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# THE DESIGN AND DEVELOPMENT OF AN INTELLIGENT PLANNING AID

Stephen J. Andriole

Perceptronics

for

Contracting Officer's Representative
Judith Orasanu

BASIC RESEARCH LABORATORY
Milton R. Katz, Director





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This research note discusses progress in developing an intelligent tactical planning aid. It documents the development of a decision-making, planning, and decision-aiding analytical framework comprising a set of models, a generic task/behavior taxonomy, and an inventory of decision-aiding methods. Six U.S. Army officers participated in two videotaped experiments designed to capture the essence of tactical military planning. Results suggested that tactical planning at the Corps level was goal-oriented and hierarchical, that tactical planning (over)

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tasks were essentially mediational in nature, and that the "best" methods available to satisfy the requirements could be found in multi-attribute utility assessment, artificial intelligence, and interactive graphic display techniques.

The TACPLAN aid assists tactical military planners at the Corps level by developing new defensive plans via the use of an intelligent tactical planning template which will elicit judgements from the planner, link the judgements to knowledge bases related to the planning process and the problem at hand, and permit the planner to draw his candidate plans through an interactive video disc-based graphic interface.

Phase Two research goals include the development of these environmental and challenger capabilities, the development of additional template dimensions, the testing of an evaluation at the Army War College, and documentation.

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# SUMMARY

This report discusses progress made toward the development of an intelligent tactical planning aid. It documents the following steps:

- The development of a decision-making, planning, and decision-aiding analytical framework comprised of a set of decision-making and planning models, a generic task/behavior taxonomy, and an inventory of decision-aiding methods;
- The conduct of a set of tactical planning experiments, conducted at the Army War College, designed to capture the essence of tactical planning;
- The development of an analytical framework based on the results of the experiments comprised of a model of the tactical planning process, a list of tactical planning tasks, and a list of aiding methods most likely to satisfy those tasks;
- The development of an aiding functional description, comprised of tasks and sub-tasks, goals and sub-goals, for the "TACPLAN" aid; and
- The development of a concept of operation for TACPLAN.

The initial analytical framework comprised of decision-making and planning models, a generic task/behavior taxonomy, and a list of candidate aiding methods was based on a great deal of work conducted during the past decade. A number of characteristics of this work are worth noting. First, by and large, it resulted from "technology push" and not "requirements pull." Models and computer-based aids were developed because the technology underwrote their development, not because they were inherently valid. At the same time, many of the task and methods taxonomies

that evolved were comprehensive and anchored in some defensible notions about the range of analytical requirements and useful tools.

Our requirements analysis involved six U.S. Army officers who participated in two videotaped experiments designed to capture the essence of tactical military planning. The results of these experiments suggested that tactical military planning at the Corps level was goal-directed and hierarchical, that tactical planning tasks were essentially mediational in nature, and that the "best" methods available to satisfy the requirements could be found in multi-attribute utility assessment, artificial intelligence, and interactive graphic display techniques.

The TACPLAN aid reflects this tasks/methods assessment. It will assist tactical military planners at the Corps level develop new defensive plans via the use of an intelligent tactical planning template, which will elicit judgments from the planner, link the judgments to knowledge bases about the planning process and problem at hand, and permit the planner to draw his candidate plans through an interactive video disc-based graphic interface.

The TACPLAN prototype aid will demonstrate several problem structuring and problem-solving approaches, including the use of "burdenless analytical spreadsheets," "graphic equivalent displays," and "rules" expressed both as constraints on the planning process and positive substantive guidelines to rapid yet diagnostic planning.

Our research has also enabled us to develop a more elaborate TACPLAN architecture, which includes the integration of environmental variables, such as the amount of time available to the planner, and the development of a tactical "challenger," which might be used to accelerate the planning process or, on other occasions, query the planner about his plan by example, alternative plan displays, and the presentation of substantive planning rules.

Phase two research goals include the development of these environmental and challenger capabilities, the development of additional template dimensions (perhaps at different command levels), testing and evaluation at the Army War College, and documentation. Phase two research will also continue development of the generic problem structuring methodology that emerged from our requirements analysis/knowledge engineering conducted at the Army War College.

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# 1.0 INTRODUCTION

## 1.1 Overview of Planning and Decision-Aiding Problems

It would be a gross understatement to declare the design and development of interactive computer-based "decision aids" a growth industry. The last decade has seen the design and development of countless information management, forecasting, evaluation, and option selection systems, systems that today are all more or less regarded as "decision aids." It is also safe to say that initial decision aid investments were decidedly technology driven and not specified by explicit requirements. This distinction between "technology push" and "requirements pull" explains as much about early investment decisions as it does technical progress. Where would the design and development of interactive decision aids be without minicomputers, microcomputers, and affordable interactive graphics?

The early investments in decision-aiding technology were instructive and suprisingly productive. Without explicit regard for requirements an impressive number of successful technology transfers occurred and were documented as much to the amazement of the systems designers as the transfer targets (Andriole, 1981; Kelly, 1981). Yet there were serious problems with the "push strategy." More often than not, prospective users were alienated from the the systems designed to solve all of their analytical problems. The alienation was traceable to the concern voiced by Meister (1976) that unless users are involved in the systems design and development process from the outset the system is far more likely to satisfy the demands of the designers than it is to help prospective users.

There were also massive conceptual problems. What is decision-making? How does one model it? How does one develop quantitative measures of decision-making effectiveness? In short, how do we know when we are witnessing a really "good" decision process, and how do we know when we have just seen a really bad one? What about the decision-making subset known as planning? How are plans made? How should they be made? What are the elements of a good plan? What features of the planning process predict to good and bad plans?

What happens when one shifts from <u>personal</u> decision-making and planning to <u>military</u> decision-making and planning? Do the personal models break down? How much can we generalize from the personal to the military environment?

What are the best ways to model an analytical process? Not very long ago the answer to this question could be found in the literature on requirements analysis, but today the rush toward the design and development of "intelligent" systems has redefined the question according to the young principles of "knowledge engineering" (Feigenbaum, et al., 1981, 1982, 1983; Hayes-Roth, Waterman, and Lenat, 1983). One of the strengths of the knowledge engineering approach to requirements definition is that it seeks to uncover the processes by which analytical problems are solved; conventional requirements analysis techniques simply try to model the symbols and symptoms of problem-solving, symbols and symptoms that may be unreliable predictors of problem-solving success. In any case, a decade ago the emphasis was infrequently on cognitive modeling, and when it was, it usually employed techniques inappropriate to the identification of diagnostic problem-solving behavior.

The early years were thus plagued by a variety of problems. The insatiable technology push undermined attempts to conduct systematic requirements analyses. The requirements analyses that were conducted employed techniques that could not possibly provide insight into complicated cognitive problem-solving. There was also a non-military bias built into many of the early decision-aiding projects, not in any ideological sense, but to the extent that unwarranted assumptions about the applicability of non-military modeling were routinely made by some of the very best and brightest participating in this revolution in analytical computing. Last, but certainly not least, was the perceived role of the computer in the problem-solving process, a role that regarded the human "user" as an "operator," not as a problem-solving assistant or partner (Andriole, 1982). This perspective--as much as anything else--doomed many early efforts.

We entered the 1980s with a set of experiences that were instructive, with a set of tools and techniques that we knew had validity, and with an inventory of interactive systems that illustrated virtually every input, output, and display technology known to man. But we were still without a developmental paradigm. We were still unsure of the role of the "user" in the design and development process, still suspect of conventional requirements analysis methods, and still married to the notion of the "computer as tool." At the same time, there were still a lot of technology pushers around.

## 1.2 Overview of Project Plan and Objectives

Our project to design and develop an intelligent planning aid was launched with the greatest of expectations about how the past could be brought to bear full force against the present. Our initial goals were, we believed, clear: to develop an aid that would have applicability in an important military problem-solving area; to develop an aid that acted like a non-threatening colleague; to work closely with those we were trying to aid; and to resist temptations to integrate "new" (hardware/software) technology into the aid unless it satisfied a bona fide requirement. Above all else, we wanted to design an aid that was anchored in a verifiable model of the problem domain, which, in our case was--and remains--tactical planning.

This interim technical report documents the progress we have made thusfar in our attempt to satisfy these and other objectives. As always, not everything went according to plan. We have been disappointed with some of our results, but happily surprised by others. We believe, for example, that great promise lies in the development of a problem-structuring methodology for systems design, a methodology that would necessarily combine elements of conventional requirements analysis with principles of knowledge engineering, systems analysis, cognitive modeling, and rapid applications prototyping (Boar, 1984).

This report documents progress made toward the development of a problem structuring methodology within our larger effort to model tactical planning for the purpose of designing and building an interactive computer-based planning aid. The report also documents progress made in the design and development of the aid itself, now known as "TACPLAN."

Finally, this report outlines the directions in which future research should move.

# 2.0 PROGRESS ON THE CONCEPTUAL DESIGN OF AN INTELLIGENT PLANNING AID

## 2.1 The Initial Analytical Framework

Our initial framework was comprised of a set of decision-making and planning models, a generic behavior/task taxonomy, and an inventory of aiding methods.

2.1.1 Analytical Perspectives on Decision-Making - There are a variety of perspectives on the decision-making process. Some regard it as goal-directed (Pearl, Leal, and Saleh, 1982), some as utility-driven (Raiffa, 1968; Brown, Kahr, and Peterson, 1974), and some as simplistically sequential (Dewey, 1910). Nearly all of the perspectives can be distilled to a common diagnostic property: optimization. All decision-making is designed--at least in the abstract--to produce some measurable return, yield some goal, or accomplish some task. Disagreements arise regarding the best routes to optimization, but a rough consensus exists about the purpose of decision-making.

The simple notion of optimization guided us through the initial conceptual stages. We noted that in spite of the simplicity of the concept many previous decision aids did not help their users make optimal decisions. In fact, some were designed to increase the number of options identified and scrutinized during the decision-making process, some to decompose complex "one shot" problems, and some to evaluate a limited number of decision alternatives against a limited number of evaluative criteria. Some of these "aids" were excellent in the limited operations that they performed, but many of them fell far short of calculating an optimal course of action.

Previous research suggested clearly that decision-making is a behavior targeted at optimization, and that a decision aid can only be effective if it leads its partner toward some kind of measurably optimal action.

This perspective on decision-making excludes those that regard decision-making as part of a larger "decision support" process. While we have no quarrel with the broad view of decision support as encompassing problem identification, problem structuring, information gathering, information fusion, information display, option identification, option evaluation, option selection, option execution, and evaluation, our view of decision-making is more restricted. Why? Because our research goal is to build an aid that assists real tactical planners formulate good, i.e., optimal, tactical plans. Our goal is not to design an interactive, overarching tactical planning support system. It is significant that such a system could not be built until its decision-making core was described; in other words, the essence of decision support should only be measured in terms of the extent to which the support contributes to optimal decision-making. Designers of decision (or planning) support systems that do not understand the (optimal) core requirements cannot hope to build a useful system because all decision support by definition must support optimal decision-making. (It is interesting to overlay this view of decision support onto the commercial decision support system marketplace, which is fond of describing nearly everything but optimization as "decision support.")

2.1.2 Analytical Perspectives on Planning - Planning is a special kind of decision-making that is inherently goal-directed, though not all views of planning recognize it as such. Efficient planners are in full command of their resources, have a clear view of their requirements, have an explicit schedule, a definition of their environment, and are rational information processors. Such planners are not always successful, however. Just as it is possible to make a "good" decision that results in a "bad" outcome, so too is it possible to formulate a "good" plan that fails to realize its goals. The disconnect results from the uncertainty that can never be completely eliminated in the decision-making or planning process. The best decision-makers and planners can do is to implement a process likely to result in a "good" outcome. Keep in mind that "good" in this context means optimal--the best that can be achieved given a set of constraints, resources, opportunities, and an "algorithm" for calculating the course of action likely to achieve the greatest percentage of one's (qualitatively or quantitatively) articulated goal.

These general planning concepts have yielded some perspectives worth noting here. One, developed largely at the Rand

Corporation by the Hayes-Roths (1978, 1980) regards the planning process as "opportunistic." Opportunistic planning is adaptive planning, or planning that reacts optimally to changes in one's planning progress and one's (friendly or adversarial) environment. Opportunistic planners are realistic planners that never lose sight of their goals as their plans unfold, fall behind, and break down. They are also relatively unrestricted planners, with the ability to alter their plans quickly and effectively. As an analytical perspective on the planning process the opportunistic perspective is useful, but not entirely satisfactory. Among other problems, it is abstract to the detriment of efforts to extrapolate its components to reality, especially military reality.

Other perspectives on planning include the view that planning is goal-directed (Sacerdoti, 1974, 1977) or "top-down." Top-down planning is believed to be initially abstract, but, over time, increasingly specific and substantive. This view of planning is akin to the military view of planning as "mission oriented": candidate plans are iterated against a set of goals and sub-goals until an optimal plan emerges.

In 1978 the Hayes-Roths concluded that the top-down or hierarchical model of planning was less diagnostic than their multi-directional, opportunistic model. In subsequent tests they demonstrated empirically that aspects of the planning process can be explained by the opportunistic model, but failed to generate enough evidence to displace the hierarchical model. When the problem domain is military, the evidence is even less convincing. Nevertheless, and as the Hayes-Roths and others suggest, there is merit in both views of the planning process. As always, the requirements-driven application should determine which model is most likely to satisfy the most cognitive requirements.

2.1.3 A Generic Behavior Taxonomy - A cornerstone of any decision aid design is the identification of the tasks that the aid is expected to perform. As already suggested, there are a variety of requirements analysis techniques. Some are better than others, but they are all designed to identify and define a set of (in this case, planning) tasks amenable to computerization. Previous research (Crolotte and Saleh, 1979; Galitz, 1980; Bennett, 1971) has, however, already taken some steps to reduce the complexity of the requirements analysis/knowledge engineering process via the development of generic behavior taxonomies, such as the one below (Crolotte and Saleh, 1979):

A GENERIC BEHAVIOR TAXONOMY

- Perceptual Behavior
  - Searching for and Receiving Information
    - -- Detects
    - -- Inspects
    - -- Observes
    - -- Reads
    - -- Receives
    - -- Scans
    - -- Surveys
  - Identifying Objects, Actions, and Events

- Discriminates
- Identifies
- Locates

- Mediational Behavior

  - Information Processing

    - Categorizes
    - Calculates
    - Codes
    - Computes
    - Interpolates
    - Itemizes
    - Tabulates
    - Translates

  - Problem-Solving and Decision-Making

    - Analyzes
    - Calculates
    - Chooses
    - Compares
    - Computes
    - Estimates
    - Plans

- Communication Behavior

  - Advises
  - Answers
  - Communicates
  - Directs
  - Indicates
  - Informs
  - Instructs
  - Requests
  - Transmits

- Motor Behavior

  - Simple/Discrete

    - Activates
    - Closes
    - Connects
    - Disconnects
    - Joins
    - Moves
    - Presses
    - Sets

- Complex/Continuous

  -- Adjusts
  -- Aligns
  -- Regulates
  -- Synchronizes
  -- Tracks

TABLE 2.1: A Generic Behavior Taxonomy

Behavior taxonomies are extremely valuable compasses. They forbid one to assume or ignore the components of behavior; they also help structure and interpret one's specific requirements analysis.

2.1.4 A Methods Inventory - Our initial analytical framework also included an assessment of decision-aiding methods. Unfortunately, the selection of a decision-aiding method can usually be explained by the preferences of aid designers, rather than by a matching of available methods with the tasks revealed by a systematic requirements analysis.

There are four general classes of aiding methods. They include decision analytic methods, operations research methods, methods grounded in computer science, and methods that extend from the use of advanced man-machine interfaces and interactive graphics. The chart below, modified from Crolotte and Saleh (1979), suggests the variety of methods available to the decision aid designer, as well as the designer of all kinds of interactive aids.

## A DECISION-AIDING METHODS INVENTORY

- Decision Analytic Methods
  - Value Models
    - -- Utility Assessment Techniques
    - -- Multi-Attribute Utility Analysis
    - -- Cost-Benefit Analysis
    - -- Discounting Models
    - -- Monte Carlo Methods
    - -- Group Utility Aggregation
  - Probability Models
    - -- Probability Elicitation
    - -- Bayesian Updating
    - -- Sensitivity Analysis
    - -- Group Probability Aggregation
  - Probability and Value Models
    - -- Subjective Expected Utility
    - -- Probabilistic Multi-Attribute Utility Analysis
    - -- Risk-Benefit Analysis
    - -- Decision Tree Structuring
    - -- Group Decision Analysis
    - -- Partial Information Based Decision Analysis
    - -- Fuzzy Decision Analysis
- Operations Research Methods
  - Analytic Models
    - -- Warfare Area Models
    - -- Lanchester's Theory of Combat
    - -- Game Theory
  - Detection and Search Techniques
    - -- Time Invariant Statistical Detection
    - -- Signal Detection
    - -- Search Modeling
  - Optimization Methods
    - -- Simulation and War Gaming
    - -- Scheduling
    - -- Mathematical Programming
  - Facilitation Techniques
    - -- Tactical Simulation

- Coverage Templates
- Time/Distance Algorithms

- Computer Science Methods
  - Information Management Techniques
    - Data Base Organization
    - Man-Machine Communication
    - Message Processing
  - Pattern Recognition Techniques
    - Clustering
    - Classification
    - Information and Discrimination Measures
    - Linear Discriminant Functions
  - Artificial Intelligence Techniques
    - Problem Representation
    - Problem Solving
    - Learning Systems
    - Pattern-Directed Inference Systems
    - Planning Mechanisms
    - Knowledge Representation Techniques
    - Natural Language Interfaces

- Advanced Man-Machine Interface/Graphic Methods
  - Situation Displays
    - Dynamic Displays
    - Geographic Highlighting
    - Alternative Backgrounds
    - Automated Overlays
    - Selective Callup Techniques
    - Innovative Symbology
  - Pattern Analysis
    - Center-of-Mass Computations
    - Movement Trend Analysis
    - Terrain Models
    - Graphic Summarization
    - Zooming/Windowing
    - Annotation Techniques
  - Planning Tools
    - "What If" Projections
    - Sketch Models
    - Optimal Routing

-- Target Aggregation

TABLE 2.2: A Decision-Aiding Methods Inventory

At the very least, a methods inventory can assure the consideration of a variety of aiding methods and techniques, and permit the matching of a wide range of methods, initially with a generic taxonomy of behavior and then with a more specific definition of requirements.

A major initial concern of ours was to avoid--at all cost--a "methodological forcefit." Far too many aids are driven by methods which must be learned by their users, methods that are at once complicated and often inappropriate to the aiding function. An example will illustrate the danger. In the late 1970s several aids for intelligence analysis were developed based upon the use of Bayes' Theorem of Conditional Probabilities. Bayes' Theorem permits forecasters to revise the probability of an event based upon new information according to the formula presented below. It is a powerful and deceptively simple formula

BAYES THEOREM OF CONDITIONAL PROBABILITIES

$$\frac{P(H_1/D_1)}{P(H_2/D_1)} = \frac{P(D_1/H_1)}{P(D_1/H_2)} \cdot \frac{P(H_1)}{P(H_2)}$$

where

| | |
|---|---|
| H | = hypotheses or explanations of information |
| D | = data or Information |
| $P(D_1/H_1)$ | = the probability that a piece of information, $D_1$, would be observed assuming that hypothesis one, $H_1$, is true |
| $P(H_1/D_1)$ | = the probability that hypothesis one, $H_1$, is true assuming that a piece of information, $D_1$, has been observed |
| $P(H_1)$ | = the forecaster's initial or prior opinion that hypothesis one, $H_1$, is true, i.e., before $D_1$ is considered |
| $\frac{P(D_1/H_1)}{P(D_1/H_1)}$ | = the likelihood ratio, i.e., the forecaster's relative judgment regarding the likelihood that a piece of data or information would be observed given that the first hypothesis, $H_1$, is true over the second hypothesis, $H_2$ |
| $\frac{P(H_1)}{P(H_2)}$ | = the prior odds that $H_1$ is true over $H_2$, i.e., the odds before a piece of data or information is considered |

TABLE 2.3: Bayes' Theorem of Conditional Probabilities

for assessing the impact of new information on a prior probability estimate. Unfortunately, and as the above suggests all too painfully, the logic that underlies Bayes' Theorem is convoluted. Intelligence analysts are not accustomed to asking questions about the likelihood of international crises by first inquiring about the likelihood of observing a piece of data given the likelihood of one versus another hypothesis. In test after test, intelligence analysts found it almost impossible to deal with the requirements of Bayes' Theorem until the designers solved the problem by developing yet another "aid" called "SCORE," which was intended to train analysts how to use Bayes' Theorem and think "probabilistically" (Gulick, 1980).

Bayesian aids continue to be designed for intelligence applications with little or no regard for the inapplicability of the methodology to many intelligence problems (Hunter, 1983). Bayes' Theorem remains popular with many designers because it represents a normative forecasting tool, normative, that is, from the designer's perspective. Intelligence analysts resist the theorem because it is incompatible with the processes by which intelligence analyses and estimates are produced, and, relatedly, because no organizational support can be found for aids that require a great deal of time to learn how to use, and that, in turn, produce forecasts that are difficult if not impossible to assimilate into the overall intelligence process. In retrospect, it appears that the forcefitting of analytical methods usually occurred when the designers preferred to skip the tedious requirements analysis process, when they were more interested in championing a new method than solving real problems, or when they believed that the analytical process should be changed to accommodate a more powerful method. While their intentions may have been good, the results were usually bad.

2.1.5 The Research and Development Plan - Our initial analytical framework, comprised of decision-making and planning models, a generic behavior taxonomy, and an inventory of analytical methods, enabled us to identify an analytical strategy for the design and development of a tactical planning aid.

The strategy included the exploitation of previous research findings, the conduct of a detailed requirements analysis, the re-modeling of the planning process, the selection of aiding methods based upon the results of the requirements analysis and re-modeling procedure, the functional design of a prototype planning aid, and the development of the TACPLAN aid itself. The following sections discuss each of these steps in the order in which they were taken.

## 2.2 Planning Requirements Analysis: The Carlisle Experiments

Previous research in decision-making and planning suggests that these two "mediational" behaviors are context-dependent. Generalizations from non-military environments are virtually impossible to make. The first order of business was thus a thorough requirements analysis of the planning process.

A search was launched to find expert planners, not because we were predisposed to the development of an expert planning aid, but because the best way to model a behavior is to observe experts in action. We contacted a number of U.S. Army offices and agencies, the National Defense University's War Gaming and Simulation Center, and planners at the Army's War College at Carlisle Barracks, Pennsylvania. The planners at the War College were expert and enthusiastic; they were also the acknowledged Army experts in the formulation of tactical plans, especially as they involved the defense of Western Europe. After a series of meetings an agreement was reached with planners in the College's

Contingency Planning Group (which later evolved into the Center for Land Warfare). The planners agreed to provide us with information about the planning process via some experiments.

It is important to note that the Army War College has several programs of study and research in strategic and tactical planning. Students from throughout the Army spend time at the College; there are also students from other services as well as some foreign students. All of these students are expected to learn about the planning process generally and specifically with reference to a number of explicit scenarios. Given the Army's role in the defense of Western Europe, scenarios involving the defense of Germany and the whole of Western Europe are common.

The scenario we used to conduct our requirements analysis is one that has been used repeatedly at the Army War College, though always with some twists. Frequently, however, the mission involves the defense of Western Europe given the likelihood of a Soviet, or "Red," invasion of the West.

We used the scenario because the expert planners were familiar with it, and because it is representative of a "typical" tactical planning problem. At the same time, our use of the scenario called for the development of a Corps level plan, or one that would yield many sub-plans down the chain of command.

We ran two experiments, one involving three 06 officers and one three 05s. They took place over a two day period in January 1984. The results, along with a description of the experiments themselves, are reported below.

2.2.1 The Tactical Scenario - The U.S. Corps/Soviet Combined Arms Army Command Post Exercise (Letort 84) and the Soviet Combined Arms Army Scenario, Command Post Exercise (Letort 84) served as our scenario. Very succinctly, this scenario describes a hypothetical situation where:

> . . . political and economic actions have led to greatly increased tension between NATO and the Warsaw Pact. Over a period of time, US reserve units had been activated and some regular Army units had been reconstituted. In early 1987 a number of these units had been deployed to Europe . . . by 1 July 1987, the United States had deployed the XI Corps headquarters, 4th Armored Division, 90th Infantry Division (Mech), 80th Infantry Division (Mech), 14th Armored Cavalry Regiment, and the 22nd Aviation Brigade to West Germany. The theater commander assigned the XI Corps and attached units to the newly formed Middle Army Group (MIDAG), which had been given responsibility for a sector in the vicinity of Hannover, West Germany . . . (Letort 84)

This situation is further defined by the theater commander who offers the following guidance to his planners:

> Gentlemen, you have been issued, and have had an opportunity to review, OP PLAN 3-87. Our mission is to defend in zone, focusing on the destruction of Pact forces. I see our initial operations occurring in three phases. First, we must defend against an attacker who can pick the time and place in which substantial force in the form of maneuver units and firepower will be employed. We will face an attacker intent on shattering our forward deployed units and making a rapid thrust to cross the river and canal barriers in our sector

as he carries his attack forward across the Rhine, into the low countries and the ports which are the heart of our logistical lifeline . . . his immediate objective will remain crossing the Rhine. He expects the Ruhr as a bonus . . . XI Corps will conduct the main defensive effort in the northern portion of the MIDAG sector . . . you must preserve your command, while inflicting maximum damage on the attacker . . . (Letort 84)

Figure 2.1 illustrates the XI Corps' area of responsibility, an area that had to be defended with a limited number of combat assets. The two groups of planners were each required to develop a plan that would result in the successful defense of their area.

The planners were given, as part of the scenario, intelligence about the location and composition of Soviet forces, information about the terrain and general area characteristics, and intelligence about their own combat capabilities. As expert planners, they also had insight about adversary doctrine and the opportunities and constraints provided by their own doctrine. Their task was to optimally deploy their own forces given assessments about likely adversary courses of action.

2.2.2 The Planning Experiments - The two experiments were conducted on January 18 and 19, 1984 at the Army War College at Carlisle Barracks in Carlisle, Pennsylvania. We ran the scenario with the O5s (three Lieutenant Colonels) on January 18 and with the O6s (three Colonels) on January 19. Both sessions were prepared by setting up a tactical map of the situation, which involved spending approximately one hour placing forces around

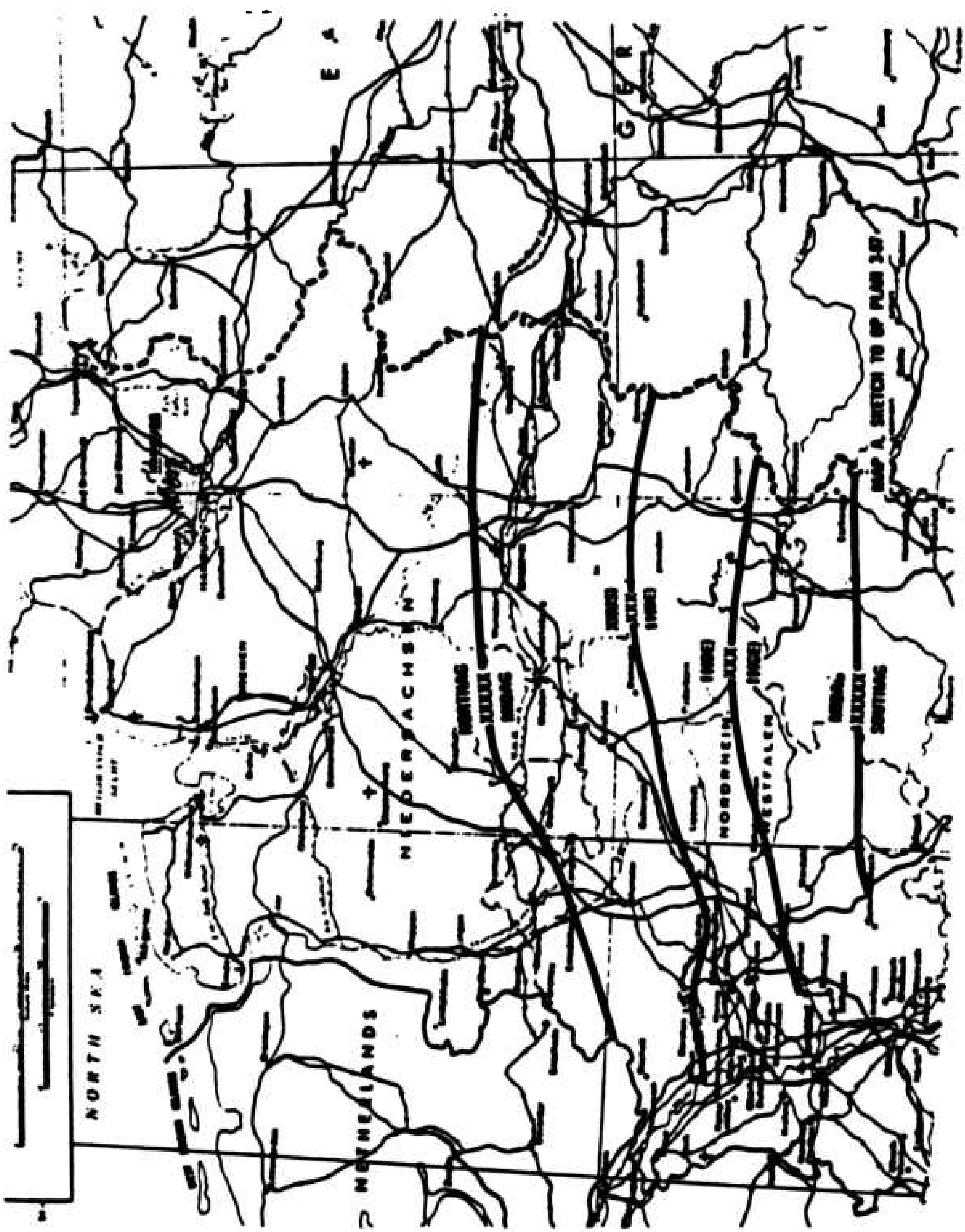



FIGURE 2.1: XI Corps' Area of Responsibility

the map. The group that was to conduct the exercise did the placing, which they saw for the first time. After the O5s were finished, their "solution" was removed. The O6s repeated the process. Both groups were confronted with exactly the same deployment of adversary forces and were given exactly the same combat assets and planning guidance.

Each group also spent some time reviewing the scenario prior to the simulation. Since both groups were familiar with the scenario, not unlike the way a Corps commander would be responsible for formulating plans for a set list of contingencies, a good deal of realism was preserved.

The problem backdrop assumed that a Corps commander was about to formulate a plan in response to a set of adversary actions that were not totally unanticipated, though perhaps never really imagined in the detail that the scenario assumed. The actual placing of Soviet/"Red" forces was done within certain constraints that have been built into a computer program that the Army War College uses to run its war games. It is modestly random, in the sense that it will deploy adversary forces within certain realistic assumptions about the nature of Red force structures, orders of battle, doctrine, and the like. Before the exercise, we ran the computer program to determine where adversary forces should be positioned. We then positioned the forces on the large map on the wall, a 4' by 8' map that was overlayed with a clear sheet of acetate. Grease pencils were provided, and adversary and friendly forces were represented by magnetic symbols, or "icons," that could be moved as the simulation evolved.

A number of assumptions were made about Red and Blue forces. We assumed that, for example, Red had been moving around for approximately three months prior to the snapshot that we took for experimental purposes. We assumed that the Blue Corps commander had approximately seventy-two hours to formulate his plan. We assumed that the "plan" would be in the form of a concept definition, or "concept of operation," the required form for a Corps level plan. A good concept of operation illustrates and describes the deployment of Blue forces in a way likely to satisfy mission objectives. It is also flexible and relatively abstract, enabling lower level commanders to interpret some of its components with reference to their specific mission objectives.

The planning problem itself saw massive deployment of Red forces along the NATO/Warsaw Pact boundary. Red forces were deployed all along the boundary, from North to South, and very deep in the East. Blue forces were relatively scattered and outnumbered, at least in terms of the number and size of available divisions. Again, the Corps commander had seventy-two hours to formulate a plan for deploying his forces given an imminent attack by Red forces.

The O5s and O6s were videotaped as they formulated their plans. The suggestion to videotape was made by Dr. Robert M. Sasmor, who hypothesized that a great deal of information about planning could be gleaned not only from the conventional audiotaping of planning utterances, but from the observation of actual motor behavior as well. In retrospect, the suggestion yielded enormous dividends. The videotape reference of the planning process has enabled us to study the process from a variety of cognitive and analytical perspectives. It has also augmented the conventional (audio) recording of "protocols," and permitted a much more thorough analysis of their content.

But perhaps most importantly, the videotape documentation permitted us to test a number of hypotheses about planning well after the fact. Months after the experiments took place, and after we were well into the functional modeling of the TACPLAN planning aid, we were able to refer back to the tapes to determine the analytical methods that might best satisfy specific planning requirements, and to design input, output, and display routines likely to capture and support the essence of tactical defense planning at the Corps level.

Six hours of planning were filmed over the two day period. Set-up time involved another two to three hours. During the filming the planners were asked to develop their plans but also to step away from the process from time to time to describe exactly what they were doing and why they were doing it. Dr. Stephen J. Andriole served as an informal "moderator" of the process, prodding and challenging the planners for clearer explanations of their behavior. This "inside/outside" role that the planners were forced to play threatened the realism of the experiments, but, just as in the conventional audio collection of protocols, was necessary if our requirements analysis was to yield diagnostic results. As it turned out, given the experience of our planners, there were few real instances of "cognitive break"; the planners were able to continue with the planning process while commenting upon their behavior within that process. Clearly, the level of experience is crutial to the success of any conventional or unconventional collection of protocols. If one's experts are really not very expert then the data is likely to be inconsistent and unreliable; conversely, genuine experts can rather easily time-share across several analytical roles before, during, and after the process in question. Indeed, <u>one of the characteristics of expertise lies in its ability to introspect upon its own application</u>, and at least one way to measure the depth of expertise involves determining the extent to which an expert can roam within and beyond the area in which he or she is supposed to be expert. "Experts" that have great difficulty introspecting upon the application of their expertise are either (a) inherently inarticulate, or (b) not very expert. Once the first possiblity has been eliminated, then a search for experts with a deeper understanding of the problem area should be launched.

A final point about the experiments. We assumed a seventy-two hour window, yet captured only six hours of actual planning. In fact, given the nature of the planning process that was actually taped, we captured but four to five hours of tactical planning. This apparent unrealism was mitigated by the absence of a large, time-consuming planning staff, the absence of continual G-3 (intelligence) on the tactical situation, and--most importantly--by tactical planning precedent, which nearly always yields an initial concept of operation fairly early on in the seventy-two hour (or however long) planning process. In other words, Corps commanders frequently develop a concept of operation several hours into a planning session and then iterate on it until happy with its form. Interviews with expert planners, conducted to corroborate this hypothesis, went even farther. One expert planner actually suggested that any "Corps commander worth his salt already knows what he's going to do as soon as he receives even the grossest guidance." This suggests that what we captured was perhaps a first iteration on what would eventually emerge (in seventy two hours) as a final concept of operation. It was also suggested that Corps commanders frequently accelerate the planning process because of the likelihood of additional theater guidance and requirements. Again, regardless of how much time is available, good Corps commanders can formulate plans rapidly. While we would have ideally preferred filming actual or simulated Corps commanders for seventy-two hours, we believe that sufficient realism was captured during the two experiments that we conducted.

2.2.3 Results - Figures 2.2 and 2.3 summarize the results of the planning experiments. It is interesting to note that

| • THE MILITARY PLANNING PROCESS | • MILITARY VS. NON-MILITARY PLANNING (MP/NMP) |
|---|---|
| • **Highly structured**<br>  • *Sequential*<br>  • *Procedural*<br>  • *Doctrinal*<br>  • *Integrated . . .*<br>• **Highly repetitive**<br>  • *Planning, re-planning, & contingency planning*<br>• **Mission-oriented**<br>• **Verbal, graphic, non-numeric process** | • **Planning guidance originates from above in MP, but from within in NMP**<br>• **MP is usually adversarial; NMP is usually not**<br>• **MP is accompanied by high accountability, while NMP is usually not**<br>• **MP is explicitly goal-directed, while NMP is frequently opinion-driven**<br>• **MP planning receives near-immediate, highly structured feedback, while NM — especially personal — planning is often stimulated from directly within the planner**<br>• **MP is by nature & definition distributed, while NMP is frequently localized with one or two planners** |

FIGURE 2.2: Results of the Carlisle Planning Experiments

## GROUP #1 VS. GROUP #2

- Group #1 (06 expert planners) considerably more risk averse than Group #2 (05 student planners); Group #2 expressed greater certainty re adversary intentions
- Group #1 more deliberate (i.e., more options, more dimensions of value) than Group #2
- Group #1 expressed considerably LESS confidence in their solution (plan) than Group #2
- Group #1 institutionalized "Devil's Advocate" role, while Group #2 avoided structured challenges to solutions to various parts of the planning problem
- Group #1 relatively more devoted to military (Army) doctrine than Group #2, perhaps as much a reflection of familiarity with doctrine as devotion to it

FIGURE 2.3: Group Results of the Carlisle Planning Experiments

above all else the tactical military planning process is excrutiatingly procedural and doctrinal. During the planning process both groups made repeated references to the "book" on planning and what doctrine had to say about operations and deployment. Unlike personal planning, the military planning exercise is relatively inflexible, permitting judgment and intuition to play limited--though not insignificant--roles. Generalizations about planning gleaned from non-military experiments are of little real utility to attempts to model the military planning process, except perhaps at the most general level.

There is no question that the tactical planning process is sequencial and iterative. The first step involves understanding or defining the problem. In tactical language, this means defining the mission on several levels. More abstractly, this means that goals and sub-goals must be specified. This hierarchical process supports the view of planning as "top-down" and "goal-directed." The first definition of the mission lists the desired effects of a successful operation via the implementation of an optimal plan. Our scenario called for the defense of Western Europe against Red aggression at various points in time and at various geographical locations.

During the experiments both groups then turned their attention to an aggregate assessment of adversary intentions. Intentions estimation is, of course, a classic intelligence problem, though in this case the groups were aided by intelligence (comprised of enemy capabilities, doctrine, rules of engagement, and the like), and notions of Red commander behavior developed from prior planning exercises and some structured vicarious observations and analyses. This vicarious aspect is worth noting. Both groups kept saying things like, "that's what I'd do," and "if I were him then I'd . . . " After a while they were queried about what they were doing and they said that they were listing the adversary's preferred courses of action and goals and then, based upon intelligence data, ranking the courses of action in terms of their likelihood. This is akin to what formal decision analysts try to get decision-makers to do. Interestingly, tactical planners--due more to training, procedure, and doctrine--do this routinely.

They also spend a lot of time studying the specific characteristics of the area in which they both (Red and Blue) must maneuver. This analysis is also highly procedural and involves studying everything from geography to transportation, telecommunications, culture, and the like. During the experiments references were frequently made to cities, canals, rivers, and other area realities, suggesting the importance of seemingly unspectacular characteristics.

Relative combat power was also assessed. It was interesting that the tendency was to look for weaknesses within enemy and friendly forces and then look for strengths.

The planners next formulated several concepts of operation by re-analyzing their own as well as enemy capabilities, interests, goals, and courses of action. Courses of action (COAs) were extremely important focal points for the planners. COAs guided assessments about combat capabilities and area characteristics; they also performed double duty as the primary mechanism for challenging alternative planning concepts.

There was also a great deal of discussion and disagreements as the planners began to convert their COAs into a concept of operation. In a sense, all of the analyses and assumptions made during the planning process became exposed during this translation process; the newly tangible naturally triggered a lot of verbal response.

As suggested in Figures 2.2 and 2.3, a number of explicit results emerged from the experiments. Nearly all of these results have implication for the design and development of an interactive computer-based planning aid. The procedural nature of the planning process, its iterative character, and its overwhelmingly visual components all suggest a number of very specific aid characteristics.

The differences between the two groups, summarized in Figure 2.3, are also worth noting. While genuine differences did exist, they were not the kind of differences that would suggest the design and development of two different planning aids. In fact, most of the differences were explained by the differences in experience within the two groups. Significantly, there was little intra-group disagreement and only precedural inter-group disagreements. We hope to conduct additional experiments to control for variables like planning experience, rank, age, and prior combat performance.

## 2.3 The Revised Analytical Framework

Recall that we began our research with some models of the decision-making process, models of the planning process, a generic behavior/task taxonomy, and an inventory of methods. Our target area was pre-set as tactical military planning. We conducted a set of experiments to gain insight into the planning process and then developed a working analytical perspective from which to design our aid.

2.3.1 Tactical Military Planning as Goal-Directed - The variety of available models of the decision-making and planning processes provided a rich source of information against which we could interpret our experimental findings, which suggested initially and unequivocally, that tactical military planning at the Corps level is top-down, hierarchical, and goal-directed. The very fabric of military planning is weaved with considerations of the goal, and how to implement a very explicit planning procedure. Military planners are trained to adhere to this perspective, practice this perspective, and quite normally resist any attempts to alter it. It is fascinating to postdict the reactions that planners and decision-makers had to decision aids that challenged such perspectives. It is clear now that such aids were doomed to failure, that aids can only succeed if they find just the right combination of technology, requirements, and doctrine. Many past aids suffered from too much technology, while some newer ones from inadequate requirements. We now know that technology and requirements can only be usefully combined through an understanding of doctrine, training, and precedent.

2.3.2 Planning Tasks - The experiments also suggested that planning is essentially mediational, as suggested below in Table 2.3. But note also that the requirements analyses also revealed several perceptual and communication behaviors. Analysis of the videotaped experiments even suggested that some planning tasks can be found in our list of motor behaviors. The solid lines in Table 2.3 suggest the primary planning tasks, while the dotted lines suggest the secondary tasks. When in doubt about the inclusion and weighting of individual tasks we referred back to the videotapes, studied Army Field Manuals and Officers' Handbooks (U.S. Army, 1983), and consulted the interviews with our expert planners.

A GENERIC AND TACTICAL PLANNING BEHAVIOR TAXONOMY

- Perceptual Behavior
  - Searching for and Receiving Information
    - -- Detects
    - -- Inspects
    - -- Observes
    - -- Reads
    - -- Receives

-- Scans
-- Surveys

- Identifying Objects, Actions, and Events

-- Discriminates
-- Identifies
-- Locates

● Mediational Behavior

- Information Processing

-- Categorizes
-- Calculates
-- Codes
-- Computes
-- Interpolates
-- Itemizes
-- Tabulates
-- Translates

- Problem-Solving and Decision-Making

-- Analyzes
-- Calculates
-- Chooses
-- Compares
-- Computes
-- Estimates
-- Plans

● Communication Behavior

- Advises
- Answers
- Communicates
- Directs
- Indicates
- Informs
- Instructs
- Requests
- Transmits

● Motor Behavior

- Simple/Discrete

-- Activates
-- Closes
-- Connects
-- Disconnects
-- Joins

-- Moves
-- Presses
-- Sets

- Complex/Continuous

  -- Adjusts
  -- Aligns
  -- Regulates
  -- Synchronizes
  -- Tracks

TABLE 2.3: Primary and Secondary Planning Behavior

Table 2.3 identifies the tasks that goal-directed planners perform whenever they develop a tactical plan at the Corps level. A further stipulation is that these tasks hold only for the development of defensive plans. The stipulations are stressed here because it is difficult to generalize up or down command levels without studying each level thoroughly. While planning is likely to remain goal-directed up and down command levels, aspects of the process may change substantially across the levels. Platoon leaders, for example, may well plan very differently from Corps commanders because of the nature of their missions, their areas of responsibility, and training, among other possible differences. Before an aid designed for use at other command levels could be extended to these levels, additional requirements analyses would have to be conducted.

2.3.3 Planning Methods - Table 2.4 suggests the methods most likely to satisfy the task requirements identified in Table 2.3. The bold lines suggest the primary methods, while the dotted lines suggest the secondary ones, or those less likely to satisfy primary planning tasks. But keep in mind that there is not a one to one correspondence between the tasks identified in

A DECISION-AIDING AND TACTICAL PLANNING METHODS INVENTORY

- Decision Analytic Methods
  - Value Models
    - Utility Assessment Techniques
    - Multi-Attribute Utility Analysis
    - Cost-Benefit Analysis
    - Discounting Models
    - Monte Carlo Methods
    - Group Utility Aggregation
  - Probability Models
    - Probability Elicitation
    - Bayesian Updating
    - Sensitivity Analysis
    - Group Probability Aggregation
  - Probability and Value Models
    - Subjective Expected Utility
    - Probabilistic Multi-Attribute Utility Analysis
    - Risk-Benefit Analysis
    - Decision Tree Structuring
    - Group Decision Analysis
    - Partial Information Based Decision Analysis
    - Fuzzy Decision Analysis
- Operations Research Methods
  - Analytic Models
    - Warfare Area Models
    - Lanchester's Theory of Combat
    - Game Theory
  - Detection and Search Techniques
    - Time Invariant Statistical Detection
    - Signal Detection
    - Search Modeling
  - Optimization Methods

-- Simulation and War Gaming
-- Scheduling
-- Mathematical Programming

- Facilitation Techniques

-- Tactical Simulation
-- Coverage Templates
-- Time/Distance Algorithms

• Computer Science Methods

- Information Management Techniques

-- Data Base Organization
-- Man-Machine Communication
-- Message Processing

- Pattern Recognition Techniques

-- Clustering
-- Classification
-- Information and Discrimination Measures
-- Linear Discriminant Functions

- Artificial Intelligence Techniques

-- Problem Representation
-- Problem Solving
-- Learning Systems
-- Pattern-Directed Inference Systems
-- Planning Mechanisms
-- Knowledge Representation Techniques
-- Natural Language Interfaces

• Advanced Man-Machine Interface/Graphic Methods

- Situation Displays

-- Dynamic Displays
-- Geographic Highlighting
-- Alternative Backgrounds
-- Automated Overlays
-- Selective Callup Techniques
-- Innovative Symbology

- Pattern Analysis

-- Center-of-Mass Computations
-- Movement Trend Analysis
-- Terrain Models
-- Graphic Summarization
-- Zooming/Windowing

-- Annotation Techniques

- Planning Tools

  -- "What If" Projections
  -- Sketch Models
  -- Optimal Routing
  -- Target Aggregation

TABLE 2.4: A Decision-Aiding and Tactical Planning Methods Inventory

in Table 2.3 and the methods identified in Table 2.4. The goal-directed planning model, as well as the (tactical military) context, intervened between the tasks and methods tables to make certain that the matching procedure was compatible with the substance of the application. What does this mean? In short, it suggests that methods will only satisfy task requirements if they are appropriate to the operational environment in which they are to be applied. This dictum applies regardless of whether the application involves the use of scratch pads or software. If a method disrupts, threatens, or confuses a process anchored in decades of precedent, it will fail.

This is not to suggest that one should never apply sophisticated methods to military problems, but rather that the application cannot expect to uproot years of experience, training, and doctrine. Moreover, the prudent application of new methods assumes that the method will be unobtrusive and, to some extent at least, transparent to the problem-solver. (See Appendix A for more discussion of abstract problem structuring and the use and mis-use of sophisticated analytical methodology.)

The methods identified in Table 2.4 represent those most likely to satisfy the requirements of a Corps commander developing a tactical defensive plan. Some of the specific methods are worth discussing in detail here while some of the others were selected according to some obvious criteria. The use of some artificial intelligence techniques, for example, was justified on three levels. First, artificial intelligence (AI) techniques lend themselves nicely to procedural management, that is, to the management of the planning process. AI techniques can be used to "moderate" the planning process. They can be used to determine if the planner is behaving soundly and consistently. They can order the tactical planning process and regulate the number and variety of deviations from an "ideal" process. AI techniques can also provide substantive direction to the planning process. Knowledge about terrain, trafficability, force strengths, doctrine, and orders of battle can be represented in several ways and brought to bear on the planning process at various points and in response to various judgments made by the planner during the process. Such knowledge can be used to check the consistency and accuracy of the planner's judgment, and to stimulate the planner with alternative scenarios and planning solutions. Finally, AI techniques can be used to reduce the cognitive burden placed upon the planner.

All of these applications of AI techniques are consistent with what the planning task analysis revealed. Note that we are not proposing to use AI as a means to the automation of the planning process. Our research has suggested that the kinds of inferences made during the planning process by human planners naturally result from a properly conducted planning exercise, and that the formulation of a plan bears no resemblance to the diagnosis of a disease. By nature, planning is a much fuzzier domain, and therefore resistent to techniques that deduce inferences from "known" rules of thumb, or heuristics.

The identification of advanced man-machine/graphic interface methods is a direct outgrowth of the planning experiments and our subsequent analysis of the experimental data, which suggested that huge components of the planning process are graphic, symbolic, and decidedly non-numeric. Our data suggested that it would be impossible to design an interactive planning aid without an interactive graphic interface that was directly manipulatable by the planner. Non-computer-based planning is accomplished only with the aid of maps and other "props," such as acetate overlays, grease pencils, tactical icons, and the freedom to move easily through the map space. Time after time during the experiments discussions were organized around the drawing of yet another course of action, the moving of icons, and the erasing of previously discarded ideas. It was obvious after a very short period of time that an interactive, "intelligent" planning aid would also have show movies, or more accurately, "movie maps." It would do no good to integrate static maps, either. The requirements called for zooming capabilities, capabilities to annotate directly onto dynamic maps, and capabilities that would permit planners to test tactical hypotheses without having to learn how to program a sophisticated computer. One of the capabilities that grease pencil/acetate planners do not have is the ability to store old ideas for comparison with new ones. Computer-based graphics provide the capability to store and retrieve ideas that are quickly forgotton once they are erased from acetate. The use of advanced man-machine/graphic interface methods thus satisfies a variety of important manual requirements as well as a number of requirements that conventional planning apparati can never hope to satisfy.

We should also note that the identification of methods is never really complete. This is because the aiding design and development process is iterative (with expert planners) and therefore likely to uncover new requirements and new corresponding methods as time goes by.

There are also a variety of hybrid combinations of methods that can sometimes satisfy a particularly recalcitrant requirement. Sometimes, for example, totally new methods can be developed for a special, one-of-a-kind application, while other problems may require a multi-method strategy.

This overall approach to problem structuring is documented in more detail in Appendix A. One of the most exciting by-products of our planning research has been the refinement of this approach, an approach which we believe can be applied to a variety of cognitive modeling, requirements analysis, knowledge engineering, and interactive systems design and development problems.

## 2.4 TACPLAN Functional Design

Our approach to the design and development of an interactive planning aid flowed directly from our revised analytical framework, which told us a great deal about the problem that we faced. Because of the characteristics of the problem, we decided to implement an applications prototyping strategy toward the design and development of intelligent planning templates. We then produced a strawman functional design of the TACPLAN aid. The next step involved developing a concept of operation for the aid.

### 2.4.1 The Applications Prototyping Strategy

From the outset we have assumed that the conventional approach to interactive systems design and development (Andriole, 1983) would not satisfy all of our requirements. Instead, we expected to implement some form of rapid applications prototyping strategy (Boar, 1984). Why? For many interactive systems design and development problems the target tasks are primarily perceptual (see Table 2.1). The methods available to satisfy perceptual tasks are well known and effective. Consequently, it is often possible to develop a system likely to satisfy nearly all of its tasks and users. Systems intended to satisfy mediational tasks, however, are much more difficult to design and develop.

Mediational systems have a high rate of failure with their intended "users," who often make distant use of the systems, or ignore them altogether (Ramsey and Atwood, 1979). There is also usually considerable debate about the essence of the cognitive tasks themselves and the methods most likely to satisfy them. The conventional approach to interactive systems design and development, shown in Figure 2.4 (Andriole, 1983), will not often lead to the design and development of a successful mediational system because it does not institutionalize the iterative process. According to Bernard H. Boar (1984), the only sensible way to proceed is to implement a procedure known as applications prototyping, which, according to Boar, is "an alternative approach to requirements definition." The idea is simple enough. Build a strawman system and then let your intended users tell exactly what it is they like and don't like about it. Check these suggestions against your task/requirements analysis, make some changes, and go back to the users. Repeat the process until you get close enough to satisfy as many requirements as time, money, and patience permit. Not unlike Mumford and Henshall's (1979) "participatory approach," Boar's applications prototyping strategy can save countless dollars and hours of frustration. It can also support basic research, since the strategy assumes that hypotheses can be efficiently tested "on-line," and that a lot can be learned from the utterances of--in this case--planners planning on TACPLAN.

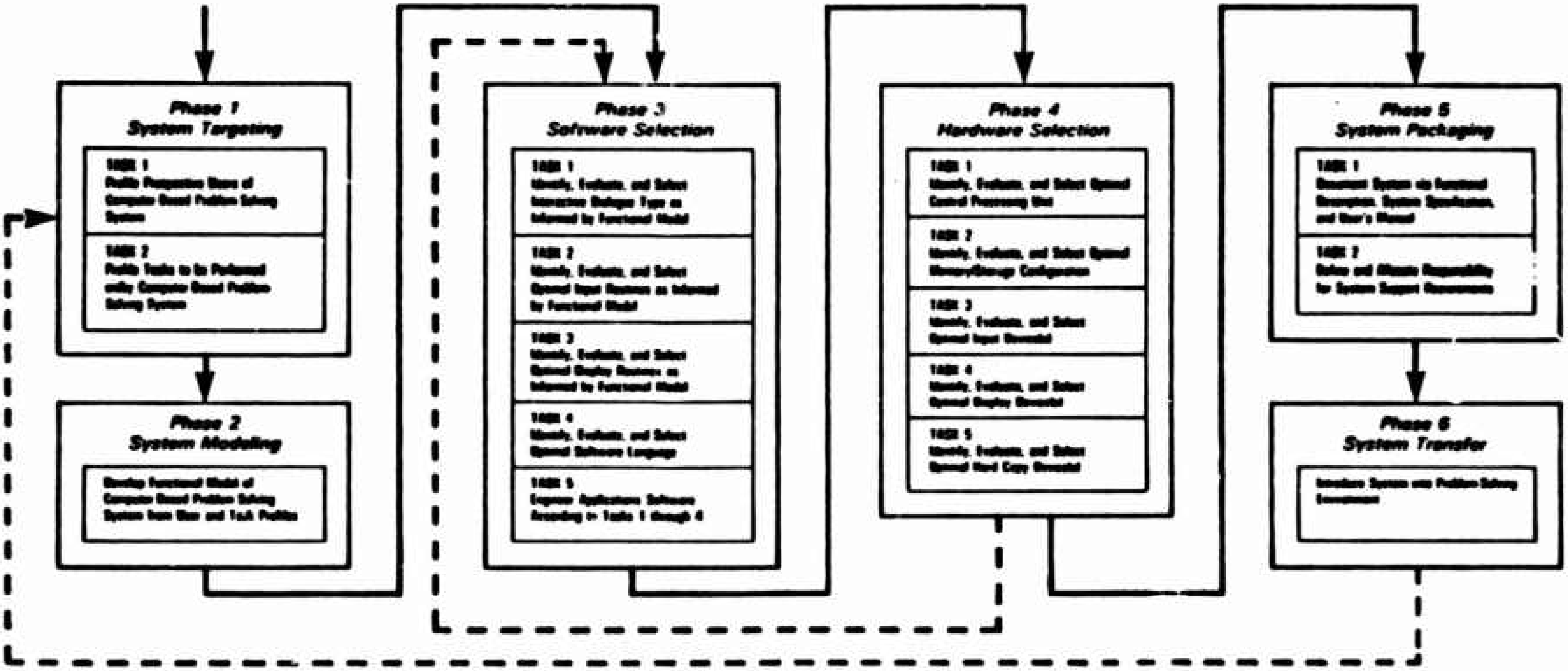



FIGURE 2.4: The Conventional Systems Design and Development Process

2.4.2 Intelligent Planning Templates - The use of templates to solve analytical problems is not unusual. In fact, templates have been used to solve all kinds of perceptual, mediational, communication, and motor problems (Kelly and Stewart, 1980). Templates are really procedural blueprints for solving problems. They can be detailed or general, abstract or substantive. In their simplest form, they represent checklists; in their more complex form, they represent a set of hierarchical tasks and sub-tasks.

Templates have been used in a number of decision aids to solve a variety of military problems (Gulick, 1981; Kelly and Weiss, 1980; Kelly and Stewart, 1980). They have been used to determine optimal evacuation strategies, effective hostage negotiation positions, and likely adversary hostilities. Why use templates? First, they accelerate problem-solving. They direct the problem-solving process, and they reduce some of the burden placed upon the problem-solver, regardless of whether a computer, scratch pad, or unaided group of experts is applied to the problem. They stimulate creativity by proposing a strawman problem strucutre to which the problem-solver can react; and they accommodate change and revision in the problem-solving process.

"Unintelligent" templates have been successful problem structuring and problem-solving tools; "intelligent" templates have yet to be developed or applied. We believe that artificially intelligent substantive and procedural problem-solving templates hold great promise for accelerated, burden-reduced tactical planning.

Figures 2.5 and 2.6 list the elements and functions that we expect to be in our Corps level defensive tactical planning template. The template itself will contain information about the planning process and the substance of planning generally and specifically (at the Corps level in a defensive posture). The use of templates is also consistent with the design and development of a modular aid, where additional template (representing different command levels in different postures) modules can be added to the TACPLAN aid as they are developed and tested.

The use of templates also supports the applications prototyping strategy and larger participatory approach to systems design and development. Since templates are by nature comprised of bits of substantive and procedural information, they lend themselves well to structured definition. Not unlike the way circuit boards are tested one by one until the fault is found in modern solid state electronic appliances, template components can be tested against a set of internal and external performance criteria, and then modified or deleted as the results suggest. Whole new components can be added if new or previously undiagnosed needs are disovered.

But perhaps most importantly, templates suggest how to functionally describe a prototype aid. The TACPLAN aid, described in detail below, was designed with reference to an intelligent planning template that was the result of our

- **Elements of Tactical Planning**
  - *Commander's guidance*
  - *Mission definition (goals/sub-goals)*
  - *Area characteristics*
  - *Friendly/adversary combat power capability*
  - *Adversary intentions estimation/adversary Course Of Action (COA) evaluation*
  - *Friendly COA assessment vis-a-vis all*
  - *Concept of operations*
  - *Formulation of tactical plan*
  - *Evaluation & replanning . . .*

FIGURE 2.5: Components of the Tactical Planning Template

- **ACTIVE aiding functions**
    - *Elicitation of planning element characteristics*
    - *Measurement of tendencies toward risk*
    - *Sensitivity (what-if) analysis*
    - *Graphic displays of planning logic/illogic, deviations from doctrine, etc.*
    - *Rule-based challenges of planner and plan(s)*
- **Linkages among elements & functions within the planning process**
- **Embedded multi-attribute assessment methods arranged in a "diagnostic hierarchy"**

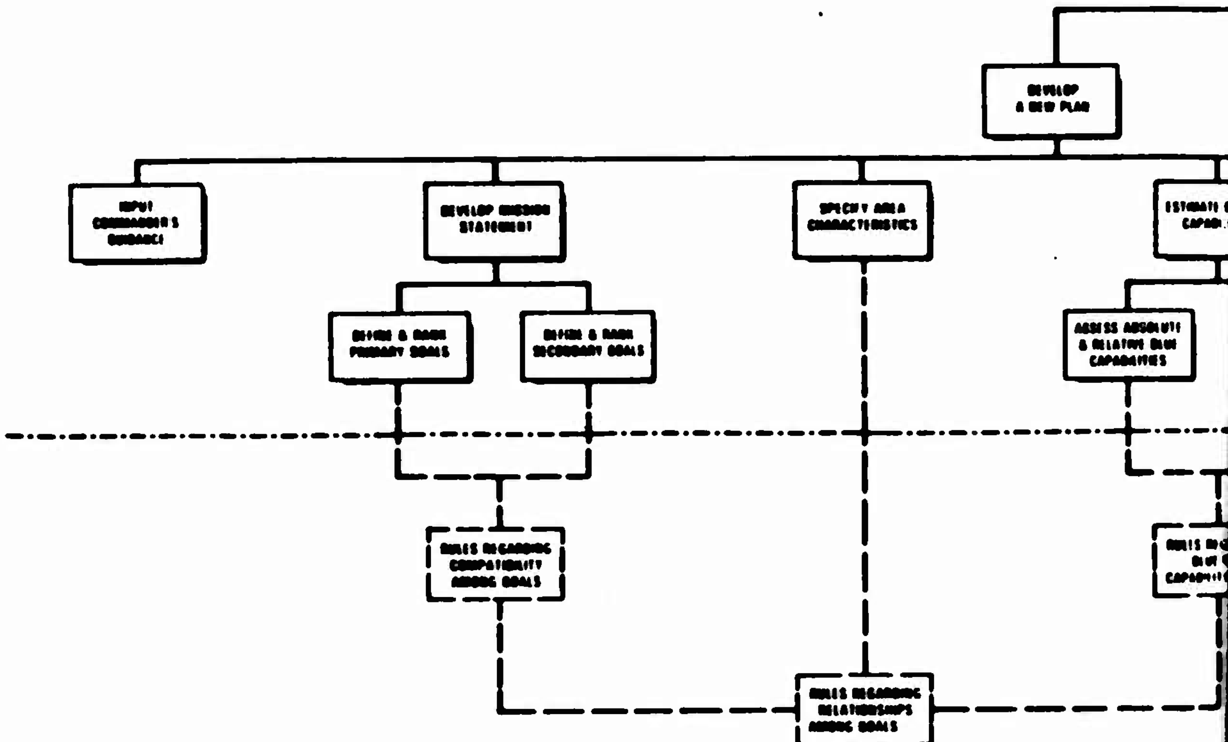
FIGURE 2.6: Intelligent Template Functions

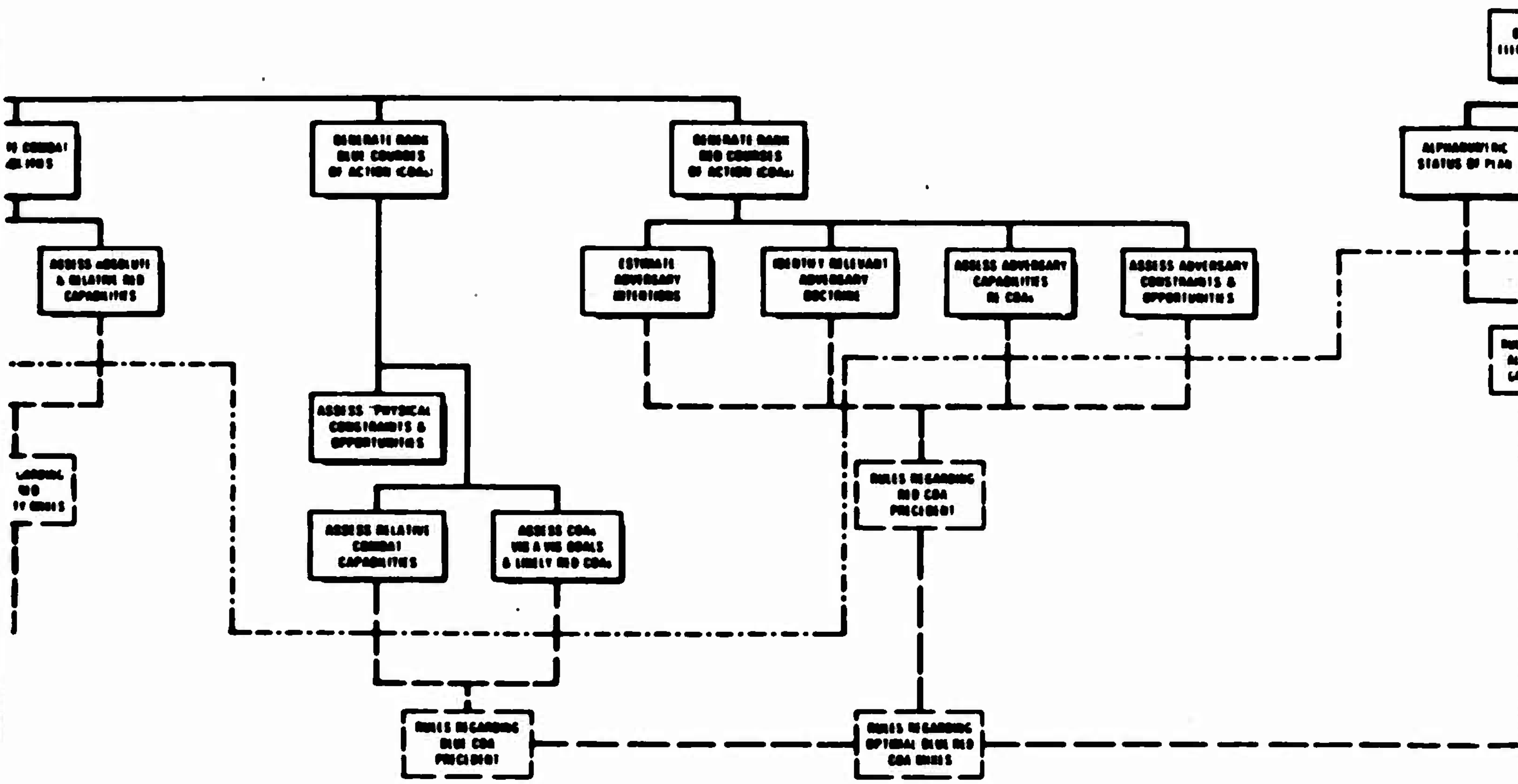
tasks/methods matching procedure.

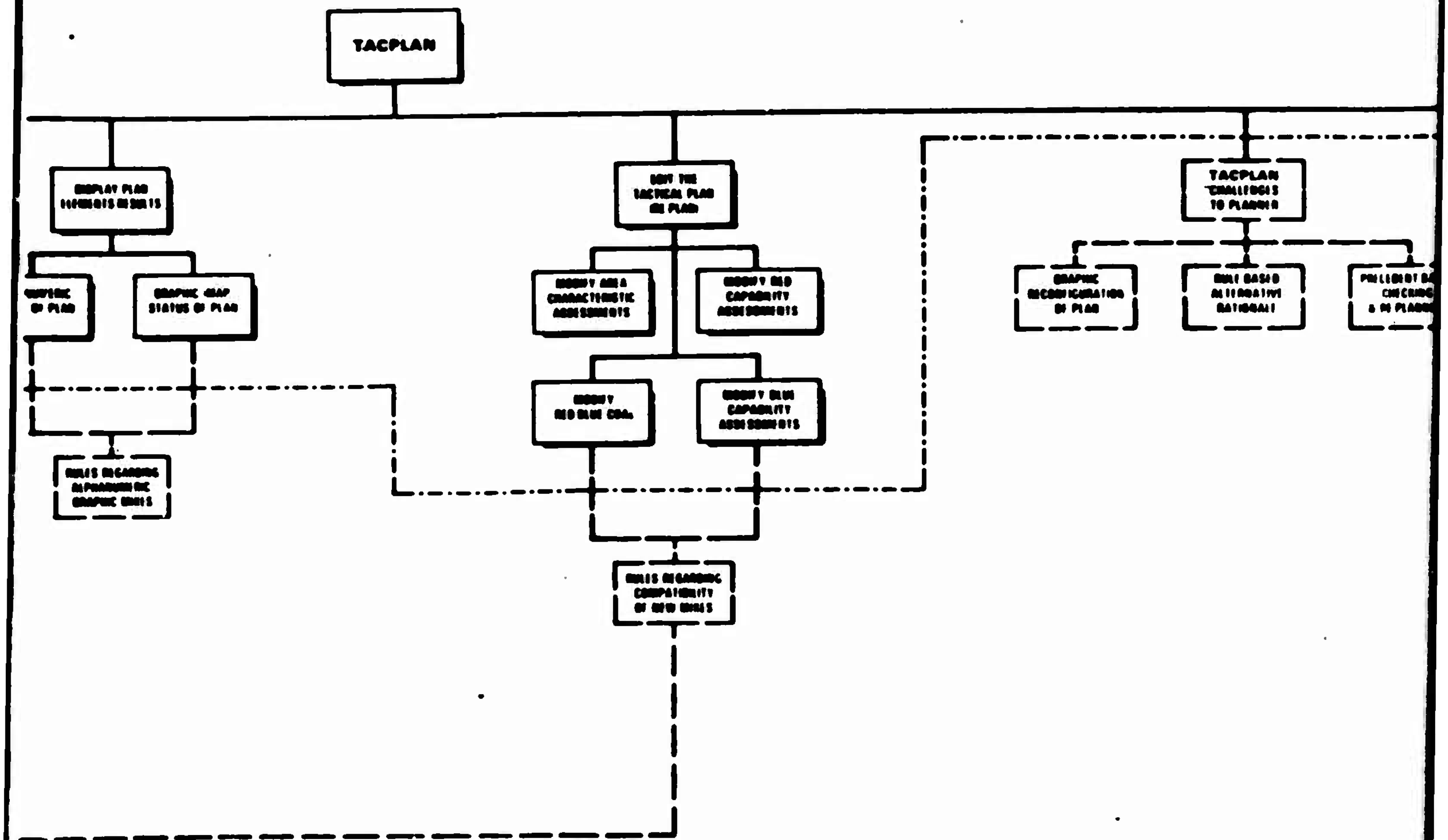
2.4.3 TACPLAN Functional Description - Figure 2.7 presents the large functional description of TACPLAN. Keep in mind that this description is as comprehensive as possible, a blueprint in its own right for the development of an intelligent planning aid. The above discussed template is represented in the top left hand node, "Develop a New Plan"; the other nodes are procedural and substantive. Some refer to plan editing and manipulation functions, while others refer to changes in procedure rooted in alternative (situational) environments. There is also a node representing the computerization of a critical function observed over and over again during the Carlisle experiments, "TACPLAN 'Challenges' to Planner."

All of the nodes in the functional description have correlates in the manual (grease pencil/acetate) planning process. The description itself, however, should be understood on two dimensions, one that occurs above the dotted line which extends from left to right in the figure and one that occurs below the dotted line. All of the functions above the line represent the tasks that an unintelligent template should perform, while those below the line suggest how and where the template should behave intelligently.

Recall that AI techniques are proposed as performing three distinct roles--as a planning procedural "moderator," as a creative stimulant, and as an input burden reducer. The boxes


DEVELOP A NEW PLAN
INPUT COMMANDER'S GUIDANCE
DEVELOP MISSION STATEMENT
SPECIFY AREA CHARACTERISTICS
DEFINE & RANK PRIMARY GOALS
DEFINE & RANK SECONDARY GOALS
ASSESS ABSOLUTE & RELATIVE BLUE CAPABILITIES
RULES REGARDING COMPATIBILITY AMONG GOALS
RULES REGARDING RELATIONSHIPS AMONG GOALS


ASSESS "PHYSICAL CONSTRAINTS & OPPORTUNITIES
ASSESS RELATIVE COMBAT CAPABILITIES
ASSESS ADVERSARY CAPABILITIES IN COAs
ASSESS ADVERSARY CONSTRAINTS & OPPORTUNITIES
STATUS OF PLAN


TACPLAN
TACPLAN

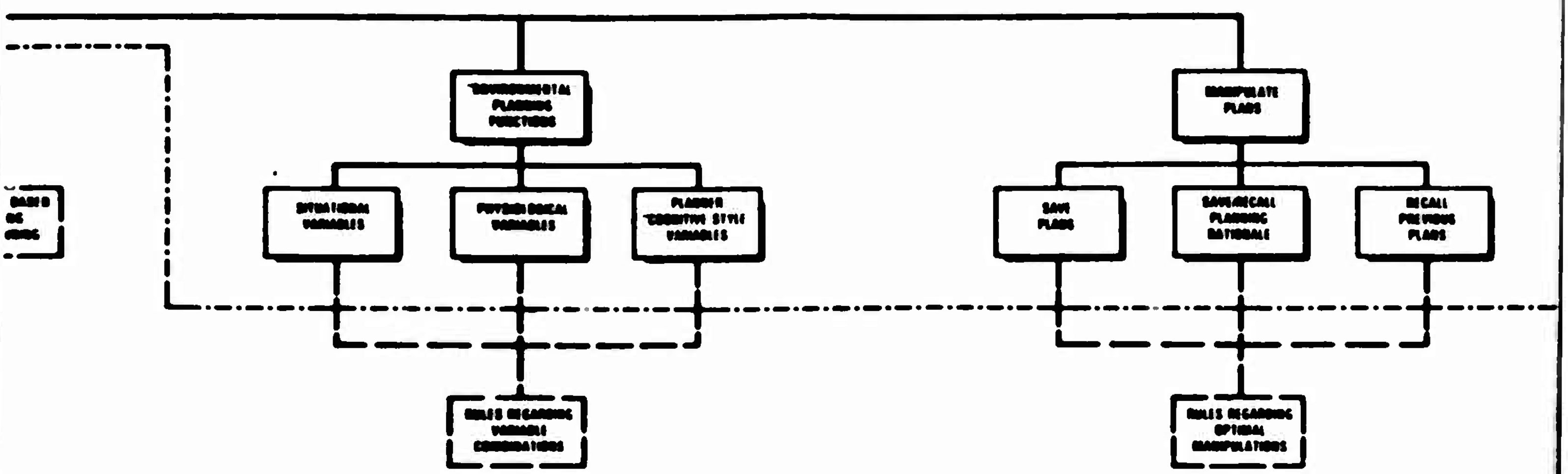


Figure 2-7

**TACPLAN**
**Functional Description**

input, output, and display routines, but clearly states our goal. Many previous decision aids have placed enormous burdens on their users, burdens that usually require them to learn a whole new methodology and then "feed" the methodology almost continually. Many of the decision analytic aids, for example, require their users to input hundreds of numeric values expressed either as probabilities or utilities. One planning aid, known as CONSCREEN (Martin, Esoda, and Gulick, 1983), requires planners to evaluate courses of action via the use of a multi-attribute utility structure that requires planners to weight criteria and score each course of action against each of the criteria in a tedious process that requires numeric expressions of value along a scale. While the multi-attribute utility assessment technique is a powerful one, forcing the planner to make hundreds of quantitative assessments places far too much burden on him.

The trade-off of course is diagnosticity. Decision analytic methods can only "guarantee" results if all of their procedures are carefully followed. If the procedures are amended or short-circuited, then the results will be undiagnostic. Or will they? One of the hypotheses we are testing tries to determine the level, nature, and structure of the expert judgment one needs in order to be analytically effective. Perhaps a great deal <u>less</u> information is necessary. Perhaps we have been burdening our users for a disproportionate return. We plan to test this and some other hypotheses in an effort to design and integrate "spreadsheets" that are both analytically powerful and easy to use.

TACPLAN now has a number of spreadsheets, based upon multi-attribute utility assessment, embedded into the flow of the planning process. While the planner still has to make assessments, they are high level and basically qualitative. TACPLAN will convert these aggregate judgments into quantitative form, perform some calculations, and then rank-order the objects under evaluation, like adversary courses of action, friendly courses of action, and relative combat capabilities. If--and only if--this initial evaluation fails to produce a clear winner, TACPLAN will require the planner to perform a more diagnostic (and slightly more tedious) assessment. We hope that the more complicated procedure will take approximately ten minutes, or roughly twice as long as the burdenless procedure. Note that present multi-attribute utility assessments, such as those required in CONSCREEN, can take several hours or even days to perform.

Another set of hypotheses we plan to test will measure the analytical pay-off derived from the use of graphic equivalent displays. Recall that the Carlisle experiments suggested conclusively that tactical defensive planning at the Corps level was substantially graphic and symbolic, that new ideas were scrutinized via grease-penciled illustrations and old ones discarded by a quick reference to realities clearly visible on a map. Aids like CONSCREEN do not display the actual area for which the planner is responsible. He cannot "see" courses of action as they are conceived and evaluated. As the evaluation unfolds he must refer to other maps and alphanumeric information. This searching can require him to travel through several levels of information that are usually stored in several different forms. While using CONSCREEN he must continually stop and refer to additional pieces of information. He may even stop to draw on a paper map.

Since planning is a graphic, spatial, and symbolic problem-solving process, planning aids should also be graphic, spatial, and symbolic. Moreover, planners should be able to see their concepts as they are developed and evaluated. Assessments about capabilities, routes, courses of action, and area characteristics can be made more efficiently spatially and graphically than they can be made numerically. While we will have to wait for the results of the evaluation, we expect this and related hypotheses to be confirmed. We also expect the notion to hold up and down command levels.

TACPLAN will permit planners to draw plans, move units, designate courses of action, and even annotate their drawings directly on an actual terrain map, not on a computer-generated one. The system will also permit planners to zoom in and out, in much the same way planners move closer to and stand back from paper maps. They will be able to scan across their areas of responsibility, call out terrain characteristics, and even "de-clutter" the video image (see Section 3.1.2 for a more detailed discussion of the graphic interface to TACPLAN).

Our assumption is that a great deal of problem structuring, alternative hypothesis testing, and simple and complex evaluation will be accelerated by the use of interactive mapping techniques. A corollary assumption is that graphic interfaces can be used to lighten the analytical workload of the planner, that what previously would be required to determine analytical consistency and reliability can be reduced significantly if not eliminated altogether via the use of high resolution graphics.

The use of graphics also supports our use of embedded multi-attribute utility assessment, since graphics can communicate more information to planners, information that can be used to generate more reliable analytical judgments.

The third major aspect of TACPLAN's concept of operation worth discussing is its use of rules to represent procedural and substantive information and knowledge, respectively, about the planning process. We plan to develop a set of rules (see Appendix B) that will help manage the planning process and will also help the planner formulate an optimal plan. Recall that our view of the role of AI methods and techniques falls into three categories. First, AI can contribute to plan management. Second, it can contribute to plan consistency while simultaneously stimulating creative planning; and third, it can reduce the burden placed upon planners via the application of a knowledge base about tactical defensive planning at the Corps level. Procedural rules are straightforward, but no less important than substantive ones, which will guide, check, accelerate, and--eventually--criticize the planning process. The same rules can reduce the planning workload by embedding knowledge about the relationships among specific planning variables, like terrain, trafficability, force structure, orders of battle, and doctrine.

We do not anticipate a huge rule base for the TACPLAN prototype; nor do we anticipate a large rule base for the more fully evolved TACPLAN, as least not as part of the defensive Corps level template. As TACPLAN evolves, additional rule sets can be integrated depending upon the kind of planning and the level at which it is occurring. While it is difficult to determine the precise number of rules that might be used in a given template, it is difficult to imagine rules sets of larger than 100 rules for any given template designed to support the development of new plans (assuming that rules constitute the best way to represent knowledge; see Appendix A). More complicated applications, such as plan execution, monitoring, and re-planning, may require more sophisticated knowledge bases.

"Burdenless analytical spreadsheets," "graphic equivalent displays," and procedural and substantive rules comprise the essence of the TACPLAN concept of operation. But they do not exhaust the contents. There are additional ideas and hypotheses that will be tested along the way, such as the use of narrative rationale as a means of tightening decision-making during the planning process, the use of graphic menus to accelerate the assessment process, and the use of "logic finders" to let the planner know where he can find information or how he can recall and display his rationale and TACPLAN's responses. To a significant extent, the TACPLAN design process has given us the opportunity to examine the relationships among cognitive requirements, analytical methodology, and interface technology--all with reference to one goal, to build an interactive planning aid that will lead to the development of better plans faster and more efficiently.

## 3.0 PROGRESS ON THE DEVELOPMENT OF THE TACPLAN PROTOTYPE

### 3.1 Delivery System Configuration

The Carlisle experiments, refined analytical framework, TACPLAN functional description, and TACPLAN concept of operation all determined the TACPLAN "delivery system." There were also a number of overarching technical and applications guidelines that determined the configuration. Compatibility across these two data bases yielded the delivery configuration described below.

3.1.1 "Personal" Planning Aid - A common technology need heard over and over again these days calls for the design and development of "low cost," "portable," and "distributed" "personal" decision aids. All of these terms are of course relative. Low-cost generally means less expensive than a minicomputer. Portable usually means "trans-portable," and distributed usually means accessible and sometimes "networked." But "personal" has some interesting connotations beyond the literal derivatives. Personal should mean controllable and manageable. It should mean non-threatening and supportive; and it should mean flexible and adaptive. The planning process is certainly compatible with these definitions.

Our observations of the planning process clearly suggest the appropriateness of "personal aiding." There are also no computational or display requirements that cannot be satisfied with a personal aid. "Low cost," "portable," "distributed," and "personal" thus suggested to us the use of a microcomputer with interactive graphic display capabilities. We selected the IBM Personal Computer (PC) with ample storage and memory capabilities (IBM/PC/XT). The TACPLAN prototype can easily be implemented on this microcomputer (though future versions may require the capabilities of an IBM/PC/AT, which has larger memory and storage capabilities). This system gives us the option of color or black and white (monochrome) displays as well as several input options. The prototype will permit keyboard and joystick/mouse input; it will also be configured to interact naturally and synergistically with the interactive graphic interface.

3.1.2 The Graphics Interface - TACPLAN will have a graphics interface comprised of an interactive video disc, video disc player, and video disc/mapping control panel. Video disc-based maps are made by first filming the area that is to become the disc-based map. Perceptronics has already filmed the areas necessary to implement the TACPLAN prototype. The NATO/Pact areas of Western and Eastern Europe are already on disc at multiple scales.

The video disc will display actual maps of the Corps area of responsibility at near perfect resolution. In fact, the video disc-based map is clearer and much more flexible than any conventional paper map. It permits planners to annotate what appears on the the display (which will be located right along side the IBM/PC/XT display) with nodes and symbols for later reference. It also enables planners to create their own personal symbols for annotation purposes. It supports de-cluttering, a simple operation that removes (stores or erases) annotations.

The video disc-based mapping system also permits planners to "fly" around a map, which, if laid out, might cover a warehouse floor. Under joystick control, planners can fly across great spans of maps, switch off to other kinds of data (photographs, films, weapons descriptions), and even zoom in on an image or location of particular interest.

The most important capability of the video disc-based mapping system that we plan to link to the (IBM/PC resident) TACPLAN analytical system is its ability to communicate symbolically with both the planner and the analytical side of TACPLAN. When a planner illustrates an enemy course of action by drawing it on the video display, TACPLAN will immediately "know" something about this course of action. It may know, for example, about the terrain that might constrain or propel the course of action, it may know about the relationship between the course of action and force structure, and it may know about the relationships among doctrine, orders of battle, and trafficability. Coordinates on the video disc-based map will be the link to analytical routines and knowledge bases stored in TACPLAN. When planners illustrate courses of action, annotate on the disc image, or erase an idea, TACPLAN will know what has happened and react accordingly. The nature, timeliness, and depth of the reaction will be determined by the analytical routines and knowledge bases resident in TACPLAN not by the capabilities of the interactive video disc.

In time it should be possible for a planner to draw a complete route across a map, or deploy several divisions along a border, and expect TACPLAN to react immediately, consistently, and substantively about the implications of the route or plan (see Section 4.1.2 for more information on this capability). Once the technology that links locations on the video disc to analytical routines and knowledge bases is fully developed, then the possibilities are unlimited. Procedural and substantive rules can be invoked spatially. Alternative plans can be generated once a planner has entered his first candidate; and narrative criticism and advice can be offered--all from what the planner does via TACPLAN's graphic interface.

## 3.2 Status of TACPLAN Prototype

The TACPLAN prototype is currently under development. The target delivery date is February 1985. The progress made to date in the four primary areas is outlined below.

### 3.2.1 Menu Development

- Nearly all of the menus that appear in the TACPLAN concept of operation (Appendix B) have been programmed. These menus will elicit plans, missions, analytical judgments, and rationale from planners as they develop a new plan. This progress has been recently documented (Perceptronics, 1984).

3.2.2 Analytical Routines - The many analytical routines that will drive the evaluation of terrain opportunities and constraints, capabilities, and courses of action will be modified multi-attribute utility algorithms (Edwards, 1983; Gulick, 1980; Andriole, 1983; Hill, et al., 1981). The major difference will be in the elicitation procedure, not in the calculation of overall utility. These algorithms have been programmed to work with the menu structures described above and in Appendix B.

TACPLAN's analytical routines will also include the specification of the relationship between unintelligent analytical processing and the procedural and substantive rule bases. This work is ongoing.

3.2.3 Procedural and Substantive Rule Development - Progress on the development of procedural and substantive rules has been steady since the Carlisle experiments were conducted. Work has been iterative; a number of rules are included in the TACPLAN concept of operation in Appendix B. The "depth" of the rule bases will be determined by our ability to derive rules from the experimental data, field manuals, interviews, and ongoing discussions with experts at the Army War College.

3.2.4 IBM/PC/XT Link to Interactive Video Disc - Progress here has also been steady. As of this date, the IBM/PC/XT "talks" with the video disc mapping system quite fluently. It is possible, as it has been for some time now due to applications in other areas, to annotate direcly onto the disc, zoom in and out, store, erase, and retrieve annotations, and pick up and move, or remove, tactical symbols. Work continues on the linkage between locations on the map image and the procedural and substantive knowledge bases.

### 3.3 The Iterative Strategy

Special mention should be made of our progress to implement an iterative strategy to the design and development of TACPLAN. From the outset it was clear that given the number, nature, and complexity of the hypotheses that we hoped to test, and given the goal of incarnating the results in an interactive computer-based aid, we would need a procedure for checking and rechecking our work. We were fortunate to find a dedicated group of expert planners at the Army War College, and have long since developed an appreciation for codified doctrine and instruction. The challenge lies in knowing how and when to iterate on research progress as it is made. Our approach has involved the development of a wide communications channel with a growing number of designers, developers, and planners. We hope to widen the channel even more as TACPLAN emerges as a real system. In retrospect, had it not been for the wide communications channel we would never have thought to ask many of the questions posed above, let alone ever had an opportunity to answer them.

We are also dedicated to the applications prototyping strategy. Fuzzy analytical problems cannot be structured overnight or straightforwardly. A great many requirements will only emerge over time. Our expectation is that the TACPLAN prototype will uncover even more requirements and, as a prototype, accelerate the requirements definition and problem structuring processes. It will also help institutionalize our iterative strategy.

# 4.0 PHASE TWO RESEARCH, DESIGN, AND DEVELOPMENT PLAN

Following the development of the TACPLAN prototype we hope to continue our research and development along four distinct lines. The first will involve the development of yet another analytical framework. The second will be devoted to enhancing the TACPLAN aid. The third will be devoted to testing and evaluation, while the fourth to documentation.

## 4.1 Iterative Analytical Framework

Research progress thusfar has suggested a number of potentially profitable directions in which we might move. They include the integration of situational or "environmental" variables into the planning process, the development of an embedded plan "challenger," the continued development of procedural and substantive rules (as well as other forms of knowledge representation), and the expansion of the master planning template to include additional command levels and different planning problems, such as plan execution, plan monitoring, and re-planning.

4.1.1 Environmental Variables - The Carlisle experiments suggested that the planning process is susceptible to a variety of perturbations from the environment. The amount of time available, for example, changes the way the process is implemented. Similarly, differences in planning "style" can affect the process, just as the psychophysical condition of the planner can dramatically accelerate or retard the process.

Perhaps the most important environmental variable is time. Research suggests that time can affect the problem-solving process in some strange, counterintuitive ways (Nisbett and Ross, 1980; Nisbett, et al., 1982). There is no correlation, for example, between the amount of time available and the quality of an analytical solution, given a bare minumum or benchmark allotment of time. After a few hours, a problem that should have taken a few minutes to solve is no easier to solve, and may in fact be impossible to handle _because_ of the extra time (Nisbett and Ross, 1980). Additional time also provides an opportunity to gather more information, information that presumably would contribute to a better solution. But here too we find no correlation between the amount of information available to a problem-solver and the quality of the solution (Heuer, 1980; Tversky and Kahneman, 1982; Nisbett, et al., 1982). Additional time and information can complicate an otherwise straightforward problem-solving process.

The presence or absence of time should be treated as an independent variable that may or may not impact upon quality, specificity, consistency, reliability, and accuracy. If research could confirm or reject these hypotheses then it would be possible to re-design TACPLAN to accommodate the findings. It is interesting that the TACPLAN prototype will ask the planner about his time constraints. While the prototype will only respond to the 72 hour option, how might it respond to much shorter or longer time constraints? Should it become more abbreviated in dialogue and interaction, or should it become much more deliberate? Notice that no suggestion was made regarding possible relationships. Intuitively, one might assume that the shorter the available time, the more abbreviated TACPLAN should behave, and the longer the time, the more deliberate it should be. But these relationships may indeed be backward. It may be that TACPLAN should slow down--but attempt to do a little less--when time is short, and speed up--and attempt to do a little more--when a lot of time is available.

The amount of time available to a planner will also affect the amount of information brought to bear on the planning problem. But how? We know that more information does not predict to higher quality plans. But we also know that information paucity predicts to bad plans. Where is the balance? What is the right mix? Is it linked to the individual problem-solving style of the planner? These are research questions for phase two.

The literature on cognitive style is inconsistent where its application to computer-based problem-solving is concerned. In non-computer-based contexts there is evidence to suggest that people learn and remember in some very different ways. Ragan, Back, Stansell, Ausburn, Ausburn, Butler, and Huckaby (1979) have identified ten cognitive styles appropos to the study of learning systems. They include:

- Field Dependent-Field Independent Styles

  - An analytic as opposed to global manner of perceiving. Field independent thinkers reflect the ability to perceive visual stimuli as separate from an embedded context;

- Impulsive-Reflective Styles

  - Individual differences in speed and errors when faced with response uncertainty. Reflective thinkers study hypotheses longer and are usually correct when choosing a response, while impulsive thinkers tend to select the first response and are usually wrong;

- Visual-Haptic Styles

  - Visual thinkers use their eyes as the primary sensory intermediary, while haptic thinkers rely much more on kinesthetic and body orientation;

- Leveling-Sharpening Styles

  - Levelers tend to incorporate new ideas with old memories, blurring the original image, while sharpeners can add new ideas without distorting the old;

- Constricted-Flexible Styles

  - Constricted thinkers are very susceptible to distraction while flexible ones are not;

- Broad-Narrow Categorization Styles

  - Broad thinkers prefer broad categorization, while narrow thinkers prefer narrower categorizations;

- Scanning Styles

  - Differences among thinkers in their extensiveness and intensity of attention;

- Tolerant-Intolerant Styles

  - Tolerant thinkers can accept perceptions that are at variance with normal experiences, while intolerant thinkers cannot;

- Cognitively Complex-Simple Styles

  - Complex thinkers see the world multi-dimensionally and in a discriminating manner, while simple thinkers do not; and

- Conceptualizing Styles

  - Different thinkers categorize stimuli with perceived similarities and differences very differently; they also utilize different approaches to conceptualization.

These styles suggest ways to present computer-generated information and enhance man-computer interaction. For example, visual perceptual types would benefit from the use of graphical output (so long as the application called for it) just as "scanners" would feel comfortable with abbreviated display formats (so long as the impact of available time and information was well understood).

In addition to cognitive style, experience is part and parcel of the overall cognitive profile hypothesized here as integral to enhanced computer-based problem-solving. Has the planner dealt with similar problems before? How familiar is he with planning aids? What level "user" is he?

Cognitive variables are important because behavioral decision-making research suggests that decision-makers (and planners) tend to underutilize appropriate inferencial strategies and overutilize more primitive ones. The typical decison-maker, for example, often fails or performs suboptimally when he undertakes the inferencial tasks of covariation assessment, causal explanation, and prediction. Significantly, all of these--and many other mediational and perceptual--tasks are regularly performed by planners. Suboptimal performance can be traced to a whole host of cognitive, personality, and perceptual phenomena which are only partially understood by behavioral scientists. We should thus focus upon the cognitive strengths and weaknesses of planners. Some relevant questions here concern the limits of cognitive information processing _in tactical planning_, the mechanics of problem-structuring _in tactical planning_, the identification and description of planning heuristics, and the larger categorization of cognitive planning styles. All of these are phase two research questions.

The last set of environmental variables to be examined are the psychophysiological ones. At some point we must develop verifiable generalizations about the psychophysiology of decision-making and its subset activities, like planning. The current state of this research includes some indicators which are more or less useful for detecting emotional states in general and especially for identifying peaks of arousal. Of great potential is the array of nonverbal, physical, physiological, and especially psychophysiological indicators now beginning to receive serious attention (Hopple, 1980; Druckman and Slater, 1979; Andreassi, 1980). It is not at all clear how such indicators can be linked with interactive computing, but they do respresent a source of information that has to date been ignored by all but a handful of systems designers (Donchin, 1979; Andriole, 1982; Andriole and Hopple, 1982).

While it is easy to speculate about just how psychophysiological indicators might be used to alter man-system interaction (lots of mistakes make the system slow down; delayed responses change the interaction mode, and the like), it is not clear which combination of indicators and system reponses will enhance performance. These are core phase two research questions.

Finally, the integration of environmental research findings into TACPLAN has implications for the nature, size, and depth of TACPLAN's knowledge bases (see Section 4.1.4 below). Should environmental research findings be flexible and dynamic and expressed as networks and scripts, or should they be rule-based and relatively inflexibly invoked? Our limited research to date suggests that rules would capture the essence of environmental findings accurately and efficiently.

4.1.2 The Embedded "Challenger" - Perhaps no greater challenge in interactive systems design exists than one that requires on-line system introspection. We intend to respond to the challenge in the context of tactical planning in a number of ways. First, we intend to explore, via our expert planners at the Army War College and elsewhere, the appropriate role of a challenger or plan critic. We need to understand the potential contributions that such a function can make, as well as the threats it may pose to the planning process. In preliminary discussions with Army War College planners held on October 4, 1984, it was suggested that a challenger--if informed by analogy (Silverman, 1983), precedent, experience, and doctrine--could be an invaluable planning assistant. It could stimulate thought and discussion and, when available time was short, help the planner develop a plan through a set of iterative steps and judgments made vis-a-vis a series of increasingly specifc and relevant strawmen. Imagine, then, a Corps commander with awesome requirements and but a few hours time asking TACPLAN to respond to his mission guidance with several concepts of operation that the commander could massage until he felt as though he had hit upon the optimal plan (which would then still be subjected to TACPLAN's same critical personality).

In order for a challenger to perform credibly it must have intelligence in a number of areas. First, it must have the capability to develop a plan based upon incomplete, or "fuzzy" information. It must be able to suggest alternatives to existing concepts of operation, and it should be able to distinguish between, compare, and contrast existing plans and alternatives with plans that may have been developed six months ago. One way to accomplish this is to store a limited but representative number of alternative concepts of operation. These plans could be stored as complete concepts of operation that could be altered by the planner as the situation required. Stored plans are not unlike stored templates. They could be used to stimulate the planner or accelerate the planning process.

Stored plans could be stored narratively and graphically. If a planner asked TACPLAN to provide an alternative, TACPLAN would respond by describing the plan narratively and by drawing it directly onto the video disc-based map. The difficulty with this approach is to pre-select a representative enough sample of plans to be of real value to the full range of Corps (or whatever) level planning problems.

This is an interesting problem. On the one hand it is easy to find experienced tactical planners convinced that the number of planning solutions for a given theater on a given command level is relatively few; on the other hand, there are some that are just as convinced that the number of optimal solutions is infinite. As always, the "truth" lies somewhere in the middle. It's discovery remains a research question for phase two.

If plans cannot be stored <u>in toto</u>, then the means by which they can be quickly produced must be created. One approach might involve the development of <u>tactical planning scripts</u> for multiple command levels. Scripts are flexible data bases that permit the creation of solutions from a set of variables that a planner might provide. But scripts are not capable of producing infinite numbers of plans, either. Deep scripts could probably produce many plans that could be efficiently stored in toto (or generated on-line), but shallow scripts would probably perform no better than a reasonably large library of tactical plans.

Inference networks represent another strategy, as do the use of simple and complex rules, that would create plans from information about the planning problem at hand. A rule-based challenger would be fast and flexible, but perhaps not as expert as a script- or inference network-based challenger.

The selection of one (or more) knowledge representation strategies will depend upon a requirements/task analysis, an assessment of the strengths and weaknesses of each strategy, and and assessment of the costs and benefits of integrating the strategy into our delivery system.

4.1.3 Additional Command Levels and Planning Functions - The TACPLAN prototype will only permit the development of a new plan. It will not permit re-planning based upon adversary movement and the evolution of battle. In other words, it will not permit the planner to execute his plan and monitor its status in much the same way a war game proceeds. TACPLAN also only permits the development of Corps level plans. It does not permit planning, except at a crude level, at the Division, Battalion, Brigade, or Platoon command levels.

There are a number of reasons why widening the scope of TACPLAN's applicability make sense. First, plan execution and monitoring (and the re-planning that then occurs) are natural extensions of the development of new plans, regardless of command level. It is difficult to determine the success or failure of a plan, except against an absract "ground truth," unless it is implemented. The feedback planners get from battle, adversary responses, and unanticipated events is the data used to re-plan, adapt, and learn.

An argument can thus be made that we have truncated the tactical planning process by limiting TACPLAN's capabilities to plan development. One solution is to build a gaming capability into TACPLAN that would permit planners to execute and monitor their plans, and then re-plan as the need arises.

Simulated battle systems are numerous and efficient, but they also have serious limitations. First, they have almost all been designed for war gaming/training purposes. They are therefore instructional, not operational, in nature. Second, they do not have interactive spatial capabilities. Third, they are not "intelligent." While phase two research will have implications for the design and development of more sophisticated war games and simulations, the primary focus will involve the merger of three distinct technologies: simulation models, artificial intelligence/knowledge representation techniques, and interactive graphic interface technology. The work will be informed by previous work in simulation, war gaming, and intelligent adversary behavior (Lehner, 1983), but will go beyond this work, integrating new ideas and capabilities within the TACPLAN structure.

As with the development of the TACPLAN new plan challenger, a variety of techniques will be explored. Should re-planning direction be stored as alternative re-plans? Should they be re-generated each time Red moves, Blue fails, and unanticipated events occur? Or should they emerge from the firing of rules? Once a plan is executed, should inferences be made about its likely success or failure? Would it be feasible and/or desirable to show planners ahead of time where and how their plans might fail?

What about additional command levels? How does planning and computer-aided planning change as one moves up or down the command level? Beyond the development of different templates (comprised of different systems options, different evaluative criteria, and different displays), how should intangibles like risk be handled? How should situational and cognitive style variables be integrated (if at all)? How should the challenger behave?

We propose in phase two to identify two additional command levels and to develop two additional templates. The two levels will be the Division and Platoon levels. The Division level will be templated because it is important to test the synergism betweeen two contiguous command levels, to determine the compatibility between TACPLAN-developed Corps and Division plans. The Platoon level will be templated because of the dramatic contrast between Corps/Division and Platoon level plans, and because of the hypotheses that Platoon problems will allow us to test. The development of new templates will require us to reconstruct planning at the two new levels, run some experiments (at the Army War College and perhaps elsewhere), identify Division and Platoon tasks, match the tasks to the best methods, determine the best way to represent knowledge, and modify TACPLAN to accommodate the new templates. Given that TACPLAN will be of modular design, we do not anticipate major changes to the program; the real challenge lies in the development of the substantive templates.

The new templates will also be developed with reference to research findings in the environmental and plan challenger areas. We hope to expand the number of templates so that commanders at all three levels can build, execute, and monitor plans against different environmental backdrops with and without the aid of a plan challenger.

In order to accomplish these additional command level and functional tasks we plan to use the same geographical area and similar scenarios (perhaps simulating a TACPLAN network). This will facilitate testing across levels and guarantee a cost-effective research approach.

4.1.4 <u>Multiple Knowledge Representation Strategies</u> - Reference has been made throughout this report to procedural and substantive rules. While the TACPLAN prototype will use rules to represent knowledge about terrain, trafficability, and the like, phase two research may well suggest the need to represent knowledge in some other ways. Alternatives include the use of inference networks, frames, scripts, and a variety of hybird techniques. The knowledge representation approach will be determined by the task analyses that will be conducted for the additional (Division and Platoon) command levels and additional (execution and monitoring) functions.

The approach to problem structuring and interactive systems design and development applied to the development of the TACPLAN prototype will be applied to the design and development of the proposed enhancements. We are committed to the systematic analysis of military planning requirements and the use of analytical methods and techniques that satisfy those requirements. The iterative strategy with operational planners will thus also be maintained.

## 4.2 Testing and Evaluation

The number of evaluations of interactive computer-based decision support, information management, and forecasting systems is far less than the number of systems that have been sponsored by the U.S. government. In fact, reliable evaluations are conducted of less than one in ten systems. There are a variety of reasons why decision (and related) aids are seldom evaluated. Some are bureaucratic and some are technical.

We plan to evaluate each iteration of TACPLAN in a number of ways that we hope will provide us with good feedback about what is right and what is wrong with TACPLAN.

4.2.1 <u>Testing and Evaluation at the Army War College</u> - We plan to test and evaluate TACPLAN at the Army War College. We plan to structure the evaluation around so-called "internal criteria" and "external criteria." Internal criteria measure planning performance defined in terms of planning thoroughness, diagnosticity, and consistency. How many planning options are considered? How many dimensions of value are used to determine the likelihood of adversary courses of action? How consistent is a planner from problem to problem? Answers to questions such as these will permit us to measure how well a planner structures a plan. But what about the quality of the plan? External criteria measure the extent to which the planning solution approximates what is regarded as the correct solution to the planning problem, or "ground truth." Ground truth is usually determined by a group of independent planners who do not subsequently participate in the planning evaluation.

A unique opportunity presents itself at the Army War College not only because of the critical mass of expert planners that can be found at Carlisle, but because the College has sponsored some planning research of its own. In several instances this research has resulted in the development of an interactive planning aid. One, known as CONSCREEN (Martin, Esoda, and Gulick, 1983), which uses a decision theoretic framework, can be evaluated against TACPLAN to determine which aid best supports the tactical planning process and why. The proposed plan calls for the evaluation of three groups of expert planners: one with CONSCREEN, one with TACPLAN, and one with neither aid. We may also vary the situations (wartime versus peacetime), the command levels, and planning functions to learn as much as we can about the effect of alternative methods and displays on planning performance.

4.2.2 Testing and Evaluation in Operational Environments - If TACPLAN "passes" some important tests at the Army War College we plan to transfer it to at least one operational or quasi-operational setting for further testing and evaluation. This plan is consistent with the overall applications prototyping approach to interactive systems design and development. If the early prototypes are successful--and successfully iterated upon--then the last prototype should "graduate" to a more challenging environment.

## 4.3 TACPLAN Documentation

Upon completion of phase two of the project TACPLAN will be documented according to conventional documentation procedures. But in addition to the usual functional description, system specification, and user manual TACPLAN's knowledge bases will be documented. The evolving problem structuring methodology will also be documented, especially as it has contributed to the design and development of TACPLAN.

# 5.0 CONCLUSION

This report has documented progress made on the design and development of an intelligent tactical planning aid. It is important to note that the above reports on a planning project, not on an artificial intelligence project, an interface project, or a project on analytical methodology. The processes of tactical planning have determined the research questions. Our work began with an analysis of the planning process, not with an assessment of some interesting approaches to modeling or with the programming of a planning aid. As the research unfolded it became clear that the only way the tactical planning process could be supported by yet another aid is if that aid was the product of an interdisciplinary effort. We thus ended up integrating a top-down, hierarchical, goal-directed model of the planning process with some multi-attribute utility assessment capabilities and knowledge bases, and packaged it all in a computer-based aid with an intelligent graphic interface. Had we left any one of the ingredients out the aid would have had no chance at all to succeed.

We have come full circle. We began with the notion that tactical planning was a soft problem domain, unwilling to yield to any single analytical perspective. Our research thusfar has convinced us that we were right, and that there is much left to do.

NOTES

*International Information Systems, Inc., under sub-contract to Perceptronics.

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# APPENDIX A

## PROGRESS ON THE DEVELOPMENT OF A GENERIC PROBLEM STRUCTURING/SYSTEMS DESIGN METHODOLOGY

# A GENERIC PROBLEM STRUCTURING METHODOLOGY FOR INTERACTIVE COMPUTER-BASED SYSTEMS DESIGN & DEVELOPMENT

Conventional computer-based systems design and development directs us to first look at the requirements that the system is intended to satisfy. It then suggests that some kind of modeling of the mock system can redefine our requirements which, in turn, will permit us to develop yet another functional description of the system, and so forth until the model accurately represents and satisfies the requirements. Then, and only then, we're told, should we turn to software design and engineering, and that these steps should in turn determine our hardware configuration. Bringing up the rear are "packaging" tasks, such as the preparation of users' manuals, and "technology transfer" tasks, such as the introduction of the system into the target environment.

Systems analysts differ on the role of the user in this process but more and more we hear cries about the neglected user who must become involved in the systems design process if the system is to have any chance at all of satisfying user needs.

Finally, there are debates about the way the first iteration of the system itself should be developed. Some hold that a thorough requirements analysis will assure the development of a responsive system, while others feel just as certain about the wisdom of some kind of "prototyping" strategy. Because of the complexity of the tasks that interactive systems are expected to perform, the prototyping strategy is becoming more and more popular.

The process itself is anchored in the quality of the requirements analysis. If the analysis is conducted poorly then the system will fail. If it is conducted well then the system has a better chance of succeeding. What does this mean? First it means that without a structured, quantitative, verifiable requirements analysis the system cannot possibly fulfill user needs. On the other hand, a well conducted requirements analysis by no means guarantees success.

Where is the problem here? Requirements analysis techniques are more than fallible, and the techniques that we use to convert requirements to systems functions are only barely developed

This appendix presents some ideas about how to identify and structure analytical problems and how to convert the problems into representative and responsive computer-based systems.

## The Requirements Dilemma

Requirements analysis is boring, time-consuming, and expensive. Unless conducted by professionals it is also often a waste of time. Yet, without some formal "definition of requirements" many managers will not permit systems development, and the systems that do get developed usually fall far short of expectations.

Budgetary constraints also assault the requirements analysis process. It is usually very difficult to convince managers and sponsors that a large front end investment will pay huge analytical dividends during the entire length of the systems design and development process.

Finally, because requirements analyses are often poorly conducted a lot of managers and sponsors have a negative view of their utility.

## The Road to Systems Targeting

Systems targeting consists of two assessments. One has to do with the users and one with the tasks. "User profiling" is easy compared with task analysis. There are several typologies of user characterisitics, but a limited number of typological criteria. For example, users can be categorized according to their experience with interactive computing, according to their job description, and/or according to how frequently they are likely to use the system. There are also more exotic criteria, like cognitive problem-solving style, that, on some occasions, may be used to categorize users. One simple typology might thus recognize "naive," "managerial," and "scientific technical" users. Another might just recognize "frequent" and "infrequent" users," while yet another might categorize users according to their attitudes toward interactive computing. The key is criteria-based classification that is consistent and appropriate to your application. With regard to interactive tactical computing, for example, familiarity with computing, rank, and training might be used to classify users.

The very first step should involve an assessment about user characteristics. This assessment should not be static, but should assume that the system will be successful in time and that users will "graduate" from class to class.

The second step should turn to requirements definition. What will the users be expected to do on the system? How will they be expected to do it?

"Task profiling" requires an identification and assessment of the tasks that will convert into the functional essence of the system. How should tasks be identified. Classic requirements analysis tells us that the best way to find out what someone does for a living manually is to ask them to describe exactly what it is that they do. Interviews and ad hoc working groups are very popular techniques for identifying requirements, as are the use of structured questionnaires and surveys. Simulations are also popular, especially for very large and complex problem domains.

Conventional wisdom suggests using at least one of these techniques to identify requirements. But which ones? Research after the fact suggests that some techniques are better at identifying certain requirements, but since you don't know the requirements how can you know which technique to select?

The appraoch recommended here is to employ a generic task taxonomy (or two) to identify the general class of requirements you will have to satisfy. Two taxonomies appear below. The first belongs to Wilbert O. Galitz (1980), while the second to Crolotte and Saleh (1979).

### GALITZ' GENERIC TASK/BEHAVIOR TAXONOMY

- Cognitive Behavior
  - Information development/gathering
  - Information storage and retrieval
  - Reading and proofreading
  - Data analysis and calculation
  - Planning and scheduling
  - Problem-solving and decision-making
- "Social" Behavior
  - Telephoning
  - Dictating
  - Conferring
  - Meeting
- Procedural Behavior
  - Completing forms
  - Checking documents
- "Physical" Behavior
  - Filing and retrieving
  - Writing
  - Mail handling
  - Traveling
  - Copying and reproducing
  - Collating and sorting
  - Pickup and delivery
  - Typing and keying
  - Keeping calenders
  - Accessing equipment

### THE CROLOTTE/SALEH GENERIC TASK/BEHAVIOR TAXONOMY

- Perceptual Behavior
  - Searching for and Receiving Information
    - Detects
    - Inspects

-- Observes
-- Reads
-- Receives
-- Scans
-- Surveys

- Identifying Objects, Actions, and Events

-- Discriminates
-- Identifies
-- Locates

● Mediational Behavior

- Information Processing

-- Categorizes
-- Calculates
-- Codes
-- Computes
-- Interpolates
-- Itemizes
-- Tabulates
-- Translates

- Problem-Solving and Decision Making

-- Analyzes
-- Calculates
-- Chhoses
-- Compares
-- Computes
-- Estimates
-- Plans

● Communication Behavior

- Advises
- Answers
- Communicates
- Directs
- Indicates
- Informs
- Instructs
- Requests
- Transmits

● Motor Behavior

- Simple/Discrete

-- Activates
-- Closes

-- Connects
-- Disconnects
-- Joins
-- Moves
-- Presses
-- Sets

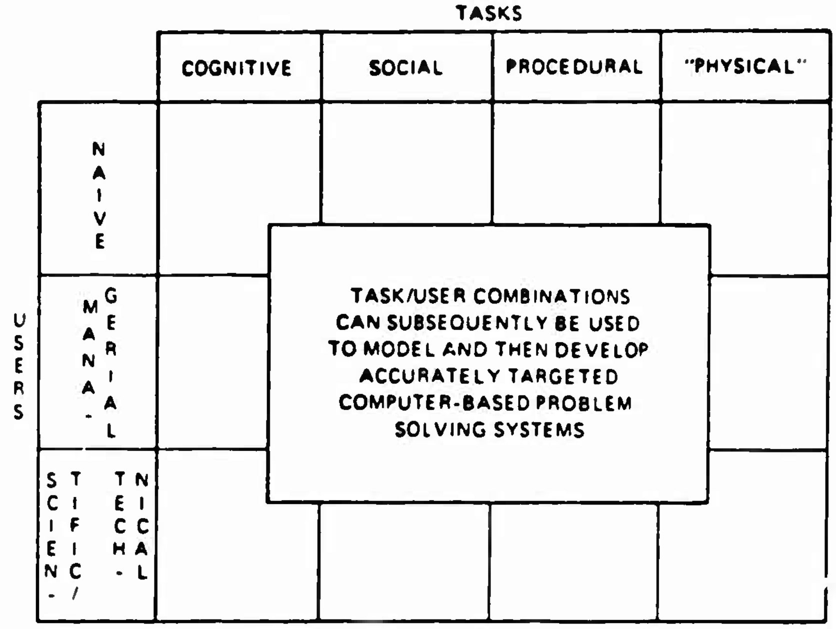
- Complex/Continuous

  -- Adjusts
  -- Aligns
  -- Regulates
  -- Synchronizes
  -- Tracks

These two taxonomies suggest a number of strategies. First, they suggest a way to get an immediate handle on the nature of the tasks that have to be modeled. They also suggest how to select the "best" requirements analysis technique.

Before a preliminary requirements methods assessment takes place, however, a general user/task matrix, like the one below, should be constructed. The user and task categories in the figure are not important. The key is to identify those general user and task categories most likely to inform the selection of an appropriate requirements analysis method.

Research reported in Ramsey and Atwood (1979) suggests that techniques have certain known strengths and weaknesses. For example, all survey, questionnaire, and interview techniques are notoriously inaccurate because they more often than not measure users' perceptions of what they do as well as their biases and oversights. As Ramsey and Atwood suggest, "users are expert at doing jobs, not describing them." Ad hoc working groups also suffer from these and related problems. Job analysis techniques




EXEMPLAR USER/TASK MATRIX

are best suited to the identification of clerical type tasks, not cognitive ones. Simulation and gaming techniques can be very insightful. So-called "paper simulations," where prospective users perform tasks similar to the target ones, can yield a great deal of useful information in cognitive areas, as can the use of formal "protocol analysis," a technique that requires prospective users to comment extensively on tasks performed during a simulated problem-solving session. This technique is especially powerful for identifying cognitive and mediational tasks. Finally, all-machine simulations, while expensive, may be the only way to capture a variety of complex distributed tasks.

Our tactical planning problem fell primarily into the mediational and cognitive task categories, but we didn't know exactly what sub-tasks comprised the domain until we conducted the requirements analysis. We used several techniques. First, we structured a number of questions that we intended to ask at some point during the analysis. These were critical questions designed to measure the primary components of the planning process, like probability assessment, criteria-based utility assessment, and "payoff." Based upon an initial screening of our taxonomies, we decided to conduct a paper simulation of the planning process. We also decided to introduce aspects of the protocol collection technique, aspects that we hoped would not be too intrusive. As a precaution, we decided to implement Dr. Robert M. Sasmor's suggestion to videotape the simulation/protocol collection procedure.

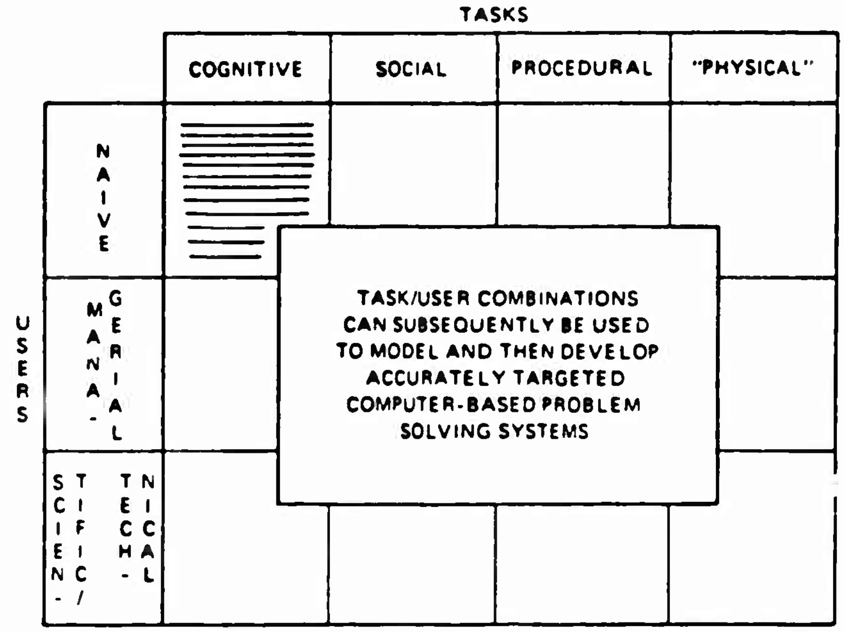
Videotaping yielded enormous dividends. Initially we decided to videotape because we felt that if protocol collection became too intrusive we could back off and still capture a great deal of information. Videotape, we reasoned, would permit us to alter the requirements analysis on-line. Dr. Sasmor assumed that videotaping would yield insight into some tasks and requirements that might otherwise go unstated or unobserved. All of his assumptions were validated. Due to the constraints imposed by the simulation, and the intrusions necessary to collect protocol data, some tasks simply went unreferenced. When we observed the videotape after the simulation we noticed that at times the words were out of sync with what was happening during the simulation, not because of any technical difficulty, but because our expert planners found it easier to simply proceed with the planning process than to describe it at every turn. Videotape fills in the gaps in the "thinking aloud" and "participant observation" process.

Videotape also documents the simulation in a way that audiotaping simply cannot match. The recollections of the participant observer are nearly as faulty as many of the utterances of the subjects. Videotape helps validate the data immediately and long after the experiments are completed. They also contribute to the development of a task/requirements analysis data base that can be used by other investigators to study identical or similar behavior.

After your general user/task matrix has suggested the appropriateness of a particular requirements analysis technique (or techniques), and you have implemented the method(s), then you can redevelop your user/task matrix, as suggested below. In the example, the matrix has been prepared for naive users performing cognitive (planning) tasks.

The importance of structured requirements analysis cannot be overstated. The approach outlined above will yield reliable task definitions, but sometimes the process must be repeated several times. Depending on the application, one or two requirements analysis techniques may yield more than enough diagnostic data;

sometimes, however, several techniques must be applied several times.




"NAIVE" USER/COGNITIVE TASK MATRIX

## Tasks/Methods Matching

There are a variety of techniques for identifying just the right combination of tasks and analytical methods. The method used for our tactical planning work, as well as a method that can be applied to many matching problems, involves the use of generic methods inventories, such as the one below from Crolotte and Saleh (1979).

## AN ANALYTICAL METHODS INVENTORY

- Decision Analytic Methods

  - Value Models

    - -- Utility Assessment Techniques
    - -- Multi-Attribute Utility Analysis
    - -- Cost-Benefit Analysis
    - -- Discounting Models
    - -- Monte Carlo Methods
    - -- Group Utility Aggregation

  - Probability Models

    - -- Probability Elicitation
    - -- Bayesian Updating
    - -- Sensitivity Analysis
    - -- Group Probability Aggregation

  - Probability and Value Models

    - -- Subjective Expected Utility
    - -- Probabilistic Multi-Attribute Utility Analysis
    - -- Risk-Benefit Analysis
    - -- Decision Tree Structuring
    - -- Group Decision Analysis
    - -- Partial Information Based Decision Analysis
    - -- Fuzzy Decision Analysis

- Operations Research Methods

  - Analytic Models

    - -- Warfare Area Models
    - -- Lanchester's Theory of Combat
    - -- Game Theory

  - Detection and Search Techniques

    - -- Time Invariant Statistical Detection
    - -- Signal Detection
    - -- Search Modeling

  - Optimization Methods

    - -- Simulation and War Gaming
    - -- Scheduling
    - -- Mathematical Programming

  - Facilitation Techniques

    - -- Tactical Simulation

- Coverage Templates
- Time/Distance Algorithms

- Computer Science Methods

  - Information Management Techniques

    - Data Base Organization
    - Man-Machine Communication
    - Message Processing

  - Pattern Recognition Techniques

    - Clustering
    - Classification
    - Information and Discrimination Measures
    - Linear Discriminant Functions

  - Artificial Intelligence Techniques

    - Problem Representation
    - Problem Solving
    - Learning Systems
    - Pattern-Directed Inference Systems
    - Planning Mechanisms

- Advanced Man-Machine Interface/Graphic Methods

  - Situation Displays

    - Dynamic Displays
    - Geographic Highlighting
    - Alternative Backgrounds
    - Automated Overlays
    - Selective Callup Techniques
    - Innovative Symbology

  - Pattern Analysis

    - Center-of-Mass Computations
    - Movement Trend Analysis
    - Terrain Models
    - Graphic Summarization
    - Zooming/Windowing

  - Planning Tools

    - "What If" Projections
    - Sketch Models
    - Optimal Routing
    - Target Aggregation

There are other useful inventories. The key is to use an inventory to determine the range of methods that can be incarnated into software to satisfy the tasks identified in the requirements analysis. At a general level the following relationships between behavior types and methods can be specified:

SOME BEHAVIOR/METHODS RELATIONSHIPS

Perceptual Behavior ------> Computer Science & Operations Methods

Mediational Behavior ---> Decision Analytic, Computer Science, & Operations Research Methods

Communication Behavior --------> Computer Science & Advanced Man-Machine Interface Methods

Motor Behavior ----------------> Computer Science & Advanced Man-Machine Interface Methods

These relationships are general; before proceeding with a specific matching each sub-task should be compared with each sub-method. After our planning requirements analysis we compared as many tasks and requirements as we could to methods and sub-methods in our generic inventory and identified what we believed were good matches. Subsequent testing and evaluation will determine if we were right and if our matching procedure should be altered.

What about prospective users in this process? Users should be involved in both the task requirements analysis and the matching procedure, not as members of the systems analysis or design teams, but as the intended users. Their views should be solicited, and their insights should be fed into the development of a requirements definition and the tasks/methods matching procedure. Systems designers cannot completely interpret requirements data, nor can they always make completely perfect tasks/methods matches. Users can help in both of these areas.

Modeling

Problem structuring for interactive systems design and development is not complete until the matching process is functionally modeled. The model itself can take many forms. It can be narrative, in a flow-chart, mathematical, and/or in a "storyboard." The storyboard approach to modeling is new and powerful. Succinctly, storyboarding requires designers to design every single display of the system in sequence with explanations and descriptions of each display. All methods (and algorithms) should be explained, and users should be able to get a solid feel for how the eventual system will function just be thumbing through the pages of the storyboard.

Storyboards can be developed as strawmen or as blueprints for programmers, or both. The sensible approach involves soliciting help from the users to develop the storyboard; the "final" board can then be treated as a programming agenda.

It is important to remember that the development of a storyboard assumes that the developer(s) know something about the principles of software design. This assumes an understanding of the range of available input and output technology, display devices, and the human factors connected with interactive systems operation. Without this "knowledge base," the system cannot hope to satisfy user requirements.

Models provide an opportunity to check and re-check your work. The TACPLAN functional description went through several iterations until we felt comfortable with its contents.

## Prototyping

Problem domains that are especially resistent to requirements analysis and tasks/methods matching make bad interactive system candidates. Over the years we have determined that the number of domains that lend themselves well to computerization is relatively small. This is because much of our past work has been in the cognitive and mediational areas, areas that are extremely difficult to decompose and translate into analytical software. The inherent difficulties connected with cognitive and mediational modeling suggest the need for iteration. Applications prototyping (Boar, 1984), the strategy that assumes that several iterations of an interactive system are necessary and desirable, has become very popular over the past few years.

Among other advantages, prototyping supports modular software engineering, permits user participation in the design process, and protects project resources from the jaws of tunnel programming. Most importantly, the applications prototyping strategy permits you to keep the requirements analysis process alive during the critical conversion process.

Prototyping assumes that the first version of your interactive system will be rejected and modified. It assumes that users and designers will have some difficulty identifying and defining critical system functions, and that a limited amount of money should be spent on each prototype until a durable system definition emerges. The money saved should be plowed back into requirements defintion, tasks/methods matching, and modeling.

We have adopted the prototyping strategy to the design and development of TACPLAN. The February 1985 version will be evaluated by our expert planners from the Army War College as well as by a team of independent systems designers. It will then be modified to accommodate their recommendations.

## Guidelines

The structuring process is not nearly as straightforward as the above implies. One must be flexible and adpative. Sometimes, for example, just the right method cannot be found on any lists. Sometimes a hybrid method must be developed. Sometimes it is just impossible to define all of the tasks that the system should perform. Problem structuring is an art, not necessarily a science, even though many structuring steps are "quantitative" and "verifiable." The real challenge lies in the combination of steps. Often requirements analyses go well enough, only to be followed by a frustrating search for the right method.

The outcome is also never assured. Just as it is possible to make a "good" decision that results in a "bad" outcome, so too is it possible to carefully execute all of the structuring steps and produce a really terrible interactive system. Hence, the prototyping strategy, which can help mediate the impact of unpredictable and imponderable events.

In the near future we hope to refine this whole approach even more, especially by developing some explicit tasks/methods matching procedures. We also hope to develop a generic military task/behavior taxonomy and a generic military problem-solving methods inventory. We thus hope to develop and refine a military problem structuring methodology comprised of task/behavior and methods taxonomies, assessments and recommendations about requirements analysis techniques, and algorithms for integrating requirements methods, tasks, and analytical methods into functional descriptions. There is also no reason to believe why such a structuring methodology could not be incarnated in a problem structuring "expert system."

APPENDIX B

TACPLAN CONCEPT OF OPERATION

# TACPLAN CONCEPT OF OPERATION

Stephen J. Andriole

INTERNATIONAL INFORMATION SYSTEMS, INC.

802 WOODWARD ROAD

MARSHALL, VIRGINIA 22115

(703) 364-1504

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## NOTE

This concept of operation was prepared to communicate TACPLAN's design capabilities and goals to the systems analysis/programming team. It represents the first strawman concept of operation that has already undergone extensive changes.

This concept of operation also fails to present displays regarding the operation of the interactive video disc-based interface. This is because it was prepared prior to the completion of the IBM PC/XT-based tactical video mapping (TVM) system that will be linked to TACPLAN. References are made throughout this concept of operation to "graphic equivalent displays," "annotations to the video disc," "drawing," and "illustrations," among other spatial and graphic references. These reflect TACPLAN's dual screen configuration which will permit planners to analytically construct a plan and then see it unfold directly on a video disc-based map image.

Finally, this version of the concept of operation has been reviewed by several expert planners and experts in the design and development of interactive computer-based decision aids, as well as human factors experts and experts in the psychology of analytical computing. These and other comments have been integrated into subsequent concepts of operation.

TACPLAN PROCESSOR ACTIVIATED

TACPLAN is a tactical planning processor that permits commanders to develop, display, and test tactical plans under conditions of uncertainty, threat, and peacetime. TACPLAN is interactive and flexible; it is also knowledgeable about tactical planning.

This first TACPLAN prototype permits users to develop, display, and test tactical defensive plans in a NATO/PACT threat scenario developed by the tactical planning experts at the Army War College, Carlisle Barracks, Pennsylvania.

This prototype demonstrates a number of interactive problem structuring and problem solving approaches, including the use of "burdenless" analytical spreadsheets, "graphic equivalent displays," and "rules" expressed both as constraints on the planning process and positive guidelines to rapid yet diagnostic tactical planning.

Future research will see the development of additional (tactical and strategic) templates, situational flexibility, automated "challenges" to the planner, additional rules, and and the integration of an advanced situational display system.

**TACPLAN**

Options

[1] Develop a New Tactical Plan

[2] Display Plan(s)

[3] Modify Plan(s)

Select An Option By Touching the Appropriate Function Key (or By Moving the Cursor into the Option Box and Pressing 'RETURN': 1 (2 or 3)

NOTE: I have assumed the use of the above input/dialogue techniques. Your hardware and software may give you other options, i.e., windows, other kinds of menus, and the like. So long as the interaction is graceful and consistent across option selection, then feel free to use whatever technique makes the most development sense.

Also note that these are but the options for the first prototype. As the systems grows, so too will the initial menu of options.

**NEW PLAN**

Options

1. Profile Tactical Planning Problem
2. State Mission Goals
3. Assess Area Characteristics
4. Assess Combat Capabilities
5. Determine Adversary Courses of Action
6. Determine Friendly Courses of Action
7. Develop a Concept of Operations

Select One Option by Inputting the Appropriate Number (or by Moving the Cursor to the Box . . .): 1, 2, 3, . . .

PLANNING PROFILE

Nature of Planning Problem (Select One):

1 Defensive Operations

2 Offensive Operations

3 Movement of Military Units

Planning Problem #?: 1, 2, or 3

---

Command Level & Available Time (Select One Combination):

| Time / Level | 24 hrs. | 48 hrs. | 72 hrs. | 72+ hrs. |
|---|---|---|---|---|
| Corps | | | | |
| Division | | | | |
| Brigade | | | | |
| Battalion | | | | |
| Platoon | | | | |

Select One Combination By Inputting the Appropriate Number (or By Moving the Cursor . . .): 1, 2, 3 . . .

---

Available Templates (Select One):

1 Western Europe/NATO/PACT

2 Middle East/Lebanon

3 Middle East/Persian Gulf . . .

Select One Template by . . .: 1, 2, 3 . . .

NOTE TO 'PLANNING PROFILE' DISPLAY: The prototype will only be capable of assisting the planner in the development of a defenseive plan at the Corps level for the Western European Theater. The assumption, based on the scenario and requirements analysis, is that 72 hrs. are available for planning.

The PLANNING PROFILE display suggests that the PLAN PROCESSOR can grow over time via the additional of templates for additional command levels and different geographical locations.

Templates include "knowledge" about command level responsibilities (within the context of the nature of the offensive/defensive planning problem), about the characteristics of the geographical area (terrain, weater, and the like), and information about force strengths. In addition, each level/area template combination will contain rules about the planning process, rules expressed as constraints and rules expressed as positive guidelines about how to accelerate and improve the planning process.

Note that information pertaining to the prototype scenario (defensive operations/corps level/Western Europe) is traceable to the requirements analysis/filming that took place at the Army War College in January, 1984, the US Corps/Soviet Combined Arms Army Command Post Exercise (LETORT 84), and the Army FMs that pertain to command decision-making, planning, and operations, especially the Staff Officers' Handbook, RB 101-999.

## MISSION STATEMENT & DESCRIPTION

**Profile:**

Defensive Operations/Corps Level/72 hrs./Western Europe

**Specify & Illustrate Responsibilities & Goals:**

**Describe Primary Goals:**

**Describe Secondary Goals:**

**Graphically Illustrate Primary & Secondary Goals:**

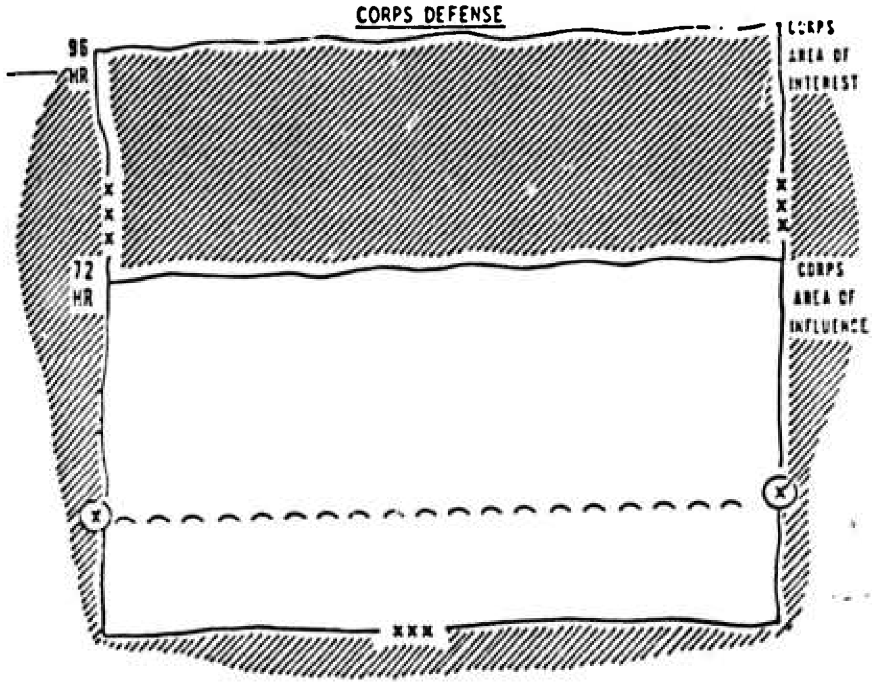
Designate Corps Areas of Interest & Influence

Designate Corps Rear Area & Communications Zone

Designate Covering Force Area, Forward Edge of the Battle Area (FEBA), the Main Battle Area (MBA), and

Designate the Areas of Division Interest & Influence in the Corps Areas of Influence & Interest

NOTE: The designation of the corps areas of influence and interest (as well as the other designations) shouldbe made accroding to Army conventions as illustrated below:




The designations should be overlayed onto the video disc image of Western Europe (the NATO/PACT boundary). Note also that the scenario calls for the IX Corps (comprised of three divisions) to occupy the MIDAG (the MIddle Army Group's position). All of this is described in the scenario (LETORT, p. 2). The composition of IX Corps is a given that should be input by the hypothetical planner.

It is also important for force strengths to be designated. Rather than have the planner locate all of the 19 Soviet divisions, as well as the NATO forces (all spelled out in LETORT), they should be on the disc when the template is selected. The assumption should be that intel has located and described adversary force strength and that friendly force strength is known.

Finally, no instructions have been provided on the above display for working with the graphic (video disc) image. The planner will build the display according to the interface requirements of the system; precise instructions can be added after the interface in completed.

## RULES FOR MISSION STATEMENT & DESCRIPTION

1. The first "rule" for mission statement & description should be model based. A model of the corps areas of interest and influence (as presented above and as discussed in LETORT and the Staff Officers' Handbook) should determine if the planner has designated all of the requirements and if the designations make ratio sense. Remember that IX corps has three divisions, and that the divisions should be lined up side by side, and so forth.

2. If possible, there should be synergism between the narrative description of the goals and the graphic illustration of same. A narrative out of sync with what the planner builds on the video disc should flagged, for example. Narrative should also be checked against the following doctrine:

Defensive Operations Must Be organized Around One or More Goals:

a. Cause adversary attack to fail;

b. Gain time;

c. Concentrate forces elsewhere;

d. Wear down adversary forces as prelude to offensive operations;

e. Control essential terrain;

f. Retain tactical, strategic, or political objectives; and

g. Create opportunities to return to the offensive.

If these goals are not present in the narrrative of primary and secondary goals the planner should be quizzed further about what the defensive mission is all about . . .

**AREA CHARACTERISTICS ASSESMENT**

Defensive Operations/Corps Level/72 hrs./Western Europe

| Forces / Characteristics | NATO CORPS | | PACT | | |
|---|---|---|---|---|---|
| | Opportunities | Constraints | Opportunities | Constraints | Rationale |
| Tranportation/Telecommunications Networks | 1 | 2 | 3 | 4 | |
| Topography | 5 | 6 | 7 | 8 | |
| Hydrogrphy | 9 | 10 | 11 | 12 | |
| Climate/ Weather | 13 | 14 | 15 | 16 | |
| Urbanization | 17 | 18 | 19 | 20 | |
| Other (Specify) | 21 | 22 | 23 | 24 | |

Designate the Opportunities, Constraints, & Rationale for Each Force By Inputting the Appropriate Numbers (and Narrative) . . . Then [1] Stop & Store Assessments, [2] Return to Higher Menu, or [3] Continue Planning Process

NOTE: The information about terrain that should be embedded into the system (for this scenario) is attached. It is extracted from the LETORT scenario. The information about the % of urbanization and the location and nature of mountain ranges and rivers, for example, can be on the disc image when it is displayed. On the other hand, it is not necessary to embed all of this data. The planner should be able to demonstrate knowledge of the terrain by judging whether NATO or PACT has the advantage or disadvantage in a given category and by providing rationale for the judgments.

For the demonstration of the TACPLAN system the terrain features should probably be designated on the disc or embedded in the software.

RULES FOR AREA CHARACTERISTICS ASSESSMENT

1. Can be gleaned from the attached.

2. Judgments and rationale regarding the opportunities and constraints vis-a-vis area characterisitics will be used subsequently to determine the prudence of judgments about enemy courses of action and friendly courses of action, and, ultimately, the concept of operations. That is, if judgments are made regarding constraints at this point in the process, and then forces are deployed inconsistently with these judgments then the planner should be alerted to the inconsistency.

3. All area characterisitics must be specified; default should not be permitted here (as it will in subsequent analytical operations).

## TERRAIN OVERVIEW

"Knowledge of the country is to a general what a rifle is to an infantryman and what rules of arithmetic are to a geometrician. If he does not know the country, he will do nothing but make gross mistakes. Without this knowledge his other projects, be they otherwise admirable, become ridiculous and often impracticable."

Frederick the Great, 1745
- To his generals -

The terrain within the XI Corps area of interest within West Germany is divided into two contrasting parts for which the Mittelland Canal can generally be depicted as the demarcation line. In the south are the Central Uplands with the Harz Mountains, the Lower Saxon Hills, the Weser Hills and the Westphalian Basin being the major land forms. To the north is a sandy northern lowland stretching to the west as far as the coastal marshes. Between these two parts, the Central Uplands and the northern lowland, runs the narrow fertile loess belt of the Hercynian Foreland.

Northern Lowland - The fundamental physical dividing line runs just north of Braunschweig, Hannover and Osnabruck. Going north, there is a change from loess to sand, from wheat to rye growing, from dense agricultural populations and industrial towns to relatively unpopulated heaths. Although the area had been glaciated, it lay outside the limits of the latest glaciation and the drifts are substantially leached, and the few remnants of terminal Moraines are greatly eroded. Large sheets of sand and gravel are predominant and these are divided into a number of separate sandy blocks (Geest) by channels cut by melting glaciers. The growth of vast peat bogs, especially in ill drained depressions, was favored by the oceanic climate. In the coastal areas and by the estuaries, however, fertile marshes are found. The largest of the Geest blocks is the Luneberg Heath (Luneburger Heide), in general overview, the area between Celle and Hamburg, with the Weser drainage basin (glacial spillway) forming the western boundary of the Geest block. The poorest land has been planted with spruce. The sandy soil grows rye and potatoes and all of the valleys and swampy depressions provide pasture for cattle. Although well north of the XI Corps sector, the Worthe terminal Moraine, which rises to over 500 feet and forms a hilly spine from northwest to southeast across the Luneburg Heath, is a noticeable terrain feature in the area. The Western Geest, to the west of the Aller and Weser Rivers, is lower and more level than the Luneburg Heath, and is split into many separate blocks by poorly drained depressions. The whole region lacks industry and the towns are small, with the exception of Oldenburg.

Hercynian Foreland Loess Belt - The Mittelland Canal links the West and East German Canal system along the line of the Hercynian Foreland. This dry loess terrain was used by the great medieval highway following the Hercynian Foreland to the Elbe and beyond. Where routes out of the hills to the south emerged to intersect the highway, towns such as Hannover and Braunschweig, grew up. The highway, railway and canal routes from the Ruhr to East Germany and Berlin today follow much of the route of the earlier highway.

Portions of the lower Saxon Hills to the south intrude into the loess belt as widely spaced escarpments standing as wooded islands in wide stretches of loess-covered plain.

The Harz - This massif stretches some 100 Km from southeast to northwest. The slates and granites of this terrain feature form a rolling surface at 1600 to 2000 feet which in turn is overlooked by the bare, windswept granite rocks of the Brocken (3747 feet) just east of the international boundary. Streams from the Harz have cut narrow and steep-sided valleys. The rainfall and steep slopes have encouraged the preservation of forests with beech and oak below 1300 feet and spruce reaching up as far as the Brocken.

The Lower Saxon Hills - These hills are the outcrops of secondary rocks which extend to the north, west and southwest from the Harz. Towards the south the rocks are horizontal or gently domed, but in the north they are folded into a series of southeast to northwest-trending anticlines and synclines. In the south, where the hills extend a short distance to the south of Gottingen, the rivers Leine and Weser have quite contrasting courses. Although the Leine is the smaller stream, the nature of the land has allowed it, using a rift valley, to open an 8 Km wide passage. This is the route followed by the main north-south railway and autobahn between southern Germany and the ports to the north. The Weser, on the other hand, has cut across sandstone. The narrow, winding valley created has traditionally not been used as a thoroughfare and no important towns are found along the Weser in that area. In the north the towns of Helmstadt, Salzgitter and Hildesheim generally define the transition to the loess belt. The folded rocks of the northern portion of the Lower Saxon Hills have eroded into escarpments of sandstones and limestones, with alternating small valleys of less resistant materials. The ridges are wooded with forest of beech or spruce and fruit trees cover the lower slopes. The loess-covered small valleys contain large villages of half-timbered houses set among the open farm fields. The Lower Saxon Hills project westward to, and in some cases beyond, the Weser River and adjoin the Weser Hills.

The Weser Hills - These hills to the west of the Weser River are essentially a westward extension of the Lower Saxon Hills and have many of the same characteristics. Two notable features are two southwest facing escarpments, the Wiehen Hills and the Teutobruger Wald, which define the northern and western boundaries of the Weser Hills. These hills push to the northwest, separating the Westphalian Basin from the Northern Lowland.

The Westphalian Basin - The Ruhr, the industrial heart of North Rhine-Westphalia, is probably the best known feature of the Westphalian Basin. The heart of the basin, the area around Munster, has overlying clays which form the damp lowland of the Munsterland, which is broken only by occasional low ridges of sandstone or limestone. The basin's western outlook results in high rainfall and ideal grazing country. The countryside has what has been called a very "English" appearance with cows grazing in hedged fields and large isolated farmhouses set in clumps of trees.

Urbanization - The XI Corps area of interest covers portions of three West German states. The percent of built-up area in each of these is shown below:

| | |
|---|---|
| Hesse | 10% |
| Lower Saxony | 9.5% |
| North Rhine-Westphalia | 15% |

Of particular interest are the Ruhr (1155 sq Km) and the Hannover area. The urbanization in the Hannover area has taken the form of growth along the E-8 autobahn toward Brunswick in the east and Buckenburg in the west. Smaller cities such as Celle, Munster and Kassel also are growing in area and population. The Rhine-Ruhr area is converging with the Dutch Randstand. When this convergence occurs, a single gigantic urban barrier 300 Kilometers long, stretching down the Rhine from Bonn to the Hook of Holland, will be formed.

Rivers - The Weser River first takes its name at the confluence of the Werra and Fulda Rivers at Munden. Flowing generally north, the shallow stream follows a winding course through hilly countryside until it pierces the Wiehen Hills escarpment at the Porta Westfalica at Minden and enters the northern lowland. The river has maximum flow in the winter, at a time of least evaporation, and a period of summer low water, and associated navigation difficulties. Drifting, or continuous ice, appears on the Weser at Minden for fourteen days a year on the average. North of Minden, the river is deep enough to provide a 1350 ton water route to the Weser ports.

The Rhine River in its northward passage attains a width of 3000 feet as it flows past Bonn. At Duisburg, in the Ruhr, there is one of the world's largest inland harbors. This harbor is the head of deep-sea navigation on the Rhine. Almost immediately after crossing the Dutch frontier at Emmerich, the Rhine divides into two parallel streams, the northern being called by the Dutch the Neder Ryn and later the Lek, and the southern, the Waal. As it flows through the Dutch lowlands, the Rhine splits up again into the many arms of its delta, a network of rivers and canals that give access to the great ports of Rotterdam, Amsterdam and Antwerp, and finally, at the Hook of Holland to the North Sea.

## COMBAT CAPABILITY ASSESSMENTS

| Elements \ Assessment | Favors NATO | Favors PACT | Rough Equivalency | Rationale |
|---|---|---|---|---|
| Composition | 1 | 2 | 3 | |
| Numeric Strength | 4 | 5 | 6 | |
| Types & # of Weapons | 7 | 8 | 9 | |
| $C^2$ | 10 | 11 | 12 | |
| Location & Disposition | 13 | 14 | 15 | |
| Logistics | 16 | 17 | 18 | |
| Reinforcements | 19 | 20 | 21 | |
| Other (Specify) | 22 | 23 | 24 | |

Designate the Combat Elements that Favor NATO or PACT Forces By Inputting the Appropriate Numbers . . . Then [1] Stop & Store Judgments, [2] Return to Higher Menu, or [3] Continue Planning Process

NOTE: This display/operation assumes that NATO & PACT forces will be displayed on the video disc image with all of the proper tactical symbology. The planner should be able to look at the display and determine where the advantages/disadvantages are. Rationale needs to be collected to check for consistency along the way and, as always, to store the reasoning that went into the formulation of the plan, reasoning that can be called upon later for "audit" purposes or to refresh the memory of the planner if the planning process is interrupted.

Also note that all assessment about combat capabilities are necessarily relative to the sector and mission in question.

## RULES FOR COMBAT CAPABILITY ASSESSMENTS

1. There are a thousand rules regarding force mixes; we cannot identify, develop, or include them all in the prototype.

2. If NATO or PACT forces are adjudged to be vastly superior to the other (by "winning" five or more elements) then:

   If NATO forces win heavily then offensive operations should be considered; and

   If PACT forces win heavily then the planner (as corps commander) should reformulate primary and secondary goals.

3. Only two additional combat elements should be permitted; there are already eight "accepted" elements, so we are already over-extending the plus-or-minus . . . rule. At the same time, at least but no more than two should provide the planner with all of the flexibility needed to customize his/her assessment.

ADVERSARY COAs

Specify (Up to Five) Adversary Courses of Action (COAs):

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Designate Each COA Graphically By Symbol, Number, and/or Name:

NOTE: Instructions will have to be provided to the planner regarding how to annotate the video disc according to TVM or other specs and symbology.

Evaluate Each COA With Reference to Explicit Criteria:

| Criteria \ COAs | Favors COA #1 | Favors COA #2 | Favors COA #3 | Favors COA #4 | Favors COA #5 | Rationale |
|---|---|---|---|---|---|---|
| Military Intentions | 1 | 2 | 3 | 4 | 5 | |
| Area Characteristics | 6 | 7 | 8 | 9 | 10 | |
| Combat Capability | 11 | 12 | 13 | 14 | 15 | |
| Doctrine | 16 | 17 | 18 | 19 | 20 | |
| Other(S) Specify | 21 | 22 | 23 | 24 | 25 | |

Evaluate the COAs By Inputting the Appropriate Numbers . . . Then [1] Stop & Store Judgments, [2] Return to Higher Menu, [3] Continue Planning Process

NOTE: TACPLAN should determine the obvious "winner" by stating the COA that has been adjudged the most likely by the tactical planner. It is important that the planner be made aware that his/her judgments are with reference to a likelihood, that the results of the judgmental analysis should produce a ranked list of the most-to-least likely adversary COA:

***COA #3 IS THE MOST LIKELY COA***

***COA #2 IS THE LEAST LIKELY***

***COAs #1, 4, & 5 ARE RELATIVELY UNLIKELY***

However, if rough parity exists, then the system should require the planner to implement the next, more diagnostic, method for evaluating COAs. This method, a derivative of the multi-attribute utility (MAU) approach, requires the planner to be more explicit and quantitative in his/her evaluation(s), though only a little more burdensome. In fact, the version of the MAU technique described below is much less burdensome then existing MAU techniques, though no less diagnostic (assuming that the tactical planner is not a novice planner).

At the same time, the planner should have the option of implementing the second, more diagnostic, technique if he or she so desires. The second analysis might be conducted when there is some doubt about the initial judgmental rankings or when the rankings produce no clear "winner."

Like all of the assessments made during the planning process (like area characterisitics, adversary COAs, friendly COAs, and the like), the results will be used to determine--during formulation of the concept of operation--if the planner has been consistent with his/her own judgments throughout the planning process and to make certain that the graphic representations of the plan--which will become part of the concept of operations distributed, in this case, to lower level (division) commanders, is consistent with what TACPLAN already knows about planning in general and the planner's judgments in particular. Many of the "rules" which govern the operation of TACPLAN will thus be implemented when the concept of operation is input. This will be true for both positive and negative (constraint) rules.

ADVERSARY COAs

Specify (Up to Five) Adversary Courses of Action:

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

Evaluate & Score Each COA With Reference to Each Criterion:

| COAs / Criteria | COA #1 | COA #2 | COA #3 | COA #4 | COA #5 |
|---|---|---|---|---|---|
| Military Intentions | | | | | |
| Area Charac-terisitics | | | | | |
| Combat Capability | | | | | |
| Doctrine | | | | | |
| Other(s) Specify | | | | | |
| | | | | | |
| TOTALS | | | | | |

Score the COAs eith reference to the criteria by inputting a scale of your choice (1 = best, 5 = worst; 1 = best, 10 = worst; etc.); TACPLAN will total your judgments & prepare a ranked listing. Then [1] Stop & Store Judgments, [2] Return to Higher Menu, or [3] Continue Planning Process

NOTE: The planner should be able to weight the criteria as well. This can be either a requirement or only suggested as yet another level of diagnosis. Weighting is a natural companion of scoring, but scoring should always be done first and before and totals are displayed; ideallly the user would score the criteria and then on another VDT page, the weights should be elicited. This guards against biasing.

The weighting procedure is as attached. All the planner has to do is determine which of the criterion is the most important, second most important, third most important, . . . and least important; alternatively, the planner can input percentages about the "worth" of the criteria, percentages that may or may not total to 100% (TACPLAN can normalize more or less than 100% judgments).

# HANDBOOK OF PROBLEM SOLVING

## An Analytical Methodology

Stephen J. Andriole

PBI
a petrocelli book
new york / princeton

ods permit decision-makers to select a specific option without regard to any uncertain events or conditions that might exert an impact upon the selection process. Other methods enable decision-makers to deal with uncertainty in a manner which permits them to maximize the value connected with individual options.

*Option Selection Under Conditions of Relative Certainty*

Imagine a scenario where you have decided to purchase a new car. You have the money, and cars are available, so there is no uncertainty connected with the decision. But you have looked at and test-driven no less than seven cars and cannot make up your mind.

The first step toward a quick selection involves making a list of the factors (or selection criteria) important to your choice. They might very well include cost, gas mileage, comfort, appearance, and overall quality of construction. The next step is to define these criteria so they will be consistently used when you perform the next step, scoring (on a scale of 1 to 10), as suggested in Figure 7.1.

The scoring itself can be done in absolute terms, quickly, and extremely easily, as Figure 7.1 suggests. Note also that car #1, with a score of 31 is the winner and car #4 a close runner-up with a score of 30. But note that #1 is extremely expensive and that #4 is extremely inexpensive. One variation to the process, then, might involve weighting the criteria in terms of their overall importance to the decision. In the new car selection example, if cost were heavily weighted in terms of importance, then car #1 could not possible "win."

| Criteria / Cars | # 1 | # 2 | # 3 | # 4 | # 5 | # 6 | # 7 |
|---|---|---|---|---|---|---|---|
| COST | 1 | 6 | 4 | 9 | 2 | 7 | 3 |
| GAS MILEAGE | 9 | 7 | 4 | 5 | 2 | 1 | 1 |
| COMFORT | 8 | 4 | 6 | 4 | 7 | 3 | 1 |
| APPEARANCE | 7 | 8 | 4 | 6 | 5 | 7 | 2 |
| QUALITY | 6 | 2 | 7 | 6 | 6 | 6 | 4 |
| TOTAL | 31 | 27 | 25 | 30 | 22 | 24 | 11 |

FIGURE 7.1
QUICK (UNWEIGHTED) NEW CAR SELECTION

The steps necessary to conduct a *weighted* attribute analysis, as suggested in Percy Hill, et. al's *Making Decisions* (Reading, MA: Addison-Wesley, 1980), are as follows:

1. Identify decision alternatives.
2. Define decision alternatives.
3. Identify evaluation selection criteria.
4. Define evaluation selection criteria.
5. Rank the criteria according to their relative importance.
6. Determine criteria weighting factors according to the formula below:

| Evaluative Criteria | Rank/ Points | Weighting Factors |
|---|---|---|
| Cost | 1/5 | 5/15 = 0.33+ |
| Mileage | 2/4 | 4/15 = 0.26+ |
| Appearance | 3/3 | 3/15 = 0.20+ |
| Quality | 4/2 | 2/15 = 0.13+ |
| Comfort | 5/1 | 1/15 = 0.06+ |
| | 15 | 15/15 = 1.0 |

7. Develop a decision matrix, as suggested in Figure 7.2.
8. Score the alternatives against the criteria, one criteria at a time, on a 10-to-1 (highest-to-lowest) scale.
9. Multiply the scores X the weighting factors.
10. Select the alternative with the highest total/weighted score, as suggested in Figure 7.3.

The above unweighted and weighted decision option selection methods are useful when the alternatives are relatively few in number (ten or less), when the criteria are few and one dimensional, and when speed is required. But they are not the most diagnostic methods available.

Another "multi-attribute utility" evaluation method formalizes and extends the above procedures. Developed by Ward Edwards in his "How to Use Multi-Attri-

| Criteria \ Weighting Factors | Cars | # 1 | # 2 | # 3 | # 4 | # 5 | # 6 | # 7 |
|---|---|---|---|---|---|---|---|---|
| Cost | 0.33 | | | | | | | |
| Gas Mileage | 0.26 | | | | | | | |
| Appearance | 0.20 | | | | | | | |
| Quality | 0.13 | | | | | | | |
| Comfort | 0.06 | | | | | | | |
| TOTAL | 1.00 | | | | | | | |

FIGURE 7.2
WEIGHTED SELECTION MATRIX

| Criteria | Weighting Factors | #1 | #2 | #3 | #4 | #5 | #6 | #7 |
|---|---|---|---|---|---|---|---|---|
| Cost | 0.33 | 1 / 0.33 | 6 / 1.98 | 4 / 1.32 | 9 / 2.97 | 2 / 0.66 | 7 / 2.31 | 3 / 0.99 |
| Gas Mileage | 0.26 | 9 / 2.34 | 7 / 1.82 | 4 / 1.04 | 5 / 1.30 | 2 / 0.52 | 1 / 0.26 | 1 / 0.26 |
| Appearance | 0.20 | 7 / 1.40 | 8 / 1.60 | 4 / 0.80 | 6 / 1.20 | 5 / 1.00 | 7 / 1.40 | 2 / 0.40 |
| Quality | 0.13 | 6 / 0.78 | 2 / 0.26 | 7 / 0.91 | 6 / 0.78 | 6 / 0.78 | 6 / 0.78 | 4 / 0.52 |
| Comfort | 0.06 | 8 / 0.48 | 4 / 0.24 | 6 / 0.36 | 4 / 0.24 | 7 / 0.42 | 3 / 0.18 | 1 / 0.06 |
| TOTAL | 1.00 | 5.33 | 5.90 | 4.43 | 6.49 | 3.18 | 4.93 | 2.24 |

FIGURE 7.3
WEIGHTED NEW CAR SELECTION

RULES FOR ADVERSARY COA EVALUATION

1. The number of COAs considered should be limited to five.

2. The number of criteria should be limited to seven, which means that the planner can add only three additional criteria.

3. The planner must consistently implement one scoring scale, a scale that should be used throughout the planning process. For example, if the planner selects a one to five scale, then when friendly COAs are evaluated the 1 to 5 scale should be treated by TACPLAN as a given.

4. It is not necessary to have the planner define the criteria in detail, at least not for this initial version of the system. The hypothesis is that far too much detail has been required of the planner/decision-maker in the past because of the desire to forcefit preferred methods onto the analytical problem-solving process. We shall try to maintain diagnosticity and drastically reduce the amount of work the planner has to do.

5. It should be possible to equally weight up to three criteria but no more than three. Diagnosticity suffers when more than three (out of a posssible seven) are equally weighted. If, however, no additional criteria are added then the planner should only be allowed to equally weight two (out of the four) criteria.

6. After the COAs have been ranked according to their likelihood (by whatever means) then TACPLAN should automatically display the rankings by means of an annotation on the video disc. As the rankings change, because of modifications to the process or sensitivity analyses, then the video disc annotations should also change.

7. In keeping with the burdenless concept, rationale should only re required if the the results of the COA evaluation are not clear-cut, regardless of the evaluation method selected. If there is little distance between the likelihood of three or more COAs, then rationale should be required; if there is a clear-cut winner then the planner should not have to labor over long narrative input. The idea is to require the planner to input just enough information to make diagnostic evaluations and plans and to have enough information for later study. While rationale would always be nice in principle, at this point, given the user load, it can be skipped if the results of the evaluation are clear.

8. The COA evaluation should be guided with judgments previously made about area characteristics and combat capabilities. The most likely COA should be consistent with judgments made about adversary terrain constraints and combat capabilities, for example. If a COA is determined to be highly likely, but conflicts with judgments about enemy terrain constraints and capabilities then the planner should be made aware of the discrepency.

DEFENSIVE DEPLOYMENT/COAs

NOTE: This procedure will be exactly the same as the evaluation of adversary COAs except that the criteria to be used are as follows:

1. Adherance to Goals
2. Combat Capability
3. Area Characteristics
4. Adversary COAs
5. Adversary Combat Capabilities
6. Adversary Doctrine
7. Other(s) (Specify)

The two level procedure (favor/no favor and numeric scoring) procedures should both be available, just as they are for the evaluation of adversary COAs. Only five COAs should be allowed and the planner should have the option of implementing the more sophisticated evaluation procedure if he or she wants, so long as none of the rules are violated.

Again, the planner will have to designate COAs by working with the video disc. The attached provides some examples of what visual/graphic courses of action look like. They should be used for both adversary and friendly COAs annotations. Here is an example of graphic equivalency in the system, where the planner thinks verbally about a COA and then sees it unfold on the screen.

## RULES FOR FRIENDLY COA EVALUATION

1. The number of COAs considered should be limited to five.

2. The number of criteria should be limited to nine, permitting the user to add only two additional criteria.

3. The planner must consistently implement one scoring scale, as suggested in the rules for the evaluation of adversary COAs.

4. Rules 4-8 for adversary COA evaluation should be applied faithfully to the evaluation of friendly COAs.

## CORPS COMMANDER'S CONCEPT OF OPERATION

Steps

1. Distribute Forces Graphically Along Primary Adversary COA, including reinforcements

2. Designate Priority of Deployment; Sequence the Movement of Adversary & Friendly (Defensive) Units

3. Formulate, if Desired, a Contingency Plan, Based Upon the Next Most Likely COA, or in the Event of a Failed Plan, by Re-taking Steps 1, 2, and 3 . . .

4. Develop a narrative of Primary & Contingency Plans

NOTE: The planner will take the above steps with reference to the evaluations of friendly and adversary COAs above. The most likely adversary COA and the optimal friendly COA (conceived in response to the most likely adversary COA) should feed directly into the concept of operation. The graphic illustrations of friendly and adversary COAs will be general, with sweeping arrows, and the like. The most likely/optimal adversary/friendly COA combination should be displayed on the video disc when the planner completes the evaluation phases and moves on to the formulation of his/her concept of operation. Then the planner can distribute forces in detail along the adversary and friendly COAs. He/she can also locate the specific adversary combat capabilities along the adversary COA, and so forth.

The planner should also designate graphically the phasing or sequence of the attack and the defensive operations. The attached should help conceive of how this should be done on the video disc, but conceptually it is straightforward.

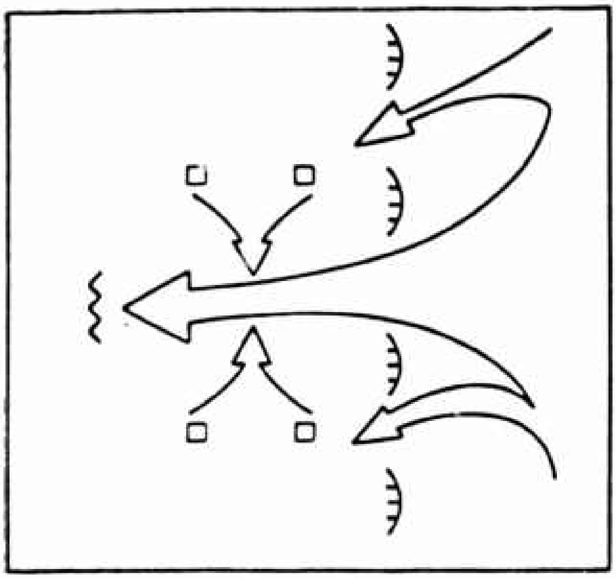
The planner can then retake the steps to formulate a contingency plan based upon the next most likely COA, and so forth, by re-cycling through the steps in the concept of operation phase of the planning process.

and Doctrine Command, NATO armies committed to Forward Defense on the Central Front agreed to standardize the general principles of a tactic described as *Active Defense*. In terms of genealogy, this was a tactic whose design from the outset was predicated on the context of Forward Defense. The originality of the Active Defense is not in the invention of radically new methods of fighting but, rather, in the way that it borrows concepts from established tactics, combines them in a unique sequence, and applies them at a lower level of organizational implementation.

The first phase in the active defense sequence begins immediately at the inter-bloc border with a *covering force*

## Traditional Defensive Tactics

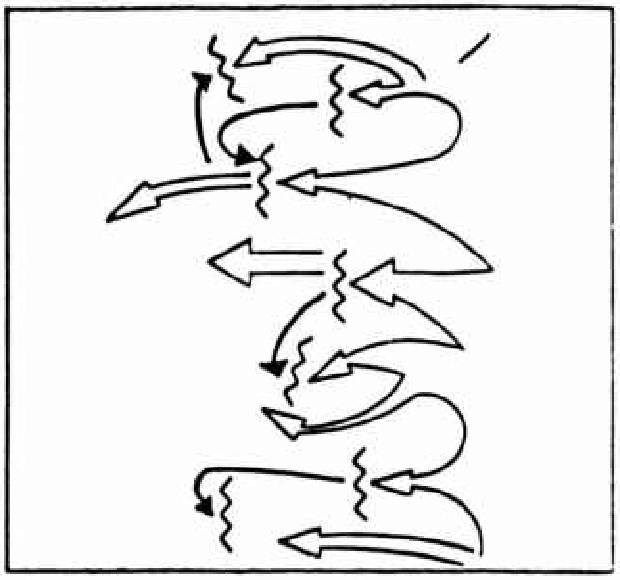
### Mobile Defense



+ Aggressive; seeks initiative
+ Sets up opponent's over-extension
+ Large Counterattack

– Takes high risks
– Divides force
– Vulnerable to multiple penetration

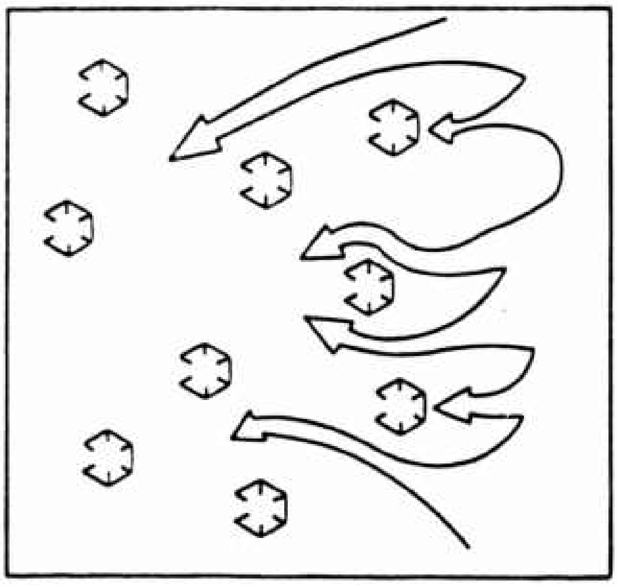
### Delay/Screening Defense



+ Screens broad frontage
+ Repeated ambush slows attack
+ Avoids decisive engagement

– Gaps; multiple penetrations
– Rapidly-declining combat power
– Danger of disorganization

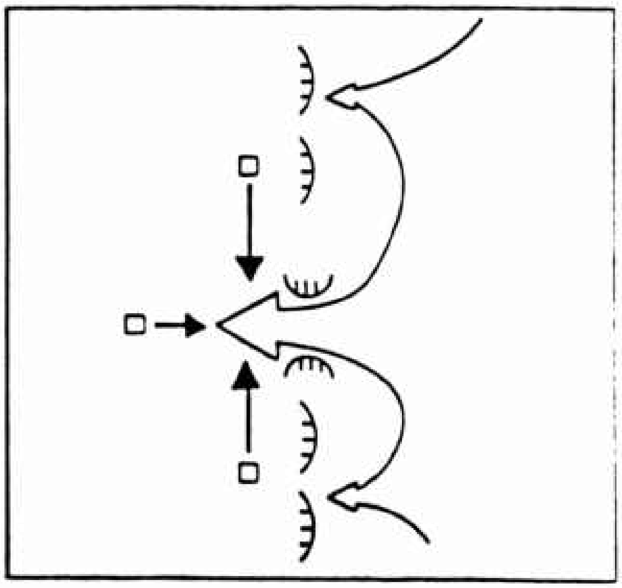
### Area/Hedgehog Defense



+ Slows down high-speed attack
+ Takes advantage of existing terrain
+ Needs minimal command/control

– Easily enveloped; units lost
– Passive; no counterattack
– Piecemeal defeat

### Positional Defense



+ Maximum preparation of terrain
+ Attacker must suffer heavy attrition
+ No gaps for penetration

– Passive; waits for attack
– Vulnerable to massed echelon breakthrough
– Brittle; difficult to disengage

nificant antitank barrier, most of the terrain is broken by large stretches of forest (the hilly woods of central and southern Germany) or soft soil (the marshes of northern Germany). While the density of roads, from Autobahn to logging trail, makes every kilometer accessible to tracked vehicles, this terrain is nevertheless not particularly conducive to a high-speed advance by massed armor. From the perspective of trafficability, as opposed to topography, the infamous North German Plain is not an area like the Russian Steppe where entire armored divisions, not to mention tank

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armies, can meander at will. Rather, an attacker must repeatedly subdivide units on multiple axes and proceed through constricted passages—often in march formation. Likewise, one looks in vain for the Fulda *gap*, which in reality is merely a series of narrow mini-gaps with relatively higher viscosity than some other sectors of the front. Scattered across the breadth of Germany are large built-up urban areas which, while they permit high offensive trafficability, also give the defender unusually favorable points of observation, fields of fire, and protective cover. Even where open terrain is prevalent, it is dotted by a town, village, or hamlet an average of once every six kilometers.

For the defender, this terrain is best suited to the antitank ambush, where, from under cover and from hull defilade, the lead elements of an armored column are suddenly engaged from multiple directions. By the time the attacker recovers from the surprise and prepares for an organized assault with heavy suppressive artillery support, the defender has covertly withdrawn to the next ambush site several kilometers down the corridor—leaving behind a favorable 1:6 loss exchange rate. This tactic, repeated over and over, can slow the most aggressive armored advance to a crawl and drain the attacker of his quantitative superiority.

Nevertheless, the very aspects of West German terrain which can permit a defender to fight outnumbered and win, can also work against him. The absence of "big" *gaps* means that the defender cannot concentrate his forces in a few *high-threat* areas, but must cover all the routes of potential ingress. The terrain is only of advantage to the defender if he occupies it; otherwise it permits the attacker to maneuver large numbers of small formations very deeply, very quickly. The high interconnectivity of these many corridors means that the defender cannot merely focus on east/west routes—lest an attacker veer into the flank or rear of an unsuspecting adjacent defender. To realize the full advantage of these terrain compartments requires the defender to be in position long enough to undertake considerable preparation (demolition and emplacement of obstacles to channelize movement; mining of high-speed approaches; construction of alternate hull defilade firing positions for vehicles; entrenchment, overhead cover, and barbed wire for infantry).

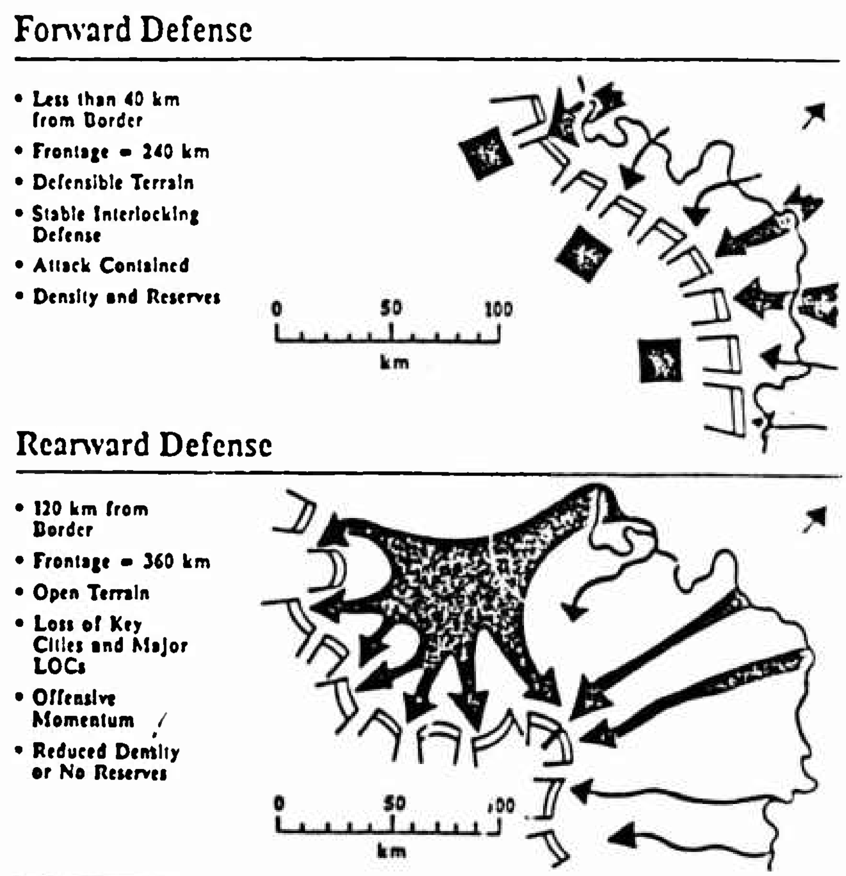
While defended forests and urban areas make rapid mechanized assault difficult for the offensive, they are particularly vulnerable to traditional dismounted infantry infiltration. To truly hold this terrain for any length of time requires a high concentration of defenders—indeed the larger urban areas are manpower "black holes" capable of consuming multiple divisions.

The most significant aspect of West German terrain is where the poor trafficability areas are located with respect to operational depth. Within the 150 kilometer band discussed earlier, the most defensible terrain for virtually the entire breadth of the front is near the inter-bloc border. Behind the first 50 kilometers, the terrain tends to open up—corridors become wider, with a higher degree of intersection, and north/south movement is easier—none of which facilitates a stable defense. Beyond 100 kilometers there are large areas of concentrated urbanization and forest, but their isolation and sheer size do not provide the interlocking defensibility available near the border.

## Density: The Ratio of Force to Space

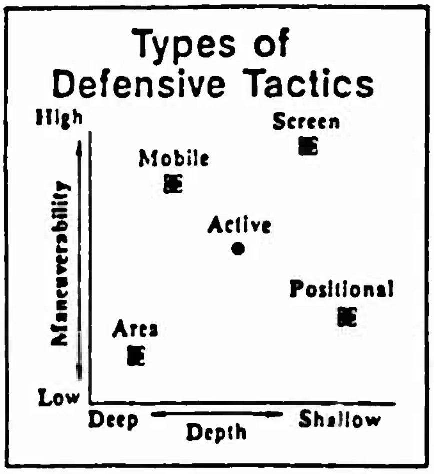
One of the major difficulties of selecting where to defend is correlating the position to the quantity of forces needed to hold it successfully. For over a gener-

### Increased Density from Defending Forward




Source: Charles T. Kamps, Jr., *Hof Gap: The Nurnberg Pincer*, SPI, NY, 1978 vulnerable rear area that a Forward Defense provides means tha', unless the Soviets can effect a large number of simultaneous deep penetrations all across the front, the few that do get through can be sealed off and destroyed by reserves. The more mobilization time NATO has: the greater the difficulty the Warsaw Pact first echelon will have in penetrating the Forward Defense line; the stronger the rear area security will be to contain raiding forces; and the larger the tactical and operational reserves that will be available to destroy an OMG.

The ultimate success of a Forward Defense is less dependent upon the relative margin of superiority of the aggressor than on the amount of clear and unambiguous warning that an attack is imminent, and the strength of the political will of NATO to respond before it occurs.



Types of Defensive Tactics

## Tactical Development

There is no aspect of Forward Defense that has produced more controversy than the discussion of which tactics are *best*. There are virtually as many variants as there are commentators. Nor is it uncommon for critics to describe a certain "straw man" tactic as endemic to Forward Defense and then attack it in detail.

In fact, the strategy of Forward Defense could be implemented by any number of different tactics, and at the time NATO adopted it, each national army tended to have its own preference (reflecting historical experience, level of technological modernization, limitations of force structure, and the terrain it would have to defend). Thus, the British tended to prefer the security of the traditional *positional defense* with dug-in infantry maximizing the use of prepared terrain and natural obstacles, with armor dispersed to support them. The Germans were attracted to the flexibility of the *mobile defense* (at least at the brigade/battalion level), with infantry deployed in strong points and a heavy armored force withheld in reserve for local counterattacks. The French, with only light units and a broad frontage, were the most experimental—refining the *delay* or *screening action* into a form of antitank guerrilla warfare. The US Army reflected all three types of tactics, depending on the branch of the unit: *delay* for cavalry regiments; *positional defense* for infantry divisions; and *mobile defense* for armored brigades.

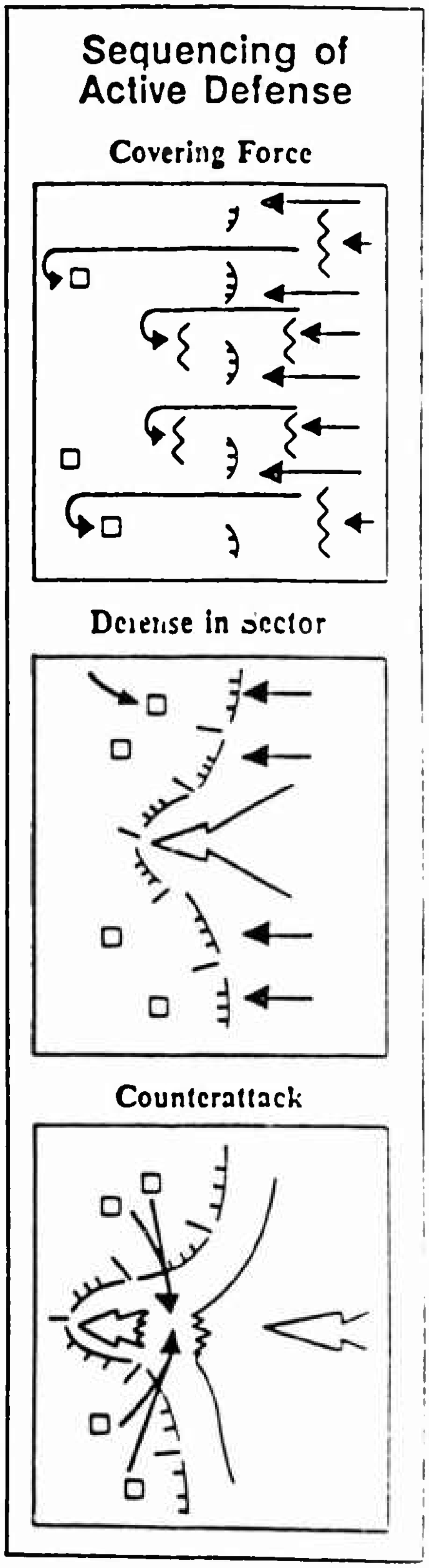
Each of these tactics has its inherent strengths and weaknesses, and their difference are illustrated on page 45 by contrasting the way they employ maneuverability and depth. In terms of Forward Defense, the *positional tactic* makes the best use of terrain preparation and density of fire, offers the maximum initial resistance, but also takes the longest time to set up. Given the passivity of the positional defense, an attacker with superior forces can ultimately concentrate against a narrow sector, and once penetrated, the static nature of this tactic means it can be rolled up by shallow envelopment. The *mobile defense* is most dangerous to an attacker because it threatens him with decisive engagement (rather than incremental losses) when he is overextended—with open flanks—and least prepared for it.

However, unless the mobile tactic has a sufficiently strong defensive line in front of it to channelize the route of attack and prevent multiple simultaneous penetrations, it will not have time to take advantage of one opposing formation's vulnerability before being bypassed by another. The deeper (rearward) a mobile defense is executed, the more catastrophic the results if its drive for decisive engagement fails.

At first impression the *delay tactic*, with its heavy emphasis on maneuver, would appear to offer considerable depth to the defense. But in practice, a screening force which actually attempts to slow an attacker (rather than merely reconnoiter his approach) can only engage in several skirmishes in rapid succession over a shallow area before it either becomes decisively engaged (without benefit of terrain preparation, secure flanks, and a cohesive reserve) or lost in a fog of disorganized retreat.

A tactic with recurring popularity developed by European neutrals with rugged geography and territorial armies is the *area* or *hedgehog defense*, which uses terrain choke points and towns which sit astride the axis of advance as bastions to protect local militia from being swept away in an armored avalanche. As a pure form of defense this tactic has little to recommend it—other than peacetime cost savings—since defeat in detail is inevitable. But when employed as a supplement to a forward strategy, a rapidly mobilizable area of defense can make the sting of the screening forces more virulent, can secure the rear area of prepared defense positions and provide a series of stabilizing pivots around which a mobile defense can maneuver with elan. To date, however, no NATO army has adopted the area defense, even for territorial forces, but it continues to be a tactic generating considerable discussion in Europe.

In the mid-1970s, after considerable innovation by the US Army's Training



Sequencing of Active Defense

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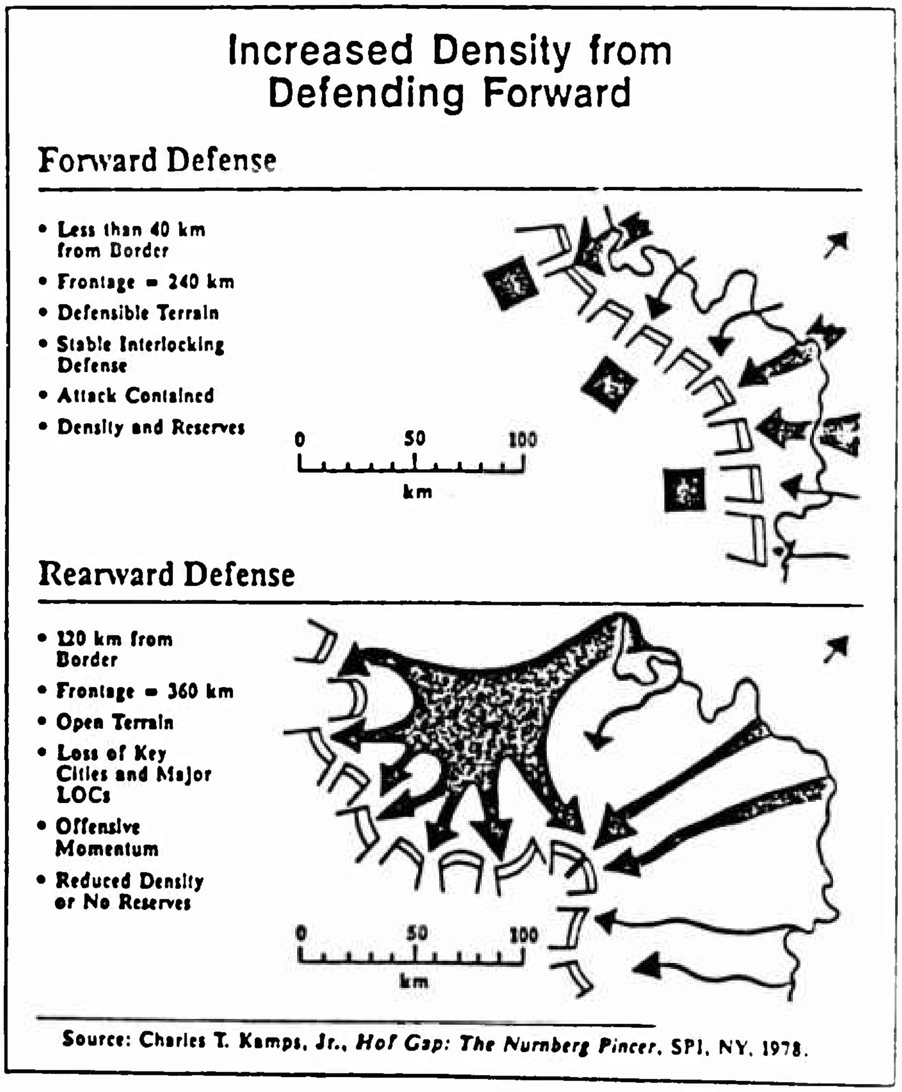

Source: Charles T. Kamps, Jr., *Hof Gap: The Nurnberg Pincer*, SPI, NY, 1978.

## RULES FOR FORMULATION OF CONCEPT OF OPERATION

1. A number of rules converge on the formulation of the concept of operation. Judgments made about terrain and area characterstics, for example, should be checked against the concept of operation (as well as with the evaluation of enemy and friendly COAs). In many respects, the tactical planning process at the Coprs level is iterative, building upon successive steps in a logical and consistent manner.

2. If judgments about terrain/area characterisitics conflict with the concept of operation then the planner should be quizzed about his/her COO.

3. If judgments about combat capabilities conflict with the COO (by, for example, massing troops at the least likely location) then the planner should be quizzed about his/her rationale.

4. The concept of operations must be consistent with the evaluations of likely adversary COAs and friendly responses. If the planner distributes forces that are inconsistent with the COAs then the system should constrain the planner or else require the planner to rethink the evaluations of the most likely/optimal adversary/friendly COAs.