconstrue the predicted Red objective and manuever to be an established fact if no measure of uncertainty is associated with the prediction.

The two features listed below made development easier but were not required.

12. The shell has a shell-specific editor.

13. The shell has a menu-interface for the expert system developer's use.

## Tool Selection

Five expert system shells available at AFIT were evaluated using the above requirements:

1) EXSYS
2) GURU
3) INSIGHT 2+
4) KES
5) PC+.

All evaluations were taken from an expert system shell review conducted by AI Expert (14:69-73) or hands-on experience unless otherwise noted. In addition, a beta-version (developmental-stage version) of a future expert system shell entitled EXSYS Professional was evaluated based on the feature descriptions in its manual (11:1-65). Database capability (requirement four) is possible with EXSYS and EXSYS Professional by using external program calls to DBASE III (5:DBFRAME 1). Evaluations are summarized in Table IV.

The only expert system shell evaluated that satisfies all requirements is EXSYS Professional, although several of the shells had very similar capabilities. The biggest discriminator between shells was the author's subjective evaluation of their ease-of-use, user's manual, and user-support.

Drawbacks to using EXSYS Professional that are not apparent from Table IV are that the shell is not commercially available, not tested, and a runtime version is not available for distributing a completed expert system. The lack of commercial availability of the shell and its

Table IV. Tool Evaluation

| TOOL / REQUIREMENTS | EXSYS PRO | EXSYS | GURU | INSIGHT 2+ | KES | PC+ |
|---|---|---|---|---|---|---|
| 1. Runs on Z-150 | Yes | Yes | Yes | Yes | Yes | Yes |
| 2. Backward & Forward chaining | Yes | Yes | Yes[1] | No | Yes | Yes |
| 3. Math functions | Yes | Yes | Yes[1] | Yes | Yes | Yes |
| 4. Database system | Yes | Yes | Yes | No | No | Yes |
| 5. Loops easily | Yes | No[2] | Yes | Yes | Yes | Yes |
| 6. Frames | Yes[3] | Yes[3] | Yes[1] | Yes | Yes | Yes |
| 7. Inheritance | Yes[3] | Yes[3] | No | No | No | No |
| 8. How & Why explanations | Yes | Yes | Yes | Yes | Yes | Yes |
| 9. Internal Graphics or graphics compatible | Yes | Yes | Yes | Yes | No | Yes |
| 10. Easy-to-read manua | Yes | Yes | No | Yes | Yes | No |
| 11. Predefined confidence factors | Yes | Yes | NO[2] | Yes | Yes | Yes |
| 12. Shell specific editor | Yes | Yes | Yes | Yes | No | Yes |
| 13. Menu development interface | Yes | Yes | Yes | Yes | No | Yes |

NOTES:

1. Information comes from a user's evaluation and conflicts with Freedman's review.

2. Shell may be forced to perform function with additional programming.

3. EXSYS by itself does not have inheritance capability. The FRAME utility offered with EXSYS does have inheritance capability.

runtime version are insignificant because the prototype is not intended for distribution. If serious bugs are discovered in EXSYS Professional its knowledge bases can be converted to the well-tested EXSYS shell by eliminating the more advanced features available only in EXSYS Professional. An extra advantage to using EXSYS Professional has been the accessibility of its developer. Therefore EXSYS Professional was the tool selected for prototype development.

Re-assessment of Tool Selection

Changes to the tool requirements evolved during prototype development. Two of the initial requirements became irrelevant; two additional requirements satisfied by Exsys Professional became very significant, as did three new requirements not satisfied by Exsys Professional.

The two irrelevant requirements were for the shell to be installed on the TEMPEST computer and to have inheritance. The prototype never contained the sophisticated knowledge that would warrant classification or a sophisticated inheritance mechanism. These two requirements do become more significant as the level of knowledge contained in the Red estimator increases. The simple inheritance mechanism actually used in the prototype is discussed in the next chapter.

The two significant new requirements satisfied by Exsys Professional were :

1. A sophisticated command language to provide flexibility in the control of rulebases. The eventual system design required the shell to execute multiple rulebases and external programs dependent on different conditions.

2. Sophisticated control of the way confidence values are computed. This aided in determining which information contributed to which results and led to the development of rules to aid intelligence collection management.

The three additional requirements not satisfied by Exsys Professional were:

3. The ability to create new frames as opposed to filling in the values of previously created blank frames. The new frames would contain information that had changed with time, while the old frames would be stored to provide complete historical data.

4. A sophisticated list processor to store and keep track of hypotheses.

5. Dependability.

The first two unsatisfied requirements were not critical to the success of the prototype because enough blank frames could be prepared to handle a sample scenario and Professional's command language provided a means to keep track of which objectives and maneuvers had been examined. However, the number of errors in the beta version of Exsys Professional prevented development of a fully-functional prototype. Some of the errors occurred during critical development chores, such as the storage of rules. The developer of Exsys Professional provided new versions and quick fixes to the errors, but in the short time available for prototype development not all of the errors could be overcome. Table V lists the author's evaluation of the strengths and weaknesses of Exsys Professional. The prototype was not converted to standard Exsys because Exsys does not satisfy the first two new requirements.

Table V. Evaluation of Exsys Professional

(Versions 0.0.8 to 1.0.0)

Major Strengths

Sophisticated Command Language
Sophisticated Confidence Value Control
Easy Interfacing with External Programs
Easy to Learn and Use
Excellent User Support

Major Weaknesses

Not yet a commercially reliable product due to software errors
Difficult to Perform List Processing

## Conclusions

None of the expert system shells at this time are flexible and dependable enough for the development of a Red estimator. A sophisticated prototype will need to be developed using a well tested AI environment that provides a sophisticated control structure, flexible control of confidence value computations, easy list processing, the ability to create frames, and the ability to call conventional external programs. In addition, the AI environment must be installed on a TEMPEST computer to protect authentic rules and classified knowledge. Such an environment was not available to this researcher.

# V. System Design

This chapter describes the system design used to implement the tasks and knowledge requirements of the Red estimator in the expert system shell. The Red estimator uses knowledge stored in rules, frames, or calculated by external programs to predict Soviet tactical manuevers. Three databases store working knowledge in frames consisting of each data record. Five rulebases contain most of the doctrinal knowledge. Four external programs, represented in the prototype by look-up tables stored in text files, calculate numeric values needed by the Red estimator. Figure 2 depicts this system design. Arrows point toward the component receiving the inputs.

## Databases

Three databases contain the working knowledge used in the Red estimator. The Red units database maintains a frame for every reported Red unit. The information about a particular unit may be updated by the intelligence fusion reports or inferred by the Red estimator. An example frame is shown in Figure 3. The objectives database maintains a frame for every possible predefined objective, including any Blue military units in the proximity of a Red unit. An example frame is shown in Figure 4. The terrain database consists of a look-up table in the prototype but should consist of well-prepared computer files in an

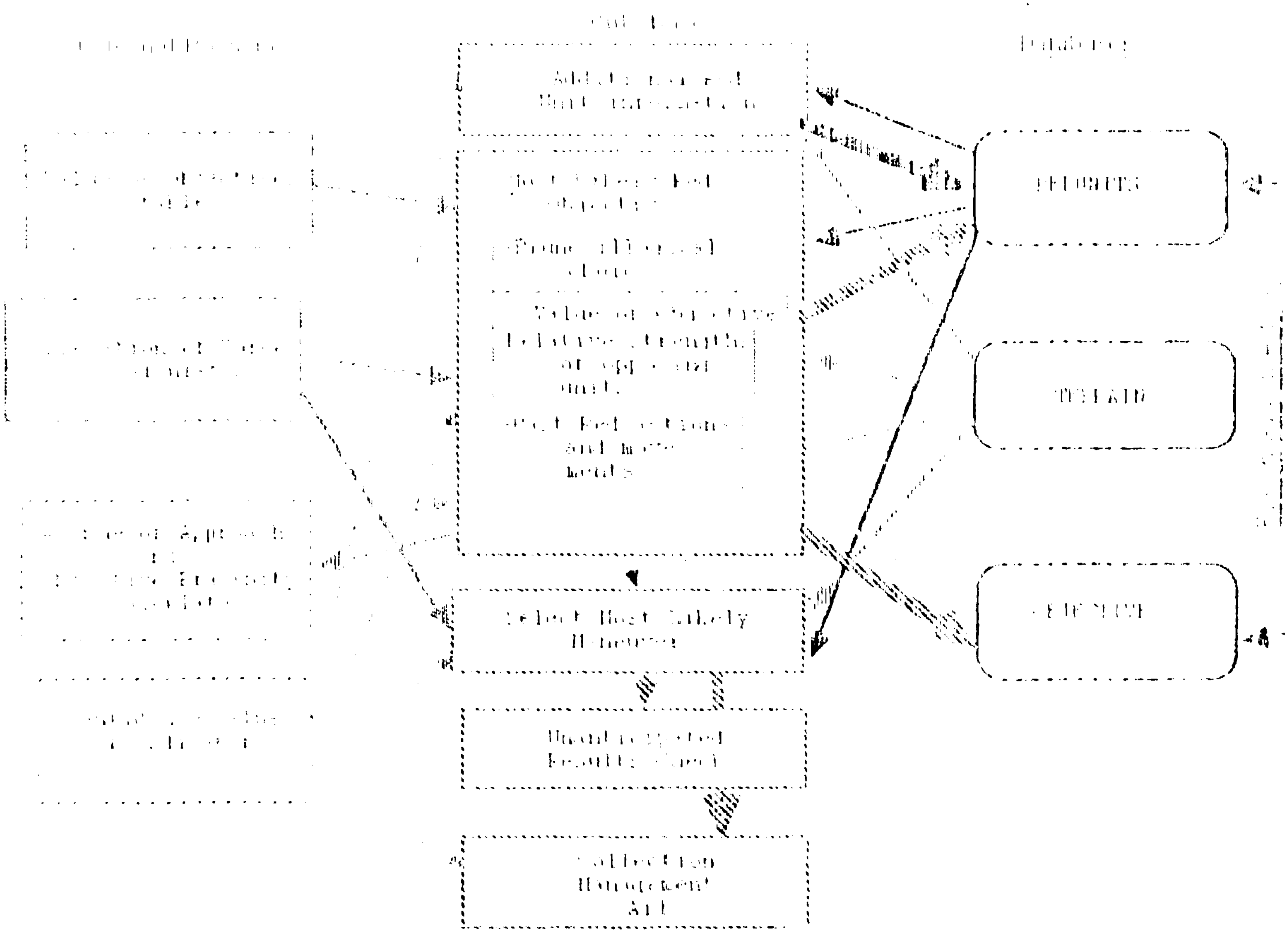



Figure [illegible]. System design

Record #

| REDUNIT | NCOORD | ECOORD | AT_TIME | DTG | TYPE |
|---|---|---|---|---|---|
| Redunit1 | 5035.00 | 0945.00 | 0600 | ZuluDay065Time0630 | Motorized Rifle |

| HEADING | SPEED | TROOP_QUAL* | MOUNTED** | RSRV AVAIL | FORMATION** |
|---|---|---|---|---|---|
| Southeast | [illegible] | A | Yes | March | High |

| SUBUNITS | NUCLEAR* | AIRSTRIKES* | IMMED_OBJ | NEXT_OBJ |
|---|---|---|---|---|
| Engineer | Likely | Possible | Unknown | Unknown |

| ADVANCE | MANEUVER | PAST_ACTS | PAST_OBJ |
|---|---|---|---|
| Unknown | Unknown | Engineer Preparations | Unknown |

Figure 3. Red Unit Frame

*Information not transmitted in proposed fusion systems

**Information not transmitted in proposed fusion systems and available only from HUMINT

Record # [illegible]

| OBJECTIVE | TYPE | SECTOR | NCOORD | ECOORD |
|---|---|---|---|---|
| Nenhof Nuclear Storage | Nuke_storage | 1 | 5038.00 | 1000.00 |

| AT_TIME | IN_CONTROL | UNDERATTAK | POS_ATTAKR | CONFIDENCE |
|---|---|---|---|---|
| [illegible] | Blue | .F. | Redunit1 | .50 |

Figure 4. Objective Frame

operational system containing information about obstacles, electronic lines-of-sight, and traversability during varying weather conditions. The terrain data should be digitized to support graphical displays.

## Rulebases

Five rulebases derive supplemental facts about particular Red military units, the most likely Red objective, the most likely Red manuever, the existence of unanticipated results, and information needed to increase confidence levels in the results. An example rule from each rulebase is shown in Figure 5.

The decision aid first selects a reported Red military unit and forward chains through rules to derive information that cannot be directly observed, such as the level of emphasis that the Red unit is placing on military principles of surprise, mobility, and firepower. This information is stored with other information about the Red unit for use by other rulebases.

The next rulebase backward chains through a set of rules to pick the most likely Red objective out of those expected to be in the proximity of the Red unit during the time frame of interest. The prototype design assumes that the system will run faster if traditional location/time comparisons prune the search space; the system will be more widely accepted if multiple sub-rulebases based on different theories are used to predict Red actions; sub-rulebases using different indicators for predicting Red actions are less likely to be fooled by

```
/*  RULE NUMBER: 4

RULE: INFO 4


IF:

        [EMISSIONS LEVEL] = 'LOW'


THEN:

        THE DETECTED EMISSIONS LEVEL ON THE RED COMMAND NET IS (LOW)

and:    [INDICATIONS OF SURPR] IS GIVEN THE VALUE [INDICATIONS OF
           SURPRISE] + 1
```

Figure 5a. Example Rule to Infer Additional Red Unit Information

```
/*  RULE NUMBER: 10

RULE: OBJ 2

IF:

        [SIDE IN CONTROL] = 'BLUE'

and:    [THE CORRELATION OF FORCES] < 3



THEN:

        > THIS IS THE ACTUAL RED OBJECTIVE - Confidence=[ORDERS VALUE] *
           [%C 1]/ [PRIORITY]

and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] POS_ATTAKR [RED
           UNIT UNDER INVESTIGATION])

and:    [C5_CONF] IS GIVEN THE VALUE [%C 5]

and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] CONFIDENCE
           [C5_CONF])

and:    [%[OBJECTIVE]] IS GIVEN THE VALUE [%C 5]

ELSE:
        > THIS IS THE ACTUAL RED OBJECTIVE - Confidence=[ORDERS VALUE] *
        1/[PRIORITY]

and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] POS_ATTAKR [RED
           UNIT UNDER INVESTIGATION])

and:    [C5_CONF] IS GIVEN THE VALUE [%C 5]

and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] CONFIDENCE
           [C5_CONF])

and:    [%[OBJECTIVE]] IS GIVEN THE VALUE [%C 5]

NOTE:
IF THE CORRELATION OF FORCES IS RELATIVELY LOW, THEN THE RED UNIT MUST
DEPEND MORE ON MOBILITY THAN OVERWHELMING STRENGTH TO SUCEED IN AN
ATTACK

REFERENCE:
FM 100-2-1, PP 5-14,15
```

Figure 5b. Example Rule to Select the Most Likely Objective

/* RULE NUMBER: 13

RULE: MAN 2

IF:

[SIDE IN CONTROL] = 'RED'

THEN:

> THE INTENTIONAL OR THE FORCED DEFENSE - Confidence=.8

and: > THE WITHDRAWL - Confidence=.2

ELSE:

> THE INTENTIONAL OR THE FORCED DEFENSE - Confidence=0

and: > THE WITHDRAWL - Confidence=0

NOTE:

RED DOCTRINE STRESSES TENACITY AND RED IS MORE LIKELY TO DEFEND CAPTURED OBJECTIVES THAN TO WITHDRAW FROM THEM. IF RED DOES NOT CONTROL THE OBJECTIVE, THEN IT CANNOT DEFEND THE OBJECTIVE.

Figure 5c. Example Rule to Select the Most Likely Manuever

```
/*  RULE NUMBER: 26

RULE: COLLECT 6


IF:

        [ANSWER] <> 'N'

and:    [SIDE IN CONTROL] = 'BLUE'

and:    [THE CORRELATION OF FORCES] <3


THEN:

        [MOBILITY CONF] IS GIVEN THE VALUE ([INDICATIONS OF MOBILITY] +
        [UNKNOWN MOBILITY INDICATORS]) / [POSSIBLE MOBILITY INDICATIONS]

and:    [MAX NEW CONF IN THE ] IS GIVEN THE VALUE [NEW ORDERS VALUE] *
           [MOBILITY CONF] / [PRIORITY]

and:    X> REPORT(FINAL.RPT)

and:    X> DISPLAY(COLLECT.MGT)

ELSE:
        [MAX NEW CONF IN THE ] IS GIVEN THE VALUE [NEW ORDERS VALUE] *
        1/[PRIORITY]

and:    X> REPORT(FINAL.RPT)

and:    X> DISPLAY(COLLECT.MGT)
```

Figure 5d. Example Rule to Compute the

Impact of Missing Information

misinformation. Therefore sub-rulebases use different approaches to calculate the confidence they contribute to the Red unit's most likely objective. The first sub-rulebase prunes illogical choices. The next sub-rulebase considers the doctrinal value of the objective, independent of the situation. The third considers the Red view of the correlation-of-forces and its emphasis on various military principles to foresee where the Red unit is likely to perceive it can take the advantage. The final sub-rulebase, not implemented in the prototype, would compare the Red unit's past movements with those deemed necessary to take a particular objective.

The decision aid then passes the most likely objective to a forward chaining rulebase that selects the most likely manuever that the Red unit will use to capture his objective.

A few rules check the results for unanticipated situations that require human interpretation, low confidence levels, and very high confidence levels before the aid displays final results. Any of these results may indicate Red deception efforts or changes in tactics.

The last rulebase is an intelligence collection management aid which searches for unknown information and computes the impact that such knowledge might have on the Red Estimator's results. The user selects an objective which he would like this rulebase to consider. The rulebase then backward chains to find all indicators with a default value of 'unknown' that could increase or decrease the confidence in that objective. The confidence is recomputed using both the best and worst values for each indicator, similar to a sensitivity analysis. After the possible confidence change is computed for each unknown indicator, the total change in confidence possible by using the best value for all unknown indicators is computed and all the indicators and their possible impacts are displayed. The operator may now judge if the change in confidence warrants allocating resources to collect any of the unknown information.

## External Programs

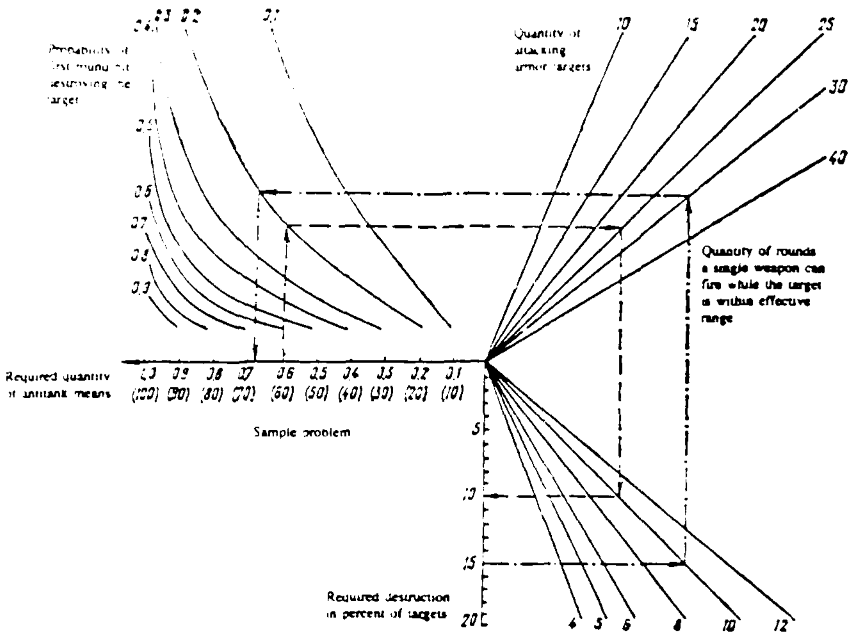
External programs used by the prototype are merely look-up tables stored as text files. The operational Red estimator, however, will require more complex programs.

The first external program looks-up the doctrinal value of objectives. This program may remain a text file in the operational Red estimator to facilitate user modifications. Figure 6 depicts a sample file.

The next external program outputs the ratio of Red combat power to Blue combat power as perceived by the Red unit. In an operational system this program must take inputs concerning the estimated number and type of equipment and men assigned to a unit, the length of time a unit has been in combat, and the readiness level of a unit, and compare these values using nomograms issued to Soviet commanders for estimating the correlation of forces. Of course this presupposes that such nomograms are possessed by NATO. A sample nomogram to calculate the required number of Soviet anti-tank weapons for conducting a defense is shown in Figure 7 (2:141).

| OBJECTIVE_TYPE | [PRIORITY] | [REFERENCE] |
|---|---|---|
| NUKE_STORAGE | 1 | TAKTIKA,pp35,63 |
| KEY_TERRAIN | 6 | TAKTIKA,pp85 |
| MAJOR_BLUE_GRPING | 10 | TAKTIKA,pp35 |

Figure 6. Sample Objective Value File




Problem: How many antitank means are needed to destroy not less than 60% of the attacking enemy tanks?

Given: Expected quantity: 25.

Probability of first round hit: 0.2.

Rate of fire while target is in range: 10.

Solution: Find required destruction and read up to probability of first round hit. Read across to expected quantity of tanks. Read down to rate of fire. Read across to quantity of antitank means.

Answer: 10 antitank means are required.

Figure 5.7. Nomogram for computing the required quantity of antitank means

Source: Col. A. Ia. Vainer, "Takticheskie Raschety," Moscow: Voenizdat, 1982, p. 54.

Figure 7. Sample Soviet Nomogram (2:141)

(Not implemented in prototype)

The next external program outputs the expected locations/times for all units and objectives. In an operational system it must be capable of distinguishing possible avenues of approach from impassable obstacles. TRW is currently designing such a system to be a component of an operational prototype data fusion device, the Limited Operational Capability-Europe (LOCE) (27:1-1).

The last external program needed is a table of the values that certain pieces of information contribute to the confidence levels. Such a table allows the user to easily modify which information contributes the most to the results should the Soviets change tactics to counter the Red manuever estimator.

The simple components in the system design conceal complex development issues that must be resolved before the Red estimator becomes operational. The next chapter discusses these issues.

## VI. Issues, Future Implications, and Conclusions

This chapter reviews the issues that arose during prototype development, summarizes the prototype's performance, delineates the benefits from this research effort, and draws general conclusions about the future of AI and RAAP. New complexities inherent in predicting Red actions were revealed with the development of each component of the Red estimator. Table VI presents these issues, their impact on an operational Red estimator, and the research needed on these issues in other disciplines (as well as in AI) prior to the development of an operational Red estimator.

### Knowledge base Issues

Common issues that arose while developing the inputs to the Red estimator include the resolution of the databases and the extensive preparation that they require. Issues specific to the Red Units database are the availability of signalling elements and inheritance.

Resolution. The one issue pertaining to all the data used by the Red estimator is its resolution. The prototype uses a generic size military unit, assumed to be a regiment, which is the smallest Soviet tactical unit capable of conducting independent operations for an extended period of time (8:5-22). If the Red estimator is used at command and control levels above the ATOC, the appropriate sized unit

Table V. Summary of Issues

*Legend:*

Impact on an Operational System:

Critical -- Operational Red estimator might damage NATO $C^3I$ efforts if issue is not resolved.

High -- Cannot become an operational system unless issue is resolved.

Medium -- Issue effects system design and/or the scope of operational use.

Low -- Results of Red estimator may improve if issue is resolved.

Applicability of AI to Issue:

High -- Strictly an AI issue.

Medium -- AI may be used to resolve issue, such as by using rules to infer needed information.

Low -- Issue not related to AI.

| COMPONENT | ISSUE | IMPACT ON AN OPERATIONAL SYSTEM | APPLICABILITY OF AI TO ISSUE | OTHER APPLICABLE DISCIPLINES |
|---|---|---|---|---|
| KNOWLEDGE BASES: | | | | |
| Red Units database | -Availability of Signalling elements. | High | Low | Intelligence, Electronic Warfare (EW), Interfacing of RAAP decision aids. |
| | -Resolution | High | Medium | Intelligence, Command & Control level |
| | -Inheritance | Medium | High | None |
| | -Characteristics of Specific, Individual Red units and leaders | Low | Medium | Intelligence |
| Terrain database | -Extensive preparation | High | Low | Intelligence, Geography, Cartography, Computer Graphics |
| | -Resolution | High | Medium | |
| | -Weather effects | Medium | Medium | Geography, Meterology |

| COMPONENT | ISSUE | IMPACT ON AN OPERATIONAL SYSTEM | APPLICABILITY OF AI TO ISSUE | OTHER APPLICABLE DISCIPLINES |
|---|---|---|---|---|
| Objectives knowledge base | Updating of Blue force data | High | Low | Command & Control |
| RULEBASES | Security | Critical | Low | DOD procedures, TEMPEST technology |
| | Maintenance of rulebases (effects of political-military events) | High | High | Intelligence |
| Additional info about Red units rulebase | Time representation | Medium | High | Command & Control (desired planning cycle duration) |
| Most likely Red objectives rulebase | Multiple experts | Medium | High | Intelligence |
| Collection management rulebase | Best methods of collection | Low | Medium | Intelligence, EW, User interface |

| COMPONENT | ISSUE | IMPACT ON AN OPERATIONAL SYSTEM | APPLICABILITY OF AI TO ISSUE | OTHER APPLICABLE DISCIPLINES |
|---|---|---|---|---|
| EXTERNAL PROGRAMS: | | | | |
| Correlation-of-forces calculator | Availability of Soviet nomographs* | High | Medium | Intelligence, Game Theory (what does Blue think Red knows about Blue?) |
| Avenue of Approach and proximity calculator | where are the best places to look for Red? | High | Medium - High | Intelligence, Network and Pattern Recognition Theory, Conventional programming, Computer graphics |
| Confidence Values | Reliability | Medium | High | Probability, decision analysis. |

would be division or army. Larger Soviet units, however, have subunits performing different tactical manuevers at the same time. This makes identification of the overall manuever more difficult unless the manuevers of several of the subordinate regiments are known. Further research is needed to decide if the actions of larger units may be inferred without first examining the actions of the subunits. The Red estimator then must focus its output on the unit size most appropriate for the command and control level it is aiding.

The level of detail contained in the databases, particularly in the terrain database, needs to conform to the resolution of the Red units. The prototype divided terrain into undefined sectors of interest, assumed to contain the area that a Red unit was capable of covering during a user-specified period of time. This technique was used to simulate pruning the search space containing possible Red objectives. An operational system, however, must compute the appropriate area to search. Operations research techniques might provide appropriate subroutines for selecting the appropriate terrain sector size.

Extensive Preparation of Databases. The accuracy and usefulness of the Red estimator will always depend on the quality of the data available to it. The terrain and objectives databases require extensive development before the Red estimator will become operational. Their preparation must include procedures for special updates due to weather and the movement of Blue forces. While a Red Units database modeled after that of the prototype does not require extensive preparation, an extension to the database to examine individual Red units in closer detail would.

The terrain database is the largest. It must be detailed enough to reveal obstacles, possible avenues of approach for different sized units, concealment, lines-of-sight for electronic communications, expected rates of movement or traversability, and the effects of varying weather conditions. Weather effects are an important consideration because they may turn a possible avenue of approach into an obstacle, such as when a river floods a bank that is normally suitable for a river crossing.

The objectives database must be developed and updated to include all military facilities, key transportation routes, and key terrain features that are likely to be Soviet tactical objectives. This database must interface with the Blue decision aid to update the location of NATO forces, which also may be Red objectives. The Red estimator assumes that it has perfect knowledge of the location of Blue forces. In the fog of war, however, such an assumption may be invalid.

Another database that could be developed is one containing the characteristics and quality of individual Soviet units and leaders, as observed during Soviet training exercises. This would increase the detail of available Red unit data should one of these units be observed during a conflict. Of course, much more detailed rules than are demonstrated in the prototype would be required to take advantage of such a database.

The success of an operational Red estimator will depend on the extensive preparation and maintenance of its databases. The one database that does not depend on extensive preparation poses two unique problems: the availability of signalling elements and the degree of inheritance required.

Availability of Signalling Elements. The prototype Red estimator assumed that the indicators or signalling elements that it uses are collectible. However, some of the indicators it depends on are not transmitted by proposed fusion technology systems (21). Other indicators would be available only from Human Intelligence reports, which may be scarce. These indicators are annotated in Figure 4. It is important that the developers of fusion technology systems and the Red estimator cooperate to ensure that the outputs from one decision aid match the input requirements of the other.

It is also possible that today's intelligence collection efforts do not emphasize the best doctrinal indicators. A research effort is needed to ensure that the best inputs to the Red estimator are collectible and contained in the outputs from the data fusion system.

Inheritance. The prototype uses very simple inheritance so that information known about a Red unit in one time-frame includes the unchanged information from the previous time-frame. This is done by using the same database record for each unit and overwriting the previous values when new information is received. While adequate for demonstrating this prototype, a more realistic decision aid would store old information (database records) to compare with current information for trend analysis. This would necessitate a more complex inheritance scheme, to allow intelligence updates to create new database frames reflecting values observed at one time, yet referencing the information stored in older frames to supply missing or unchanged values.

## Rulebase Issues

Security and maintenance are issues that effect all of the Red estimator's rulebases. Issues that effect the development of specific rulebases are time representation, incorporating the knowledge of multiple experts, and the management of intelligence collection requests.

Security. The largest challenge an operational Red estimator would face is the chance that the Soviet military would obtain a copy of its rulebases. By knowing exactly how much confidence each indicator lends to a specific outcome, the Soviet forces could provide NATO intelligence with just the right indicators to predict the wrong Red objective. Soviet military writings indicate that they foresee the development of automated systems similar to the Red estimator (9:295). Their writings also stress the value of deception in military tactics (23:45, 2:30). Therefore it is logical to conclude that the Soviet military would actively attempt to deceive the Red estimator.

Rules will be implemented as described in Chapter Five to check for Soviet deception efforts. However, should the Soviets receive a copy of the rulebases, they would know which indicators to avoid to prevent suspicion. It is imperative that the security of the rulebases be protected once the development of the Red estimator includes authentic rules.

Maintenance of Rulebases. The doctrinal knowledge in the Red estimator is embedded in the rules, which are the most difficult part of the system to modify. While tactical doctrine governs the training and equipping of forces, and therefore cannot be changed quickly or inexpensively, a major political-military event or military efforts to counter the effectiveness of the RAAP program may create doctrinal changes significant enough to impair the Red estimator.

One political-military event that might significantly affect Soviet doctrine would be the elimination of tactical nuclear, biological, and chemical weapons. A great part of Soviet doctrine is based on the need to disperse troops to protect them from these weapons, and maintaining the mobility necessary to cross contaminated areas (23:54-56,79). Such a change would affect rules in the Red estimator dealing with the width of avenues of approach, rates of advance, the massing of forces, and other topics that are not obviously related to the use of nuclear, biological, or chemical weapons. The prototype does not contain enough detailed knowledge to be affected by such a change. However, an operational system would need to be maintained by experts on Soviet doctrine aware of the possible impact of major political-military events.

Time Representation. The prototype Red estimator represents time as "snapshots." Fused intelligence inputs update the database files until a run begins, overwriting changed values while leaving default or previously updated values unchanged. The Red estimator does not receive any new information during the run and treats it's database files as a "snapshot" of the state of the world at the time of the last update. After the run the database files are again updated with any information that came in during the run time.

Another way to handle time might be to continuously check new inputs, as they arrive, for information that confirms or disputes previous Red estimator results. If confirming information is received, the confidence level is increased; if disputing information is received, the confidence level is decreased and previously inferred facts are retracted. This representation provides continuous updating and would notify the user of changing results sooner. Possible disadvantages to this representation are that it would either require more rules to send the incoming information directly to the appropriate rulebase, or it would require the entire program to run again. Either alternative may lead to longer total run times. With these considerations, further research is needed to select the best time representation.

Multiple Experts. Diverse opinions exist among intelligence experts as to how reliable different approaches are for estimating Red actions. The prototype loosely models current Army methods for intelligence preparation of the battlefield (7:1--4) in that its inferencing is largely driven by the relative locations and times of units and objectives. The prototype design departs from current methods with a sub-rulebase to compare past events (to those events necessary to complete a hypothesized manuever) in order to fine-tune the confidence levels reached by location/time comparisons. This approach is favored in the contractor's proposed Red estimator design (10:8-10). Due to constraints on the time available to develop the prototype, the event-driven rules were not actually implemented. The prototype does implement another expert's opinion in an additional sub-rulebase that compares the relative doctrinal strengths of opposing units to those needed to capture particular objectives (1). By segregating the experts' opinions into separate rulebases, each approach is considered without forcing the individual experts to form a consensus that may be weaker than the individual methodologies. Because each sub-rulebase uses different indicators, there is also a lower chance that the final outcome can be manipulated by Red deception efforts. Subjective evaluation of the utility of multiple sub-rulebases by several intelligence experts is needed to confirm these assumptions.

Management of Collection Requests. The prototype Red estimator demonstrates the ability to show its user which information, if known, could most improve the confidence in its results. This capability could guide the user's submittal of priority information requests and current operation's re-tasking of available reconnaissance assets. Further research would be necessary to associate the best methods of collection with the indicators requested by the Red estimator. Human intervention would be necessary to confirm that any additional confidence gained by collecting the desired information would be worth the expenditure of the reconnaissance assets.

## External Program Issues

The external programs calculate complex numerical values for the Red estimator, or contain values that the user should be able to modify easily. The data used to create these programs is as important as the careful preparation of the knowledge bases. Related issues concern the availability of Soviet nomograms, knowing where to look for the Red units, and reliability of the Red estimator's results.

Availability of Soviet Nomograms. The correlation of forces should be calculated from the Red point of view, based on what Blue believes Red knows about the Blue forces. This job necessitates using Red nomograms. Consequently the Red estimator must be secured for the level of classification of these nomograms, assuming that NATO possesses them, and still be accessible to its users in the ATOC. A more complicated issue highlighted by this component but implicit throughout the design of the Red estimator, is that Blue must estimate not only what Red is doing, but what Red thinks Blue is doing. As a worst case, Blue can always assume that Red has virtually perfect information about Blue.

Where to Look for Red? The avenue-of-approach and proximity-of-units calculator provides information about how far a Red unit must travel to reach particular objectives considering possible routes. This program was not implemented in the prototype due to time constraints and the reality that it is a difficult problem in itself. This program must also interface with the terrain and Red units databases, and may involve some AI techniques (27:1-6). Further research is needed to implement this component.

Confidence Value Reliability. Changes in Soviet tactics, or perhaps just the masking of the indicators used by the Red estimator, may result from the Soviet military leadership's attempts to counter RAAP. By using different formations, disregarding or delaying some preparations, or concealing preparations, the Soviets may eventually render some rules unreliable. In this case, the user could reduce the confidence contribution of the affected rules by editing the values in the external text file containing confidence values.

The prototype uses confidence values based on the number of indicators received divided by the total number of indicators possible. Users can modify the weights assigned to each indicator; otherwise each indicator is treated as being of the same information value as any other indicator.

Future research might include a value of information study on the indicators to be used in an operational system. User confidence in an operational system would probably be increased by comparing Red estimator results to Soviet exercise scenarios in order to verify that the decision aid produces reliable results.

## User Interface

The prototype Red estimator displays only text files, due to the time constraints during its development. It's future users, however, are accustomed to performing the intelligence preparation of the battlefield by studying maps. The ATOC currently relies on eight different maps or graphics to present the information to be output by an operational Red estimator (20:B-4 to B-9). For best user acceptance, an operational system must display it's outputs in the form that is used and understood by military operators -- maps and graphics.

## Prototype Performance

The prototype proved to be a very useful tool for exploring these complex issues inherent in an automated Red estimator. However, its actual performance is less than desirable.

Due to the lack of development time, errors in the beta version shell, and inadequacies in the fall back commercial expert system shell for handling the complexities of the issues involved, the prototype does not demonstrate all of the features proposed in the system design. The missing features include the external table of confidence values, the avenue of approach and proximity calculator, and the sub-rulebase to assign confidence to a possible objective based on past Red movements. The system is not robust and does not consistently complete its runs. Although the rulebase for collection management has been successfully tested, it has not been successfully integrated with the entire system. The latter problems associated with executing the program are caused by documented errors in the beta version expert system shell.

Despite these problems in the prototype, it can still be used to demonstrate the system design with the exception of looking-up modified confidence values. The collection management rulebase must be demonstrated independently from the system.

Further development of the prototype built in this study is unnecessary. A more productive effort would be to implement the same system design in an expert system environment for further exploration of the issues raised in Chapter Six. The Red estimator fulfilled its purpose by raising issues about its required inputs, outputs, and proposed capabilities that can be used to critique the contracted Red estimator.

## Summary

The major benefits from this study are the issues raised, the use of rules to evaluate the impact of unknown information, and a Red estimator system design that is robust in an environment with changing Red indicators. Table VI can serve as a checklist of research efforts that need to be conducted and expertise that needs to be gathered before full scale development of an operational Red estimator begins. The key issues are: rule base security, because the impact of a loss of security would be so detrimental; the availability of signalling elements, because a system that uses unavailable information would be useless; and the need for an interdisciplinary approach to developing the Red estimator, because without adequate knowledge and proper interfacing between the RAAP decision aids the Red estimator cannot become functional. The next major benefit from this study is the use of rules to evaluate the impact of unknown information. These rules, identified in the appendix as "Collect" rules, demonstrate an approach that is applicable to any expert system which works with missing information that is expensive to collect. The final benefit of this study is its design of a Red estimator that emphasizes reliability in a changing environment. Its main features for enhancing reliability are the use of sub-rulebases incorporating different approaches and indicators (there is some overlap of indicators) to identify the [illegible] and a confidence value table that adjusts the weighting of the confidence contributed by different indicators to the results. Both of these features protect against Soviet efforts to conceal the indicators of their objectives and manuevers.

## Conclusion

The development of the Red estimator as a knowledge-based system is appropriate and feasible, but it will require the integration of AI, conventional programming, and operations research techniques together with a great deal of operational knowledge that still needs to be assimilated. This will require more research, the support of many military agencies in the gathering of data, the coordination of contractors designing the different, interfacing decision aids to be used for RAAP, and careful management to see that all issues are resolved. This effort is technologically feasible, but may require years of research and development to become operational.

Appendix: Prototype Red Estimator Software

DEVELOPED USING EXSYS PROFESSIONAL

Subject:
This prototype Red estimator assigns a confidence level to possible objectives and maneuvers that the Red unit may be trying to obtain

Author:
A.M. FLETCHER

Derivation: ALL RULES USED

PROBABILITY SYSTEM: 5

INITIAL CHOICE CONFIDENCE: 0.000000

DISPLAY THRESHOLD: 0

QUALIFIERS:

* Qualifier 1
Q THE RED UNIT'S TROOPS ARE

V UNKNOWN IF MOUNTED OR NOT
V MOUNTED
V DISMOUNTED

Name: MAN FIRE
Default Confidence = [illegible]
Default Value = 1

/* Qualifier 2
Q> THE DETECTED EMISSIONS LEVEL ON THE RED COMMAND NET IS

V> NORMAL
V> HIGH
V> LOW

Name: SURPRISE
Default Confidence = 100.000000
Default value = 1

/* Qualifier 3
Q> THE RED UNIT COMMANDER'S ORDERS ARE

V> UNKNOWN BY BLUE
V> TO WITHDRAW
V> TO TAKE THIS OBJECTIVE

Name: RED ORDERS
Default Confidence = 1.000000

CHOICES:

/* Choice 1
C> THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS HIGH

/* Choice 2
C> THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE IS HIGH

/* Choice 3
C> THE RED UNIT'S LEVEL OF EMPHASIS ON FIREPOWER IS HIGH

/* Choice 4
C> THIS IS NOT THE ACTUAL RED OBJECTIVE

/* Choice 5
C> THIS IS THE ACTUAL RED OBJECTIVE

/* Choice 6
C> THE ATTACK OF A DEFENDING ENEMY FROM THE MARCH

/* Choice 7
C> THE ATTACK FROM CONTACT

/* Choice 8
C> THE BREAKTHROUGH OF ECHELONED DEFENSES

/* Choice 9
C> THE INTENTIONAL OR THE FORCED DEFENSE

/* Choice 10
C> THE MEETING ENGAGEMENT

/* Choice 11
C> THE WITHDRAWL

/* Choice 12
C> UNABLE TO IDENTIFY RED TACTICS

VARIABLES:
[MOUNTED TROOPS] THE ANSWER TO THE QUESTION, ARE THE RED UNIT'S TROOPS MOUNTED?
Default Confidence = 100.000000
Type = S

[THE CORRELATION OF F] RUN(TABLET PWRRATIO [[RED UNIT UNDER INVESTIGATION]] [[DEFENDER]] /C /M) THE RATIO OF RED COMBAT POWER TO BLUE COMBAT POWER AS ESTIMATED BY THE RED UNIT
Default Confidence = 100.000000
Type = N
Lower limit = 0.000000

[RED UNIT UNDER INVES] THE NAME IN THE REDUNITS DATABASE OF THE RED UNIT BEING INVESTIGATED
Default Confidence = 100.000000
Display at end
Type = S

[DEFENDER] THE NAME ASSIGNED TO THE BLUE UNIT CURRENTLY DEFENDING THE POSSIBLE RED OBJECTIVE.
Default Confidence = 100.000000
Display at end
Type = S

[OBJECTIVE] THE AVAILABLE TARGET (OBJECTIVE) LOCATED IN THE RED UNIT'S ESTIMATED TERRAIN SECTOR OF INFLUENCE
Default Confidence = 0.000000
Display at end
Display confidence
Type = S

[CHOICE TEXT] The possible tactical plays the Red Unit might try are:
Default Confidence = 100.000000
Type = T

[C1_CONF] THE CONFIDENCE IN CHOICE #1
Default Confidence = 100.000000
Type = N
Upper limit = 100.000000
Lower limit = 0.000000

[C2_CONF] THE CONFIDENCE IN CHOICE #2
Default Confidence = 100.000000
Type = N
Upper limit = 100.000000
Lower limit = 0.000000

[C3_CONF] THE CONFIDENCE IN CHOICE #3
Default Confidence = 100.000000
Type = N
Upper limit = 100.000000
Lower limit = 0.000000

[C5_CONF] THE CONFIDENCE IN CHOICE #5
Default Confidence = 100.000000
Type = N
Upper limit = 100.000000
Lower limit = 0.000000

[I] A COUNTER TO INCREMENT RULE CONTROL IN THE COMMAND FILE
Default Confidence = 100.000000
Type = N

[SECTOR] THE TERRAIN SECTOR THAT THE RED UNIT IS PROJECTED TO BE IN AT THE TIME OF INTEREST
Default Confidence = 100.000000
Display at end
Type = N

[CHECK SECTOR] A VALUE USED TO CHECK THE DATABASES FOR INFORMATION ABOUT THE SECTOR OF INTEREST
Default Confidence = 100.000000
Type = N

[TOTAL NUMBER OF RECO] THE TOTAL NUMBER OF POSSIBLE OBJECTIVES LISTED IN THE OBJECTIVE DATABASE
Default Confidence = 100.000000
Type = N

[EMISSIONS LEVEL] THE DETECTED RELATIVE LEVEL OF COMMAND RADIO NET EMISSIONS
Default Confidence = 100.000000
Type = S

[INDICATIONS OF MOBILITY] THE NUMBER OF INDICATIONS THAT THE RED UNIT IS
EMPHASIZING MOBILITY
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[TOTAL DETECTED MOBILITY] DETECTED NUMBER OF INDICATORS OF THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[INDICATIONS OF FIREP] THE NUMBER OF INDICATIONS THAT THE RED UNIT IS STRESSING FIREPOWER
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[TOTAL DETECTED FIREP] THE DETECTED NUMBER OF INDICATORS OF THE RED UNIT'S LEVEL OF EMPHASIS ON FIREPOWER
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[INDICATIONS OF SURPR] THE NUMBER OF INDICATIONS THAT THE RED UNIT IS EMPHASIZING THE PRINCIPLE OF SURPRISE
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[TOTAL DETECTED SURPR] THE DETECTED NUMBER OF INDICATORS OF THE RED UNIT'S LEVEL OF EMPHASIS ON SURPRISE
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[POSSIBLE MOBILITY IN] THE POSSIBLE NUMBER OF INDICATORS OF THE LEVEL OF EMPHASIS ON MOBILITY
Default Confidence = 100.000000
Type = N
Initialize = 2.000000

[DETECTED OPERATIONS] A LIST OF PAST OPERATIONS DONE BY THE RED UNIT THAT WERE DETECTED BY THE BLUE SIDE
Default Confidence = 100.000000
Display at end
Type = S

[SIDE IN CONTROL] THE SIDE CONTROLLING THE OBJECTIVE
Default Confidence = 100.000000
Type = S

[PRIORITY] RUN(TABLET PRIORITY [OBJECTIVE TYPE] /C) THE PRIORITY OF THIS TYPE OF OBJECTIVE (INDEPENDENT OF THE SITUATION) ON A SCALE OF 10 TO 1 (ONE BEING THE HIGHEST PRIORITY).
Default Confidence = 100.000000
Type = N

[REFERENCE] THE REFERENCE FOR THE DOCTRINAL PRIORITY ASSIGNED TO THE OBECTIVE TYPE UNDER CONSIDERATION
Default Confidence = 100.000000
Type = S

[OBJECTIVE TYPE] THE TYPE OF OBJECTIVE UNDER CONSIDERATION
Default Confidence = 100.000000
Display at end
Type = S

[COLLECTION FILE] THE NAME OF THE FILE CONTAINING REPORT SPECIFICATIONS FOR A PARTICULAR TYPE OF INFORMATION NEEDED TO IMPROVE THE CONFIDENCE IN THE RESULTS
Default Confidence = 100.000000
Type = S

[GREATEST CONFIDENCE] THE GREATEST CONFIDENCE ASSIGNED TO AN OBJECTIVE SO FAR
Default Confidence = 100.000000
Type = N
Initialize = 0.000000

[MOST LIKELY OBJECTIV] THE OBJECTIVE WITH THE GREATEST CONFIDENCE SO FAR
Default Confidence = 0.000000
Display at end
Display confidence
Type = S

[C12_CONF] THE CONFIDENCE IN CHOICE 12
Default Confidence = 100.000000
Type = N
Initialize = 0.000000
Upper limit = 100.000000
Lower limit = 0.000000

[ORDERS VALUE] THE INCREASE OF CONFIDENCE THAT THIS IS THE OBJECTIVE DUE TO THE INTERCEPTION OF RED ORDERS
Default Confidence = 0.000000
Type = N
Initialize = 1.000000

[POSSIBLE SURPRISE IN] THE POSSIBLE NUMBER OF INDICATORS OF THE RED UNIT'S LEVEL OF EMPHASIS ON SURPRISE
Default Confidence = 0.000000
Type = N
Initialize = 2.000000

[ANSWER] THE DATA RECORD NUMBER OF THE OBJECTIVE
Default Confidence = 0.000000
Type = S

[NEW CONF IN THE OBJE] THE CONFIDENCE IN THIS OBJECTIVE WOULD INCREASE TO
Default Confidence = 1.000000
Type = N
Initialize = 0.000000

[NEW ORDERS VALUE] THE INCREASE IN CONFIDENCE DUE TO KNOWLEDGE ABOUT THE RED COMMANDER'S ORDERS
Default Confidence = 0.000000
Type = N

[MOBILITY CONF] THE INCREASE IN CONFIDENCE THAT THE RED UNIT IS EMPHASISING MOBILITY
Default Confidence = 0.000000
Type = N

[UNKNOWN MOBILITY IND] THE POSSIBLE INDICATORS OF THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY WHICH ARE UNKNOWN
Default Confidence = 0.000000
Type = N
Initialize = 0.000000

[UNKNOWN FIREPOWER IN] THE POSSIBLE INDICATORS OF THE RED UNIT'S LEVEL OF EMPHASIS ON FIREPOWER WHICH ARE UNKNOWN
Default Confidence = 0.000000
Type = N
Initialize = 0.000000

[MAX FIREPOWER CONF] THE CONFIDENCE THAT THE RED UNIT IS EMPHASIZING FIREPOWER COULD INCREASE TO
Default Confidence = 0.000000
Type = N
Upper limit = 100.000000
Lower limit = 0.000000

[UNKNOWN SURPRISE IND] THE NUMBER OF INDICATORS WHICH ARE UNKNOWN BUT COULD INCREASE CONFIDENCE THAT THE RED UNIT IS EMPHASIZING THE PRINCIPLE OF SURPRISE
Default Confidence = 0.000000
Type = N
Initialize = 0.000000

[MAX SURPRISE CONFIDE] THE CONFIDENCE THAT THE RED UNIT IS EMPHASIZING SURPRISE COULD INCREASE TO
Default Confidence = 0.000000
Type = N

[MAX NEW CONF IN THE ] The maximum confidence obtainable in this objective or action is
Default Confidence = 0.000000
Type = N

RULES:

```
/*  RULE NUMBER: 1
RULE: INFO 1

IF:
       [MOUNTED TROOPS] = 'YES'

THEN:
       THE RED UNIT'S TROOPS ARE {MOUNTED}
and:   [INDICATIONS OF MOBILITY] IS GIVEN THE VALUE [INDICATIONS OF
          MOBILITY] + 1
and:   [TOTAL DETECTED MOBILITY] IS GIVEN THE VALUE [TOTAL DETECTED
          MOBILITY INDICATORS] + 1
and:   [TOTAL DETECTED FIREP] IS GIVEN THE VALUE [TOTAL DETECTED
          FIREPOWER INDICATORS] + 1


/*  RULE NUMBER: 2
RULE: INFO 2

IF:
       [MOUNTED TROOPS] = 'NO'

THEN:
       THE RED UNIT'S TROOPS ARE {DISMOUNTED}
and:   [TOTAL DETECTED FIREP] IS GIVEN THE VALUE [TOTAL DETECTED
          FIREPOWER INDICATORS] + 1
and:   [TOTAL DETECTED MOBILITY] IS GIVEN THE VALUE [TOTAL DETECTED
          MOBILITY INDICATORS] + 1
and:   [INDICATIONS OF FIREP] IS GIVEN THE VALUE [INDICATIONS OF
          FIREPOWER] + 1


/*  RULE NUMBER: 3
RULE: INFO 3

IF:
       [EMISSIONS LEVEL] = 'HIGH'

THEN:
       THE DETECTED EMISSIONS LEVEL ON THE RED COMMAND NET IS {HIGH}
and:   [INDICATIONS OF MOBILITY] IS GIVEN THE VALUE [INDICATIONS OF
          MOBILITY] + 1
```

```
/*  RULE NUMBER: 4
RULE: INFO 4

IF:
       [EMISSIONS LEVEL] = 'LOW'

THEN:
       THE DETECTED EMISSIONS LEVEL ON THE RED COMMAND NET IS (LOW)
and:   [INDICATIONS OF SURPR] IS GIVEN THE VALUE [INDICATIONS OF
          SURPRISE] + 1



/*  RULE NUMBER: 5
RULE: INFO 5

IF:
       THE DETECTED EMISSIONS LEVEL ON THE RED COMMAND NET IS (HIGH) OR
(LOW)

THEN:
       [TOTAL DETECTEDUE] IS GIVEN THE VALUE [TOTAL DETECTED MOBILITY
       INDICATORS]
and:   [TOTAL DETECTED SURPR] IS GIVEN THE VALUE [TOTAL DETECTED
          SURPRISE INDICATORS] + 1

NOTE:
THE PRINCIPLE OF MOBILITY REQUIRES FAST TRANSMITTAL OF ORDERS WHILE
MOVING.

REFERENCE:
TAKTIKA pp 50



/*  RULE NUMBER: 6
RULE: INFO 6

IF:
       [DETECTED OPERATIONS] = 'DECOYS'

THEN:
       [INDICATIONS OF SURPR] IS GIVEN THE VALUE [INDICATIONS OF
          SURPRISE] + 1
and:   [TOTAL DETECTED SURPR] IS GIVEN THE VALUE [TOTAL DETECTED
          SURPRISE  INDICATORS] + 1
```

and: [TOTAL DETECTED FIREP] IS GIVEN THE VALUE [TOTAL DETECTED FIREPOWER INDICATORS] + 1

NOTE:
THE USE OF DECOYS SHOWS THAT THE RED UNIT IS EMPHASISING THE PRINCIPLE OF SURPRISE

/* RULE NUMBER: 7
RULE: INFO 7

IF:
[INDICATIONS OF MOBILITY] / [TOTAL DETECTED MOBILITY INDICATORS] > .6

THEN:
> THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS HIGH.
- Confidence=[TOTAL DETECTED MOBILITY INDICATORS] / [POSSIBLE MOBILITY INDICATORS]

/* RULE NUMBER: 8
RULE: INFO 8

IF:
[INDICATIONS OF SURPRISE] / [TOTAL DETECTED SURPRISE INDICATORS] > .6

THEN:
> THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE IS HIGH.
- Confidence=[TOTAL DETECTED SURPRISE INDICATORS] / [POSSIBLE SURPRISE INDICATORS]

/* RULE NUMBER: 9
RULE: OBJ 1

IF:
THE RED UNIT COMMANDER'S ORDERS ARE (TO TAKE THIS OBJECTIVE)

THEN:
[ORDERS VALUE] IS GIVEN THE VALUE 2

NOTE:

THIS RULE APPLIES WHEN BLUE HAS INTERCEPTED SOME OF RED'S TROOP CONTROL (C2) COMMUNICATIONS

```
/*  RULE NUMBER: 10
RULE: OBJ 2

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] < 3

THEN:
        > THIS IS THE ACTUAL RED OBJECTIVE - Confidence=[ORDERS VALUE] *
           [%C 1]/ [PRIORITY]
and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] POS_ATTAKR [RED
           UNIT UNDER INVESTIGATION])
and:    [C5_CONF] IS GIVEN THE VALUE [%C 5]
and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] CONFIDENCE
           [C5_CONF])
and:    [%[OBJECTIVE]] IS GIVEN THE VALUE [%C 5]

ELSE:
        > THIS IS THE ACTUAL RED OBJECTIVE - Confidence=[ORDERS VALUE] *

        ./[PRIORITY]
and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] POS_ATTAKR [RED
           UNIT UNDER INVESTIGATION])
and:    [C5_CONF] IS GIVEN THE VALUE [%C 5]
and:    X> DB_PK(OBJECTIV.DBF OBJECTIV.NDX [OBJECTIVE] CONFIDENCE
           [C5_CONF])
and:    [%[OBJECTIVE]] IS GIVEN THE VALUE [%C 5]

NOTE:
IF THE CORRELATION OF FORCES IS RELATIVELY LOW, THEN THE RED UNIT MUST
DEPEND MORE ON MOBILITY THAN OVERWHELMING STRENGTH TO SUCEED IN AN
ATTACK

REFERENCE:
FM 100-2-1, PP 5-14,15


/*  RULE NUMBER: 11
RULE: OBJ 3

IF:
        > THIS IS THE ACTUAL RED OBJECTIVE- Conf.   [%V 30]

THEN:
```

```
        [%[MOST LIKELY OBJECTIV]] IS GIVEN THE VALUE [%C 5]
and:    [MOST LIKELY OBJECTIV] IS GIVEN THE VALUE '[[OBJECTIVE]]'

NOTE:
THIS KEEPS TRACK OF THE MOST LIKELY OBJECTIVE



/*  RULE NUMBER: 12
RULE: MAN 1

IF:
        THE RED UNIT COMMANDER'S ORDERS ARE (TO WITHDRAW)

THEN:
        > THE WITHDRAWL - Confidence=1
and:    > THE INTENTIONAL OR THE FORCED DEFENSE - Confidence=0

NOTE:
THE RED UNIT CANNOT WITHDRAW WITHOUT THE ORDERS OF THE SENIOR RED
COMMANDER-IN-CHIEF

REFERENCE:
TAKTIKA, p. 152



/*  RULE NUMBER: 13
RULE: MAN 2

IF:
        [SIDE IN CONTROL] = 'RED'

THEN:
        > THE INTENTIONAL OR THE FORCED DEFENSE - Confidence=.8
and:    > THE WITHDRAWL - Confidence=.2

ELSE:
        > THE INTENTIONAL OR THE FORCED DEFENSE - Confidence=0
and:    > THE WITHDRAWL - Confidence=0

NOTE:
RED DOCTRINE STRESSES TENACITY AND RED IS MORE LIKELY TO DEFEND CAPTURED
OBJECTIVES THAN TO WITHDRAW FROM THEM.  IF RED DOES NOT CONTROL THE
OBJECTIVE, THEN IT CANNOT DEFEND THE OBJECTIVE.

REFERENCE:
TAKTIKA, pp 69,35
```

```
/*  RULE NUMBER: 14
RULE: MAN 3

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] >= 3
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS
        HIGH.- Conf. > .5
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE
           IS HIGH.- Conf. <= .5

THEN:
        > THE ATTACK OF A DEFENDING ENEMY FROM THE MARCH - Confidence=
           [%C 1]

NOTE:
GENERALLY, RED PREFERS TO ATTACK FROM THE MARCH TO MAINTAIN MOMENTUM

REFERENCE:
TAKTIKA




/*  RULE NUMBER: 15
RULE: MAN 4

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] >= 3
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS
        HIGH.- Conf. <= .5
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE
IS
        HIGH.- Conf. <= .5

THEN:
        > THE ATTACK FROM CONTACT - Confidence=.5
and:    > THE BREAKTHROUGH OF ECHELONED DEFENSES - Confidence=.5




/*  RULE NUMBER: 16
RULE: MAN 5

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] >= 3
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE
           IS HIGH.- Conf. >= .5
```

```
THEN:
        > THE BREAKTHROUGH OF ECHELONED DEFENSES - Confidence=[%C 2]
and:    > THE ATTACK OF A DEFENDING ENEMY FROM THE MARCH - Confidence=(1
           - [%C 2])



/*  RULE NUMBER: 17
RULE: MAN 6

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] < 3
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS
        HIGH.- Conf. < .5
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE
           IS  HIGH.- Conf. < .5

THEN:
        > UNABLE TO IDENTIFY RED TACTICS - Confidence=(1 - ([%C 1] *
           [%C 2]))
and:    [C12_CONF] IS GIVEN THE VALUE (1 - ([%C 1] * [%C 2]))



/*  RULE NUMBER: 18
RULE: MAN 7

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] < 3
and:    [THE CORRELATION OF FORCES] >= 1
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY [illegible]
        HIGH.- Conf. >= .5

THEN:
        > THE ATTACK OF A DEFENDING ENEMY [illegible]
           [%C 1]



/*  RULE NUMBER [illegible]
RULE: MAN [illegible]

IF:
[illegible]
```

AD-A190 573 STRUCTURE FOR A KNOWLEDGE-BASED SYSTEM TO ESTIMATE 2/2
SOVIET TACTICS IN THE..(U) AIR FORCE INST OF TECH
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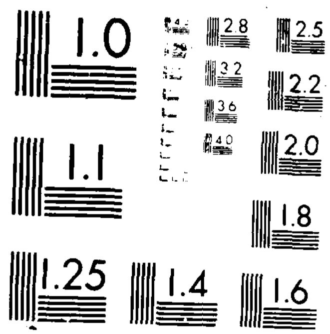
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```
THEN:
        > THE BREAKTHROUGH OF ECHELONED DEFENSES - Confidence=[%C 2]
and:    > THE ATTACK OF A DEFENDING ENEMY FROM THE MARCH - Confidence=(1
            - [%C 2])



/*  RULE NUMBER: 17
RULE: MAN 6

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] < 3
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS
        HIGH.- Conf. < .5
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE
            IS  HIGH.- Conf. < .5

THEN:
        > UNABLE TO IDENTIFY RED TACTICS - Confidence=(1 - ([%C 1] *
            [%C 2]))
and:    [C12_CONF] IS GIVEN THE VALUE (1 - ([%C 1] * [%C 2]))



/*  RULE NUMBER: 18
RULE: MAN 7

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] < 3
and:    [THE CORRELATION OF FORCES] >= 1
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON MOBILITY IS
        HIGH.- Conf. >= .5

THEN:
        > THE ATTACK OF A DEFENDING ENEMY FROM THE MARCH - Confidence=
            [%C 1]



/*  RULE NUMBER: 19
RULE: MAN 8

IF:
        [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] < 1
and:    > THE RED UNIT'S LEVEL OF EMPHASIS ON THE PRINCIPLE OF SURPRISE
IS
```

```
and:    [THE CORRELATION OF FORCES] <3

THEN:
        [NEW CONF IN THE OBJE] IS GIVEN THE VALUE [NEW ORDERS VALUE] *
           [MAX  MOBILITY CONF] / [PRIORITY]
and:    X> REPORT(OBJECTIV.RPT)

ELSE:
        [NEW CONF IN THE OBJE] IS GIVEN THE VALUE [NEW ORDERS VALUE] *
        1/[PRIORITY]
and:    X> REPORT(OBJECTIV.RPT)



/*  RULE NUMBER: 23
RULE: COLLECT 3

IF:
        [ANSWER] <> 'N'
and:    THE RED UNIT'S TROOPS ARE {UNKNOWN IF MOUNTED OR NOT}

THEN:
        [UNKNOWN MOBILITY IND] IS GIVEN THE VALUE [UNKNOWN MOBILITY
           INDICATORS] + 1
and:    [UNKNOWN FIREPOWER IN] IS GIVEN THE VALUE [UNKNOWN FIREPOWER
           INDICATORS]  + 1
and:    [MOBILITY CONF] IS GIVEN THE VALUE ([INDICATIONS OF MOBILITY] +
           1)/
        [POSSIBLE MOBILITY INDICATIONS]
and:    [MAX FIREPOWER CONF] IS GIVEN THE VALUE ([INDICATIONS OF
           FIREPOWER] +  1)/ 2
and:    X> CLEAR([NEW CONF IN THE OBJECTIVE])
and:    X> CLEAR(R 22)
and:    X> REPORT(MOUNT.RPT)



/*  RULE NUMBER: 24
RULE: COLLECT 4

IF:
        [ANSWER] <> 'N'
and:    [DETECTED OPERATIONS] = 'NONE'

THEN:
        [UNKNOWN SURPRISE IND] IS GIVEN THE VALUE [UNKNOWN SURPRISE
           INDICATORS] + 1
and:    [MAX SURPRISE CONFIDE] IS GIVEN THE VALUE  ([UNKNOWN SURPRISE
        INDICATORS] + 1) / [POSSIBLE SURPRISE INDICATORS]
and:    X> CLEAR([NEW CONF IN OBJ])
```

```
and:    X> CLEAR(R 22)
and:    X> REPORT(DECOY.RPT)



/*  RULE NUMBER: 25
RULE: COLLECT 5

IF:
        [ANSWER] <> 'N'
and:    THE RED UNIT COMMANDER'S ORDERS ARE (UNKNOWN BY BLUE)

THEN:
        [NEW ORDERS VALUE] IS GIVEN THE VALUE 2
and:    X> CLEAR([NEW CONF IN THE OBJECTIVE])
and:    X> CLEAR(R 22)
and:    X> REPORT(ORDERS.RPT)

ELSE:
        [NEW ORDERS VALUE] IS GIVEN THE VALUE [ORDERS VALUE]
and:    X> CLEAR([NEW CONF IN THE OBJECTIVE])
and:    X> CLEAR(R 22)



/*  RULE NUMBER: 26
RULE: COLLECT 6

IF:
        [ANSWER] <> 'N'
and:    [SIDE IN CONTROL] = 'BLUE'
and:    [THE CORRELATION OF FORCES] <3

THEN:
        [MOBILITY CONF] IS GIVEN THE VALUE ([INDICATIONS OF MOBILITY] +
        [UNKNOWN MOBILITY INDICATORS]) / [POSSIBLE MOBILITY INDICATIONS]
and:    [MAX NEW CONF IN THE ] IS GIVEN THE VALUE [NEW ORDERS VALUE] *
           [MOBILITY CONF] / [PRIORITY]
and:    X> REPORT(FINAL.RPT)
and:    X> DISPLAY(COLLECT.MGT)

ELSE:
        [MAX NEW CONF IN THE ] IS GIVEN THE VALUE [NEW ORDERS VALUE] *
        1/[PRIORITY]
and:    X> REPORT(FINAL.RPT)
and:    X> DISPLAY(COLLECT.MGT)
```

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## VITA

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This study presents a structure for automating the second step in the $C^2$ decision cycle as called for in the Rapid Application of Air Power concept, through a knowledge-based decision aid for estimating future Soviet (Red) tactical maneuvers using intelligence data and Red doctrine.

A complex analysis with many data and labor intensive tasks must be performed in order to prepare an estimation of Red maneuvers. A wide spectrum of knowledge is also required. While some of the task and knowledge characteristics are highly suitable to automation with a knowledge-based system, other characteristics are less suitable. A system design is presented that adapts the less suitable tasks and knowledge requirements to a knowledge-based system. A prototype Red "estimator" written in an expert system shell demonstrates most features of the system design, although it cannot actually predict Red tactical objectives and manuevers.

The prototype served its purpose as a tool for exploring the issues that must be resolved before an operational Red estimator can be built. These issues and the methods required for exploring them are enumerated. The key issues are security, the availability of signalling elements, and the need for an interdisciplinary approach to developing the Red estimator. The other benefits from this study are the use of rules to evaluate the impact of unknown information and a system design that is robust with respect to Red deception efforts. While the development of an operational Red estimator is technological ly feasible, it will require the integration of multiple disciplines and many years of research.

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