AD-A185 636

DTIC FILE COPY

DTIC
SELECTED
OCT 0 1 1987
S   D

D

Using Concept Mapping to Define
Problems and Identify Key Kernels
During the Development of a
Decision Support System

THESIS
Michael R. McFarren
Captain, UASF

Using Concept Mapping to Define Problems and Identify Key

Kernels During the Development of a Decision Support System

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

Michael R. Mc Farren, B.S., M.B.A.

Captain, USAF

June 1987

Preface

This thesis effort would not have been possible without the support and encouragement of many people. I would like to thank all the members of the RAAP working group for their patience and understanding through all the hours of interviewing and to the entire GST 87-M class for their constant challenges and inspiration.

In particular I owe the largest debt of graditude to three special people. Colonel John E. Rothrock made it possible to validate the intire concept mapping process because of his visionary thinking. Lt Col John 'Skip' Valusek, my mentor and friend, introduced me to the need and inspired me with the challenges. And to Sandra, my wife, who took the burden of running our home and lovingly cheered me on. Thank you all.

Michael R. McFarren

Table of Contents

iii

List of Figures

List of Tables

ix

CHAPTER 1

INTRODUCTION

1.00   Introduction:

Where do I begin? ...Every Decision Support System
(DSS) designer/builder must ask himself this question
every time he sets out to build a support system.

This hesitation at the start of a problem is not
uncommon. All humans have experienced this dilemma
when they are faced with a complex decision. Think
about the last time one of your home appliances broke
down. How did you go about getting it fixed? How did
you go about finishing the task that was started when
the machine failed? Do you remember all the steps you
took? What were all of the alternatives? What was
the first thing you did? If it happened right now what
would be the first thing to do? If you're like most
people, these questions are hard to answer and bring
back strong emotions like frustration, hopelessness,
or fear. And yet, these are relatively simple problems;
problems that have been solved before by you or others.

Although the DSS designer is not faced with the
same problems or emotions, he is faced with the same
questions. Where is the starting point? What are the
key points of the problem? This dilemma stems from
the lack of two important aspects of the problem. Every

decision maker must have 1) a clear definition of the problem and 2) an understanding of the decision making process used to solve the problem.

This thesis effort is an attempt to help the DSS designer/ builder in his task of finding the starting point. This paper introduces a method for defining problems and identifying the decision process. The results of this method aid the designer/ builder in the construction of a DSS by pointing out the key points or kernels of the problem where a DSS can assist a decision process.

1.10 Background:

How the human mind works is an extremely interesting topic that eludes complete understanding. Somehow the human mind takes new information and stores it. Later, when faced with a task that needs the information, the mind recalls it and performs various operations on it. These operations are known as cognitive processes. These cognitive processes are used to accomplish tasks such as problem solving and decision making.

There are times when a decision maker is faced with complex or very difficult decisions. These decisions require vast amounts of data, very complex cognitive processes, or intricate sequencing of cognitive processes. Under these conditions, the decision maker requires

2

some sort of help. This help in making decisions comes
in the form of a decision support system.

The DSS provides support for a particular cognitive
process when faced with a specific decision or problem.
A DSS is 'a system, manual or automated, that aids a
decision maker in the cognitive processes of judgement
and choice' (Valusek, 1986). To build a DSS, the cognitive
processes that make up the decision or problem solving·
process must be identified. This identification process
or search is otherwise known as defining or describing
the problem.

Problem definition requires the identification
of the solution process as an integral part of the DSS
design. This topic is crucial to the continued developm-
ent of DSS as a viable means to help decision makers
with complex tasks. Without a clear understanding of
the problem and how the decision process works, the
DSS builder is just randomly producing aids that may
or may not be effective support for the decision maker.

Decision aids are too time consuming and expensive
to be built in a haphazard manner. A process is needed
to identify the key steps in the decision process, and
suggest to the designer which elements of the problem
will benefit the decision maker most. Its result would
be a list of decision making elements that, if necessary,
can be ranked in order of most to least supportive.

3

Each item on the list of decision making elements is a potential kernel. A kernel is a key decision element in a decision or problem solving process which is a feasible starting point from which to build a DSS.

Once the designer has the list, he can construct decision aids that are based on the cognitive process and effectively support the decision maker. Using this approach, the decision maker receives the most effective support that is technologically available in minimum time and at least cost. This is a very appealing idea, but how does a designer go about finding these decision elements? Is there an existing procedure to follow?

1.11 Formal Training in Decision Making:

When decision makers are formally taught how to make decisions, they are taught two things: 1) Every problem can be approached systematically, and 2) There are a variety of problem solution techniques that can be applied given the right problem. The thing they are not taught is the skill to identify and define the problem. The lack of formal training in descriptive decision processes is a detriment to decision makers (Keen, 1978:62; Leavitt, 1976). Both authors agree that too little emphasis is placed on problem finding as opposed to problem solving. Consequently, the decision makers see decision making as a structured task and

4

concern themselves only with the content of the decision, and the analytical methods used (Keen, 1978:62). Browsing through any academic course catalog that lists decision making courses supports this observation. Figure 1-1 is a sampling of a course listing from the AFIT catalog 1985-1987.

Omitting problem identification and definition skills from academic curriculum is not the complete fault of academic institutions nor instructors. Research into how humans make decisions has not kept pace with our need to understand the decision process. Stabell identifies the need for more research into decision processes so DSS development could go forward. His call is for more research into the specific methodologies for describing the decision processes and identifying criteria for improving them (Stabell, 1975).

Without being trained in problem description techniques, our decision makers go into a world full of complex, inter- twined problems. They do not have any tools readily available that can give a descriptive understanding of the problem. Thus, until they develop a sixth sense on their own, they have a difficult time answering the starting questions. This fact is clearly evident to DSS designers.

OPER 526 - Quantitative Decision Making.

Credits: 4

Prerequisites: None.

This is an introductory-level course in operations research techniques. Emphasis in the course is directed toward understanding and application of the techniques to managerial problem solving and decision making rather than toward theorem derivations or proofs. Major topics covered include linear programming, inventory theory, queueing theory, and decision theory.

Text: An Introduction to Management Science, *by, Anderson, Sweeney and Williams.*

OPER 742 - Analysis for Defense Decisions.

Credits: 3

Prerequisites: None.

This course discusses the role of analysis in defense decisions and examines both the limitations and capabilities of analysis in the decision-making process. The distinctive features of this course are its broad coverage of analytic aids to decision-making and its focus on the needs of the user. Specific topics include: the need for analysis in public sector decisions, the basic framework for analysis, quantitative and qualitative methods, acceptance, implementation, and pitfalls and limitations of analysis.

OPER 563 - Linear Programming and Extensions.

Credits: 4

Prerequisites: None.

This is the initial course in the operations research sequence. The course begins with a discussion of the role of quantification and modeling in decision making and resource management and an overview of Air Force quantitative analysis applications. The primary types of operations research models covered in this first course are deterministic mathematical programming models, like linear programming, the transportation model, and game theory. The strengths and weaknesses of these operations research models are presented and discussed in the context of military applications.

OPER 760 - Operations Research II.

Credits: 3

Prerequisites: OPER 660, MATH 592, MATH 692

This is the second of a two course sequence introducing operations research to management students. The two courses survey operations research models and methodologies and examine the role of operations research in managerial decision making. This second course emphasizes probabilistic models and covers the topics of inventory models, queueing models, a brief look at simulation, Markov processes, and reliability models. Examples and cases from the USAF environment are emphasized.

Text: Principles of Operations Research for Management, *by Budnick et al.*

Figure 1-1. Courses from AFIT Catalog 1985-87

1.12 Descriptive Techniques:

There are several ways to describe problems. Two
of the most common are word description and visual images.
Both have advantages and disadvantages in performing
the descriptive role for problem definition. But are
these the best for problem description?

Using word descriptions is a lengthy, time consuming
and sometimes confusing exercise. The decision maker
must fully describe each detail of the problem so another
person can receive the correct meaning. If the problem
is at all complex, the description may become very lengthy
and cumbersome. The comprehension of the problem relys
heavily on the ability of the author to use the language
and organize the facts in the description. Also the
presentation of the information is forced into a linear
form which is not always conducive to effective learning.
However, the method is excellent in recording the smallest
details and relationships of problem elements.

Visual images include pictures, diagrams, charts,
blue- prints, etc. These are tools that depict a problem
in a concrete manner using lines, curves and shapes
to represent the elements of the problem. An image
is universally understood and therefore overcomes some
of the language barriers inherent in word descriptions.
Images are one way to enhance the learning process by
aiding the ability of the learner to recall. However,

7

images cannot provide the intricate detail needed for relating complete understanding of all the details in a problem.

There is another method developed by educational psychologists that may offer some ability to enhance the advantages of both descriptive techniques. Concept mapping is a combination of both word description and visual images. It is designed to represent concepts as they are understood by the mind. This capability gives two main advantages. First, the mind can more easily learn from the map. Learning is enhanced because the map is a visual representation of the concepts and their links to each other. The map shows the links in the same manner as the mind links and stores the concepts in memory. Second, there is no restriction on the organization of the map. Information is not locked into a linear presentation.

1.13 The Importance of Describing Problems:

When a decision maker realizes he cannot handle a complex problem as effectively as simpler problems, he calls for decision support. In the past, decision support might have been a ledger book, a wall chart, or drawings. Today the realm of decision aids extends into the high-tech world of computers, simulation, and artificial intelligence (AI). But the underlying dilemma

still faces the designer. What is the problem? What
are the decision processes that should be helped by
a decision aid? The only way to answer these questions
is to describe the problem. A descriptive process is
needed.

Why is the descriptive process of decision making
so important? Keen and Scott-Morton explain it best
when they say: 'Decision support requires a detailed
understanding of decision making in organizations.
A descriptive framework provides the basis for prescript-
ive design; that is, to 'improve' a decision process,
one must first define and analyze it' (Keen, 1978:61).

As a means to aid the designer/decision maker in
his understanding of the problem space and description
of the decision process, this project became one of
identifying a descriptive process that supports the
identification of key decision elements or kernels,
so that the designer produces a pertinent and effective
decision support system (DSS).

1.20 The Problem:

How does a DSS designer identify the kernel(s)
of a problem, from the user's perspective, and develop
a design for a DSS from them? The problem arises because
DSS adaptive design says 'start small and grow', but
there are no suggestions on where to start.

9

1.21 __The Challenge__:

Can concept mapping techniques be developed into
a user oriented tool to help identify kernels?

1.30 __Scope__:

This thesis addresses the primary challenge by
developing the tool, concept mapping, as a means to
identify kernels in a decision process. This is a
descriptive process that defines the problem space,
describes the decision process, and identifies the key
steps of the decision process as potential kernels.
Beyond this initial challenge is the challenge of integrating
concept mapping into the adaptive design process.

This thesis effort will take the technique of concept
mapping and use it to extract the information about
a problem from the decision maker himself. The result
of this extraction should be a well defined problem
space, a sufficiently described decision process and
a means to identify the kernels. Finally, the effort
turns to integrating concept mapping into the adaptive
design process. The integration of concept mapping
into the adaptive design process is accomplished through
a process called the problem definition process (PDP).

As a means of development of the concept mapping
technique and experimentation with the PDP, several

10

test cases of various DSSs were attempted. A few of these test cases are reported later in chapters 5 and 6 of this paper.

Because the scope of this project is to find a way to identify kernels, there are several associated areas identified that were not investigated. These areas may be the basis for further research but are beyond the scope of this project.

The first of these areas has to do with individual perceptions. Since different people have different perceptions of problems and how to approach them, they will have different details in their decision process. Therefore, no attempt will be made to determine the 'best or optimal' decision process. Only the 'accepted or agreed' decision process will be found using the concept mapping technique. Much more research into the basic understanding of cognitive processing of the human mind needs to be done before evaluations of the effectiveness of processes can be accomplished.

Pursuing this idea of cognitive optimization, no suggestions nor recommendations will be offered to the expert about changing his cognitive procedures to optimize his/her process. The expert is just that; an expert. S/he has far more experience working his/her problem than the analyst/designer. Therefore, any suggestions made would be based on total supposition since no actual

11

studies have come forth explicitly showing one cognitive procedure as more effective than another.

A third topic not addressed by this effort is the automation of the concept mapping technique. There are several places where automation may be helpful to the researcher while actually producing the concept maps, but that is beyond the purpose of this effort.

1.40 <u>Hypotheses</u>:

This thesis was designed around two basic hypotheses that are supported by several beliefs. Following are the hypotheses and the beliefs. By showing each of these beliefs to be true, the hypothesis is then assumed to be valid.

1.41 <u>The First Basic Hypothesis</u>:

Concept Mapping can, in sufficient detail, represent an individual's understanding of a problem and his description of the decision process in order to identify kernels for the design of a decision support system.

A. Multiple concept maps, created on the same problem, will have similar main concepts and key areas. This similarity should be seen between earlier and later maps of the same person and also among maps of different people.

B. One or more of the main concepts (key decision elements) will be easily identified when comparing multiple concept maps of the decision process. These main concepts will be the kernels.

C. As expert's perceptions change over time, unimportant issues will drop from the problem space. Thus, the key decision elements in a problem will repeat and be identified when compared with previous maps.

D. Concept maps are simpler to read because they present the information in the same manner that man stores information in his mind. This concept makes it easier for others to achieve the same understanding as the expert who originated the map.

E. No two people will construct identical maps on the same problem space, nor will the same person repeat identical maps after a significant period of time. But, identical key decision elements from the decision process will be repeated. This will lead the designer to give more credence to those elements as kernels than others.

1.42 The Second Basic Hypothesis:

An explicit problem definition, which includes a thorough definition of the problem space and a complete detailed description of the decision process involved in the solution of the problem, is essential to the effective design process of decision support systems.

A. Kernels can be identified only after the designer has explicitly defined the problem.

B. All problems contain elements of a decision process that traverse the entire spectrum of 'structuredness'. This means that some steps are highly structured while others are not. (Keen and Scott-Morton) (Simon)

1.50 General Approach:

To meet the challenges, this thesis divides into several goals which outline the approach taken to solve the problem of kernel identification. The first goal is to develop a tool for relaying understanding between individuals. With a tool of this nature, a DSS designer could extract an expert's understanding of the problem and how he goes about solving it. The tool selected in this project is a technique from the field of education called Concept Mapping. Concept Mapping has been shown to be an effective teaching tool for relating

new concepts and their meanings to students. By slightly altering the process used by education, the concepts and meanings about a problem can be extracted from an expert by the designer. With this technique an expert's understanding of a problem and his description of the decision process can be captured. See chapters 3 and 4 for further discussion and explanation.

The second goal was to develop the method of explicit problem definition. That is to say, what are the steps in extracting the information from the expert? Fully describing or understanding the problem requires two distinct steps. The first step is to clearly and concisely define the problem space based on the user's perception. Once the problem is defined, the second step is to identify the key elements from the user's description of the decision process. Include all the key decision steps that are identified as potential kernels.

Once the problem is described or explicitly defined, the designer can then complete the challenge of this thesis and identify the kernel(s). Therefore, the third goal was to show that the concept mapping of the problem definition and decision process does help identify the kernels of the problem.

The fourth goal was to recommend to the DSS designer how he can incorporate the steps and tools above into the adaptive design process. Adaptive design is a process

that aids a designer in explicitly defining a DSS. In

other words, adaptive design finds a simple method or

procedure that a DSS designer can use to describe the

problem and design the system. Chapter 5 explains in

detail the PDP that is proposed.

As a means to complete the goals above and verify

the hypotheses, two types of test cases were used.

Since the main emphasis of the effort was to identify

the kernels for the design of a DSS, the majority of

the applications of concept mapping were on DSS projects

for classes and thesis requirements. To test the applic-

ability of concept mapping in a larger problem domain,

a second type of test case was chosen. Concept mapping

was applied to the definition and decision process of

Rapid Application of Air Power (RAAP).

1.60 **Sequence of Presentation**:

Each of the remaining chapters were designed to

present the findings, procedures and accomplishments

of this thesis effort.

Chapter 2 explores the decision maker's world.

It explains the reason a decision maker needs the skill

of a descriptive process as the main goal of the chapter.

Chapter 3 lays the ground work of theory behind

concept mapping. It introduces the current theories

of storing knowledge in the human mind and introduces

16

Ausubel's theories of educating.

Chapter 4 describes the concept mapping tool. It explains what it is and how you can use it. A lesson plan is presented that will teach the reader how to use concept mapping.

Chapter 5 explains the proposed PDP. Although each step is explained, the main emphasis is on the role concept mapping plays in the process.

Chapter 6 documents the seven DSS projects where concept mapping was used. There are several examples of maps and kernels that were found by the designers. Some comments by the DSS designers about concept mapping and the process are listed.

Chapter 7 documents the use of concept mapping on RAAP. A very large unstructured problem was mapped using several experts. Concept maps are shown which depict the expert's understanding of the concept of Rapid Application of Air Power. The results of the mapping and the final recommendations show that concept mapping can be useful in very large problem spaces as a tool for planning and designing large systems.

Finally chapter 8 concludes the paper with a summary of findings about the concept mapping technique as well as the summary of results from the problem definition experiments. Recommendations for future research and the conclusion are included.

Chapter 2

The World of the Decision Maker

2.00 Introduction:

This chapter focuses on the abstract problem solving
world of the decision maker and that environment in
which s/he operates. The rest of this discussion concen-
trates on achieving a better understanding of the conceptual
environment and explaining some of the terminology used
in the remainder of this paper.

2.10 The Decision Maker's Environment:

Conscious human thought resides in a conceptual
environment of memory, cognitive processes, affective
reflections, and behavioral responses. These factors
of the environment interact to sustain thought just
like air, light, water and earth interact to sustain
life. Within this environment, the human mind combines
these factors in the intricate process of decision making.

All humans continuously make decisions. However
the range and complexity of the decision spans from
basic daily decisions of 'when to eat' to abstract problems
like 'solving Maxwell's equations'. The mind performs
these feats by accomplishing complex cognitive tasks
like data collection, situation awareness, alternative
generation, evaluation, judgement, choice, etc.

18

2.11 Problem Domain - Problem Space:

There are three key terms that need to be understood by anyone involved in defining a problem and identifying the kernels of the decision process. The first term is Problem Domain. The problem domain is a sphere of understanding or range of problems associated with a specific field. For example, aircraft maintenance, flight take-off, and crew training schedules are in the problem domain of scheduling.

The second key term is Problem Space. The problem space is a conceptual area within the problem domain that is defined and bound by the factors of the problem. The bounds on the problem come from factor limitations. Factors reach their limits when they no longer pertain to the specific problem at hand.

The definitions of these two terms falsely lead one to believe that there exists explicit delineation between problem domains and spaces. Quite the contrary is true. Problems are not delineated and are not easily identified. The natural camouflage created by the lack of delineation and differentiation can be seen in the way information is communicated to the decision maker.

Problems are not presented to decision makers in nice, neat, easy to understand forms. They are hidden in the day-to-day noise of communication. Every decision maker sends and receives thousands of pieces of information

daily, involving a variety of past and future decisions.
The decision maker must be constantly alert to the existence
of a possible problem that would require a decision
to be made. To help him/her identify any possible problems,
the decision maker must install and implement a variety
of sensors and control mechanisms. Each of these systems
helps keep him/her informed of the status of the organiz-
ation.

Concurrent with the sensing and control process,
the decision maker must also be creative. S/He must
search out and evaluate new alternatives to recurring
decisions. They must learn to look at old problems
in new ways and generate different alternatives for
enhancement of the decision process. Along with the
constant vigilance for new alternatives, the decision
maker must also be searching for new ways to make decisions.
Technology as well as perception changes very rapidly.
New ways to look at a problem may be exploited by the
new technology. Thus the decision makers must remain
alert to take advantage of these opportunities.

These are the key functions and actions of a person
performing the complex cognitive tasks of decision making.
Since sensing, control and creativity are functions
of the decision maker, what then is Decision Making?

2.12 Definition of Decision Making:

There are many variations on the definition of decision making. Here are three that are commonly seen in the literature: 1) Decision making is a process that produces a product called a 'decision'. 2) Decision making is an irreversible commitment of resources. 3) Decision making is 'a course of action consciously chosen from available alternatives for the purpose of achieving a desired result. Thus a decision is 1) a choice, 2) the result of conscious mental activity, and 3) directed toward a purpose' (Massie, 1981:170).

Another way to define decision making is to look at how the decision maker 'models' the problem. 'At a minimum, complex decision making involves searching for information about the current and desired state of affairs, inventing possible courses of action, and exploring the impact of each possible course of action. All decision making involves predicting the likely consequences of decisions, which suggests that the decision maker have a 'model' of the problem situation being faced' (Brennan, 1985:130).

2.13 The Fog of Decision Making:

The environment of the decision maker is clouded by several factors regarding the understanding of cognitive activities within the mind. These factors cause knowledge

about the decision making process and the environment
that it resides in to be obscured.

1) Quantity of factors:

Many decisions seem to be simple at first glance
merely because the maker fails to comprehend the number
of factors that affect the situation. For example,
any scheduling problem is initially considered a relatively
simple assignment of one resource against another.
However, the assignment process must take into account
factors that are not prevalent at the surface. Factors
such as the variable rate of production, worker unavail-
ability, and demand changes are all affecting the final
schedule. "Confusion is not uncommon or unhealthy at
this stage; however, the decision maker cannot consider
all the facts and must develop a selective approach
for keeping the most important and relevant facts in
mind" (Massie, 1981:172). The decision maker copes
with this confusion by concentrating on the key aspects
of the decision at hand.

2) Lack of Judging Probabilities Under Pressure:

Decision makers are consistently required to estimate
the probability of factor results within a decision
environment. Two examples of questions that require
the decision maker to estimate a variable are: How

much conduit is needed for a building under construction? What are the best lengths of conduit? In both of these questions, decision estimates of the total length of conduit as well as the amount of waste depend on the performance of the workers. The decision maker must estimate the ability of the workers. This kind of decision is usually accompanied by some stress. In this example the stress is to complete the building on time, within code, and within costs. Are people good natural decision makers? There is now considerable evidence that they are not.

> The major advance in descriptive research over the last five years has been the discovery that people systematically violate the principles of rational decision making when judging probabilities, making predictions, or otherwise attempting to cope with probabilistic tasks. Biases in judgments of uncertain events are often large and difficult to eliminate. The source of these biases can be traced to various heuristics or mental strategies that people use to process information. In the final discussion a strong case is made that judgmental biases affect important decisions in the real world. (Howard, 1980:9)

3) Human's inability to describe the process:

Understanding how people make decisions is essentially 'explaining how people manage to cope with the demands of an environment, the complexity of which far exceeds the range of possible human responses' (Hogarth, no-date:6). Thus, the environment is clouded by the inability of

23

humans to describe their cognitive processes and ways
of thinking.

4)   Complex Combinations of Processes used:

Another factor that clouds the understanding of decision
making deals with the ability to identify the combination
of simple processes used to solve the problem. Hogarth
believes that the human mind has only a limited number
of strategies or principles for making decisions. Often
these strategies are used in complex combinations.
This combining of simple strategies requires a DSS designer
to infer the combination and the environment that existed
when the combinations were created. This inferencing
process is not a simple task. Without the understanding
of the relationships describing the combinations, no
understanding of the decision process would be possible.

2.20 Educating Decision Makers:

Most formal presentations attempting to teach decision
making set the decision maker down in a classroom and
teach him/her 'how to solve problems'. But does s/he
learn to solve problems or do they really learn to apply
the current solution technique to a given set of sifted
data?

Throughout the entire range of curriculum dealing
with problem solving, student decision makers are given

24

the encapsulated problem, which is fully defined and seldom, if at all, contains extraneous information. The emphasis is placed on the mathematical procedures or algorithms used to help the decision maker in differentiating between alternatives (i.e. the choice process). This practice of problem simplification is not unique to any course of study. Mathematics, management, engineering and the physical sciences follow the same teaching method. Students are very well prepared to handle these encapsulated problems, but the true state of the world is not this well defined or structured.

Students of decision making must attain the skills of defining the problem space and identifying the kernels of the decision process. As Massie and Douglas put it, this is the 'Art of decision making'. Unfortunately, this process of defining the problem and identifying the decision process has not been addressed by management teachings. 'A serious weakness of the whole study of management has been ignorance of, or lack of interest in, how decisions are made. A descriptive understanding of the problem-solving process is absolutely essential for decision support.' (Keen, 1978:15)

There is an entire class of problem, similar to the encapsulated problems that are referred to as 'automatic choice'. The stimulus that initiates the response is so well learned that no conscious thought is given.

In other words, the problem was previously solved, the solution documented in detail and the required actions written down for anyone to use. The response to a certain set of events or stimuli causes an immediate response by the decision maker. Many jobs are like this. Factory assembly lines operate machines by using a sequence of checklist actions. The worker just reacts to the stimuli, movement of the line, with the appropriate actions.

This thesis does not debate nor recommend changing the educational philosophy of the world but merely points out the fact that very few teachers teach the art of problem definition. Other authors have also voiced this concern (Keen, 1978; Leavitt, 1976; Stabel, 1975). Why isn't the art of problem definition taught? Teachers surely see the need for problem definition skills. It is the contention of this author that there is no suggested method or procedure available for students' use.

Teachers know every student will face a world of complex, entangled problems. Thus, it would be foolish to hold back a process that sorts out and delineates boundaries and highlights intersections between various problem spaces. Consequently, the only answer is that a process of accomplishing problem definition does not exist.

2.30 The Decision Making Process:

'Few people like problems. Hence the natural tendency
in problem solving is to pick the first solution that
comes to mind and run with it. The disadvantage of
this approach is that you may run either off a cliff
or into a worse problem than you started with. A better
strategy in solving problems is to select the most attractive
path from many ideas, or concepts' (Adams, 1986:ix).

Adams' observation tells us that humans tend to
be lazy in making decisions, and, as a result, fail
to solve the problem. Adams does recommend a solution
to this dilemma, and that is to approach decision making
with a strategy.

The main strategy undertaken by most decision makers
would be to look upon decision making as a process.
Cohen describes the decision making process as consisting
of a specific set of cognitive tasks. Figure 2-1 depicts
the arrangement of the key cognitive tasks in Cohen's
decision process. 'First, goals or objectives must
be known or identified; if these are not present, then
there is no motivation to decide or act' (Cohen, 1985:12).

In this representation of a decision making process,
Cohen recognizes two inherent facts. First, there is
no specific ordering of the cognitive tasks. Tasks
are performed in a variety of sequences based on the
decision maker and the environment. Second, the process

27

of deciding is an iterative process among the tasks.
No task is ever completely finished during the decision
process.

DECISION MAKING

| Identification of Objectives | Situation Assessment | Option Generation | Choice |

Assimilate Evidence | Infer Conclusions from Evidence | Assess Quality of Conclusions | Infer Higher-Level Conclusions etc. | Generate Possible Outcomes of Options | Assess Uncertainty of Outcomes | Assess Values of Outcomes | Select or Reject Options
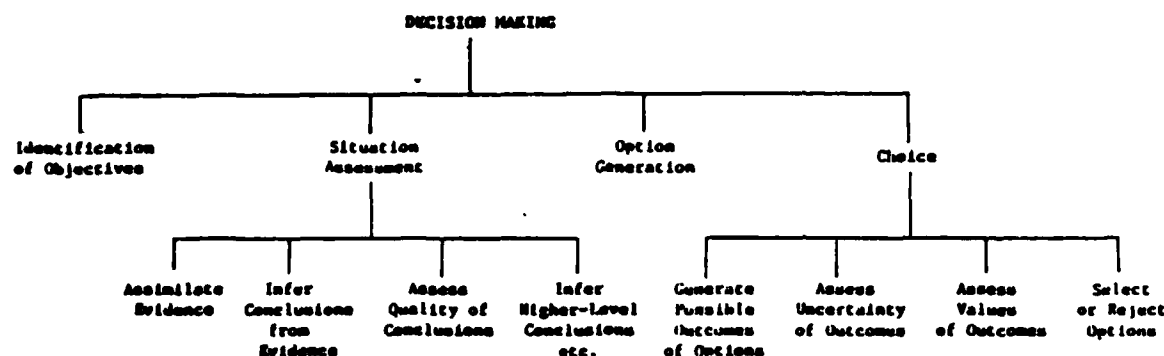
Figure 2-1. Potential cognitive subtasks in the
decision-making process.

2.31 <u>The Systematic Approach</u>:

Lt Col Robinson pointed out in TACT 6.70, Systems
Analysis and Defense Planning, that 'Operations research
may be defined as the application of scientific methods
and techniques to decision making problems' (Robinson,
1987:1). The scientific methods are simply 'logical
approaches to the solution of problems which lend themselves
to investigation' (Metcalfe, 1966:3). Thus, the curriculum,
whose sole purpose is to support decision making, puts
forth the belief that a decision maker should approach
a problem in a systematic process. Searching the literature
one finds as many variations in the steps of problem
solving as there are authors. Figure 2-2 shows several
authors' recommended steps in the process of analysis.

28

Anderson
1. Problem definition
2. Model development
3. Data preparation
4. Model solution
5. Report generation
        (Anderson, 1976:5)

Massie
1. Understand the situation
2. Diagnose and define
   the problem
3. Find alternatives
4. Select action
5. Secure acceptance of
   decision
                (Massie, 1981:171)

Quade
1. Formulation
2. Search
3. Evaluation
4. Interpretation
5. Verification
        (Quade, 1977:33)

Robinson
1. Formulate the problem
2. Model the system
3. Select a solution technique
4. Solve the problem
5. Establish controls over
   the solution
6. Implement the solution
                (Robinson, 1987:1)

FIGURE 2-2. A Variety of Algorithms for Decision Making
by Author.

2.32 The Need for Problem Identification:

     The most interesting thing about all of these processes

is the fact that they all start with the same step.

Every author recognizes the importance of understanding

the problem before applying solution techniques. 'A

clear and concise definition of the specific problem

of interest is an essential first step on any operations

research or quantitative analysis study' (Anderson,

1976:6). Quade and Boucher admit that 'formulation

is the most important stage' (Quade, 1977:35). The

importance is again emphasized in their summary of systems

analysis. The first recommendation is to 'pay attention

to problem formulation' (Quade, 1977:419). Adams proclaims

'proper problem identification is of extreme importance

29

in problem solving. If the problem is not properly
isolated, it will not be properly solved' (Adams, 1986:22).
This proclamation was based on the fact that information
is either inadequate or misleading.

Massie and Douglas also support the need for problem
identification by calling for an explicit statement
of the problem. 'Since it is impossible to weigh all
the facts, the manager must develop a means of sifting
out the relevant ones (figure 2-3). In the classification
of these facts, one can then define the problem. The
more completely the problem can be stated, the easier
the other steps will be' (Massie, 1981:173).
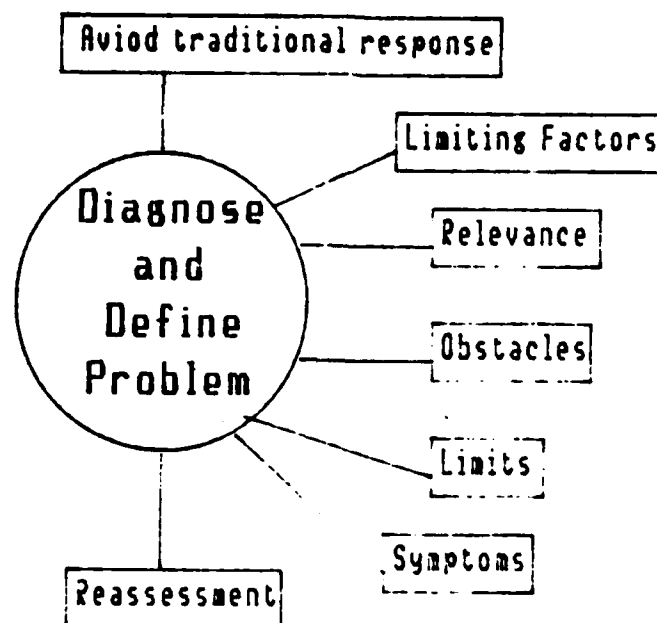
Figure 2-3. Inputs to diagnosing and defining the problem.
(Massie, 1981:173)

To achieve the understanding of the required decision
process and criteria, the problem must be fully defined.

30

`In a 'well formed problem' we know the initial state,
the goal state, and the operators. From these, we can
systematically generate all the intermediate states,
and hence we can theoretically develop a 'map' of the
entire problem space (Harmon and King, 1985:28).`

The field of OR presents hundreds of text books
and articles depicting detailed algorithms on how to
solve problems. Unfortunately this author has not found
any algorithms on suggested problem definition or problem
diagnosis procedures. Yet, every text or article dealing
with the process of analysis lists the 'problem formulation',
'problem definition', or 'problem diagnosis' as the
first step.

2.33 The Art of Problem Definition:

If it is as important as Anderson, Quade and others
believe, why then has it been so hard to develop a procedure
of problem definition? Massie and Douglas put forth
the argument that problem diagnosis is an art. They
give the example of a patient going to the doctor with
a stomach ache. The doctor just doesn't record stomach
ache. He performs an examination to find the cause
of the ache. Once the cause is found, he prescribes
the approved treatment for the cure. The same is true
of the decision maker. He/she must not be distracted
with just the symptoms but search further to find the

31

cause. This is the art.

'The diagnosis and definition of the problem is
a recurring process. Reassessment and reconsideration
of the issues help keep the decision-making process
realistic and in touch with a changing set of conditions'
(Massie, 1981:173). Thus, what we need as decision
makers is an art lesson and the tools to perform the
art. Like a painter, the decision maker must learn
to use the tools that spread the paint. Then he must
practice and develop insight to make the canvas come
alive with a correct problem formulation.

2.34 DSS and Problem Definition:

Not only is this chapter concerned with the manual
process of decision making but the automated support
for the human as well. These decision support systems
require even more explicit problem definitions because
of the need to design the system. 'Decision support
requires a detailed understanding of decision making
in organizations. A descriptive framework provides
the basis for prescriptive design; that is, to 'improve'
a decision process, one must first define and analyze
it' (Keen, 1978:61).

Based on this need for problem identification,
a process for performing the task must be developed.
The process must be simple, flexible and easily applied

to any problem space or domain.

2.35 Requirements for a Capturing Process:

To capture the factors of a problem so that its
problem space can be identified, described, and bounded
calls for a diagnosis. This diagnosis must discover
several facts about the problem so that the remainder
of the decision process is enhanced.

Massie and Douglas describe a good diagnosis as
one which has both 'the reasons leading up to the need
for a decision and obstacles standing in the way of
achieving the objectives. A diagnosis consists of a
search for symptoms. The search must be based on a
clear recognition of the desired results, the obstacles
faced, and the limits within which a solution must fall'
(Massie, 1981:173).

Another way to describe the problem space is to
define it in three dimensions. Bartee describes the
problem solving space by looking at the problem taxonomy,
problem solving modes, and problem process. The problem
space is sketched with regard to personalization, col-
laboration, institutionalization, and socialization.
These are the ways Bartee sees the decision maker developing
the ability to solve problems. Kiss judges from his
observations that 'we are now between the second and
third phases. Where we use conceptual frames for pre-

33

scriptive types of problem solving, combined with experiences, but involving some behavioral aspects' (Edwards, 1984:14-15)

Just as the other steps of the decision process are iterative and recurring, so is the diagnosis or problem definition step. As the decision maker progresses through the sequence of steps to produce the decision, s/he must continually reassess and reconsider the issues of the problem. This reassessment keeps the decision process 'realistic and in touch with a changing set of conditions' (Massie, 1981:173).

Based on this need for problem identification, a process for performing the task must be developed. The process must be simple, flexible and easily applied to any problem.

2.36 Conceptualization:

Of all the cognitive processes mentioned and discussed in this chapter, the key to understanding how a capturing process would work is conceptualization.

Conceptualization, or the process by which one has ideas, is the decision maker's ability to create concepts in the mind and link them together into a framework of understanding. 'This process is a key one in problem solving, since the more creative concepts you have to choose from, the better' (Adams, 1986:7).

Conceptualization is not monolithic, but has many
and varied 'levels of conceptualization'. Each level
contains a set of linked concepts. Each set of concepts
is a layer that can and does have links to other layers.
The layers at the top levels are very abstract and free.
These levels of conceptualization may address a variety
of problem spaces and even range across several domains.
The lower the level of conceptualization, the greater
the increase in detail and the more focus applied to
the problem space. The level of conceptualization becomes
more explicit and resides with the tiniest details of
a problem space.

2.40 Good Decisions:

If a decision maker understands the levels of conceptual-
ization inherent in the problem and completes an explicit
diagnosis of the problem space, then a 'good decision'
is more likely. 'A good decision depends upon the maker's
being consciously aware of the factors that set the
stage for the decision' (Massie, 1981:171).

Nothing is more elusive than the evaluation of
a decision as to its quality. What is meant by a 'good
decision'? Is a good decision different than a good
outcome? If so how?

Before delving into problem definition process,
a short detour discussion of 'good decision' is necessary.

35

This detour will offer a definition of 'good decision' so that the decision maker knows what to strive for in the decision making process.

The first definition comes from the field of decision analysis. 'A good decision is one based on the information, values and preferences of a decision maker. A good outcome is one that is favorably regarded by a decision maker' (Matheson, 1968:24). Although a decision maker has no control over the final outcome, he does have control over the decision. Therefore as Howard puts it '...making a good decision is only doing the best we can to increase the chances of a good outcome' (Howard, 1973:63).

Based on this discussion, a 'good decision' is one where the decision maker tries to obtain the desired outcome using the most effective and efficient means available. S/he does this by identifying the possible outcomes, and then using all the tools available to act in a way that increases the chance for the desired result. These acts and their sequence then is a 'good decision'.

A decision maker's problems are not trivial. All complex problems require some form of human judgement and cognitive processing. The human needs support when s/he is overwhelmed by the requirements of the decision task. A decision maker is vulnerable to a decision

task when the rate at which s/he must do the task exceeds
his/her capacity, or his/her ability to think is insufficient
to the task at hand. These are the problems where any
decision maker needs help. These are the situations
which call for decision support.

2.50 Decision Support Systems:

Because decision makers do become overwhelmed by
their decision task, they need some type of help or
support. Decision support systems offer a means to
aid the decision maker. `Decision support implies the
use of computer hardware and software to:

  1] Assist managers in their decision process
      in semi-structured tasks.
  2] Support, rather than replace, managerial
      judgement.
  3] Improve the effectiveness of decisionmaking
      rather than its efficiency.`
  (Keen, 1978:1)

However, the use of a computer is not absolutely necessary
for the system to be classified as a DSS (Keen, 1978:58).

2.51 Value of DSS:

For a system to be a real value to the decision
maker it must provide him/her with effective support.
The design of the system must reflect an understanding
of the management decision process. The manager, on
the other hand, must clearly recognize the criteria
for developing the aid and power of the resulting output.

"Perhaps the most practical aspect of the DSS approach is that it allows managers to initiate, design, and control the implementation of a system. That is, a DSS is built around a decisionmaking task and while the technical issues may be extremely complex, the main focus is managerial" (Keen, 1978:13).

2.52 Efficiency vs Effectiveness:

Since every human strives for the highest success possible, he'll search for the best decision possible. This search for the best decision will soon become a trade-off between efficient and effective decision making. These two terms become essential in understanding what a DSS is to provide to the decision maker. "Efficiency is performing a given task as well as possible in relation to some predefined performance criterion. Effectiveness involves identifying what should be done and ensuring that the chosen criterion is the relevant one." (Keen, 1978:7)

In providing support to a decision maker, trade-offs may have to take place. A decision maker does not have the time for all possible alternatives to be enumerated and evaluated in light of their effects on the outcome. The decision maker is constrained by time, money and the ability to comprehend. The support system must also be efficient in the presentation of the information.

The aid should concentrate on the most pertinent information
and present it in a clear concise manner that will not
interfere with the decision maker's cognitive proces-
ses. "Defining effectiveness requires a detailed under-
standing of the variables that affect performance" (Keen,
1978:10).

2.53 Perceptions Inherited by the DSS:

Keen and Scott-Morton go on to claim that the key
question for anyone building a DSS is: 'What specific
decision or decision process are we trying to support?'
When building a DSS, the designer must realize the
decision is not static but constantly changing. His
perception of the problem and the values s/he places
on the various outcomes continually change over time.
Thus the decision maker is facing a complex problem
that cannot be fully automated nor reduced to an automatic
choice. "This perspective requires the development
of methodological tools to examine the key decisions
of managers and to define the information that can or
should be made available to them. It suggests that
for a manager's information system, one should start
from his/her decision making activities and mesh the
system into the user's problem and needs (Keen, 1978:58)."

Scott- Morton recognizes that all managerial decisions
have two parts involved in the task. By evaluating

the task we should identify the key decisions it involves, and then identify the parts of the process that seem structured and which require human judgement (Keen, 1978:11).

2.54 Concept Mapping:

In this thesis effort a new tool for the decision maker is presented. It is designed to meet the requirements for capturing the problem space. By identifying the key factors and ideas of a problem space and representing their relationships to each other, the problem will be identified and described by a map of the concepts. The individual elements or tasks used in making a decision will be identified and defined by repeatedly mapping the user's or users' preception of the decision process.

This tool is concept mapping (CM). CM is taken from the cognitive theory of education. 'Concept maps work to make clearly evident to both students and teachers the small number of key ideas they must focus upon for any specific learning task' (Gowin, 1982:II-2). Used in this context, concept mapping becomes a 'technique for externalizing concepts and propositions' (Gowin, 1982: II-3).

Concept Mapping is proposed to help the decision maker better understand the problem and limit the problem space. It is a communication tool that helps decision

makers depict relationships between concepts and lend
agreement to those relationships. Thus, a decision
maker can fully map out his perception of a problem
and view it in a variety of ways. However, the greatest
power of this tool lies in human inconsistencies and
variable perceptions. As the decision maker works on
a problem, time and changes in the environment help
to change his perceptions. If he has used the tool
and made his maps, he can review them and see changes
and consistencies in perception. This comparison of
maps (overlaying) is expected to greatly aid the decision
maker in problem diagnosis.

2.55 The Problem Definition Process:

Just introducing concept mapping as a tool for
decision makers is not enough. The tool and its use
must be shown to the decision maker as an integral part
of a process. This process establishes limits on a
problem space and defines the problem explicitly. The
application of concept mapping is tied to an entire
problem definition process. This process is not to
be taken as the only possible process of problem definition
but is an approach to help lend structure for a completely
unstructured arena. The direct application of the problem
definition process will be demonstrated best in the
adaptive design of decision support systems. (chapter-5.)

2.56 Why is it important to know and define the Kernel?:

As mentioned earlier, DSS requires an explicit definition of the problem and the decision process that solves that problem. Without the information there is no basis for the design and no method of determining the effectiveness of the system.

The kernel is a key decision element within the decision process. It provides a starting point for design of the DSS. Its discovery is based on the ability of the designer to identify it among the many other concepts and possible kernels, and the current perception of the designer as he searches the decision process.

Given more than one kernel available in a decision process, an evaluation of which kernel to use in the design of the DSS can be made. The kernels can be compared based on a variety of constraints. The most common constraints are technology, cost, time to develop, the designer's expertise and the user's perspective.

Once the kernel is chosen for the DSS, the impact on the final product is as important as laying the corner-stone of a building. Changes can be made during the development, but the direction and emphasis is set. For this reason alone, the discovery of the most appro-priate kernel of a decision process is paramount for the DSS's success.

2.60 Conclusion:

This chapter has introduced the world of the decision maker in terms of the environment and the requirements s/he has for defining a problem and identifying the kernels of a decision process.

The remainder of this paper's purpose is two-fold. First, it brings greater understanding to these cognitive processes of problem definition and kernel identification. Second, it introduces, demonstrates and evaluates a tool and procedure that aid these cognitive processes.

Chapter 3

Concept Mapping

3.00 Introduction:

This chapter explains concept mapping through a
series of discussions. The first set discusses four
topics which describe and contrast a variety of cognitive
modeling schemes. The first topic defines concept mapping
according to its educational derivation. The second
topic is an overview of the various cognitive knowledge
representation models. The third topic explores the
differences between the goals, purposes and abilities
of the models. Finally, key definitions of concept
mapping are presented as it applies to the problem definition
process.

The theoretical basis supporting concept mapping
is briefly introduced in the second set of discussions.
Three theories are presented which give insight into
the mind's function. These theories are then supported
by a series of observations and views taken from various
researchers and their findings. Finally, a summary
of justifications for concept mapping is offered.

3.10 What is Concept Mapping?

This discussion overviews several topics. The
first topic is a description of the concept map as seen

and developed by educational researchers. The second discussion reviews the various knowledge representation systems. Finally, the information presented is summarized and a combined definition of concept mapping is offered. This final definition of concept mapping is from the view point of applying concept mapping to the realm of problem definition.

3.11 Concept Maps - Educational Derivation:

A concept map is two or more concepts that are linked to each other depicting a meaningful relationship. Concepts are objects or events which are assigned a semantic label. Dog, chair, and raining are all examples of concepts. The linking words are generally the verbs, but adjectives, adverbs, prepositions, and sometimes nouns can also link concepts in meaningful ways. When a map is drawn showing its relationships, the result is a schematic device that represents a set of concept meanings embedded in a framework of propositions (Gowin, 1982:2.1).

'Concept maps are intended to represent meaningful relationships between concepts in the form of propositions. Propositions are two or more concept labels linked by words in a semantic unit. In its simplest form, a concept map would be just two concepts connected by a 'linking word' and forming a proposition.' (Gowin, 1982:2.1)

45

Concept maps are very successful in providing three
benefits to the user. These benefits are 1) identifica-
tion of the small number of key ideas within a subject,
 2) a visual road map showing the conceptual journey,
and 3) a schematic summary of the cognitive domain
of interest. These are powerful tools that aid a user
in translating understanding of a subject to another.

Concept maps are also very informative in their
design. As they are constructed, a hierarchy is set
up among the concepts. This hierarchy is dependent
only upon the builder's understanding or meanings that
s/he wants to show in the relationships of the concepts.
Based on this hierarchy, the embedded meaning of the
relationships and the arrangement of the concepts give
a specific meaning to the subject matter or domain.
One way to look at this function of concept maps is
to look at the way a subject matter is organized for
teaching. 'Since meaningful learning proceeds most
easily when new concepts or concept meanings are subsumed
under broader more inclusive concepts, concept maps
should be hierarchical. The more general, more inclusive
concepts should be at the top of the map, with progressively
more specific, less inclusive concepts arranged subord-
inately' (Gowin, 1982:2.2). Figure 3-1 shows a represent-
ative concept map. This map show the meaning relationships
between each of the concepts as well as the hierarchical

46

relationship.

One more very important function of concept maps
is their flexibility. Depending on the user's view
of the concepts and their relationships the superordinate-
subordinate relationships will change. Concept mapping
allows the user to 'pull up' a subordinate concept to
a superordinate position and rearrange the relationships
to the other concepts. This function is called the
'Rubber-Sheet' effect. This is the same type of cognitive
function that occurs in the mind and results in the
alternate meanings associated with objects and events.
Figure 3-2 show the same group of concepts show in figure
3-1, but the ordonnance has been changed to reflect
a new meaning or emphasis in the domain. Some of the
concepts have been dropped because they are no longer
necessary for the meaning that is being transferred
or negotiated. Also, some of the links have changed
to show different meanings.

Extrapolating all of these functions and definitions,
concept mapping is a technique for externalizing concepts
and propositions as they are organized in the mind.
Thus, a concept map becomes a forum or tool for two
or more individuals to negotiate meanings. This negotiation
of meaning is the basic purpose for concept maps in
education.
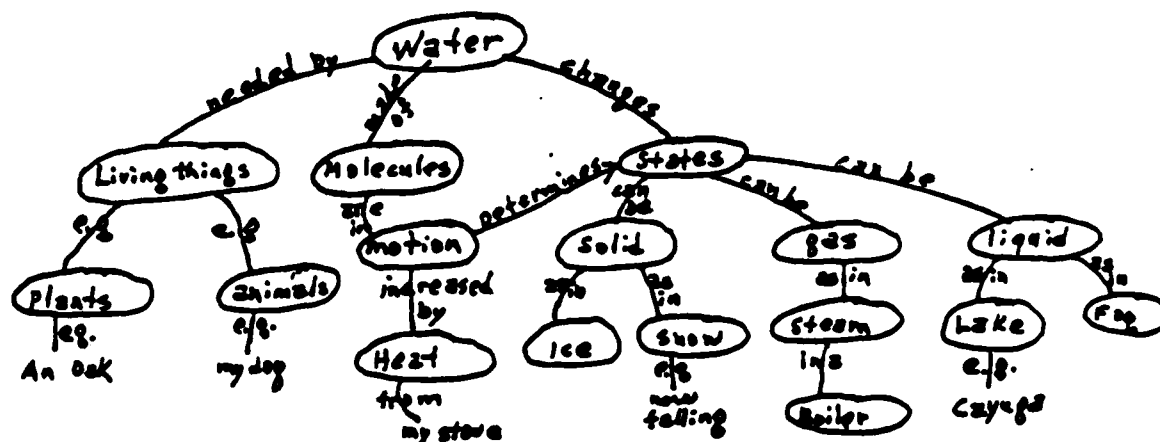
Figure 3-1. A concept map for water showing some related
concepts and propositions. (Gowin, 1982:Fig2.1)
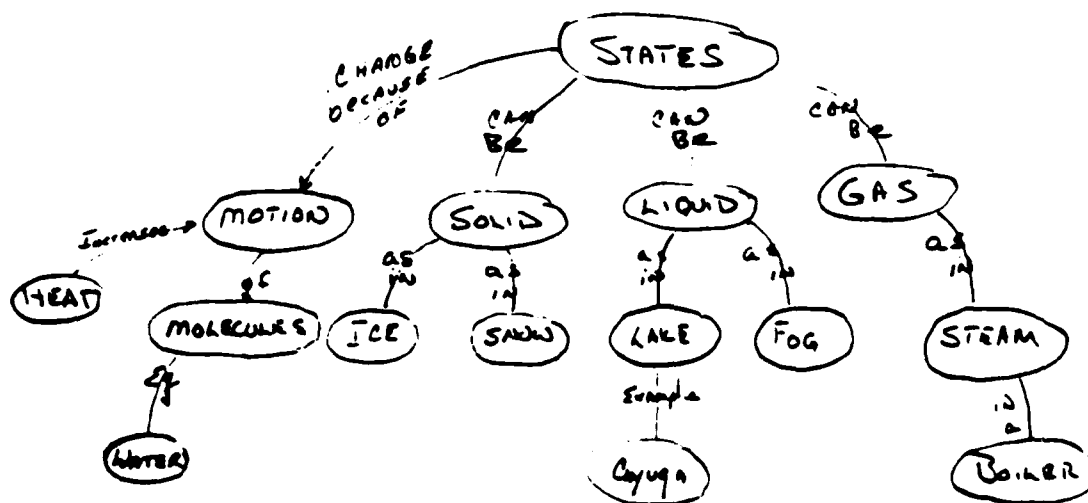
Figure 3-2. A concept map for states showing the 'Rubber
Sheet' effect.

3.12 <u>Knowledge Representation Systems</u>.

There are several knowledge representation schemes
derived by artificial intelligence research. These
include such tools as Semantic Networks, Extended Semantic
Hierarchical models, Entity-Relationships models, Object-
Attribute-Value triplets, Rules, Frames, and Logical
Expressions. Each of these tools have various advantages
and disadvantages depending on the user's needs. Below
is a brief description of each of these methods.

<u>Semantic Networks</u> - 'A semantic network is a collection
of objects called nodes. The nodes are connected together
by arcs or links. Ordinarily the nodes and links are
labeled.' (Harmon, 1985:35) The main advantage of this
method is its flexibility and ability to inherit meaning
from the relationships. Semantic nets are similar to
concept maps.

<u>Extended Semantic Hierarchical Models</u> - 'The Semantic
Hierarchical Model (SHM+) is an example of a data model
based on semantic networks. SHM+ uses the abstraction
concept to form a hierarchical network.' (Handgraaf,
1986:39)

<u>Entity-Relationship models</u> - Peter Chen defines
an entity as 'a thing which can be distinctly identified'
(Handgraaf, 1986:21). He goes on to define the relation-
ship as 'an association among entities' (Handgraff,
1986:21). A relationship can have many entities associated

49

with it. 'Works for' is a relationship of employees
to an employer. In that example there are many entities
in employees but only one in employer. 'The 'role'
of an entity in a relationship is a function that it
performs in the relationship' (Handgraaf, 1986:21).
The Entity- Relationship model is an excellent tool
for designing databases, but lacks the hierarchical
and inheritance functions found in SHM+.

Object-Attribute-Value triplets - Objects are either
physical or conceptual entities. Attributes include
the general characteristics or properties associated
with the entity. The value member of the triplet specifies
the specific nature of the attribute in a particular
situation. (Harmon, 1985:38)

Rules - 'Rules are used to represent relationships
and can be used with many knowledge representation schemes.
One of the basic structures of rules follows an 'if
then' format. Given a premise has occurred or is true
then a conclusion is presented. (Harmon, 1985:42-43)

Frames - 'A frame is a description of an object
that contains slots for all of the information associated
with the object.' (Harmon, 1985:44) Frames can hold
both declarative and procedural representation of facts.
These are two different strategies that aid in building
and using relationships between entities.

Logical Expression - There are a variety of logical

systems. Harmon and King summarize both Propositional Logic and Predicate Calculus. Again these system establish relationships between entities or objects through assertions. Thus the assertion must be established as either true or false.

All of these are schemes attempted to translate meaning or understanding by using a variety of forms. No one scheme is right nor wrong. Each scheme has its specific area where it works better than another. But, the key question is: Do they depict the relationships between entities and translate that meaning? `Any meaning representation system, either human or mechanical, must make explicit exactly what the relationships between concepts underlying a verb are.` (Schank, 1984:98)

3.13 <u>Differences between Concept Mapping and other Schemes</u>:

The technique of concept mapping is different and unique from knowledge representation systems in three ways:

1) The first difference is the goals of the systems. Concept mapping is a knowledge acquisition method. Its main goal is to capture the understanding an expert has about a problem. The acquisition process includes both the conceptualization (the individual's perception of the problem space) and solution or decision process of the problem. The other systems described are knowledge

representation systems. The knowledge representation
system is an encoding process of facts and relationships.
The 'process' of extracting knowledge from an expert
is called 'knowledge acquisition', whereas the 'procedure'
of encoding it in a program is called 'knowledge represent-
ation' and techniques to use this knowledge are called
'knowledge manipulation and retrieval'
(Yasdi, 1985:12).

2) The second difference between concept mapping
and these other schemes is the purpose of the methods.
Concept mapping's main purpose is to capture an individual's
understanding of a domain and then translate or negotiate
the meaning with another individual. The knowledge
representation systems are designed specifically for
relating meaning so machines can operate on the relationships
and conclude the same results as the human mind. There
is a difference in these operations of translating meaning.
That difference is locked in the understanding of the
concept 'understand'.

The basic idea in understanding, whether by computer
or by people, is first to figure out what concepts are
being communicated and then to use those concepts to
help in figuring out what else might be the case. Once
we know there was a 'giving' action we know that there
was a 'taking' and a 'receiving'; we know that there
was an object and that someone now has it and will probably

use it for whatever it is normally used for. Ascertaining
this kind of information is what understanding is all
about` (Schank, 1984:99).

3) The third difference lies in the abilities
of the systems. To properly capture the knowledge of
an expert, the tool must be able to reflect the cognitive
and affective functions of the mind. The tool must
be able to give multiple meanings and describe feelings
when necessary. All but concept mapping, SHM+, and
some semantic networks, are rather rigid in their structure.
They are not flexible. Therefore, it is less convenient
to represent multiple meanings between entities.

Handgraaf refers to the flexibility of a conceptual
model as semantic relativism. `Semantic relativism
refers to the ability of the user to dynamically change
the way data and relationships are viewed within an
application. If a model is to successfully move into
the realm of conceptual modeling, it should not restrict
the user to one view or another` (Handgraaf, 1986:17).
This flexibility function will also be described later
as two separate functions called `progressive differenti-
ation` and `integrative reconciliation`. Concept mapping
has the function of `rubber sheet` that gives it the
flexibility necessary to view concepts in different
meaningful relationships.

Gowin points to the need for cognitive modeling

to describe feelings. Cognitive processes and memory
recall are tied to previous feelings or emotions. For
example, if a person thinks of a birthday party feelings
of joy, excitement, or anxiety may accompany the memories.
To capture the true relationship among a group of entities,
the emotions they invoke must also be captured. These
new 'cognitive science' models fail to connect thinking
with feeling, partly because the computer metaphor on
which they are based does not involve feelings' (Gowin,
1982:1.8). Handgraaf also points out the importance
for concept models to capture the behavioral aspects.

The definitions presented below define concept
mapping with respect to its application in the problem
definition process and its goals, purposes, and function-
ality described above.

A Concept Map is a tool of knowledge acquisition
that translates and negotiates meanings between individuals.

Concept Mapping is the process of knowledge acquisi-
tion that captures an expert's conceptual structure
of a problem.

3.20 The Supporting Theory of Concept Mapping.

This discussion presents three basic theories of
the human mind and how it stores and retrieves information.
Each of these theories are very similar, yet come from
three different fields of study. All the theories lay

54

the same basic foundation for concept mapping. The
first discussion describes the current theory of how
the mind physically works using the 'Knowledge-line
or K-line' idea. Cognitive psychology offers the schema
theory and shows its application to learning. The third
discussion presents Ausubel's theory of cognitive learning.
Following these descriptions are several views and obser-
vations on conceptual structure. All of these theories
and views combine to show the functions of the human
mind. Based on this understanding of the mind, concept
mapping is introduced as a means to capture (acquire)
the knowledge in the human mind in an efficient and
effective manner.

3.21 Theory of Memory - Knowledge-Lines:

Minsky proposes the theory of 'The Knowledge-line
or K-line' as a theory of memory. 'Whenever you 'get
a good idea' solve a problem, or have a memorable experience,
you activate a K-line to 'represent it'. A K-line is
a wire like structure that attaches itself to whichever
mental agents are active when you solve a problem or
have a good idea.' (Minsky, 1986:82)

Kenneth Haase, a student at the MIT artificial
intelligence laboratory, gives an interesting analogy
of K-lines. In the following story, he redefines the
K-line in terms of colors and demonstrates their function.

'You want to repair a bicycle. Before
you start, smear your hands with red paint.
Then every tool you need to use will end up
with red marks on it. When you're done, just
remember that red means 'good for fixing bicycles.'
Next time you fix a bicycle, you can save
time by taking out all the red-marked tools
in advance.'
'If you use different colors for different
jobs, some tool will end up marked with several
colors. That is, each agent can become attached
to many different K-lines. Later, when there's
a job to do, just activate the proper K-line
for that kind of job, and all the tools used
in the past for similar jobs will automatically
become available.' (Minsky, 1986:82)

Based on K-line theory, human minds are filled
with chunks of agents that are connected by the same
K-line. When humans remember, the K-line reactivates
the connected agents and creates the idea. If the agents
were a solution to a problem and a similar problem is
encountered, then agents of the first problem may be
activated as possible solutions to the new problem.
The ideal performance of the mind would then select
the most appropriate agents necessary to solve the problem.
This results in establishing new K-lines for the second
problem, and tying agents to more than one K-line.

The K-line concept is expanded by the 'Level-band'
theory. This is basically the way the mind links agents
at different levels of strength. 'We learn by attaching
agents to K-lines, but we don't attach them all with
equal firmness. Instead, we make stronger connections
at a certain level of detail, but we make weaker connec-

tions to higher and lower levels. A K-line for a kite
might include properties like these:
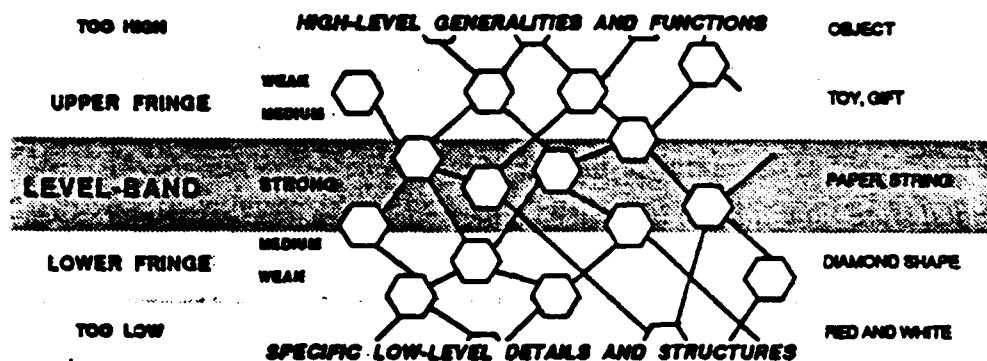
Figure 3-3. (Minsky, 1986:86)

Another expansion of the K-line theory is the idea
of `level`. The level is a way that the level-band
idea can describe the details within the memory. `The
concept of a level-band can be applied not only to
descriptions of things, but also to our memories of
the processes and activities we use in order to achieve
our goals - that is, the mental states we re-create
that once solved problems in the past. The problems
we have to solve change with time, so we must adapt
our old memories to our present goals` (Minsky, 1986:87).
`Level-band` with the added idea of `levels` transforms
a way of describing things into a way of using them
to do things.

Minsky shows the idea of level relates to the many

ways a human thinks. He goes on with the discussions
by examining the fringes of the levels. If the level
of detail about an object is too detailed (lower-band),
then it will prove to be too difficult to relate the
ideas to new situations. Consequently, if the level
of detail is too lax (upper-band) then the goals will
not be within reach of the situation.

K-line attached to many agents.   K-line attached to three K-lines.
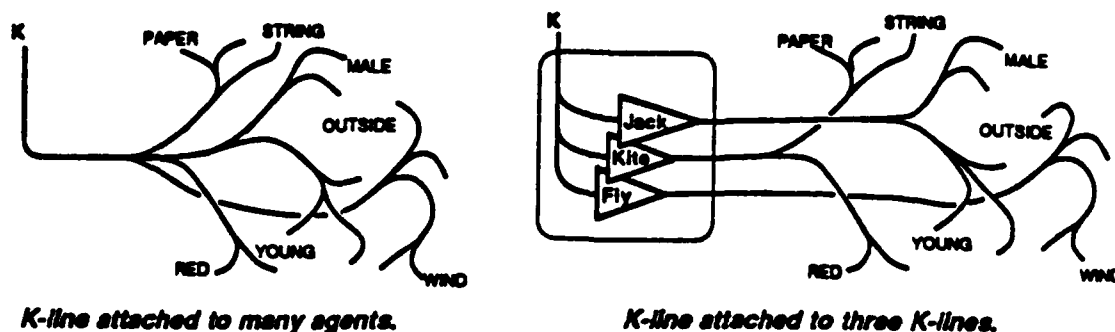
Figure 3-4. K-Line Attachments. (Minsky, 1986:89)

Another function of K-lines is their ability to
tie to other K-lines. (See figure 3-4b) This saves
the mind from having to connect K-line to all pertinent
agents. But there is a cost in making these connections.
'Our trick of connecting new K-lines to old ones will
not recapture so many of the scene's precise, perceptual
details. Instead, the kinds of mental states that this
'hierarchal' type of memory produces will be based more
on stereotypes and default assumptions that on actual
perceptions. Specifically, you will tend to remember

58

only what you recognized at the time. So something

is lost - but there's a gain in exchange. These 'K-line

memory-trees' (see figure 3-5) looses certain kinds

of details, but they retain more traces of the origins

of our ideas. ...the structured memories will be much

more easily adapted to new situations.' (Minsky, 1986:89)
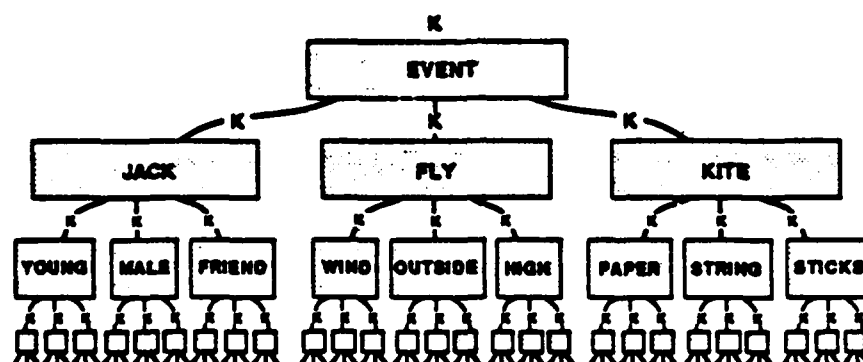
Figure 3-5. Memory Trees. (Minsky, 1986:90)

One last idea proposed by the level-band idea is

the way humans manage the levels. This management can

be thought of as organizing ideas. Figure 3-6 shows

two ways to organize the objects bird and plane. Note

that both hierarchies represent the links between the

things. Neither knowledge-tree is more correct than

the other. They are just two representations of managing

ideas.
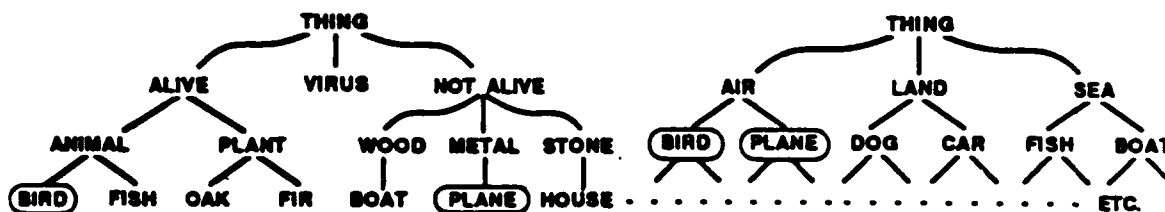
Figure 3-6.   (Minsky, 1986:91)

As an individual learns, three things occur: 1) The mind's Knowledge-trees become more detailed by tying more agents to various K-lines. These complex trees becomes a "society". 2) More knowledge-trees are created and stored by the mind. 3) With more trees and more details, more K-lines inter-connect the societies. This becomes the ultimate in learning theory. The better an individual creates and links the societies the more capability he will have to solve problem and recall descriptions.

3.22 Schema Theory:

The basic hypothesis underlying schema is that "changes in the knowledge base can produce sophisticated cognitive performance" (Glasser, 1984:97).

This hypothesis initiated many research efforts. From several studies comes the recommendation that "an

important focus for understanding expert thinking and problem solving is investigation of the characteristics and influence of organized knowledge structures acquired over long periods of learning and experience" (Glasser, 1984:98). This recommendation was also made by Minsky and Papert. In the mid 70's, the emphasis of artificial intelligence changed from a power-based strategy of thinking to a knowledge-based strategy. This change was supported by the theory that intelligence was a function of knowledge organization. "A very intelligent person might be that way because of specific local features of his knowledge organizing rather than because of global qualities of his thinking" (Glasser, 1984:98).

Schema theory is based on the idea that the human mind stores knowledge in structures. If the mind does store knowledge in this manner, then there ought to be ways to determine the organizational patterns and represent them to other individuals. "Schema theory attempts to describe how acquired knowledge is organized and represented and how such cognitive structures facilitate the use of knowledge in particular ways.

A schema is conceived of as a modifiable information structure that represents generic concepts stored in memory. Schemata represent knowledge that we experience interrelationships between objects, situations, events, and sequences of events that normally occur. In this

sense, schemata are prototypes in memory of frequently experienced situations that individuals use to interpret instances of related knowledge" (Glasser 1984:100).

Using the schema theory, educational researchers have applied the ideas to learning and teaching. To apply this theory to teaching required the development of several important teaching principles. First, one must understand an individual's current state of knowledge in a domain related to the subject matter to be learned, and within which thinking skills are to be exercised. Second, a 'pedagogical theory' can be specified by the teacher that is different from, but close to, the theory held by the learner. Then third, in the context of this pedagogical theory, students can test, evaluate, and modify their current theory so that some resolution between the two is arrived at" (Glasser 1984:101).

The basic pedagogy for schema is to develop lessons and experiences which enable learners to build, test, modify, and retest these cognitive structures. This process relys very heavily on the ability to capture the student's structure. Thus, learning, or knowledge acquisition, is the development of these structures in the human mind.

3.23 Ausubel's Theory of education

The two previous theories set the scene for a discussion

of Ausubel's theory of cognitive learning. Based on
similar understandings of the human mind proposed by
Minsky and Glasser, Ausubel developed the cognitive
theory of learning. There are five major components
to this theory and all are listed in figure 3-7.

3.24 Supporting Points of View:

The above description of how the human stores
information is supported by an observation of Roger
Schank who is working in the artificial intelligence
field. He is explaining the idea that concepts must
be linked to previous knowledge. 'We understand what
we read by adding it to what we already know; a new
meaning is always a product of a previous meaning.
Understanding a sentence involves all the knowledge
we have so far acquired about what goes on in the world.
The more knowledge we have about the world, the more
experiences we have had, the better equipped we are
to find possible meanings for whatever sentence, paragraph,
poem, or story might come our way. Language is not
in itself knowledge, but it is a medium for expressing
and organizing what we think we know, which is really
only what we believe or feel at a given time. When
we are saying to ourselves, 'whoever wrote this sentence
has some knowledge and this sentence must be his or

Ausubel's Cognitive Theory of Learning

Key Concepts

Meaningful Learning
A learner consciously and deliberately links new
knowledge with relevant concepts s/he already knows.

Rote Learning
That which occurs when a learner makes no deliberate
effort to relate new knowledge to concepts the learner
already has.

Hierarchically Organized
Cognitive structures have more inclusive, more general
concepts an prepositions superordinate to less inclusive,
more specific concepts and propositions.

Progressive Differentiation
Concepts in cognitive structures undergo `progressive
differentiation` wherein greater inclusiveness and greater
specificity of regularities in objects or events are
discerned and more propositional linkages with other
related concepts are recognized.

Integrative Reconciliation
This occurs when two or more concepts are recognized
as relatable in new propositional meanings and/or conflicting
meanings of concepts resolved.

Figure 3-7. Ausubel's Key Concepts. (Gowin, 1982)

her attempt to communicate this knowledge' ` (Shank,

1984:17).

Shank's second observation deals with the definition

of events or objects. He looks at concepts as linked

by action verbs. Using this definition each concept

gains it's identity by the combination of actions used

to describe it.

"We tend to see the world in terms of the events
that take place in it. These events usually involve one
or more actions, which we describe using the many verbs
in our language. We can think of concepts which don't involve
actions, such as a fine spring day, or a rock, or a fire
hydrant. It's easy to say that a rock doesn't perform actions
because it just sits there and doesn't move. But we have
to stop and remember that the descriptions 'just sitting
there' and 'not moving' both refer to actions.

It is extremely difficult to describe an event without
describing actions as well. We can say the words 'rock'
and 'fire hydrant'. But somehow the word 'rock ' itself
doesn't tell us much about rocks. We have to use other
words. A fire hydrant means the set of actions that are
called up when there is a fire. It refers, in an implicit
way, to the need to stop fires from destroying objects by
soaking those objects with water. If we want to describe
a fire hydrant in a useful way, we must do so almost entirely
in terms of actions. What can one do with a fire hydrant?
What comes out of a fire hydrant? What's it made of? What's
a fire? The actions involved in the concept of a fire hydrant
are discrete and unique in that they differ from those involved
in the concept of a telephone or and electric drill." (Shank,
1984:98)

Another observation about the function of the mind
comes from professor D.Bob Gowin. As an educational researcher,

determining how the mind functions is key to being able
to develop effective teaching/learning methods. He also
supports these theories as reflected in the following obser-
vations.

'Our minds seem to work 'hierarchically' as a mosaic
of interrelated concepts, but instruction is necessarily
linear in form. We must present knowledge segment A, then
segment B, then segment C and so on. Concept maps can help
us to organize the whole set of concept-propositional relation-
ships we wish to present, but then we must still reduce
this organization to some sequence of topic A, topic B,
topic C, and so on. Concept maps do not specify the exact
sequence for presentation, but they do show hierarchies
of ideas and thus suggest psychologically valid sequences'
(Gowin, 1982:4.4).

3.30 <u>Why Concept Mapping</u>:

3.31 <u>The power of Concept Mapping</u>:

>   Ausubel's Dictum: The most important single
> factor influencing learning is what the learner
> already knows. Ascertain this and teach him accor-
> dingly (Gowin, 1982:12).

In order to get at what the student knows, a tool
or device had to be developed. This tool had to be simple
and functional in ascertaining what the learner knows.
Ausubel presented the idea of cognitive maps. Gowin and

Novak continued this line of reasoning and implemented concept mapping into a variety of teaching arenas. They found concept mapping to be an invaluable tool for determining what a learner knows. "Concept mapping is an educational tool that has been developed specifically to tap into a learner's cognitive structure and to externalize for both the learner and teacher to see 'what the learner already knows'" (Gowin, 1982:12).

Gowin contrasted the benefits of the concept map against the outline. He found two distinct differences. "First, good concept maps show key concepts and propositions in very explicit and concise language. Second, good concept maps are concise and hence show the key ideational relationship in a simple visual fashion" (Gowin, 1982:4.3).

3.32 Applying Concept Mapping to the Problem:

Translating concept mapping from an educational setting to one of problem solving or decision making is not as drastic as it might seem at first. The expert replaces the teacher. The DSS designer becomes the learner. But the concept map taps the cognitive structure of the teacher instead of the learner. This creates a map of the knowledge structure of the expert. It can then be used to translate and negotiate meaning to the DSS designer. Once the DSS designer understands the problem and the process he uses the information to develop the decision aid. The map can also become a record of under-

standing for future reference.

Based on the theories presented by Minsky, Glass
and Ausubel, and the research findings from educational
research efforts, concept maps can depict the expert's knowledge
base. The K-line theory tells us that the knowledge organization
of a problem will be the agents used in defining and solving
it. Schema theory also supports this conjecture when applied
to problem solving. The conclusion is that concept maps
created by the expert capture the key concepts of the problem
and/or the elements of the decision process used by the
expert.

3.33 Reasons for Selecting Concept Mapping:

There is one final question to ask. Is there another
tool that can capture the expert's expertise as effectively
as concept mapping? The only tools available are the knowledge
representation systems discussed above. These are generally
not appropriate because they are representation systems
and not acquisition systems. It is possible to structure
SHM+ into concept mapping format, but an altered SHM+ would
become concept mapping.

The other knowledge representation models have been
used in data base system to show relationships between data
elements. They are very restrictive because of the need
to interact with machines. These models do not have the
built in flexibility and hierarchical functions of concept

mapping. Thus, the process would lose semantic relativism
and ordinate meanings. For these reasons concept mapping
is anticipated to be an ideal tool for capturing knowledge
from an expert.

3.40 Conclusion:

If the expert is really the expert in solving the
problem, then capturing the specific problem's 'agents'
(concepts) and their appropriate 'K-lines' (links) would
capture the definition and decision process elements. With
this twist in its use, concept mapping becomes the basic
tool for acquiring knowledge from an expert.

The next chapter teaches how to do concept mapping
and explains some of the techniques required in holding
a knowledge acquisition interview.

Chapter 4

The Concept Mapping Technique

4.00 Introduction:

Learning the concept mapping technique is just like learning any other skill. The student must start by learning the terms and basic rules to the procedure. Then s/he must practice, practice, and practice some more. The skill of concept mapping has relatively few terms and rules. It is a simple, functional tool that can be applied to a variety of learning or knowledge acquisition requirements.

Concept mapping comes from the field of cognitive education. A teacher who believes in the cognitive structuring phenomena of the mind will use concept mapping to introduce students to new concepts. The technique is relatively new yet it is basic to education. All of the examples in this chapter are from the author's background in applying concept mapping while teaching.

This chapter introduces the skills of concept mapping and conducting the concept mapping interview. The first parts of this chapter follow Gowin's strategy for introducing concept mapping to learners. Figures 4-1 and 4-2 list all the steps in Gowin's strategy. This lesson is in two parts. The first part introduces and defines the terms of concept mapping. The main purpose for this

A. Activities to Prepare for Concept Mapping

1. Make two lists of words on the blackboard or overhead projector using a list of familiar words for objects and another list for events. For example, object words might be: car, dog, chair, tree, cloud, book, and event words could be: raining, playing, washing, thinking, thunder, birthday party. Ask children if they can describe how the two lists differ.

2. Ask the children to describe what they think of when they hear the word car, dog, etc. Help them recognize that even though we use the same words, each of us may think of something a little different. These mental images we have for words are our _concepts_; introduce the word "concept".

3. Repeat activities in #2, using event words. Again, point out the difference we all have in our mental images or _concepts_ of events. You may want to suggest at this point that one reason we have trouble understanding each other sometimes is that our concepts are never quite identical even though we know the same words. Words are labels for concepts, but each of us must acquire our own meanings for words.

4. Now list words such as: are, where, the, is, them, with, etc. Ask children what comes to their minds when they hear each of these words. These are not concept words; we call them _linking_ words and we use these in speaking and writing. Linking words are used together with concept words to construct sentences that have meaning.

5. Proper nouns are not concept words but rather names of _specific_ people, events, places, or objects. Use some examples and help children to see the distinction between labels for _regularities_ in events or objects as contrasted to specific events or objects or proper nouns.

6. Using two concept words on the board and linking words, construct a few short sentences to illustrate how concept words plus linking words are used by humans to convey meaning. Examples would be: The dog is running. There are clouds and thunder, etc.

7. Have the students construct a few short sentences of their own and identify the concept words, tell whether each is an object or event, and also identify the linking words.

8. If you have bilingual children in the class, have them present some foreign words that label the same events or objects. Help the children recognize that language does not make the concept; it only serves as the label we use for the concept. If we learn words but fail to learn what kind of regularity in objects or events the words represent, we have not learned new _concepts_.

9. Introduce some short but unfamiliar words to the class such as: dire, terse, _cynic_. These are words that stand for some concepts they already know, but they have somewhat special meanings. Help the children see that concepts do not have rigid, fixed meanings, but the meanings can grow and change as we learn more.

10. Choose a section of a textbook (one page is sufficient) and duplicate copies for children. Choose a reading passage that conveys a definite message. As a class, ask them to read the passage and identify _key_ concepts. Usually 10 to 20 relevant concepts will be found in a single page of text material. Also have the children note some linking words and concept words that are less important to the "story line".

Figure 4-1. (Gowin, 1982:Table 2.3)

71

a. Concept Mapping Activities

1. Select a particularly meaningful paragraph or two from a text or other printed material. Have the students read the text and select the "key concepts," that is those concepts necessary for understanding the meaning of the text. List these concepts on the board (or overhead projector) as they are identified. Now discuss with the students which concept is the most important, most inclusive idea in the text.

2. Put the "most inclusive" concept at the head of a new list of "rank ordered" concept. List the next "most general","most inclusive concept," working through the first list until all concepts are "rank ordered." There will not always be agreement among the students on the ordering but usually only a few major differences in ranking of the concepts arise, and this is OK; it suggests that there may be more than one way to see the meaning of the text selection.

3. Now begin constructing a concept map, using the rank ordered list as a guide in building the concept hierarchy. Have students help in choosing good linking words to form the propositions shown by the lines on the map. One good way to practice map making is to have students write concept words and linking words on paper rectangles, and then they can rearrange these as they get new insights on the map organization. (See figure 2.9.)

4. Now look for "crosslinks" between concepts in one section of the map and concepts in another part of the concept "tree." Have students help to choose linking words for the cross links.

5. Most "first effort" maps have poor symmetry or some concept clusters, poorly located relative to other more closely related concepts or clusters of concepts. Reconstruct the map if this would be helpful. Point out to students that at least one and sometimes two or three reconstructions of a map are needed to show a good representation of propositional meanings as they understand them.

6. Discuss the concept map scoring criteria in Table 2.4 and "score" the concept map constructed. Point out possible structural changes that might improve the meaning of the map, and perhaps the map's score.

7. Have the student select a section of text or other material and repeat on their own (or in groups of 2 or 3) steps 1-6.

8. Student constructed maps can be presented to the class on the blackboard or overhead projector. By "reading" the map, it should be clear to other students in the class what the text section was about.

9. Have students construct a concept map for ideas important in a hobby, sport, or special interest area they have. These might be posted around the room and informal discussion encouraged.

10. Incorporate one or two concept mapping "questions" in your next test to illustrate that concept mapping is a valid evaluation procedure that demands hard thinking and can illustrate understanding of the subject matter.

Figure 4-2. (Gowin, 1982:Table 2.3)

72

lesson is to prepare the learner for the actual concept

mapping activity. The second lesson steps a student

through his/her first concept map. After this brief

introduction to concept mapping, the student is encouraged

to practice as much as possible.

Once the student has mastered concept mapping s/he

is ready for the interviewing session. The remainder

of the chapter explains the process used to concept

map the problem definition and decision process. Several

suggestions and rules-of-thumb are given. These sugges-

tions are based on personal experiences of over 100

hours of interviews and literature reviews of the inter-

viewing process. This portion of the chapter is not

in a lesson format, but will perform as teaching forum.

4.10 Learning How to Concept Map:

The following sections introduce the two lesson

plans. These lesson plans are generically designed

for any person interested in learning the skill.

4.11 Preparing for Concept Mapping:

Attachment A is a self-paced lesson plan for any

student wanting to learn the basics of concept mapping.

Lesson A introduces the student to the following terms:

Objects	Events	Concepts
Linking Words		Key Concepts

4.12 Concept Mapping Activities:

A student who wants to learn how to construct a
concept map should follow the activities outlined in
figure 4-2. This lesson is designed to introduce the
student to the art of making concept maps. However,
to become proficient the student must practice and perform
the steps on his own. To gain the maximum benefit from
this sequence of lessons, complete the lessons in order
and then practice at every opportunity. A good practice
scheme is to concept map class lectures give by a teacher.

4.20 The Concept Mapping Interview:

The interview is a face-to-face meeting with the
expert. Its goal is to capture the expert's understanding
of the problem and his key decision elements. The interview
is the most significant part of the entire DSS design
process because the information and perceptions gained
by the designer will be reflected in the final product.

The concept mapping interview is a process with
three distinct and separate steps. The first step is
scheduling the interviews. Choosing the expert, informing
the expert about your needs, goals, and methods, and
making the appointments takes only a little effort but
pays big dividends. The second step is setting up the
environment for the interview. The expert and interviewer
both need to be able to communicate freely and comfortably.

The last step in the process is managing the interview.
This section is designed specifically for the DSS designer
who will be using the concept mapping technique in defining
the problem and identifying kernels of the decision
process.

4.21 Scheduling the Interview:

The most important part of scheduling the interview
is identifying and choosing the problem solver. Although
you may take on the role of problem solver, in most
cases this task will be handled by another individual:
someone who by experience or position has the unique
knowledge necessary to solve the problem or make the
decision. This person is the primary user that the
DSS is intended for. This is an "expert". An expert
is one of only a few persons who has special or unique
knowledge. "By an expert we usually mean a person who
knows how to define problems and solve them. He knows
what facts or data to collect and investigate, he knows
what rules to use, and he knows how to make inferences"
(Yasdi, 1985:12).

Selecting this person requires an evaluation.
First, learn as much as possible about the problem itself.
Are there people currently solving this or similar problems?
If so, who is considered the best at solving the problem?
Next make a list of possible experts in the problem

domain. Then evaluate the list. Here are some criteria
that may be used in evaluating the list of experts.

1) Who do you as the DSS designer have access to?

2) What are the costs involved?

. (e.g. Travel, Consultation Fees, etc.)

3) What are the available resources?

Once the experts have been selected, they need
to be prepared for the interview. To prepare the expert
for the concept mapping interview, hold a meeting with
all of the experts at one time, if possible. At this
meeting brief the experts on the problem that you are
facing in trying to capture the definition of the problem
and identification of the decision process. Inform
the experts on the needs, goals and methods used in
the upcoming interview. This meeting sets the stage.
It gives the purpose for the interview and tells the
expert what role s/he is to play.

The experts are better able to organize and communicate
their cognitive structures on a subject if they know
exactly what is needed and what are the goals. Experts
need to know a variety of different types of information.
Some of the questions to be answered for the expert
in this briefing are:

1) What kind of information is being sought?

2) Which problem space are they to concentrate on?

3) What is the process being used in the interview?

4)   How much time is needed from each of them?

5)   What is the information going to be used for?

Answering these questions before attempting the interview concentrates the efforts of the expert on the problem rather than on the process.

This initial briefing also saves time. As Eden points out the first interviews rarely have content. He cites the time is taken in pleasantries, spouting 'motherhood', other general things, finding out 'What the hell's going on round here', etc. (Eden, 1985:812).

To illustrate this point, all of the RAAP experts were briefed on the purpose and process of the interviews. After introductions they were shown the basics of the concept mapping technique. This was just a general overview of the terms and an example of how a concept map is built. Once they felt reasonably comfortable with the process, they were asked to concentrate on their definition of RAAP and what they perceive the decision process to be. Finally, they were told what the maps would be used for. They were now ready to be interviewed.

The last thing to do at this initial briefing is make the appointments. The time available and the desired extent of detail in the maps, determines the number of interview appointments made with each expert.

Generally, three one-on-one interviews are best.
Make individual appointments with each of the experts.
Do not attempt to interview two or more experts at the
same time. Experience has shown that one of the experts
will do the majority of the talking while the other
just agrees. Interviewing two or more experts at the
same time does not capture the multiple understandings
that each has.

The first two interviews need to be relatively
close together in time. The first concentrates on the
definition of the problem while the second captures
the elements of the decision process.

The third interview session should have a considerable
separation in time from the first sessions. A good
separation would be anywhere from two to six weeks.
A shorter separation doesn't allow the expert's perceptions
to change very much. Separations longer than six weeks
generally are not suitable for either the expert or
the project. This separation enables the expert to
further think about the problem. As has been observed
in other concept mapping exercises, people change their
minds. Perceptions change because new experiences alter
old cognitive structures. This is the natural process
of learning at work. There is more discussion about
the benefits associated with changes in perception in
Chapter 5.

The purpose of the third interview is to review
the maps that were constructed in the previous sessions.
The expert is given complete freedom to check over the
map and ensure that it still reflects his perception
of the issue. If s/he has changed his/her view of the
problem create the new or changed portion(s) of the
concept map. Then, have the expert tie the new clusters
to the old maps.

Each of the above interviews takes about an hour.
This is about the limit any expert or interviewer will
be able to fully concentrate. If the time resource
requires back-to-back interviews, breaks are a necessity.

Interviewers have limits. It is advised to schedule
no more than four to six interviews per day. This is
also recommended by Gowin; "four to six per day is all
that most people can handle and continue to be alert,
pleasant and thorough" (Gowin, 1982:7-13).

4.22 <u>Setting-up the Interviewing Environment</u>:

The preparation of the room and keeping records
is as important as preparing the expert for the interview.
Eden insists on a particular room set up for his style
of cognitive mapping. In his review of a session evaluating
the problems of a publishing company, he cites one of
the nagging problems of a poor environment.

"The day was disappointing. The hotel provided

rooms that were cluttered with formal furniture. We
had requested three rooms in which eight people could
work in cramped conditions. The furniture was to be
easy chairs. What we finished up with were three rooms
of vastly different sizes-all too big, and with walls
cluttered with wall lights and fixed pictures. ... Because
the environment was not as intended, it took me longer
to generate the right atmosphere than would have otherwise
been the case" (Eden 1985:810).

Following are a few of the rules-of-thumb for setting
up the interviewing room for concept mapping:

1) Select a room where you and the expert can work
the entire session without interruption and limited
background noise. Heat, light and ventilation are just
as important as noise in considering the room.

2) Obtain a chalkboard or dry marker board. If
these are not available use flip chart paper and suitable
markers.

3) Record the interviews. Audio tape is relatively
cheap, easy to manage, and gives a record of the interview
in complete detail.

4) Operate the recording machines with as little
interruption as possible. (i.e. Use 120 minute cassette
tapes.)

5) Obtain comfortable chair(s) and a table.

4.23 The Interview:

The interview is critical. Conducted and managed
properly, the one hour session can return a bounty of
information. The remainder of this discussion is a
potpourri of suggestions and rules-of-thumb. Figure
4-3 lists some issues to consider while conducting an
interview. Even though the issues listed in figure
4-3 are for conducting a clinical interview for educational
research, many of them directly apply.

To acquire the most information from the expert,
plan the interview. Establish the purpose for the interview
and choose appropriate lead-off questions for each main
topic. If the interview is to capture the decision
process, ask a lead-off question that directs the expert s
thinking towards the decision process. For example,
the lead-off question may be: How would you solve this
problem?

It is also important to prepare some follow-up questions.
However, don't fall into the trap of `having to ask
all the questions on my list` syndrome. This becomes
boring for the expert and may reduce his openness toward
the interview.

WAIT! After asking a question, especially a lead-off
question, wait. Studies show that teachers seldom wait
longer than 2 seconds after asking a question before
they either answer it themselves or restate the question.

Issues of Interviewing

1. Interviewing should not be Socratic Teaching Method.

2. Interviewers must be thoroughly familiar with the subject matter.

3. Personality factor are important.

4. LISTEN to the student.

5. Wait for an answer!

6. Be cordial.

7. Head off dialogue on irrelevant discussion.

8. "I don't know" or "I forgot" answers seldom mean what the response indicates.

9. Students vary widely in loquaciousness.

10. Statements revealing feelings are significant.

11. In sequential interviews, it can be helpful to refer to prior interviews and/or relevant intervening instructions.

12. Use the student's language when rephrasing questions or probing further.

13. Do not force your logic on the student.

14. End the interview on a positive note.

Figure 4-3. Issues of Interviewing
(Gowin, 1982:13-18)

Therefore the interviewer must be extremely cautious

not to rush the expert. It is going to take the expert

some time to recall the information and organize it

in a manner that s/he can communicate it. Remember,

you're asking an expert to do one of the most complex

82

exercises for the mind to accomplish. Give him/her
time to respond.

LISTEN! After waiting for the response, make sure
you listen and understand what the expert is saying.

Don't be afraid to rephrase the expert's statements,
especially if you don't see the tying relationships
or understand the terms. He is the expert and you are
the learner. If a concept can have more than one name
or label agree on the best label as the interview progres-
ses. Much of the time, more than one label can be used
to represent a concept. Choose one and maintain it
throughout the interview unless it is no-longer the
agreed label.

As the expert starts to give the information, draw
the concept map on the board. Putting the maps on the
board allows both the expert and the interviewer to
see the map and discuss the concepts together.

Write FAST! Don't let the expert think he has
to wait on you. Encourage him to talk at a normal rate.
Remember you're mapping only the key concepts.

Don't worry about the clutter or neatness of the
map as you initially build it. There will be plenty
of time after the interview to 'clean it up'.

Use either circles or rectangles to identify the
concepts. Draw in the lines or arcs and pointers.
label each arc with the appropriate linking words.

use the expert s terms as much as possible. Go ahead
and develop clusters of maps, if that is the way the
expert is giving the information. The relationships
tying these clusters together will come out eventually.
If the relationships don t come out or you re not sure
of the relationships, ask for the relationships between
clusters during a lull in the action.

Your attitude will be reflected by the expert.
Be pleasant and positive. Show genuine interest in
the expert and his thoughts. Don t argue with nor interrupt
the expert. Negative or adversary types of actions
will discourage the expert and cause him/her to loose
his/her train of thought.

Follow the expert's train of thought. Let him
guide the flow through his knowledge. This doesn t
mean let him aimlessly meander through side issues and
other problems. Give him/her enough guidance to keep
on track, but also freedom to relate it in his/her own
manner.

Continuously use the map as a review of the problem.
Read aloud the concepts and their relationships for
the expert. Make sure s/he agrees that the map says
what s/he perceives to be correct. If it doesn't, then
change it.

If portions of the map don't seem complete, query
the expert. It may be that a portion of the information

is unclear in the expert's mind too.

After the interview, copy down the concept maps
that were drawn on the board. Don't leave out any of
the details. However, cleaning them up, correcting
spelling and reducing clutter will make it easier to
read later on. Taking a photograph of the board may
be useful and save time but is not a necessity.

4.30 Conclusion:

This chapter presented three lessons to learn,
all of which were designed to prepare an individual
to begin concept mapping on their own. Parts of the
third lesson were specifically targeted at DSS designers
so they could start applying concept mapping in the
problem definition process. After reading these lessons,
an individual should have a fair understanding of the
concept mapping skill and interviewing technique.

The next chapter shows how and where concept mapping
fits in the problem definition process.

Chapter 5

The Problem Definition Process (PDP)

5.00 Introduction:

This chapter outlines a process developed for the
adaptive design phases of DSS construction called Problem
Definition Process (PDP). The PDP is a strategy for
determining the initial and iterative design requirements
of a DSS.

The following discussion centers around two main
points. The first point discussed deals with the question
of need. Several reasons are presented which support
the need for a PDP strategy in the adaptive design method
of DSS development.

The second point of discussion addresses the PDP
itself. Each of the many steps of the PDP is briefly
explained. The roles of the concept mapping technique,
storyboards, feature charts and the iterative nature
of the PDP are emphasized in this discussion.

5.10 Adaptive Design:

A DSS's basic purpose is to support decision makers
when they are faced with semistructured and unstructured
problems. Decision makers find these types of problems
to be the greatest challenges because of limitations
in the mind. Humans do their best in structured situations.

The theories presented earlier show how the mind stores information (facts and concepts) in cognitive structures and levels of conceptualization. Links connect the various levels and concepts. Because of the mind's make-up, structured problems are more easily captured and processed. Once properly stored in the mind, cognitive processes activate and the problem is solved.

Semi- and un-structured problems are not easily captured by the cognitive structures of the mind. Consequently, the cognitive processes and sequences that solve problems do not work as well. The inability of the mind to process the information creates a greater need for external aids such as a DSS.

Since these problems are difficult for humans to store in cognitive structures and develop a sequence of cognitive processes for solving, they are even more difficult for humans to describe. The description of the problem as perceived by the decision maker and his understanding of the solution process is needed so the DSS supports his style of decision making. This description lists all the details involved in setting the requirements for the systems.

Sprague and Alavi both point out the fact that, due to the nature of the problem types, traditional methods of system development are not possible. For example, in the 'life cycle' method, the total system

requirements must be determined prior to the start of
the design and development. This can and has been done
for a variety of systems, but each of these problems
were structured and easily defined. This approach isn't
feasible in DSS design. DSS designers literally 'cannot
get to first base' because the decision maker or user
cannot define the functional requirements of the system
(Alavi, 1984:65). Sprague cites two reasons for this
inability for users to describe the decision process.
First, a single, comprehensive theory of decision making
does not exist. Second, decision makers face rapidly
changing conditions in the problem environment (Sprague,
1980:16).

The DSS must be developed in stages or iterations.
This means the DSS literally evolves into the system
the user wants. The evolution of the DSS relies on
three elements: the user, the builder, and the DSS.
The following is a simplistic recipe for building a
DSS. An initial problem definition and system design
are described and developed. The system design is
evaluated. The user provides feedback and alterations
are made depending on the current decision environment,
perception of the decision maker and new technological
capabilities. The iterative nature of the development
allows the DSS to incorporate the most current understanding
from the user and provide the specific support s/he

needs. The cycle of iterations is very rapid and may take only minutes to complete an alteration. This development process is called by many names but the most common is 'adaptive design'.

One strength of adaptive design is hidden in the process. Alavi points out the fact that as the user and builder iterate through the development of the DSS, learning takes place. 'The user and designer will 'learn' about the decision task and environment, thereby identifying new and unanticipated functional requirements' (Alavi, 1984:65).

Hogue presents a list of the 'shoulds' that adaptive design strives to produce as a DSS is developed. 'Small tentative systems should be built, used, and modified as needed. The system should reflect the user's decision making style. The user should be an integral member of the development team. The system should be built quickly, using the latest computer hardware and software technology. Development should be in the hands of the user rather than computer design professionals' (Hogue, 1984:77).

5.11 The PDP and the Adaptive Design:

The above discussion points out five characteristics of adaptive design. The characteristics are:

1) Semi- or un-structured problems.

2) Iterative process.

3) User - builder learning.

4) Specifying the user's decision making style.

5) Rapid alteration turn around time.

These characteristics set the requirements for defining a problem space. A problem definition or description is necessary because it establishes the base for the initial DSS design.

The adaptive design approach does not demand a full set of system requirements prior to development of the DSS. However, adaptive design does require an initial understanding of the problem so the iterative process can start. Therefore, a method of capturing the best possible understanding of the problem is necessary. The PDP described below is designed to give the user and builder a starting point for their DSS design. The PDP provides a description of the problem space, including a list of key decision elements, a method of representing the DSS design, and a forum for system evaluation.

The PDP has three key elements. The first element uses concept mapping techniques to describe three phases of the problem. The second element presents a pictorial representation of the DSS so the user and builder can negotiate system requirements. The final element establishes the criteria for judging the DSS design during that

iteration. There are more detailed discussions on these
three elements later.

How does the PDP meet the characteristics of the
adaptive design framework? The first challenge to answer
must be Sprague's reasons for the inability to list
the full set of system requirements before development.
The second challenge is to show that the PDP does meet
the requirements set forth by the DSS characteristics.

The PDP process includes the use of concept mapping
as a capturing tool for the problem definition and ident-
ification of key decision elements. Concept mapping
is based on a theory of structured mental storage and
linking. Various theories describe the cognitive functions
of the mind which include how the mind makes decisions.
(See chapter 3) Thus, the heart of the PDP is based
on an acceptance of a theory of cognitive thinking and
decision making.

Concept mapping also aids in answering Sprague's
second reason. Concept maps capture the current under-
standing of the user. Concept mapping is a process
that is quickly performed and easily interpreted. Because
of the technique's flexibility and rapid construction,
it works very well in a changing environment. Also,
the PDP will iterate as often as the other step in the
adaptive design. Thus, as the user and builder 'learn'
and change their perceptions, the PDP will provide the

vehicle to support the modifications.

The PDP strategy can be applied on the entire range of problems, from structured to unstructured. It captures the best understanding that the user has of the problem. Its only limitation is the user's misconception of the problem which is inherent in a DSS.

The power of concept mapping is enhanced by the variability in the environment. As the user and builder 'learn', these changes in understanding will be expressed in each new iteration of the concept map. The concept maps will also reflect changes due to the decision making environment and task. Concept maps made by multiple users or experts lend additional understanding to the description of the problem space and decision process. Thus both the degree of structure in the problem, and the limitations of the mind to describe are countered within the PDP.

Another characteristic of concept maps fulfills the requirement that a DSS should be based on the decision makers style. Concept mapping captures the user's understanding of the problem and elements of the decision process and translates that meaning to the builder. Since the description is the user's, the DSS designed from that description inherits the user's decision making style.

The PDP itself is an iterative process. Several

of the steps repeat and iterate while producing just one iteration of the design. As the design requirements change, the various steps in the PDP act to incorporate the modifications. Each of the steps are relatively simple, easy to do, and can be readily manipulated. This feature of the process fits in well with the iterative nature of the adaptive design, and the reduction in turn around time for each iteration.

There is one last feature of the PDP that is not a requirement of the adaptive design, but is extremely important to any system design. Each of the three elements of the PDP provides a historical record of the DSS as it is developed. This record can be used in a variety of ways. A DSS design manager could use the information as a cost justification record. Meador claims that managers need cost benefit figures. "Before approving large scale DSS projects most managers need evidence of some concrete benefits to offset development costs" (Meador, 1984:127). By having records of smaller projects, realistic cost comparisons can be made. Another use for the records would be in designing other DSSs from the same problem domain. Information about a DSS built for scheduling aircraft maintenance may be useful to the designer of a DSS that schedules air crew training. These records would give the user and builder a head start on understanding the problem space and elements

of the decision process.

5.20   The Process:

The process that is being proposed is nothing more
than a method of requirements determination. Yadav's
paper surveys the arena of requirements determination.
One of his findings is that a user 'needs a methodology
to carry out the process of information requirements
determination systematically' (Yadav, 1983:5). Yadav
goes on to show that 'the methodology provides a procedure
to understand an organization in order to reduce a possible
incongruence between actual and perceived requirements.
It also provides a tool to help describe organizational
functions in the form of a conceptual model' (Yadav,
1983:6). Figure 5-1 shows a diagram of Yadav's method
of determining the requirements for an information system.

Drawing from the methodologies suggested by researchers
like Yadav, Hira, Davis and the experience gained by
helping other students in designing their DSS projects,
the PDP was developed. The PDP is a tool for developing
the actual design specifications of the prototype DSS
and then aiding its expansion into the full system.
The PDP also doubled as a monitoring device to keep
track of the researcher's progress and as a guide for
the next set of actions.
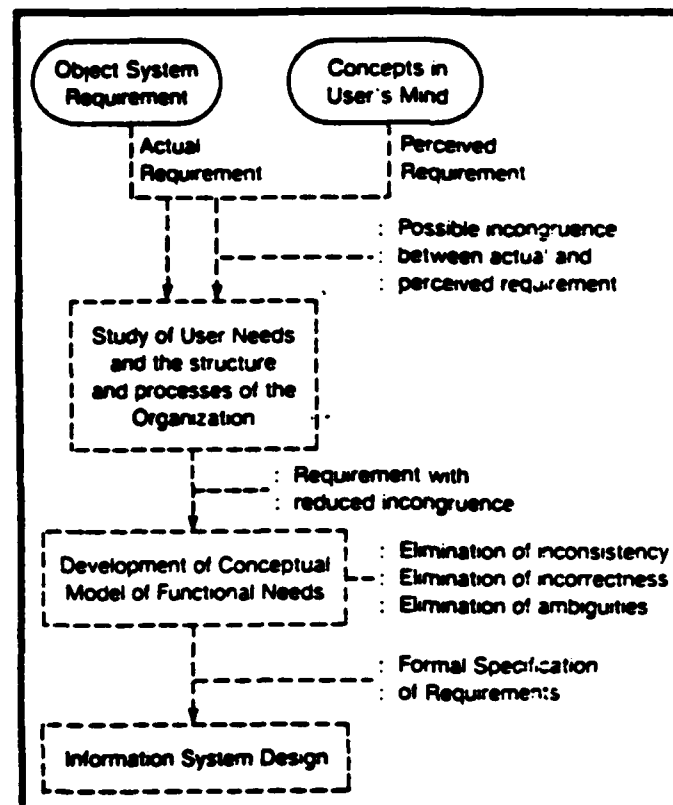
Figure 5-1. User's formal and correct requirement
and the corresponding information system design.
(Yadav, 1983:6)

As mentioned above, there are three key elements
to the PDP. Each step within the elements is explained
below. This is a suggested strategy to use in developing
the design specifications of the DSS from inception
to full operation. This method fits within the iterative
nature of adaptive design and is intended to be iterative
itself.

Davis surveyed the current field of initial requirements determination and identified four strategies. These strategies are: 1) asking, 2) deriving from existing information system, 3) synthesis from characteristics of the utilizing system, and 4) discovering from experimentation with an evolving information system (Davis, 1982:12).

The PDP strategy, as described below, actually incorporates the majority of these strategies. First, the PDP uses concept mapping in the direct asking type of strategy. As Davis points out, asking yields satisfactory results especially in the higher structured problems.

Deriving from existing systems can be easily done with the built-in record keeping function of the concept maps, feature charts, storyboards, and evaluation criteria. As mentioned above, this information will aid future DSS designers working on similar problems, as well as being a teaching aid for new designers.

Adaptive design itself exploits the third and fourth strategies of requirement determination. By rapidly building and modifying the system and using ready built hardware and software, the user and builder create the system requirements with each iteration. Thus, they use the knowledge built into the current technology and the 'learning through experimentation' to delineate the final DSS requirements.

The following discussion explains the steps of

the PDP. Figure 5-2 depicts the steps of the PDP in
a time linear relationship. Generally, the first iteration
will follow this sequence. After the first iteration,
the steps occur in the sequence that the user and builder
decide is most appropriate. As the design team evaluates
various parts of the DSS, they will find needs for changing
the current design. There is nothing wrong with returning
to the problem definition step and progressing through
the entire process. However, most designers will return
to the step in the process that is affected by the change
and make the alterations. This strategy speeds up the
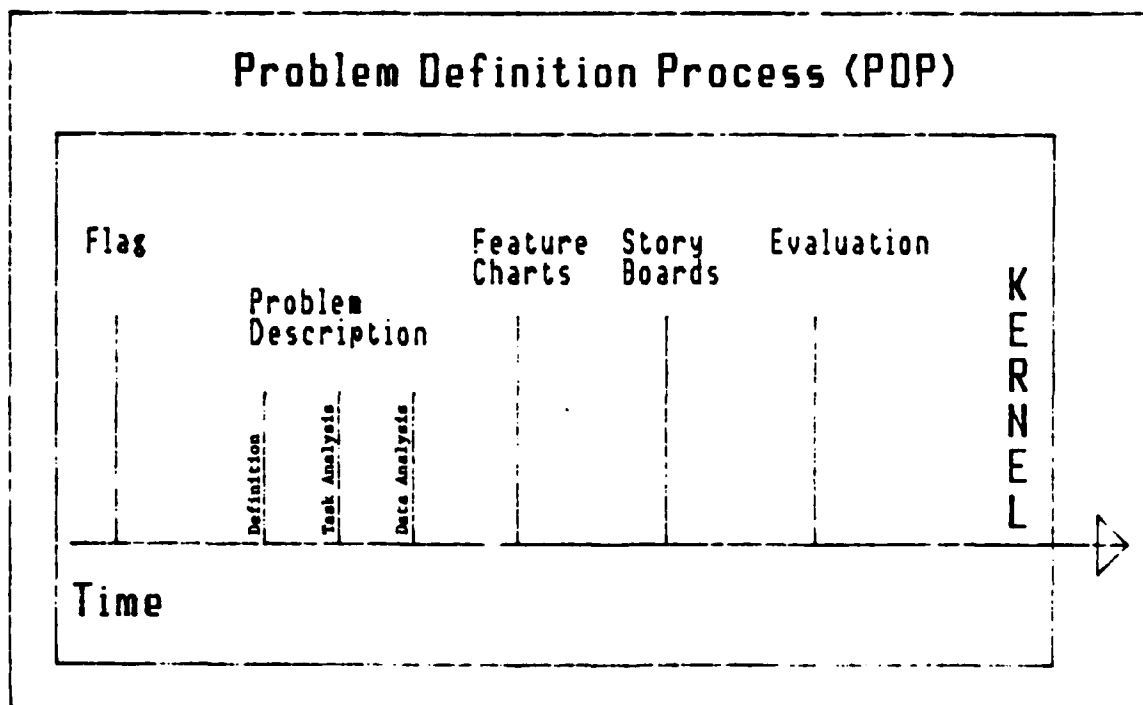iteration and aids the collection of design requirements.

Figure 5-2. The Problem Definition Process (PDP)

97

5.21   The Flag:

The flag is an indicator. It alerts the decision maker to the existence of a problem. Some control mechanism, or gut feeling will raise a signal flag informing the manager that a problem or opportunity exists. The manager may recognize that the problem is suitable for a DSS. Only then can he take action to begin the design and development of a decision support system.

5.22   Problem Description - The Role of Concept Mapping:

The first stage in designing a DSS is to identify the key decision(s). Keen talks about laying out the key decision(s) within the framework of the problem space. "This helps identify which decisions are of most importance for effective performance and, of course, which may benefit from decision support. If one then assesses the quality of informational and analytical aids for each key decision, one can begin to get a sense of potential priorities for more detailed analysis" (Keen, 1978:173).

To identify the key decision, Keen suggests a cycle of steps for the predesign phase (See Figure 5-3). In this cycle, Keen's emphasis is on the first step. The step calls for a descriptive study of the problem. "The major aim of this predesign cycle is to make sure that the right problem is worked on. There are , of

course, many interactions within the cycle; objectives influence what the key decision will be and the areas to be supported partly define available resources and vice versa" (Keen, 1978:173). His recommendation to designer's of a DSS is to complete two full iterations of the predesign cycle before beginning the detailed, more formal definition of system requirements and specifications. However, with tools like concept mapping and the overall strategies built into the PDP, two cycles are not necessary unless it's the choice of the team.
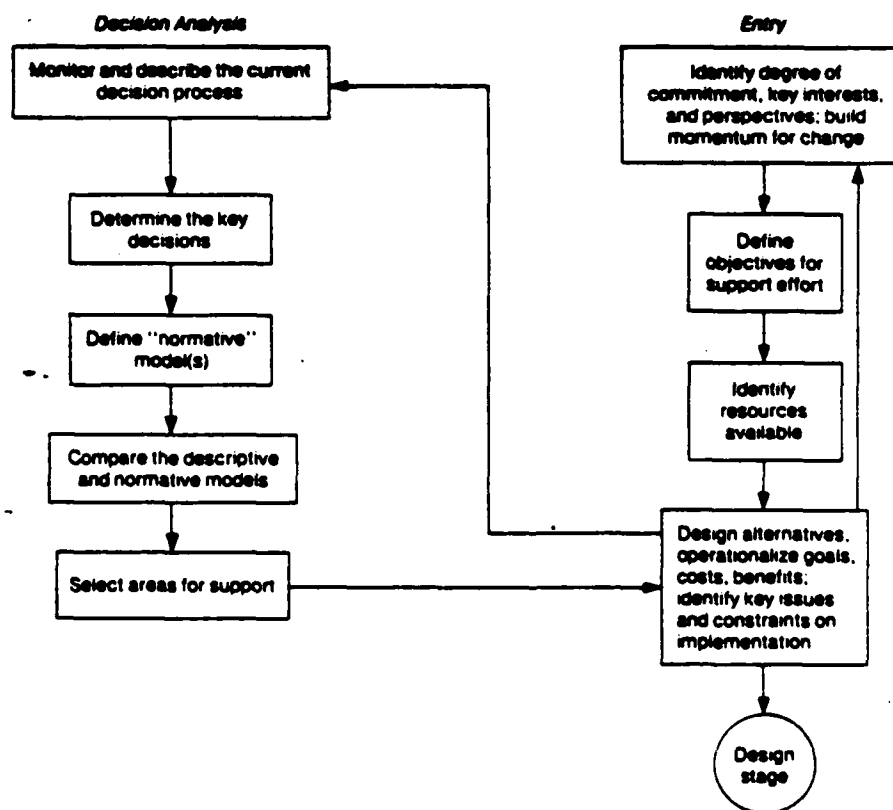

Figure 5-3. The Predesign Cycle (Keen, 1978:174)

Keen's cycle demonstrates the importance of the
problem description phase. Keen believes that by attaining
the best description possible, the user and builder
can define the key decision and elements that make up
that decision. The description phase is exactly where
the concept mapping supports the development of the
DSS. In the PDP the descriptive phase has three steps.
These three steps are the problem definition, task analysis,
and the data analysis. Concept mapping provides a vehicle
or tool for the design team to fully describe the problem.

5.221 Problem Definition:

The first use for concept mapping is to define
the problem space. The user constructs a concept map
based on his understanding of the problem. He attempts
to define what the problem is by showing the key concepts
involved in the problem and how they link together.
This map is then used by both the user and builder to
negotiate the meaning in the map. This negotiation
actually is an iteration of the definition because
the user must fully explain or restate confusing portions
of the map so the builder 'learns' and understands.

The map becomes a graphical representation of the
problem space. Since the concept map is the road map
that the design team is following, put it on large sheets
of paper and hang them on the walls for all to see.

By always keeping the map up in front of the design
team, changes in decision environment, decision task,
or perceptions can be quickly located and recorded.
Maps from several users or multiple maps from the same
user, created over time, can be compared and evaluated
for the combined understanding and identification of
key concepts and misconceptions.

The map also depicts the limits of the problem
space. The links and concepts show the boundary of
the problem and may even express it explicitly. Thus
the map allows the design team to understand the problem
and identify the bounds on the problem as perceived
by the user.

5.222 Task Analysis:

The second phase of the problem description uses
concept mapping to identify the key decision elements.
Traditional computer design would call this phase the
task analysis. A task analysis is the listing and
sequential ordering of the individual tasks necessary
to solve a problem. There are a variety of methods
designed to accomplish this task, such as flow charts
and pert charts. Task analysis, used in this sense,
operates on very highly structured problems. The task
to be captured by concept mapping is the individual
processes that are used in the solution to a semi- or

un-structured problem. In this sense, the ordering

of the task is not necessarily linear or sequentially

well defined.

There are other methods that are being developed

to identify key elements in the decision process. One

of those methods is C-MAP. C-MAP as proposed by Hira

and Mori attempts to determine the need statements of

a problem. In their problem analysis phase is a task

called 'structuring the problem'. `In this process,

complex factors are arranged in order and critical points

for problem solution are found` (Hira, 1982:118). The

process seems to be a mix of traditional task analysis

and cognitive task identification. The big drawback

of this process is the reliance on a structured problem

or process.

During the task analysis phase, the user constructs

another set of concept maps concentrating on his/her

perception of the decision process. The purpose of

these maps is to identify the cognitive task necessary

for solving the problem. The user describes the process

s/he would use to solve the problem. In reality, the

user activates his K-lines, or the ones he thinks are

most appropriate, and records the results. The map

captures the events or cognitive tasks in a graph.

The order and specific sequence is not represented except

in very structured problems or in the structured parts

of unstructured problems. But, the elements of the
decision making process are captured. This map can
then be presented to the rest of the design team for
another negotiation of meaning.

Once the decision process map is constructed, an
evaluation of the key decision elements is undertaken.
This is not a formal evaluation, but an informal search
for the kernels from which a DSS could be built. The
design team lists all of the possible kernels and their
role in the overall decision process that were found
in the process map. Chapters 6 and 7 will demonstrate
the problem description process and show the many kernels
identified from a variety of problems.

5.223 Data Analysis:

The third and final phase of the problem description
comes directly from traditional computer system design.
Once the process maps are constructed, they can be used
to establish the input and output specification of the
system.

Concept maps from the task analysis provide the
graphical representation of the processing taking place
in the system. By adding the input and output parameters
to the events represented on the process map, the design
team has a pictorial representation of the data require-
ments.

The data analysis is a rather simple process because
it works with very highly structured parts of the problem.
The design team takes the task analysis maps and identifies
the type, format, and form of information required and
lists it on the concept map. This identification is
accomplished for each event or process taking place
in a decision element. The same procedure is followed
for the output as well. After all the input and output
identifications are made, a complete set of data requirements
are compiled and form the beginnings of the system require-
ments. In actuality the user did not construct any
new maps, but modified the task analysis map to reflect
the data requirements.

The three elements of the problem description work
together to present a complete picture of the problem
space. It may have taken several iterations among the
three sets of concept maps, but the best understanding
of the problem space is understood by the design team
and is represented in an easy to review and modify format.

Once this information has been collected, the initial
design of the DSS is ready to begin. For each of the
identified kernels the team needs to create a set of
feature charts and storyboards depicting a pictorial
representation of the DSS and its functions.

5.23 Feature Charts and Storyboards:

In the phase of the problem definition process,
the design team takes what they have discovered from
describing the problem and starts to form it into a
description of the DSS. The two processes, feature
charts and storyboards, are off-shoots of the ROMC approach
of Sprague and Carlson. The following discussion takes
a brief look at the these three topics and their role
in the PDP.

Sprague and Carlson made five observations about
decision makers. First, decision makers have trouble
describing a decision making process, but they do seem
to rely on conceptualizations, such as pictures or charts,
when making or explaining a decision. Second, Simon's
intelligence-design-choice scheme can be useful in categor-
izing decision maker's activities, even though the decision
making process may be difficult to explain. Third,
decision makers need memory aids. Fourth, decision
makers have different styles, skills, and knowledge.
Finally, decision maker's expect to exercise direct personal
control over their support (Sprague, 1982:98-99).
These observations led them to propose the ROMC approach
to DSS design.

The ROMC approach is a process independent approach
to defining the requirements and specifications of a
DSS. Their original recommendation was to use flow

charts, input-output models and other pictorial devices
to represent the different parts of the DSS. The four
components of the ROMC approach are R-Representations,
O-Operations, M-Memory aids, and C-Control mechanisms.
The DSS is divided up by the four components and described
with respect to each of them. This makes the ROMC approach
'a framework for identifying the required characteristics
and capabilities of a specific DSS' (Sprague, 1982:116).

As a framework for design, ROMC works very well.
ROMC's guidance provides the design team with the basic
tools to describe and depict the DSS. However, feature
charts and storyboards, which where derived within the
ROMC framwork, provide much clearer and more flexible
description tools. These tools enable the user to 'see'
the design of the DSS as it is developed.

Feature charts provide the process aspect of the
DSS. 'The feature chart shows the features of the system
with which the user interacts. These features are the
representations, operations, and control mechanisms,
as well as the supporting memory aids' (Seagle, 1986:13).

Figure 5-4 shows a feature chart from a DSS design
as a class project. Each symbol represents a specific
component of the DSS. Solid lines depict control transfer;
parallelograms depict menus; curved rectangles are
files; and plain rectangles show operations.
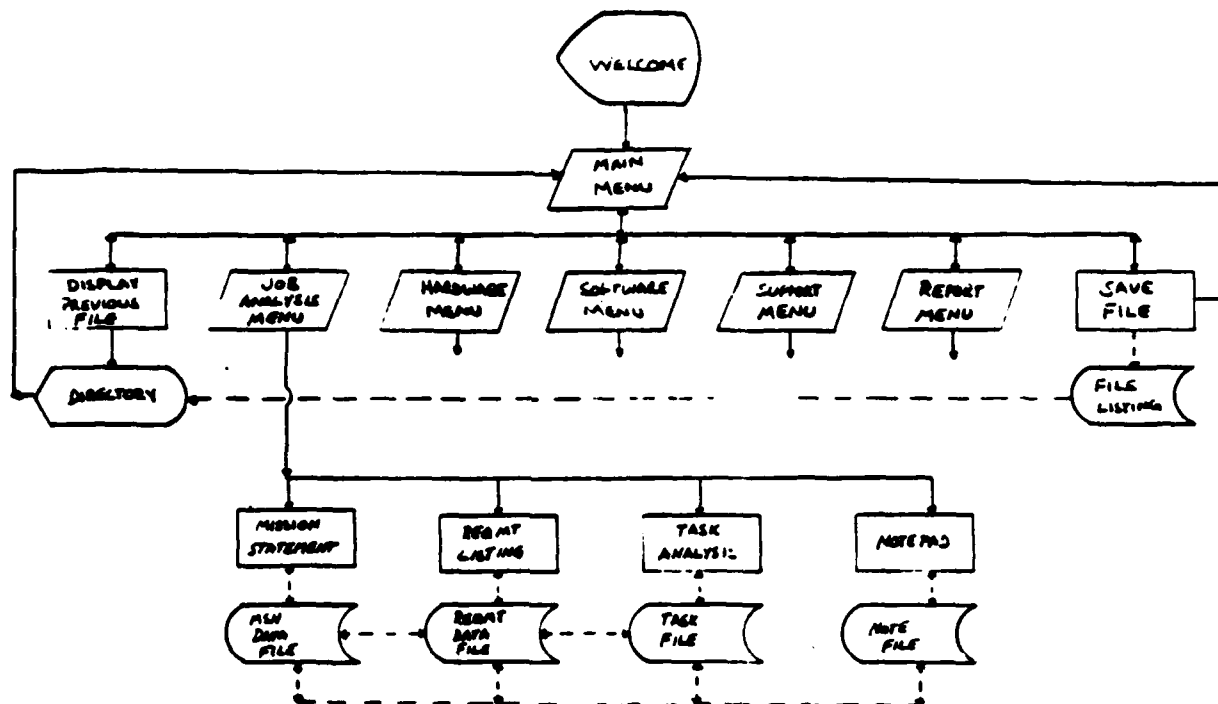
Figure 5-4. Feature Chart

The feature chart shows both the user and the builder
the perceptions of the DSS and the user's needs. This
chart shows the data flow, points of control, and proposed
paths of sequentially ordering the processes. Thus,
the feature chart is a pictorial for the design team
to negotiate the initial DSS design.

Since the feature chart lays out the organization
of the system, the storyboard details each component.

Andriole offers a tool to the design team that exploits both the ROMC approach and the human's desire to describe things with pictures. One way to explain a storyboard is to look at a comic strip. Each frame in a comic strip shows a different picture that supports the story line. The DSS storyboard does the same thing. Each frame is the proposed monitor screen that the user would see when the DSS is up and running. Comparing it to the feature chart, each component on the feature chart would have its own frame in the storyboard. Thus, the user and the builder would see and agree on the user interface.

This storyboard carries a lot of information. The user designs the frame by putting in the necessary information, suggested output format, and desired controls for the operation. It also lets the user have a forum in which to describe the underlying operation that would take place. The builder gleans the requirements from the frame dealing with the data file and processing interactions, and input/output formatting. The builder can also use the frame as a forum to describe alternative formats and controls. Storyboards, just like concept maps and feature charts, are communication devices that help the design team to determine requirements for semi- and un-structured problems.

5.24 Evaluation:

The final phase of the problem definition process is the weakest. Very little has been written on the subject of DSS evaluation, but this is the key issue in designing and successfully developing an effective decision aid. Much more research and development on the criteria for evaluating the storyboards, feature charts, and concept maps needs to be done.

As of this writing, the best recommendation for criteria lies in the common sense of the design team. However, four areas may help to focus the evaluation of the DSS design. These four evaluation areas are derived from Sprague and Carlson's four measures of DSS evaluation. These four measures are: 1) Productivity, 2) Process, 3) Perception, and 4) Product (Sprague, 1982:160).

The design team should review the products of the PDP with regard to several points of view. First, the user interface should have little if any distraction. Is the DSS, as designed, easy for the user to learn and use? How often does he need to use the help function? Second, has the decision environment, task, or user perceptions changed? If something has changed, what are the effects on the design? Third, look at the service that the DSS is providing. Does the DSS support the decision maker in the actual problem or is it not accurately

focused? Does the DSS support other problems that were
not initially stated in the design? If so, does this
extra support distract the user from the primary purpose
of the DSS? Finally, the design team needs to look
at the productivity of the DSS. How well does the DSS
perform? Is it worth the cost of development and continued
use?

While little has been written on the subject, one
paper is noteworthy. Adelman, Rook and Lehner evaluated
five USAF DSS prototypes that aid tactical decision
making. To complete this assignment, they developed
a questionnaire that looked at three separate interfaces.
The three interfaces are the DSS/user, the User-DSS/
Organization, and the Organization/Environment. (Adelman,
1985)

Although the results of the evaluation are not
important to this paper, the fact that an evaluation
could be approached in this matter is. These are just
two examples of the many ways an evaluation could be
structured and implemented.

5.25 Kernels:

This entire process of determining the specification
can be done in two ways. The choice is based on the
design team and how they view the problem space and
its kernels. First, the PDP can operate on one or more

kernels at a time. For very large problem spaces with many kernels, this is the recommended approach. This approach breaks up the design into smaller chunks or pieces. The advantage in chunking the DSS design is to allow the design team to develop kernels and groups of kernels at different rates. The rate is based on the user's understanding of that portion of the problem and the capability of technology to support the development. Thus the design team gains the ability to focus scarce resources on feasible and more highly promising parts of the DSS.

As the specifications of these pieces of the overall DSS are collected, comparisons and evaluations among the kernels and their roles in the DSS can take place. These evaluations give upper management the information they need to manage the development of the DSS.

The second strategy allows the PDP to establish the design requirements on all the kernels identified. This should be used when developing a simple DSS. This approach makes all kernels of equal value and progresses them at an equal pace in development.

5.30 Conclusion:

This chapter presented two key issues. The first issue was the need for an adaptive design for DSS develop-ment. A DSS was shown to be an aid for problems that

lacked structure and could not be defined by a complete
set of requirements prior to development. Therefore,
this type of system needed to be developed in an evolutionary
manner. The second issue proposed a method (PDP) and
the tools (concept mapping, storyboards, and feature
charts) to determine the requirements for a DSS. The
method divided into three major elements, each with
separate steps and tools. The PDP was proposed as an
iterative process that evaluates the design and records
the DSS modifications.

Chapter 6 records the results of experimenting
with concept mapping as a tool for acquiring the problem
definition and identifying the kernel. Later in chapter
6 are examples of concept mapping's integration into
the design phase of a DSS through the adaptive design
approach.

Chapter 6

Examples of Concept Mapping Applied to Problem Description

6.00 Introduction:

This chapter is a compilation of examples. Several
exercises in DSS design are listed as examples of actual
applications of the concept mapping technique. These
exercises explore a variety of problem domains.

A short discussion introduces each example and
then shows the results of the concept mapping exercise.
The concept maps that either define the problem space
or describe the decision process are shown in accompanying
figures. In some of the examples, a table lists the
kernels identified in the exercise. Two of the exercises
also include the entire DSS design showing examples
of concept mapping, feature charts and storyboards.

6.01 Source of Examples:

These problems came from three sources. The first
problem is a test case problem. It demonstrates to
analysts what a concept map looks like and how concept
mapping can identify the kernels in a DSS design. The
rest of the examples are actual DSS projects derived
from either class assignments or thesis proposals.

6.02 Crude Maps!?

The maps listed in the following exercise are, in many cases, the map exactly as it was constructed and finalized from the interview. Consequently, the maps appear in a crude format. There are two reasons the maps are left in this crude state. The first reason is to show the new concept mapper that although neatness is helpful, it is not absolutely necessary for the transfer of understanding. The crudeness of the tool does not detract from the communication ability.

The second reason for the crude state of these maps is to show that maps need to be flexible and created quickly so as not to stifle the creativity of the source. During the interview the concept mapper needs to concentrate on the source and capturing his/her concepts and links. If the concept mapper worries about neatness, the constant 'fixing' of the map will distract the source and may even lose the meaning.

There is plenty of time after the interview to clean up maps. By using the audio tape recordings, details can be added and hierarchial relationships checked. Formal presentations and reports may require the analyst to formalize the maps similar to the style shown in the next chapter. For the adaptive design process, the original maps in their original format, prominently displayed, is enough to keep the problem focused for

the entire design team.

8.03 Why the reader may not agree with the kernels:

The kernels identified are based on the perception
of the user who created the map and the reader who is
interpreting the map. With two different people reading
the same map, different kernels may be identified
because of their perceptions. This means the team of
DSS designers, users and builders, must agree by negotiating
the meaning represented in the concept map. Then the
team can list and evaluate all possible kernels to determine
the key kernel(s). This selection of key kernels sets
the DSS's style, design direction and the team's perception
of the problem solution process.

8.10 Example 1 - Buying a Car:

When concept mapping was first considered as a
technique for problem definition and kernel identification,
it needed a test case, or test problem. The purpose
for this problem was to demonstrate to a DSS designer
the ability of the concept mapping technique. The problem
had to be a reasonably good forum for a DSS and yet
common enough for any designer to relate to easily.

The problem chosen was 'buying a car'. This problem
space had one big advantage. 'Buying a car' was a decision
most people have experienced. This meant decision makers

115

already had many of the decision processes established in their minds and could readily recall them. The concept mapping technique was then introduced to the decision maker without worrying about having to teach all the details of the problem. Thus, it made a good example. The observers were relatively familiar with the problem domain and were able to concentrate on the concept mapping. The 'buying a car' problem has been the main example in every introductory presentation of concept mapping to date.

With the problem domain chosen, a concept map was created to show the tasks in the process this author would use. The map is shown in figure 6-1. Based on this map several kernels were identified. Some of them are listed in table 6-1.

Possible Kernels for a DSS on 'Buying A Car'

- Working the BUDGET portion of the decision process
    * Cash flow sheets for monthly bills
    * T-accounts for savings
    * Loan/Interest payment models
    * Leasing payment models

- Checking the Market
    * Data base on maker's offers and inventory

- Buyer Wants
    * Data base to list and rank user desires

- Other Options
    * Data base on each of the available alternatives
    * Cost modeling on each of the alternatives

Table 6-1. Possible Kernels

116

Figure 6-1. Concept Map: "Buying a Car"

Figure 6-2a. Concept Map: "Compromised Information — Problem Space"

119

Figure 6.9b & c. Concept Maps: "Compromised Information"

6.30   Example 3 - Adams' Tanks:

Capt Bill Adams' initial thesis proposal suggested
a DSS to assist the decision makers of the U.S.Army
in distributing tanks to various units. Consequently,
he worked on developing the definition of the problem
using concept mapping. After several interviews and
a variety of concept maps, he determined that DSS was
not the best way to approach this problem because the
structure of the decision.

The exercise with Capt Adams was not counted as
a failure. The concept maps created did show the problem
space. Also, the concentration required on his part
helped him to understand the problem more clearly.
Finally, valuable time was saved by not pursuing an
inappropriate solution method.

6.40   Example 4 - Pilot Training Scheduling:

Capt Paul Trapp and Capt Jeff Grechanik chose to
build a DSS that assisted a scheduler. The resources
that needed to be scheduled were pilot trainees and
instructors. Both officers had held the position in
earlier assignments. Therefore, both were taken to
be the experts as well as the builders.

This example held two noteworthy events. First,
this example was the first to apply concept mapping
to the actual design of a DSS and also continue the

process through to a fully operating prototype. Second,
it was the only example of a DSS design that used more
than one expert. Multiple experts would not be encountered
again until concept mapping was applied to the Rapid
Application of Air Power problem space.

Several specific steps were taken to concept map
the problem and decision process. First, each expert
independently prepared a list of what they thought were
the key concepts in the scheduling problem. Most of
the concepts were events, tasks that the scheduler needed
to do. From these lists the builders grouped and time
ordered the concepts. Table 6-2a through 6-2c and figure
6-3a show the concepts chosen and reordered by the builders.

Only after each expert had thought through the
exercise of key decision processes and ordering did
they come together and build their first joint concept
map. This first map accomplished two key goals. The
goals accomplished were: 1) defined the problem space
to a mutual agreement and understanding of both experts
and 2) taught this author about the intricacies of sched-
uling. During the exercise, many discussions occurred
between the two builders concerning the other's choice,
placement and grouping of concepts. The resulting problem
definition map is shown in figure 6-4b/c.

Several interviews were held. They resulted in
a series of maps that attempted to capture the process

a scheduler went through in his daily selection and

Key Items to Perform Daily

* Check yesterday's schedule to make sure all flights went as scheduled.
  - Note deviations - find reason (weather, sick, etc).
  - Update boards.

* Gather all inputs for tomorrow's schedule
  - Who's available?
  - DNIF.
  - TDY.
  - Leave.
  - Academics.
  - Appointments.

* Determine all flying/training/ground events to be filled.
  - Flights.
  - Simulators.
  - Academic Classes.

* Fill lines.
  - Make sure formations match missions.
  - Students first.
  - Shuffle instructors so that they're assigned correctly.

* Fill academics first.

* Fill duties second (important duties).
  - Big 3.
  - Ramp officer.
  - Appointments.
  - S O F.

* Fill piddly stuff last.
  - R C O.
  - Appointments.
  - Meetings.

* Deconflict throughout schedule.

Table 6-2a. Grechanik's list of key concepts.

Key Items to Perform Daily

* Fill in grease board with times, simulators, academics, meetings, which ride student's on.

* Deconflict academic classwise

* Fill in instructor absences, DNIF, meetings, on the deconfliction board.

* Fill in set rides such as check rides, DO flying with squadron.

* Look at graduation dates or class or individual furthest behind (red dots only fly once).

* Fill in student names and which ride they are on.

* Look for type rides (air-to-air) or (air-to-ground).

* Put in student names with a match from the ride they are on compared to the configuration of the planes at a specific take-off time.

* Fill in exclusive periods for each class first using previous step .

* Match IP to student names according to squadron rules. For example, the 434th has a primary and secondary IP assigned to the student. If neither the primary or secondary IP is available then match the student with a IP from his flight. If none of his flight is available, then any IP will do.

* Iterate all steps.

Table 6-2b. Trapp's list of key concepts.

Ordered Key Concepts

1) Ensure data from today's Schedule is updated once flying is complete for today's schedule.
   (night before or first thing in the morning)

2) Write up the shell on tomorrows portable grease board.

3) Write in hardlines.

4) Write in DNIFs, leaves, RCO, SOF (duty hog).

5) Talk to Big 3 (Sq CC, Ops Off, Ast Ops Off).

6) Write in academic schedule classes and instructors (weekly).

7) Matching process:
   a) students <---> instructors
      1) Look for assigned instructor
      2) Look for IP in Flight
      3) Look for anyone

8) Schedule Big 3.

9) Schedule simulators.

10) Schedule duty hog.

11) Fill in deconfliction board.

12) Write daily grease board up on large board -
    Go FIRM @ 'FIRM TIME'
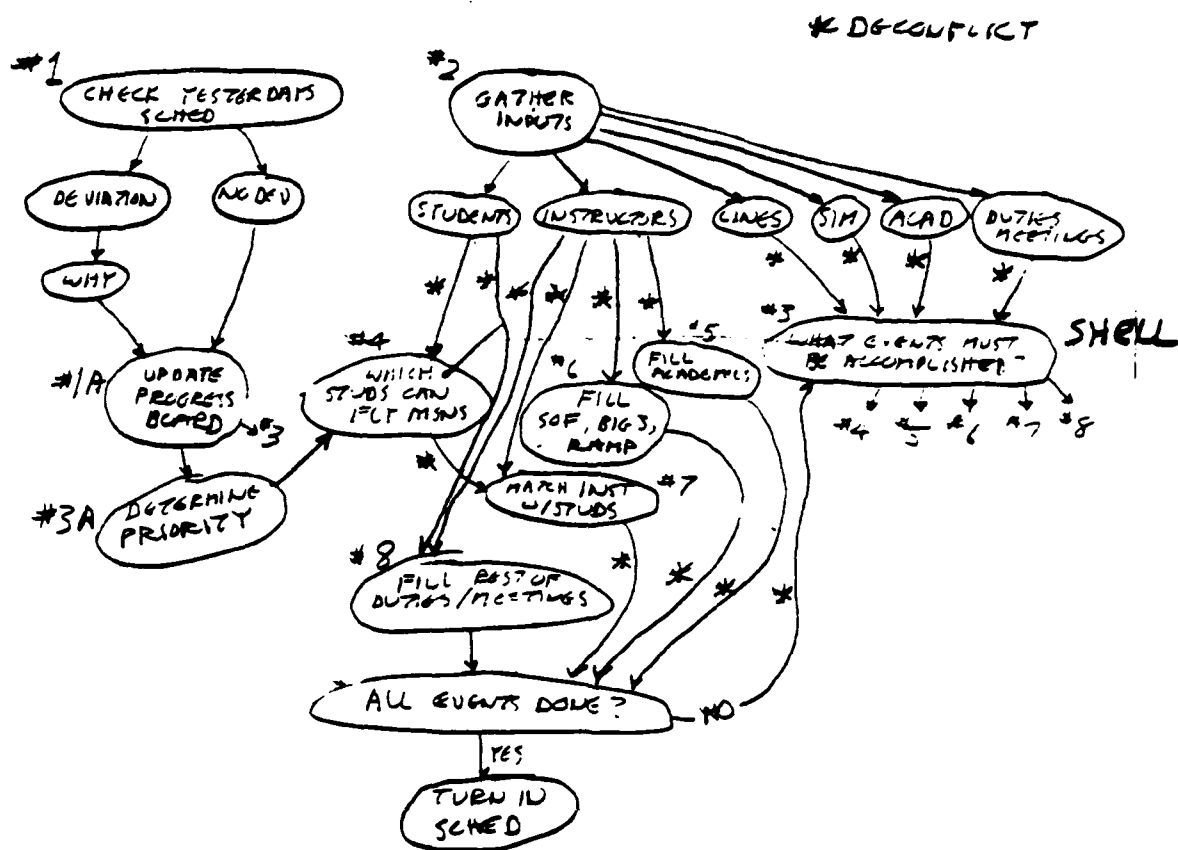
   Table 8-2c. Trapp's first ordering of key concepts.

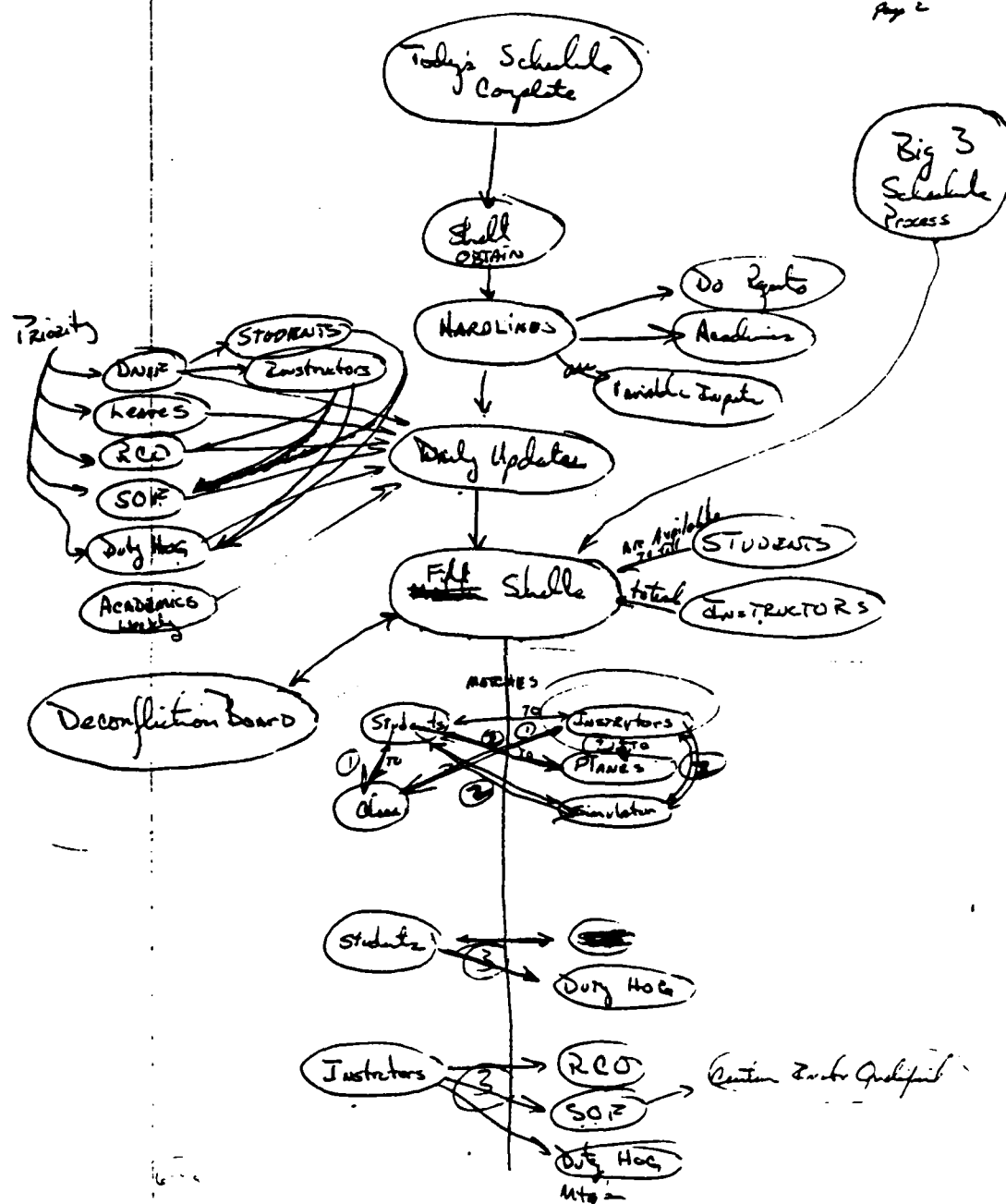Figure 6-3a. Grechanik's ordering of key concepts.

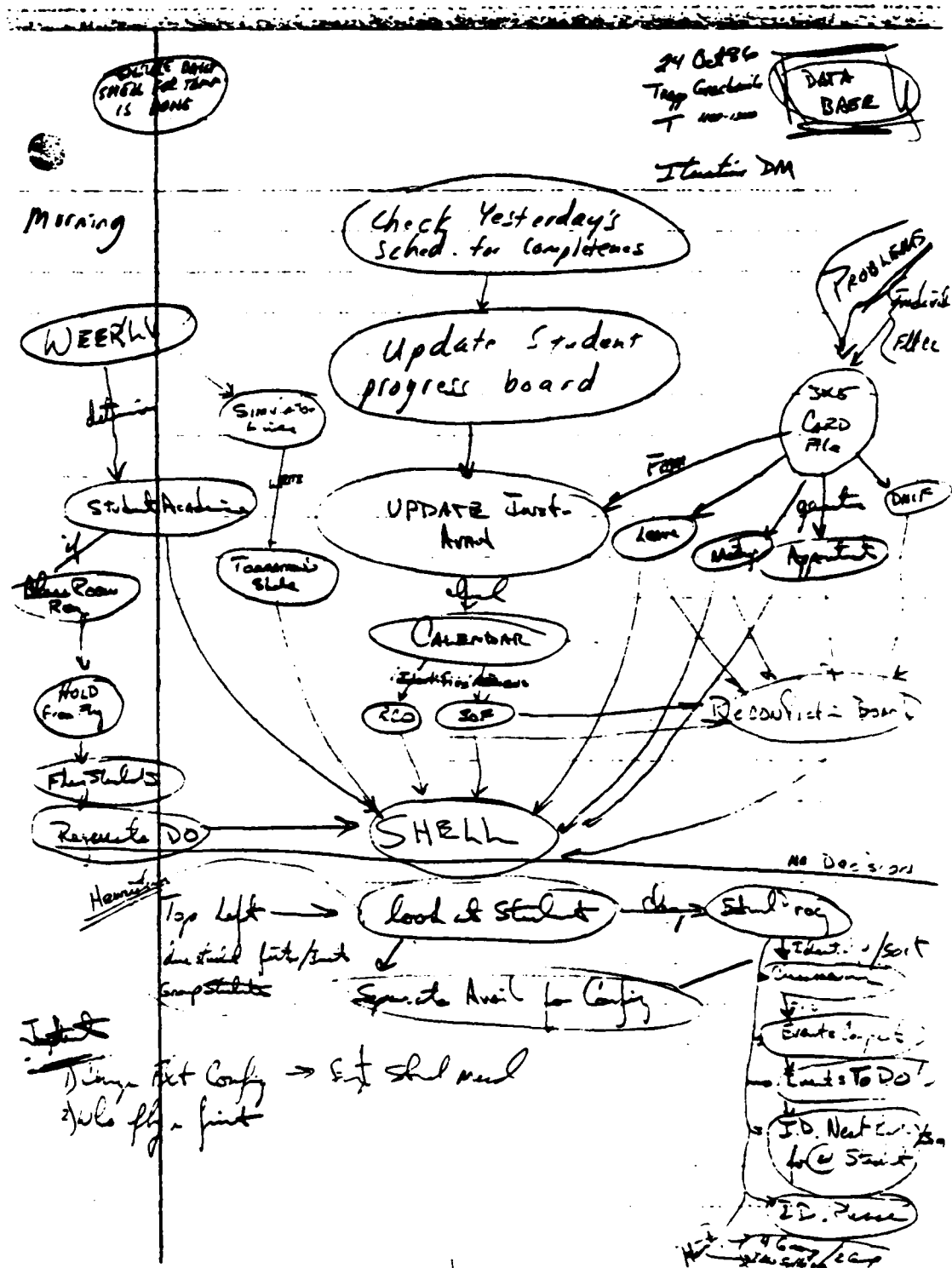Figure 6-3b.   Concept Map: First cut at Problem Space.

Figure 6-3c.   Concept Map: First Cut at Decision Process.

matching of resources. The final map, showing the combined understanding of the process, is shown in figure 6-3d. From this map, Capt Trapp and Capt Grechanik identified four key elements in the scheduler's process as kernels. The kernels used to center the development of the final DSS are listed in table 6-2d.

Kernels for a DSS - 'Pilot Training Schedule'

- Instructor Availability *
    = Input format for individual access
    = Relational data base instructor/qualifications
- Student Availability *
    = Relational data base instructor/requirements
    = Sorting routine by requirements
    = Prerequisite identifier
    = Grouping routine by class and activity
- Shell (Daily schedule sheet)
    = Automated spreadsheet showing today's activit-
ies   based on academic and flying schedules.
    = Data base of Academic schedule
    = Data base of available resources
(Planes, Take-off times, Range times, Weapon loads,etc.)
- Student Instructor Selection *
    = Automated assignment routine/expert system
      which matches student with activity.
    = Routine which automatically updates the student
      availability data base.
    = Automated assignment routine/expert system
      which matches instructor with student.
    = Routine which automatically updates the instructor
      availability data base.
- Alterations on Today's Schedule *
    = Input data of altered schedule.
    = Update student and instructor data bases
    = Update current shell
    = Identifies changes in today's schedule that
      need action.

* Key Kernels

Table 6-2d. Identified Kernels
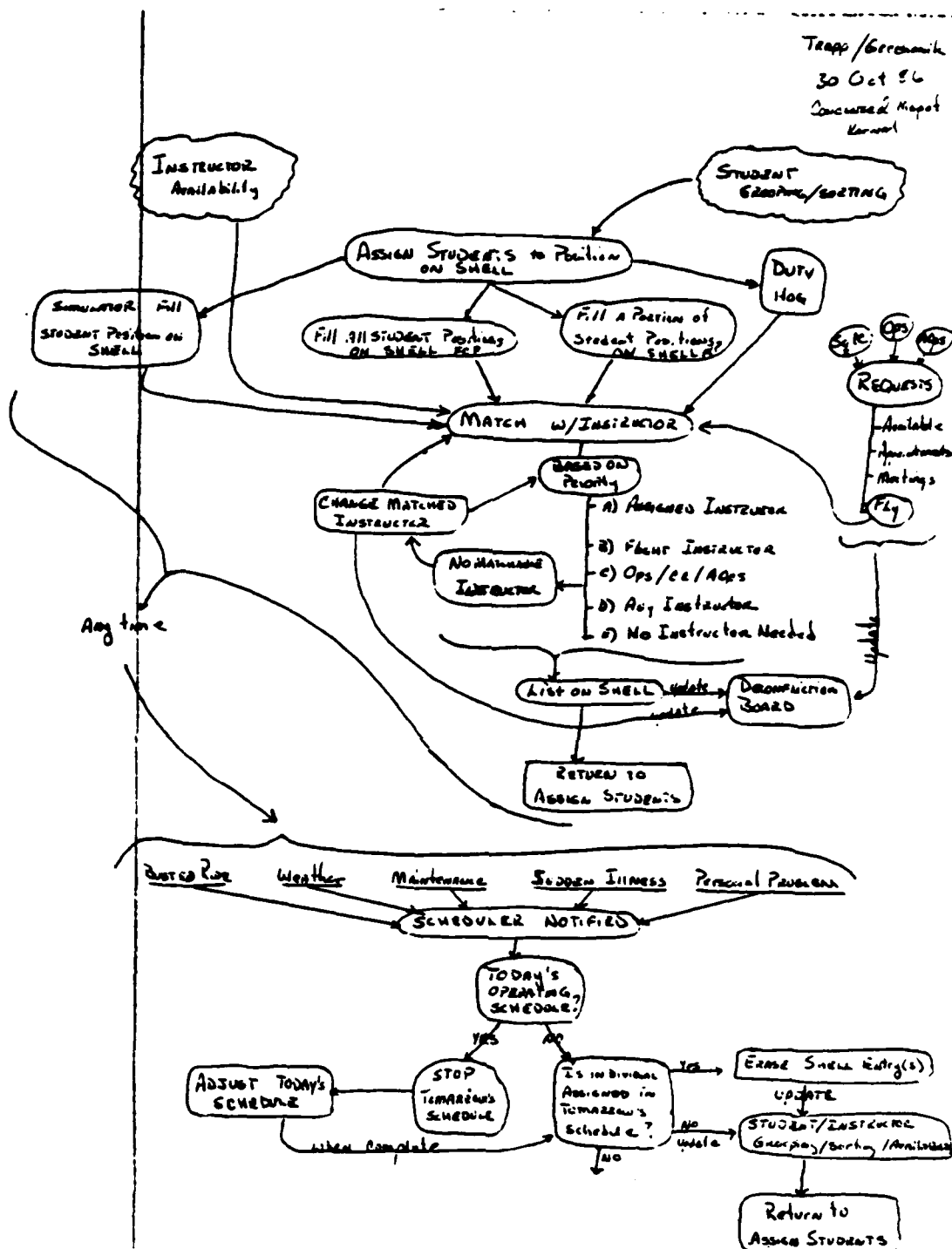
129

Figure 8-3d. Final Concept Map of Decision Process.

6.50   Example 5 - AWACS Manpower Manager:

Maj Bill Schneider's thesis effort looked at the management of manpower resources in the various positions required by the AWACS system. He built a DSS that assisted decision makers in maintaining manpower, training qualificat-ions and experience levels.

Maj Schneider used concept mapping to scope the problem and define the problem space. His resulting concept map of the problem is shown in figure 6-4. From this understanding of the problem space, he went on to full production of a prototype DSS. His prototype demonstrated that the goals of manpower management, outlined in this concept map, could be supported and maintained.

Figure 6-4.   Concept Map: `AWACS Manpower Management`

6.60   Example 6 - Tactical Nukes:

For TACT 7.61, Command and Control, Capt Bob Bivins
and I established the system requirement for a prototype
DSS. The only requirement from the course was to recommend
the design of a DSS that would assist military decision
makers with a command and control issue. Therefore
we decided to obtain the system requirements using the
PDP approach as described in chapter 5.

The problem chosen was an intriguing look at the
question; 'When should a theater level commander request
authorization for the use of tactical nuclear weapons?'.
Since no expert was available, we conducted an extensive
literature search of the problem and related issues.
This search plus our ten years experience in strategic
nuclear missile systems, established ourselves as the
best experts available.

The literature search revealed the existence of
plans requiring the NATO theater commander to ask for
the authority to arm the weapons from the President.
The commander was required to justify the arming as
a necessary and politically feasible action at that
time in the conflict. In other words, the plans expected
the action to achieve battlefield objectives without
having to release the power. None of the tactical employment
issues nor specific conditions of release were addressed
in this DSS. Only the collection of information and

evaluation of the situation which would assist the commander in making and justifying the request.

Appendix C holds the final report from the project. All of the concept maps, feature charts and storyboards are included. This was the second example of using the Macintosh computer system with Mac Draw.

6.70 Conclusion:

This chapter was designed to encourage other analysts to use concept mapping and the problem definition process in their next DSS development. The chapter has shown a variety of decision support systems and problem spaces where concept mapping and the entire problem definition process was applied. In every example the problem space was more clearly defined by using the concept mapping technique. This enhanced understanding of the problem space aided the designers in their search for the system requirements and development of a DSS prototype. These exercises have given DSS designers a variety of examples for the specific use of concept mapping in problem definition and kernel identification.

Chapter 7

Application of Concept Mapping - RAAP

7.00 Introduction:

This chapter records the experimentation done by applying concept mapping to a very large problem domain. Recalling from chapter 3, concept mapping can be used at any conceptualization level. Thus, a large, undefined or fairly new problem domain allows the demonstration of concept mapping at a higher level of conceptualization.

The following discussions look at the progression of the experiment as well as the findings and observations. The first discussion explains why the RAAP problem domain was chosen as a test bed for concept mapping. This discussion lists the several advantages which make RAAP ideal for the experiment. The second discussion looks at the facts of the experiment. Included in this section are a background on the RAAP concept, the set-up of the experiment, and the procedures of interviewing. The final discussion reports the findings and observations by dividing them into three categories: 1) results from individual mappings, 2) aggregation of group data into two maps, and 3) the general observations of the experimental procedure.

This chapter has two goals. The first and most

obvious goal is to show the power of concept mapping
on a rather large and nebulous problem area. Quite
a bit of detail is reported in the following discussions
on the procedure and results of concept mapping in this
domain. Under both the individual and the aggregated
discussions are general comments about the maps and
how they were created. The second goal is to relay
the understanding of the RAAP concept to the reader.
For this reason, large amounts of time and effort were
taken to redraw all of the maps. This ensures the reader
has the most effective map available from which they
can learn. Normally the map would not be formalized
because concept mapping is a working tool for problem
definition and kernel identification.

7.10 The Advantages of the RAAP Problem Domain:

RAAP was suggested during the preliminary thesis
proposal discussions as a problem that would be more
complex than the DSS projects. The problem space did
reside in a much higher conceptual level. This means
that the problem space crossed several knowledge domains
and utilized a variety of cognitive and decision processes.
From limited information on the concept, RAAP seemed
to be an interesting yet advantageous problem domain.
RAAP has several advantages for its choice as the problem
domain: 1) convenience, 2) size of the problem domain,

135

3) lack of universal understanding of the RAAP concept, and 4) the need for support of research and development goals.

The first advantage of RAAP was its convenience. AFIT had already made arrangements for Col Rothrock to make a presentation on the concept of RAAP. This allowed immediate access to the prime expert in the field.

The second advantage is the shear size of the problem domain. RAAP covers several knowledge domains and calls for many types of human decision processes to be captured. For example, the fusion of detailed battlefield data into a complete picture of enemy actions requires collection, counting, judgement of accuracy, collation of different sources, tracking, and unit identification as a few of the elements of the decision process. This is just one of the many decision processes involved in the RAAP concept.

The third advantage was the lack of general understanding about RAAP throughout the military establishment. Col Rothrock and Col Kline have spent several hundred manhours briefing the concept of RAAP. Many levels of the military and government establishments have been exposed to the 'new way of thinking'. However, literature searches failed to retrieve anything significant that described or explained the RAAP concept. This indicated

136

the newness of the concept and the lack of other authors
or agencies to think about enacting or implementing
it. Thus, it was concluded that few people outside
of the Air Staff, a few contractors and Rome Air Develop-
ment Center (RADC) understood the concept. This lack
of universal understanding made RAAP an ideal problem
domain. 'Experts' were much easier to identify because
there were so few.

The fourth advantage is that research supporting
RAAP is just beginning. The engineers at RADC are looking
for additional support in identifying the directions
of research and development efforts. (Papagni, 1987)
Since they are tasked with managing the research for
the RAAP support systems and building the demonstration
prototypes, they would like to know several things.

1) What part of the system gets built first?

2) Why is one element more important than another?

3) Why do we need this piece of the puzzle at all?
The Air Staff is also interested in the research goals
and the direction that RADC is taking. By knowing what
they need in the way of developments, they can assist
in the management of research and gaining financial
and political support.

In the previous chapter, there were examples where
concept mapping identified kernel(s) for DSS projects.
By extending that process to the larger domain where

several decision processes take place, the kernels identified
will be the key decision processes and major elements
of a decision process. This identification process
will produce a list of kernels for researchers to consider
as goals. Thus, an evaluation system could rank the
kernels in order of importance. A similar procedure
would be beneficial in the acquisition phase of a system
as a statement of initial requirements. If concept mapping
at this level can identify the kernels, then evaluation
of the kernel can take place and a ranked listing of
the kernels produced. This final product becomes the
basis for the advocate's request for funding and political
support (i.e. a planning tool).

Besides all the advantages favoring RAAP as the
test bed problem for the concept mapping technique is
the fact that RAAP addresses itself to the field of
command and control. There is a great need for understanding
the decision processes in command and control. "Very
little time or effort has been spent uncovering the
processes by which command decisions are made; even
less has been spent describing the cognitive operations
which decision makers perform when confronted with compli-
cated and often urgent C^2 problems.' (Andriole, 1982)
By using the concept mapping technique of RAAP some
insight into the command and control decision process
might take place.

If this insight does take place, then the research effort expended on the development of RAAP can take the 'decision maker approach'. Concept mapping would give the researcher the view of the decision process directly from the user or commander's view. Thus, the development would be built around user needs, not machine capabilities. What is meant by the 'decision maker approach' is that the command and control systems would be designed as supporting elements for the decision processes that need to take place. Andriole calls for this approach as if it were a necessity. "C^2 systems ought to be designed from the decision makers up, not from the electronics capabilities down." (Andriole,1982)

Based on these advantages and needs, RAAP was chosen to be the problem domain for this test of concept mapping. One question remained. It dealt with the procedure. Was the approach that was used in the DSS examples adequate for this level of conceptualization or were changes required? Assuming the basic procedure outlined in chapter one would result in the same or better success, no changes were made. The next discussion records the experimental procedure and the adjustments made.

7.20 The Experiment:

This is not an experiment in the true scientific sense of "a sequence of observations carried out under

controlled conditions' (Metcalfe, 1966). The experiment

is a trial. Using the concept mapping technique, an

attempt is made to achieve two goals. The first goal

is to identify key elements, kernels, in the decision

processes of RAAP. The second goal is to build a map

that aids in transferring understanding between individuals.

The trial is not in a controlled environment. The expected

result is an increased understanding in the problem

and its decision process elements. Following is the

hypothesis for this experiment:

'Concept mapping conveys understanding of complex

concepts, like RAAP, between individuals and aids

in the identification of kernels.'

The measure of effectiveness or measure of degree of

accomplishment is the response from the experts and

their eventual use of the concept mapping products.

In other words, the best measure of the success of the

experiment is the value the experts place in the maps

and the list(s) of kernels.

The main goal of this trial session is to see if

concept mapping can identify key elements or kernels

in the RAAP process. Before delving too deeply into

the procedures, there is a need for a short discussion

of command and control decision making and how RAAP

fits into the concept of operations employing air power.

7.30 RAAP - Background:

'There is no adequate foundation for a theory of command and control and, hence, no guiding principles for system design and evaluation' (Wohl, 1981:618). This was the major finding of a Secretary of Defense colloquium in 1979 on command and control. Unfortunately little has been done to improve this situation since the Secretary's colloquium.

For too long command and control has been an art form for only a few select commanders. The effort to educate and train young officers as skilled tacticians in applying air power is very weak. Even commanders in Europe at the highest level of responsibility for directing battle are not necessarily prepared for the demands that command and control require (Suter, 1987). Consequently, the emphasis in establishing command and control procedures and ensuring that those procedures take full advantage of the modern weapon system's capabilities is, to say the least, lacking.

'Western technology boasts a family of new weapons and reconnaissance/surveillance systems with unprecedented capabilities. Yet command and control of these forces has not kept pace. Today an operations decision maker would be potentially deluged with target information that can describe and display floods of eligible targets yet lacks an equivalent complement of explanatory information

141

to permit weighing and prioritising those targets relative to the combat situation confronting him. Without better development and analysis of attack options, the potency of the air arm is condemned to a reactive, target servicing posture that makes regaining the initiative under the amalgam of combat pressures virtually impossible" (Rothrock and Kline, 1987:5).

What is needed then is a theoretical basis for command and control and the procedures to enact the theory. Wohl insists that "...a theory of command and control must start with a theory of decisionmaking for command and control." (Wohl, 1981:618) In response to this need of a command and control basis, came the concept of RAAP.

RAAP is a new way of dealing with the information flow on a battlefield and the support given to the commander. RAAP offers a theoretical base from which procedures for commanding and controlling forces are derived. It is a new way of thinking about the air operations and application of air power. The RAAP concept redefines the function of command and control. It harnesses the power available in information through advanced machine capabilities. The procedures are designed around the needs of the commander and his decision processes by managing and displaying information. The result allows the commander to take advantage of preplanned actions

142

and exploit the enemy weaknesses.

This approach to command and control fits very
well with the conclusion that Maj Orr finds in his research
of Command, Control, Communications, and Intelligence
(C^3I) and combat operations. Here Maj Orr offers a
definition of command that parallels very well with
the RAAP concept of command and control. "The stochastic
nature of combat and the varying degree of actual command
decision impact on the combat process suggest that the
primary function of command in combat is managing sources
of potential power in order to be able to exploit
opportunities as they arise" (Orr, 1983:47).

RAAP finds further support from Maj Orr's definition
of control. He calls for the need of forces to exploit
the enemy's weaknesses. "A primary function of command
is deploying and maneuvering forces or other sources
of potential power to be in the best possible position
to exploit opportunities as they arise. This function
can be viewed as controlling the power distribution"
(Orr, 1983:51).

RAAP is the vehicle in which these definitions
of command and control are realized. By implementing
the RAAP concept, commanders expect to harness the true
power of the weapons systems under their command, by
using them more effectively (Rothrock and Kline, 1987).

143

7.40 Experimental Procedure:

The first task was to gain a basic understanding of the concept RAAP. The lack of literature made this a more difficult task than the DSS projects worked on earlier. However, a point paper, written by Col Rothrock, and listening to the first lecture presentation provided the initial knowledge base to support the interviews.

Two appointments for interviews were set with Col Rothrock during his visit to AFIT. The first interview consisted of a short presentation about concept mapping and its proposed value to problem definition. The main goal of the concept mapping exercise was stated as that of identifying kernels. At that time little was known of the extent of the research and development for RAAP nor of any of the researcher's needs. Col Rothrock participated in the remainder of the session as the expert. He concentrated on his understanding of RAAP from a doctrinal view. Much of his understanding came from an information processing point of view. At this point in the development of the technique, it was assumed to be a worthwhile way to approach the problem. This approach changed later in the development and will be reflected in later maps.

After both interviews and attending both of Col Rothrock's presentations, several maps were created. See figures 7-2a through 7-2o. Col Rothrock reviewed

144

a few of the maps from the interviews and agreed that they did reflect his understanding of RAAP.

Col Rothrock felt strongly that concept mapping had significant value. He provided the funds which enabled a complete set of concept maps to be generated from all the key experts in the field. This generosity provided the opportunity for a more explicit definition of the problem and more concise identification of the kernels. However the approach with the interviews had to change slightly.

In the interim between the first mapping of Col Rothrock and the mapping of the other experts, it became obvious that a complete separation of problem definition and decision processes had to take place. Defining a problem with regards to the process does not result in as explicit a definition for the problem space. Therefore, when the other RAAP experts were approached they were told that two sessions, of about an hour each, would be required. The first session would concentrate on their understanding of the problem, while the second session would emphasize how they would solve the problem or make the decision. The interviewing procedure outlined in chapter 4 was followed. The maps produced from each expert were labeled as either definition or process maps depending on the interview's approach. These multiple maps gave the experiment much more latitude with which

to work.

With the multiple maps from various experts, the
experiment expanded significantly. Testing some of
the various beliefs about concept mapping could now
be accomplished. There would be multiple maps of several
experts to aggregate into the overall problem definition
and decision process maps. This would show if there
are consistent repeatable elements that identify as
kernels. These kernels were finally identified by a
process called 'overlaying maps'.

7.50 <u>Findings and Observations</u>:

This discussion is broken into three separate parts.
The first part is a report of the concept mapping exercise
as it took place with the individual. This portion
identifies the individual's role and expertise, addresses
any changes to the normal experimental procedure, and
finally shows and comments on the individual's concept
map(s). For some of the interviews, several maps were
created. The multiple maps come from the expert's desire
to delve into topic areas in great detail and/or several
topics. Each map is introduced and key items of interest
are noted.

The second part of this section looks at results
of the aggregation process. All maps created during
this exercise are divided into two groups: problem definition

146

or decision process. The key concepts are identified from each area. This list of concepts are the concepts that seem to be universally held by the majority of experts. The identification is the author's understanding and perception gained from all the interviews and readings. From the definition list an 'aggregated' map is constructed. The aggregated problem definition map of RAAP is the author's perception and has not been fully verified by the experts. Instead, the map is shown as a demonstration of the technique to transfer understanding through concept mapping. The aggregated map shows the identification of the key concepts, and the links between concepts that create understanding.

The third section reports some of the observation noted about the concept mapping process. Interesting facts and findings from the exercise are listed.

7.51 Individual:

Readings:

The first concept map was created from the point paper obtained from Col Rothrock. This map was created so that the author could gain a better understanding of the concept RAAP. This preparation is an important first step in the process of concept mapping (Figure 7-1).

Figure 7-1. RAAP Summary Paper
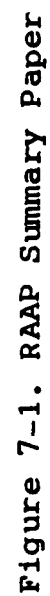
Col Rothrock:

Col Rothrock is the commander of INYX on the Air Staff, Headquarters, USAF, Pentagon. This office is responsible for the development of USAF intelligence doctrine. He is one of the initiators of the concept RAAP. His organization is the office of co-responsibility for the development of RAAP.

A detailed series of concept maps were constructed from his two presentations to AFIT classes and the many interviews with Col Rothrock . Each of these maps are shown in figures 7-2a through 7-2k. Each of the maps are individually introduced and comments provided below.

Presentations   - Figures 7-2a and 7-2b are the concept maps of his presentations to the TACT 4.12 'Strategic and Tactical Sciences Seminar' and TACT 7.61 'Command and Control' classes.

Both of the Colonel's maps were created from audio tape recordings of the presentation as well as class notes and copies of the slides. Both maps are considered to be independent expressions of the RAAP problem space because Col Rothrock approached the presentation differently due to the different make-up of the audiences. Consequently, he emphasized different key points of RAAP. These two views of the problem space gave maps that had the same key concepts but at different levels of importance.
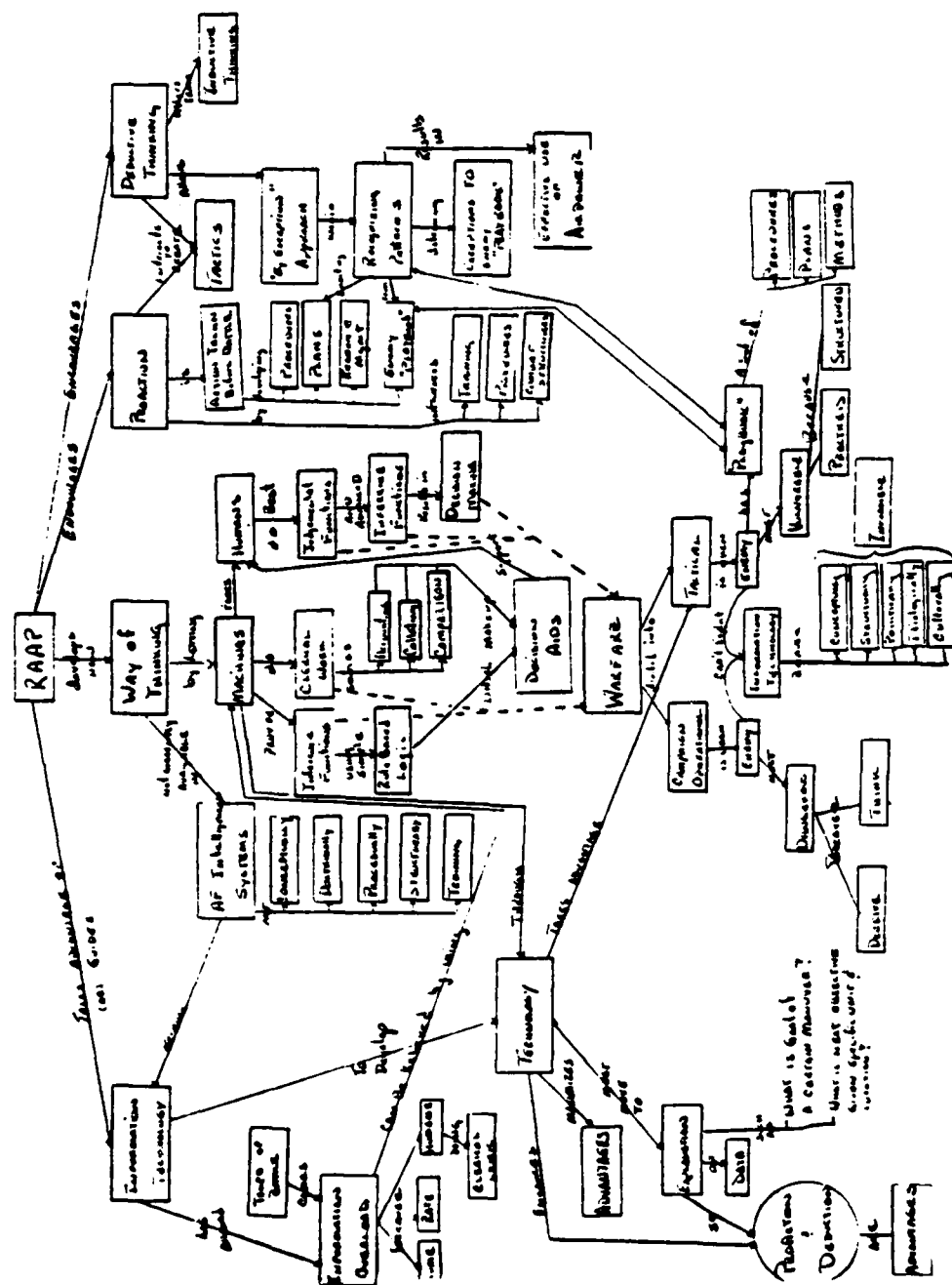
149

Figure 7-2a. Col Rothrock's Presentation to TACT 412

Figure 7-2b. Col Rothrock's Presentation to OPER 761

This was an excellent example of the 'rubber sheet' characteristic of concept maps.

First interview - Figures 7-2c and 7-2d are the two maps created during the first interview.

The first mapping session began by having Col Rothrock list the key or universal problem areas addressed by RAAP. The 6th area, that of event targeting, was further expanded during the session. The resulting map is shown in figure 7-2c. The second map was Col Rothrock's view of the process RAAP would take to make decisions. This map began to show some of the simple elements of the many decision processes. These decision process elements became more evident in later maps from Col Rothrock and others.

Second interview - Figures 7-2e through 7-2j are the maps used and created by the second interview.

The second interview was a smorgasbord of issues revolving around the concept RAAP. The first discussion started by reviewing a concept map made during the second presentation as lecture notes (See figure 7-2e). The discussion started by looking at RAAP as a process of information management. From the view of intelligence functions, the user is expected to follow a procedural framework. This framework is called the 'by exception
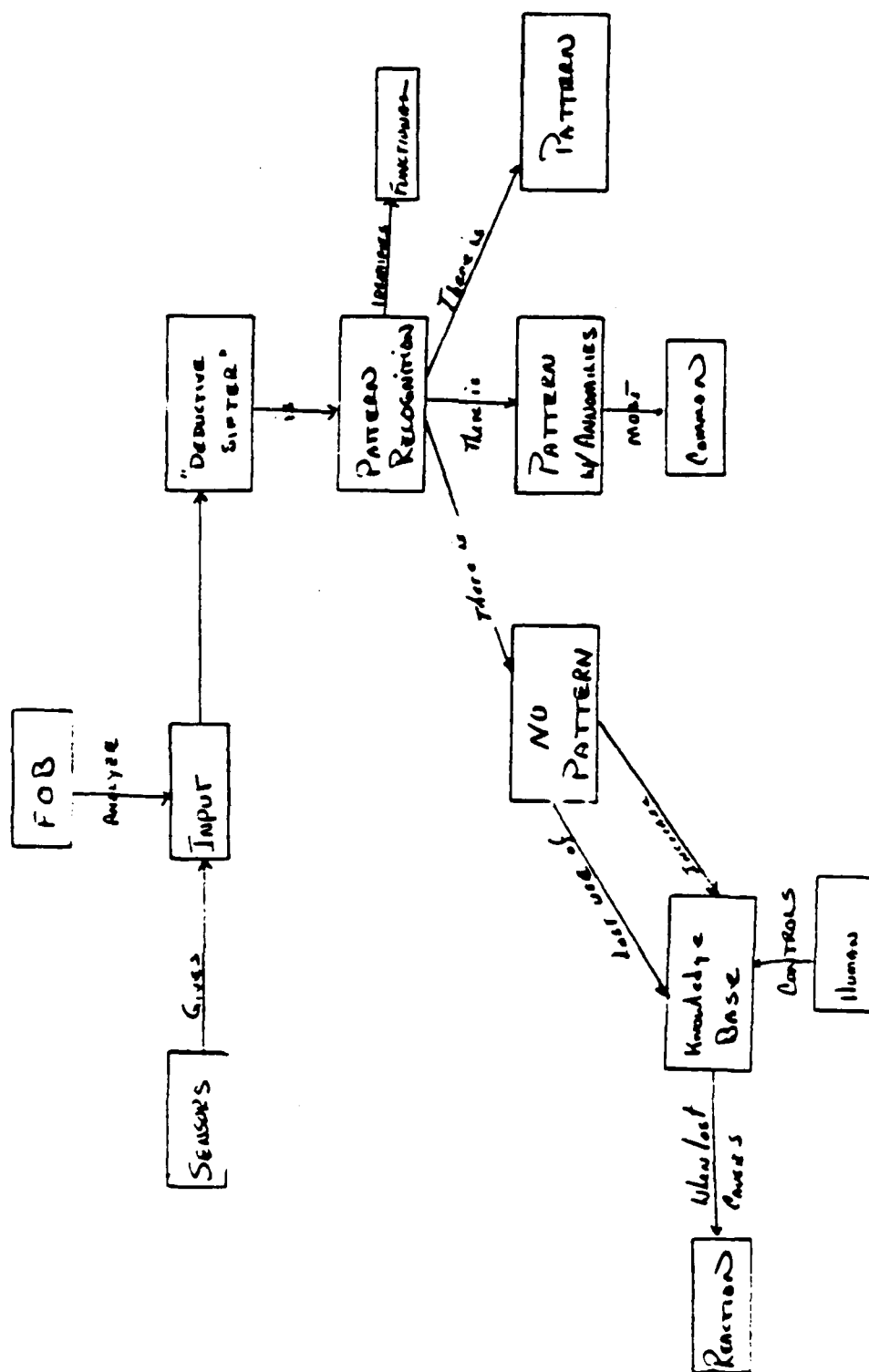
152

Figure 7-2c. First Interview: Problem Areas
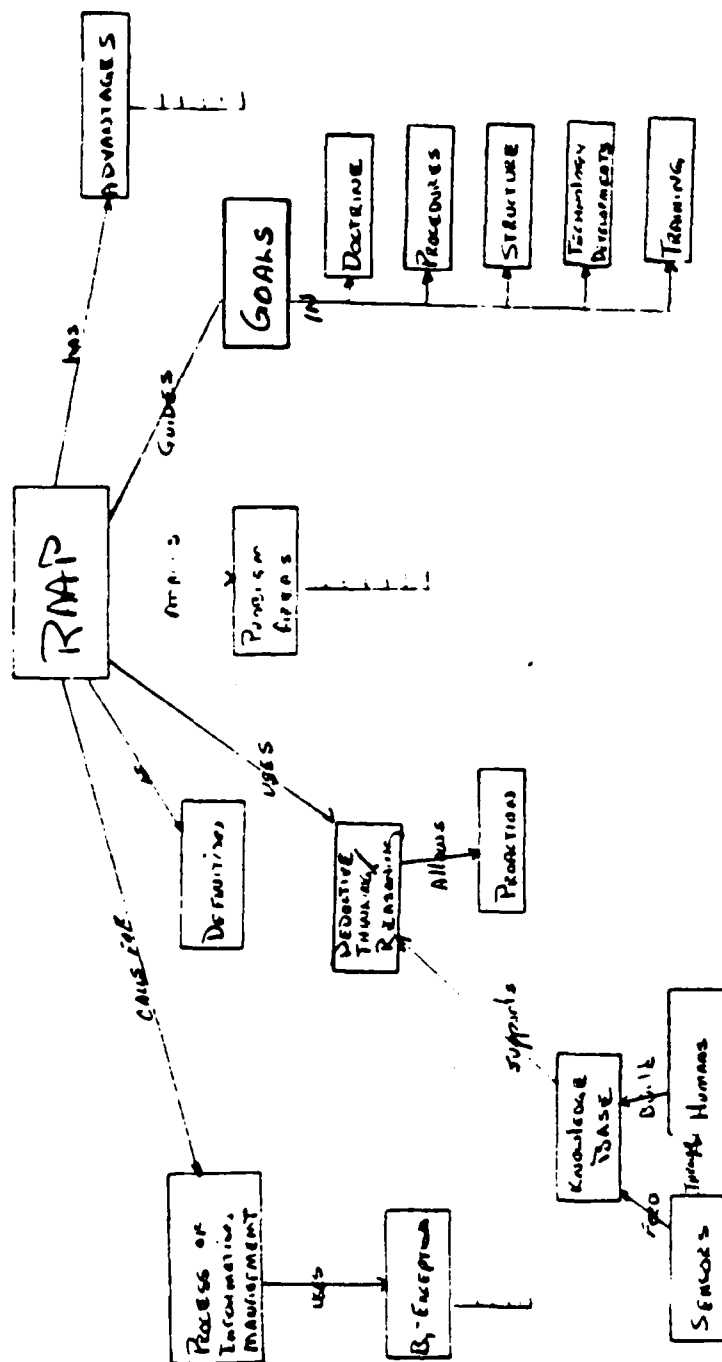
Figure 7-2d. RAAP Process

154

Figure 7-2e. Class Notes

155

approach' which is a management through deduction process.
These concepts were added to the map and is shown in
figure 7-2f. Further discussions on the management
of risk and level of command where also discussed and
added.

The interview then evolved into an extensive discussion
on technological evolution and how RAAP would take advantage
of future developments. In response to the detailed
information given by Col Rothrock, several detailed
maps were created showing the understanding between
RAAP and other concepts.

The four maps address separate relationships of
RAAP and the following concepts. Figure 7-2g depicts
the colonel's understanding of a seventh problem area
in RAAP, western advantage. This problem area points
out the lack of the west's ability to take advantage
of their technological advances because of the lack
of conceptual understanding of their application. Figure
7-2h shows how RAAP uses technology. The concept RAAP
is a thought process that can be done without any tech-
nological support. An example of using a RAAP-like
approach is the Army's Commander's Estimate of the Battle-
field. However, RAAP prescribes the need for technological
application when it is available. Figure 7-2i debates
inductive and deductive thinking and how RAAP uses them.
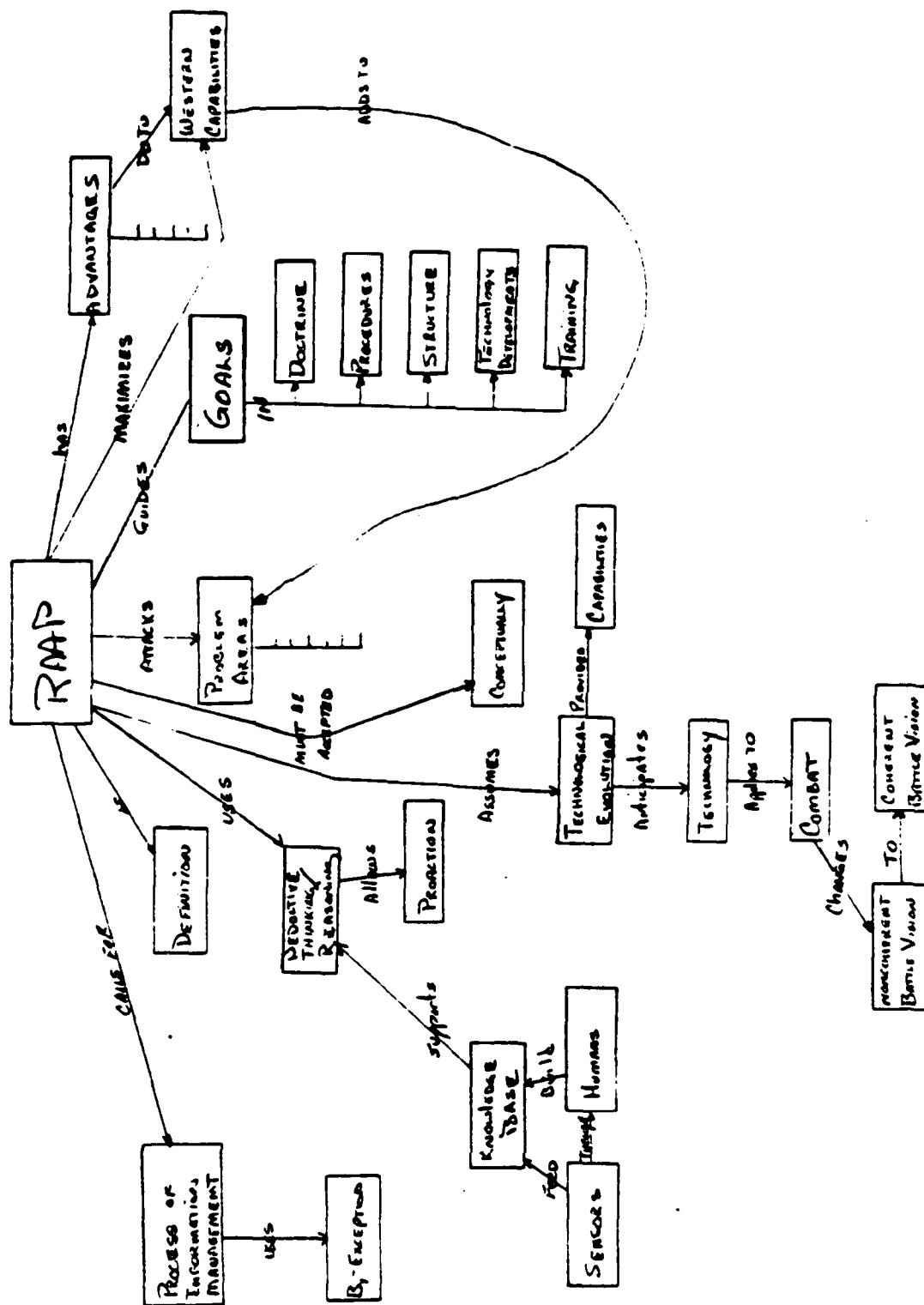One analogy to understand the difference between inductive
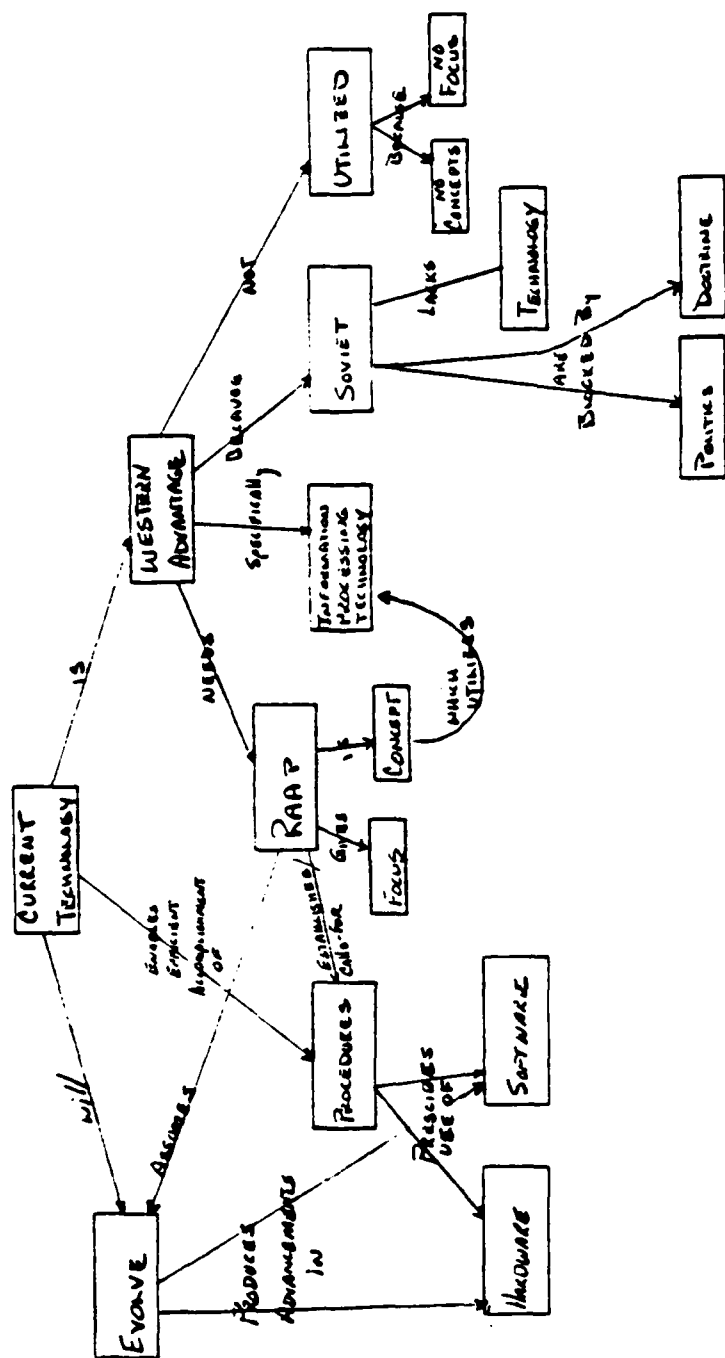
Figure 7-2f. Second Interview
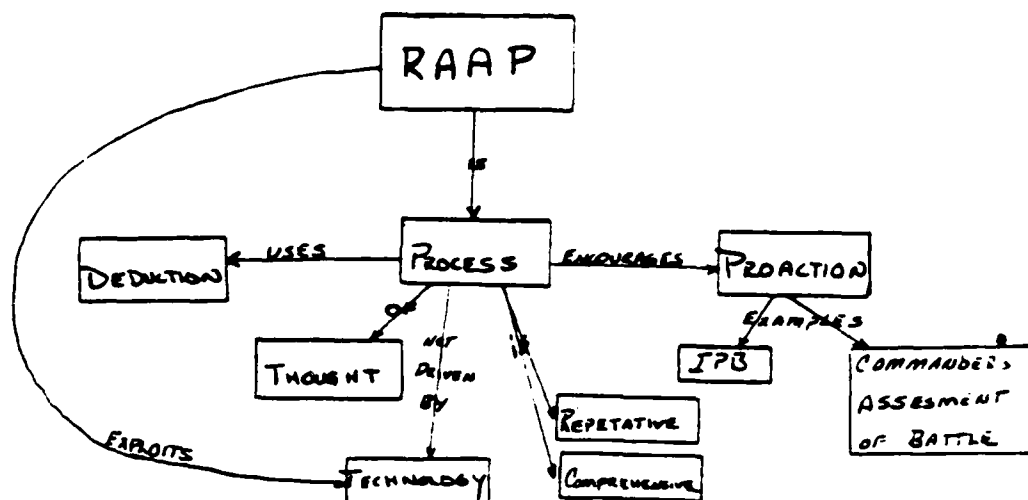
157

Figure 7-2g. Western Advantage

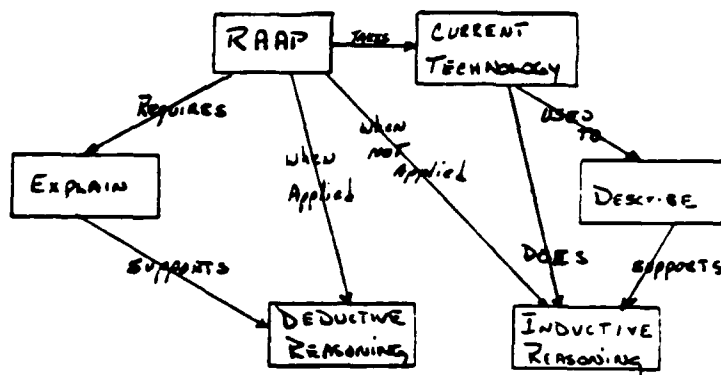Figure 7-2h. **RAAP** & Technology

Figure 7-2i. Inductive vs Deductive

and deductive thinking is the fable of the seven blind
men and the elephant. Each man inspects his part of
the elephant. He makes his identification based on the
part of the elephant he inspects. This is an example
of the inductive process. If all the men would compare
their findings and describe the elephant in terms of
each finding then they would be deducing the actual
description. Finally, figure 7-2j compares current
thinking to the way RAAP wants the user to think.

The second interview continued with discussions
on a variety of issues dealing with the development
and application of RAAP. Some of these issues included:
1) the level of command and control, and 2) the political
factors involved. One of the discussions centered on
the statement, what RAAP is not. Some of these discussions
are depicted in figures 7-2k and 7-21.

After the two interviews and his limited review
of the initial maps, Col Rothrock praised the process
as very helpful for the expert. 'This is a very good
approach. It forces me to deal with and define the
issues in ways that I probably would not have done on
my own.' (Rothrock, 1987b) Thus, concept mapping helped
the expert to deal with organizing his understanding
of the concepts. If this exercise helps in organizing
the expert's understanding, then concept mapping captures
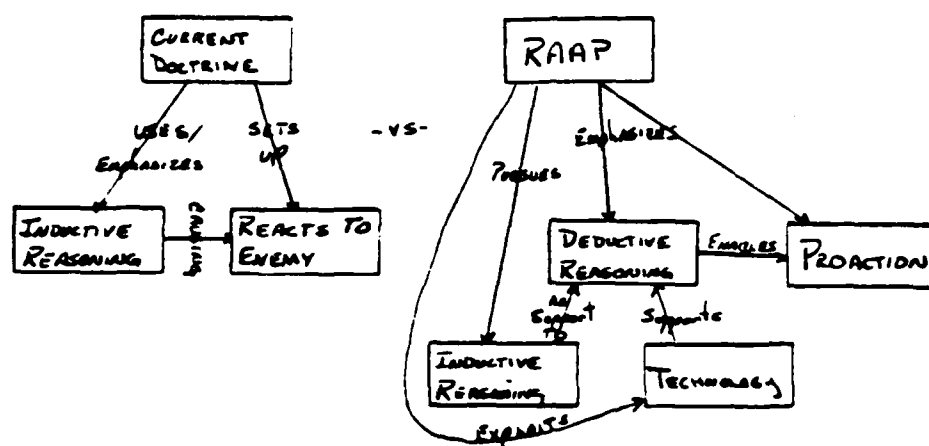his/her best understanding of the concepts <u>at that time</u>.
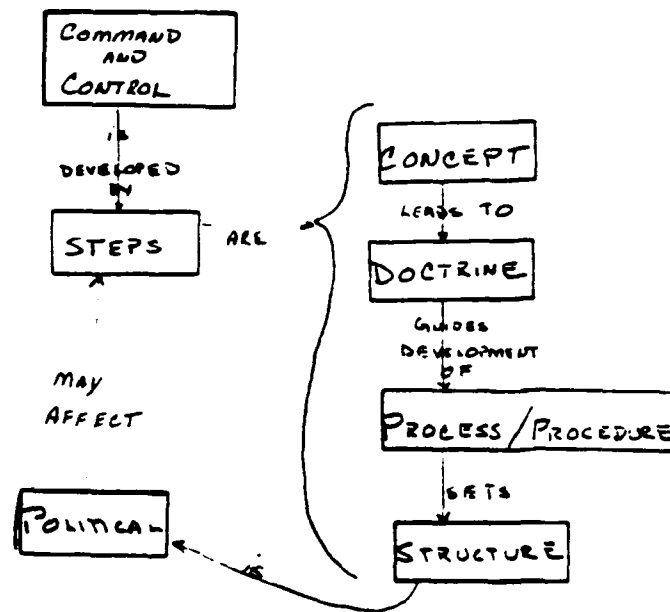
Figure 7-2j. RAAP's Way of Thinking
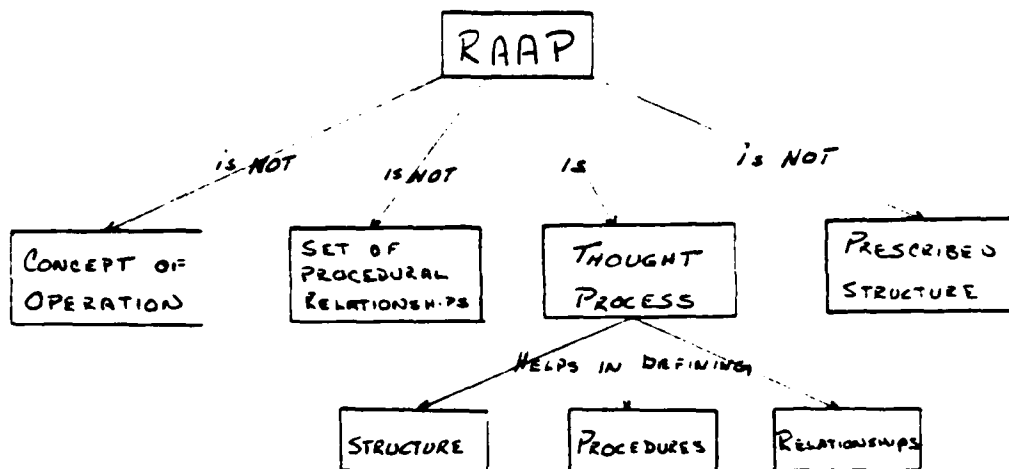
Figure 7-2k. RAAP's Evolution

Figure 7-21. RAAP is Not

Third interview - After approximately 10 weeks, Col Rothrock was interviewed again. The interview started with the review of the maps shown in figures 7-2a and b. This interview had several detailed discussions revolving around misrepresentation from these maps. Col Rothrock checked the maps for two items. First he was asked to check the maps for areas of misconceptions or misrepresentation. This included improper terms used for concepts and illogical or wrong linkages between these concepts. He agreed with the basic concepts and their linkages in both maps.

Col Rothrock was next asked to check the maps for missing concepts or linkages. He did have some additions to make to the maps. These additions are shown in figure 7-2m and 7-2n. The last exercise Col Rothrock performed was an attempt to link all previous maps together. The result is shown in figure 7-2o.
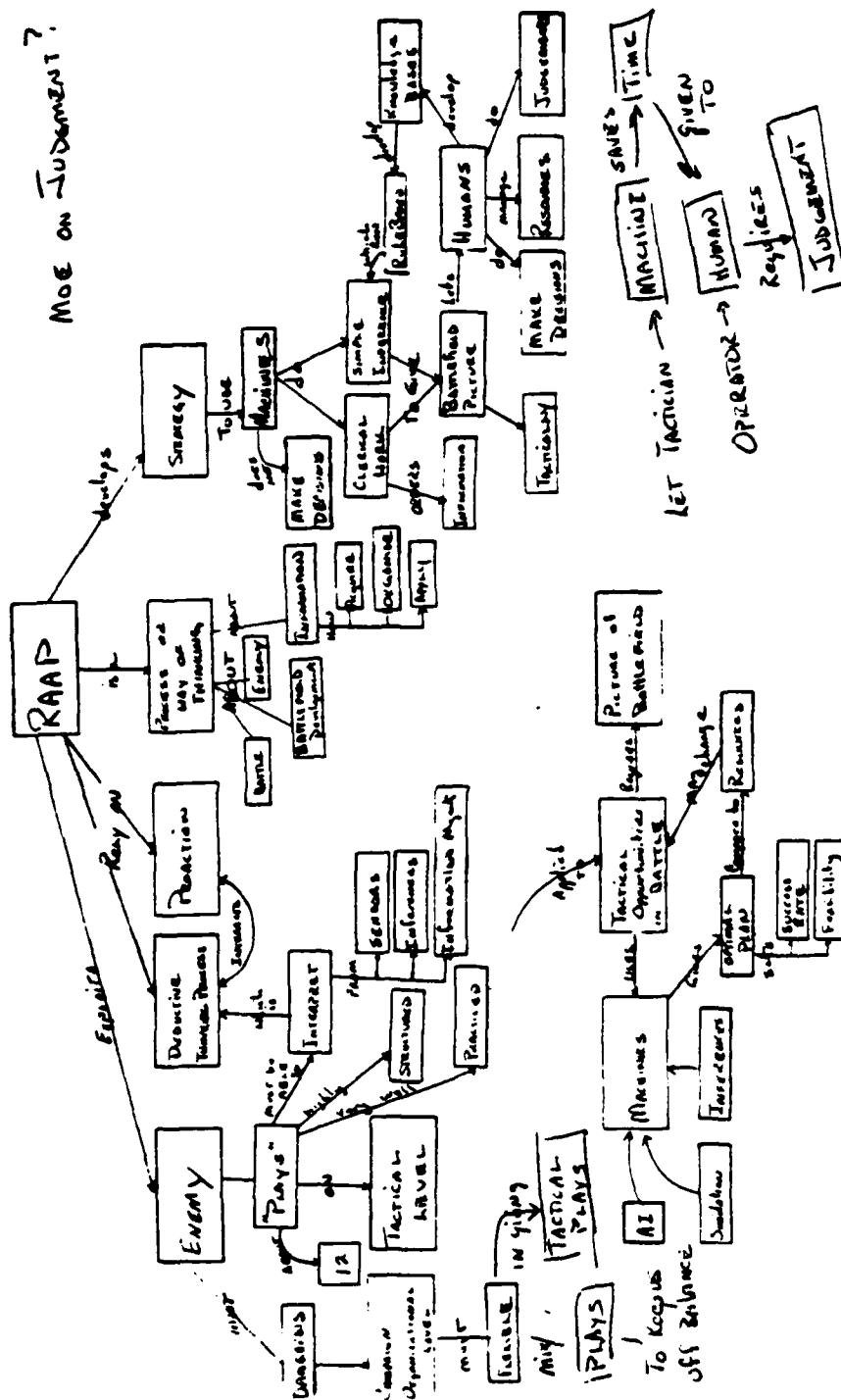
\

Figure 7-2m. Additions to 7-2a
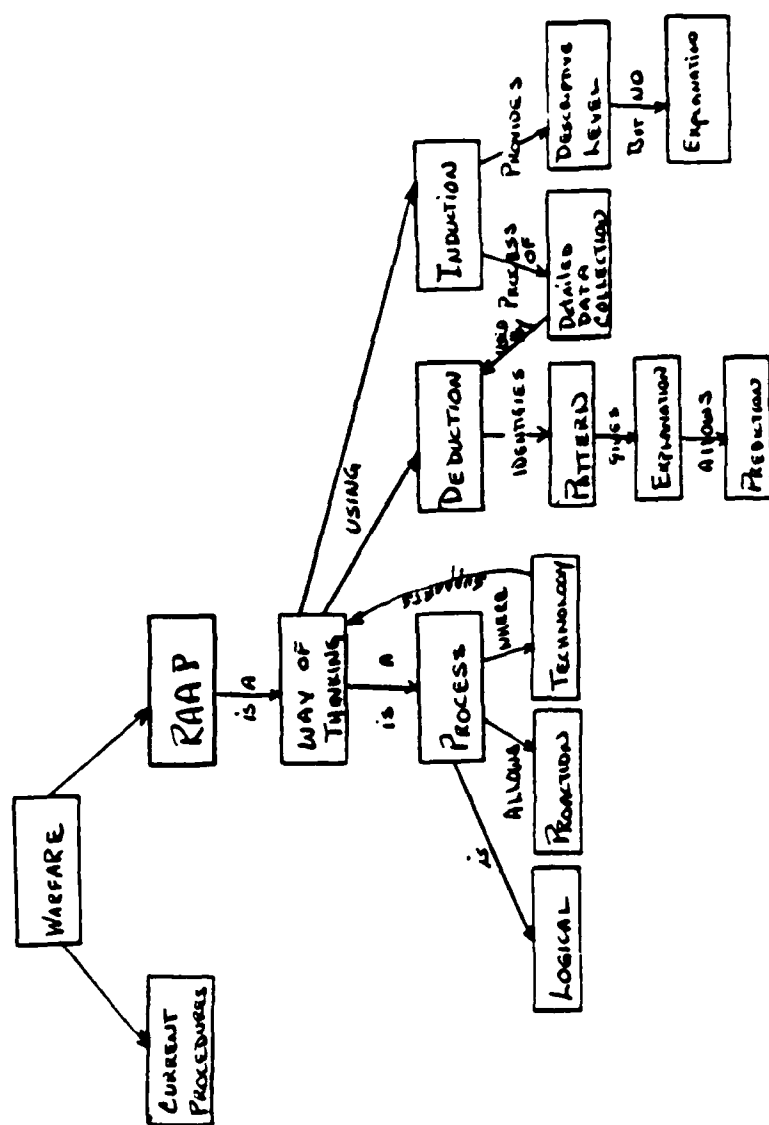
164

Figure 7-2n. Additions to 7-2b

165

Figure 7-2o. Master Links to all 7-2 Concept Maps

Maj Harrison:

Maj Harrison is an intelligence officer assigned
to INYX. He has extensive experience in the operational
intelligence field. His point of view is that of the
intelligence user. Two questions drive much of Maj
Harrison's thinking and were brought out in his map:
1) Which intelligence functions will RAAP perform?
2) How will RAAP support the intelligence functions
required in a battle?

Only one formal interview session was available
due to time constraints. The approach taken with Maj
Harrison was the two step approach. The problem definition
was emphasized in the first part of the interview while
the second part concentrated on the decision process.
He defined the problem space in terms of the process.
This gave the experiment a new twist since one map would
be considered in both definition and process.

Maj Harrison's map is shown in figure 7-3. If
one takes the time to read his map, both his understanding
of the concept and the decision process(es) of RAAP
come through clearly.

Figure 7-3. Maj Harrison's Concept Map of RAAP

Col Kline:

Col Kline is the commander of XOXID on the Air
Staff, Headquarters USAF, Pentagon. XOXID develops
the doctrine that guides the application of tactical
air power for the USAF. He is Col Rothrock's co-initiator
of the RAAP concept. His organization holds primary
responsibility for the development of RAAP.

Unfortunately, due to time constraints, only one
interview was scheduled. Since Col Kline's expertise
is in tactical doctrine, the interview was centered
around his understanding of the RAAP concept. In other
words, the interview sought his definition of the problem.
The map is shown in figure 7-4.
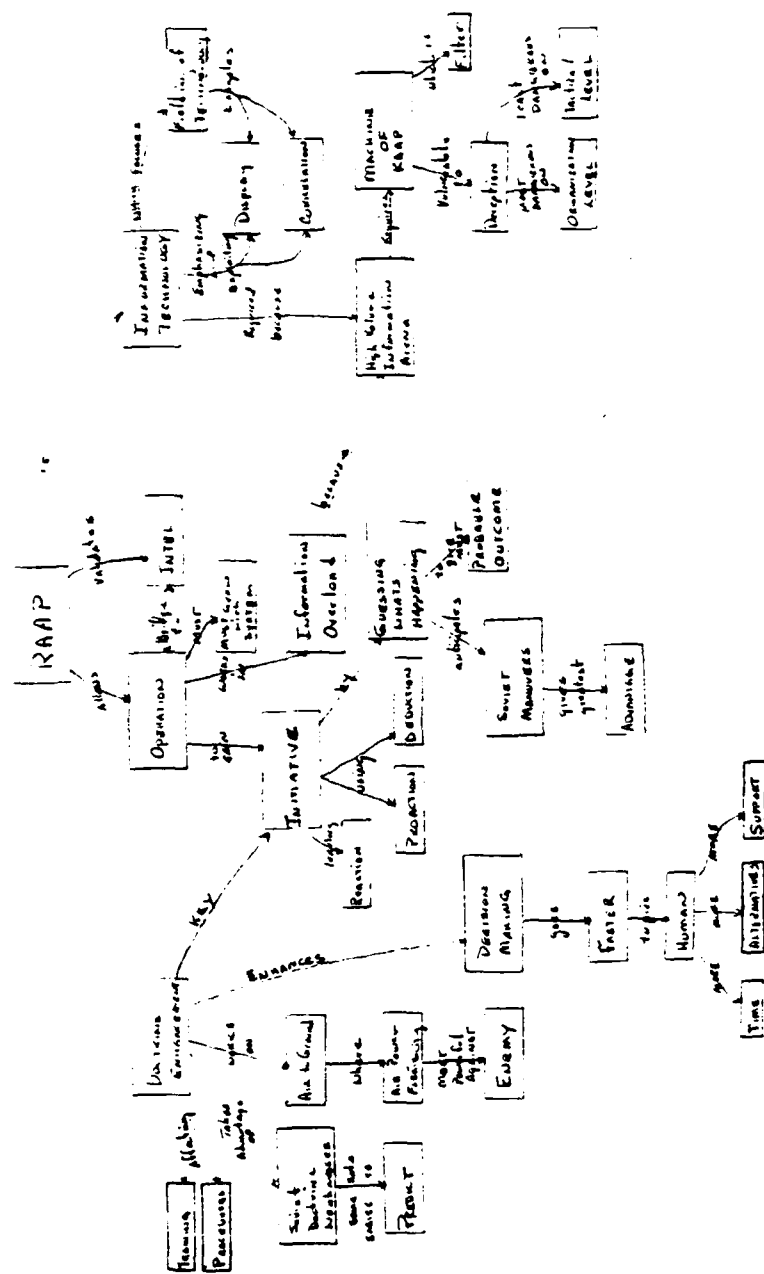
Figure 7-4. Col Kline's Concept Map of RAAP

Mr John Allen:

Mr Allen is the expert in Soviet maneuver. He is expected to determine the profiles needed to predict the red intent from the functional order of battle and the events taking place.

The interviews with Mr Allen followed the standard procedures. The first interview concentrated on his understanding of the problem. The second interview attempted to capture his understanding of the decision processes of RAAP.

The first map, figure 7-5a, shows his definition of RAAP. Figure 7-5b is the map from the second interview showing the decision processes according to Mr Allen.

Figure 7-5a. Mr Allen's First Interview
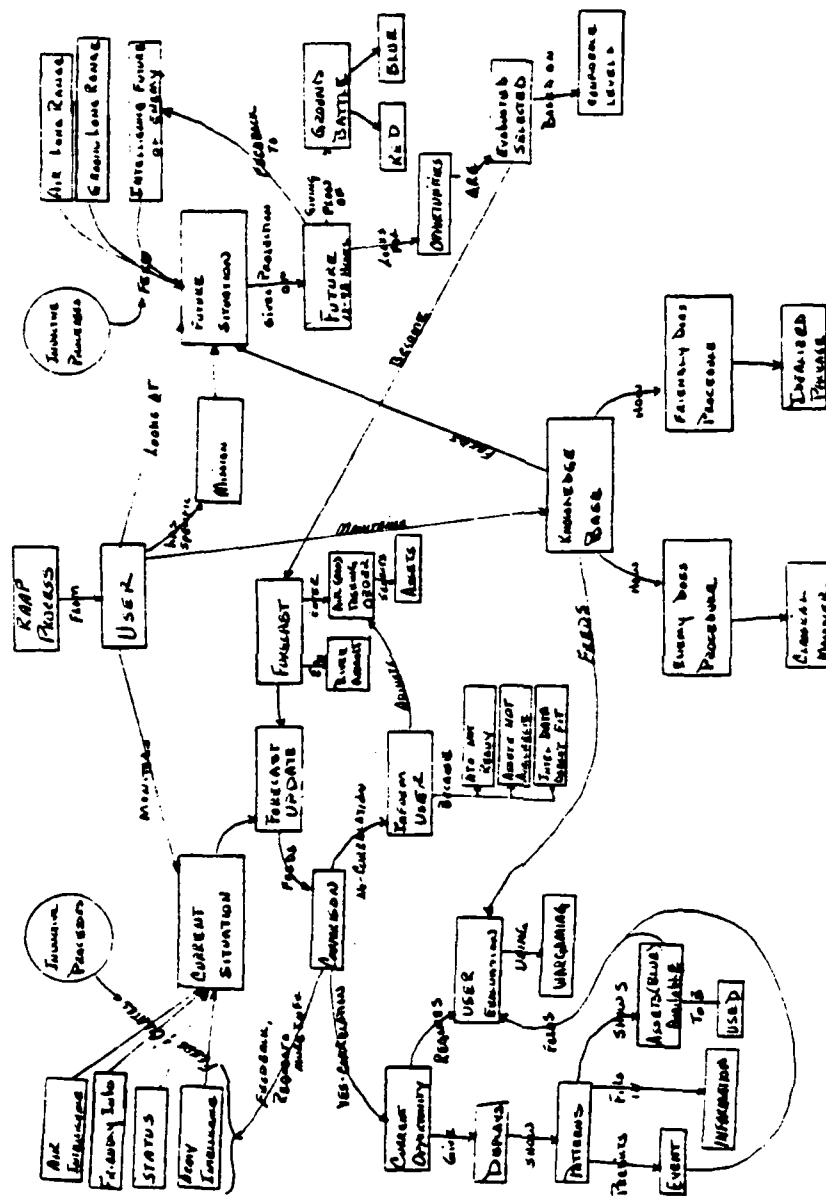
Figure 7-5b. Mr Allen's Second Interview

173

Mr Converse:

Mr Converse was chosen to be an expert because
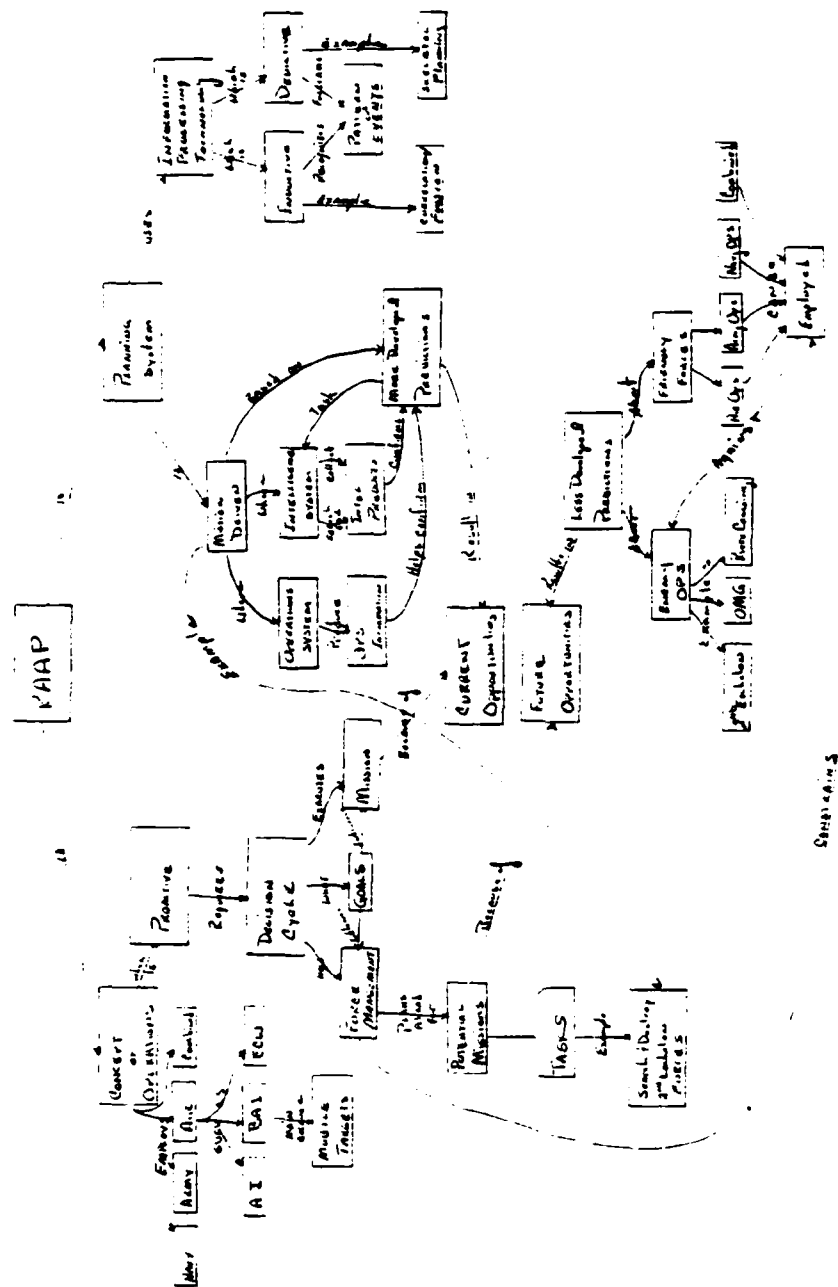of his position as a research manager over the RAAP
effort. He is a physical scientist at RADC, Group Leader
and Manager of the Advanced Sensor Exploitation Section.

Again due to time constraints, only one interview
was scheduled. The interview followed the standard
two part approach of trying to capture the problem definition
and decision process.

The resulting map is shown in figure 7-6. This
map is different than any of the previous maps in that
both problem definition and decision process are on
the same map. This was done to save space and to show
the level of conceptualization. In this interview the
level of conceptualization was not as detailed as with
other experts. The map has two halves. The left half
is Mr Converse's understanding of the problem, or his
problem definition. The right side is his understanding
of the decision processes.

Figure 7-6. Mr Converse's Concept Map

175

Mr Papagni:

Mr Papagni is the RAAP program manager for Rome
Air Development Center (RADC). Currently he is the
individual responsible for the majority of RAAP research
and research management in the Air Force.

His interviews consisted of both the problem definition
and the decision process. The maps constructed from
these two interviews are shown in figures 7-7a and 7-7b.

Lt Fye:

Lt Fye is also an engineer that is working on research
dealing with tactical sensor fusion of battlefield data.
This type of research is in direct support of the type
of technological applications that RAAP can exploit.
Lt Fye's interview centered on his understanding of
the RAAP concept. His map is shown in figure 7-8a.

Like Mr Papagni, Lt Fye also approaches the concept
like an engineer. He sees it as a 'God's eye view'
collection of data by various sensors that feed into
data bases and processors. He sees the output as recom-
mendations and basic information for the user to consider.
These comments are expressed in his second map shown
in figure 7-8b. This map also shows insight into his
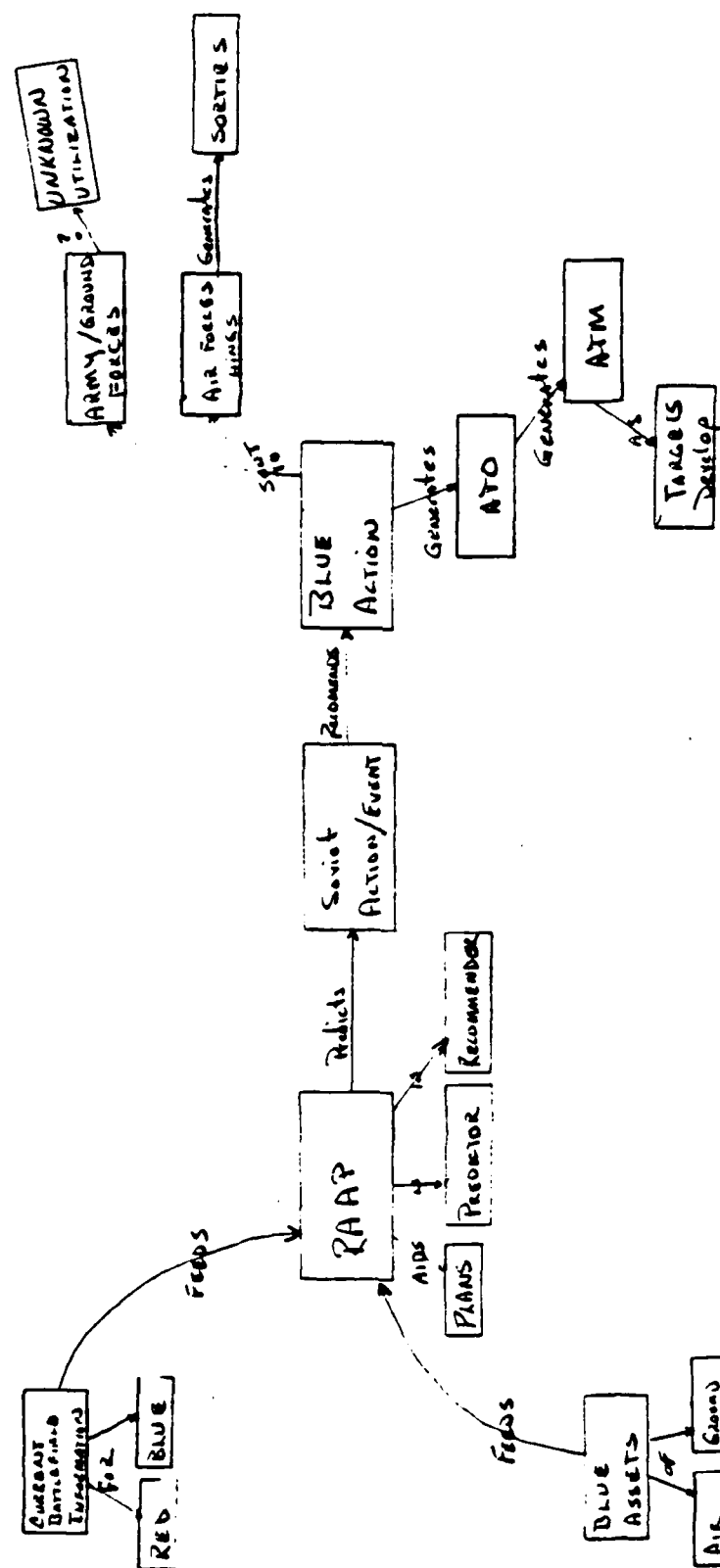understanding of the concept RAAP and its processes.

Figure 7-7a. Papagni: Definition of RAAP

Figure 7-7b. Papagni : RAAP Process

178

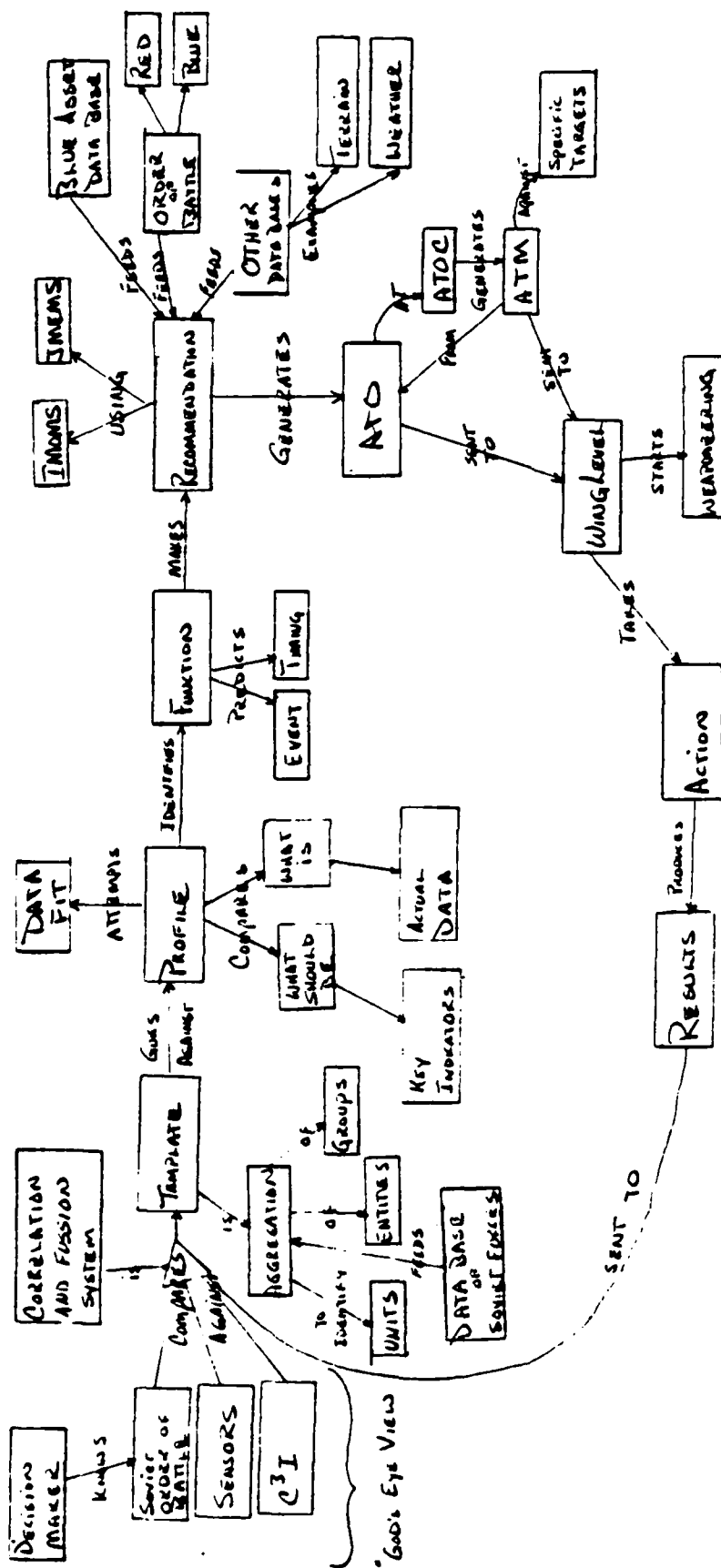Figure 7-8a. Lt Fye: RAAP Definition

179

Figure 7-8b. Lt Fye: RAAP Process

Col Moody Suter (Retired):

Col Suter is a retired Air Force Officer who is
now a consultant to E-Systems, the prime contractor
for phase I research related to RAAP. He is considered
by the Air Staff as the expert in application of modern
air power against highly maneuverable Soviet ground
forces.

Approximately four hours of interviews were held
with Col Suter. The same approach was used on Col Suter
as on the other experts: to capture first his understanding
of the concept RAAP and secondly the decision processes
as he sees them. Col Suter's maps are listed in figures
7-9a and 7-9b.

Figure 7-9a is the map showing Col Suter's understanding
of RAAP. He has centered it around the battle commander
and his responsibilities. The second map is very inter-
esting. This map is the process Col Suter sees as the
battle commander's
process and the interface that commander would have
with a RAAP system. It is constructed in a time-line
fashion. The center line depicts the progression of
time as a commander interfaces with the decision processes
and decision aids. Thus, the decision processes of
RAAP are captured by looking at the entire decision
processing of the human.

Figure 7-9a. Col Suter: RAAP Definition

Figure 7-9b. Col Suter: RAAP's Role in the Decision Process

183

7.52 Aggregation:

This section's main purpose is to summarize the lessons learned about RAAP. The procedure used is that outlined in chapter 3 called Overlaying Maps. The results of this process are described below.

The aggregation process was done twice. The first effort concentrated on the definition of RAAP. The key elements of the definition of RAAP are listed in Table 7-1. From these key concepts, the aggregated concept map was created to depict this author's definition of RAAP. This map is shown in Figure 7-10. This map was created as a demonstration that a transfer of understanding did take place between the various experts and the author.

Information
Way of Thinking
Proaction
Deductive Thinking
Information Technology
Human Judgment
Logic
Decision Making
Decision Aids

Table 7-1. Key Concepts in the Definition of RAAP

The aggregation process was reapplied to the decision processes of RAAP. Table 7-2 lists the key elements identified from the RAAP decision process maps as possible

kernels. These kernels are the areas of present and future research that will support the development of RAAP. The main purpose for this list of kernels is in evaluation of research goals, direction of research efforts and gaining support from outside agencies. This list of kernels is not intended to be exhaustive. It is only a suggestion or starting point for the experts and key research managers. Hopefully, this list will confirm some of the experts' intuitive feelings about the direction of the on-going research efforts. The list should also initiate discussion on kernels that may not have been previously considered or acted upon.

No aggregated map was constructed. An aggregated map of the decision process would not serve any useful purpose at this time. The reasons for this decision are based on the main purpose for this paper and the lack of beneficial use to the experts. It's believed that the experts will gain more from using all the individual mappings of the decision processes and the list of suggested kernels. From these resources the individual research groups can develop their own aggregated maps of the decision process and identify the key elements based on their perceptions. Due to the infancy of the research, a broad view of the possible decision approaches is needed so research efforts are not stifled by single views.
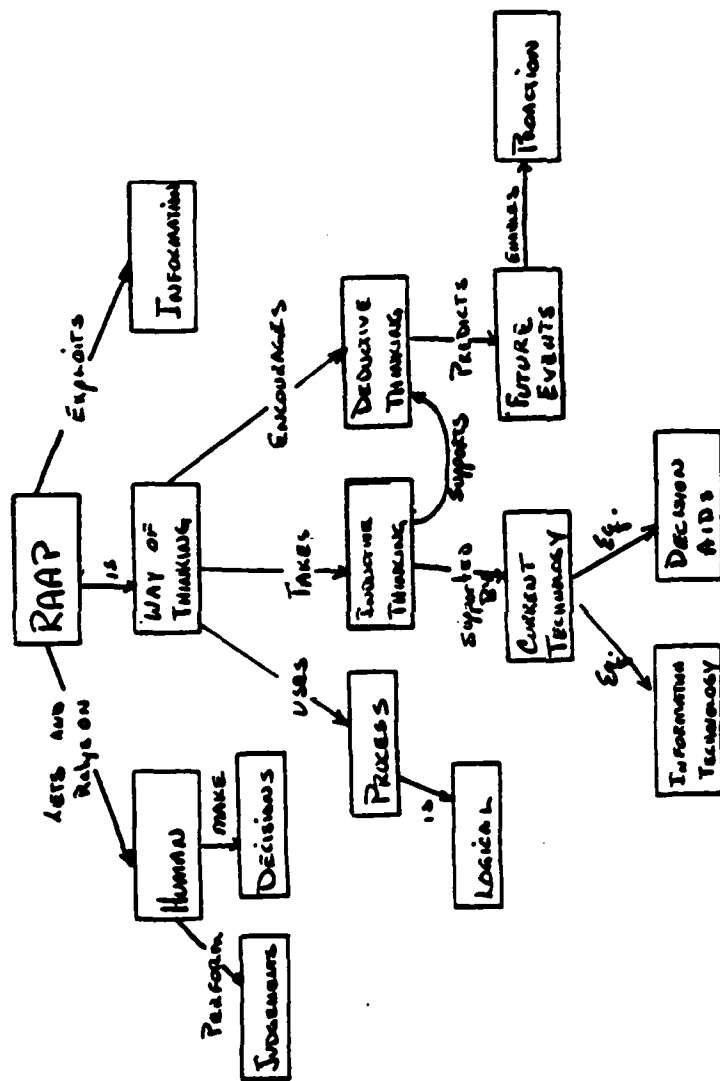
Figure 7-10. Aggregated Definition of RAAP

Information Processing
- Collection of Information
    = Who or what manages the data collection equipment
      and procedures?
    = What is the specific information that gets
      collected?
    = Who or what mechanism selects information
      to collect?
    = How is the information ranked?
    = What are the 'rules' for:
        1) collecting the information
        2) identifying pertinent information
        3) ranking the information
        4) eliminating the information
- Collation of information
    = What are the 'rules' for:
        1) combining information
        2) establishing meaning to individual
           pieces of information
        3) not combining information
- Fuser
    = What are the 'rules' for:
        1) drawing meaning from raw and collated
           data
        2) ranking the fused information
        3) presenting fused information (order)
    = Where does the information get fused?
      (central vs local)
    = Who gets fused information?
- Displays
    = How will the data (raw, collated, fused)
      be displayed?
    = Who will get/control the display?
    = How will the Battle CC get the information?
- Data Base Interface
    = Who or what controls/maintains/accesses?
    = What are the 'rules' to control/maintain/access?

Red Inference Engine
- Profiles
    = What are the 'rules' for:
        1) matching current events with past actions?
        2) handling the uncertainty?
        3) ranking the importance of the predicted
           actions?

Table 7-2. Possible Kernels in the RAAP Process

RED Inference Engine (Continued)
- Data Base of Events
  - Who or what will maintain/control/access
    this volatile data base?
  - How will the CC maintain knowledge of data?
  - How will the CC access/display logic for
    prediction based on intelligence?
- Opportunities Identifier
  - Who or what will notify the CC?
  - How will the CC be notified?
  - Integration of Opportunities/Options/Intelligence,
    how will they be displayed/managed/communicated?

BLUE Inference Engine
- Data Base of Actions-to-Take
  - Who or what will maintain/control/access
    this volatile data base?
  - How will the CC maintain knowledge of data?
  - How will the CC access/display logic for
    prediction based on intelligence/Predicted
RED action/Resources?
  - Integration of Resources and BLUE options?
- Weaponeering
  - Optimization of Force - based on:
    1) Weapons available
    2) Tactics
    3) Target characteristics
    4) Survivability

'What-If'
  - Who will control the function?
  - What functions will be contained?
    1) War Gaming
    2) Simulation
    3) Other Optimization and Gaming Models
  - How will functions interact with the current
    information available in the system?
  - Display of results?
  - Who manages/control/access displays?
  - How do results from 'What-If' integrate with
    actual data displays?

Table 7-2.   Possible Kernels in the RAAP Process
(Continued)

7.53 Observations:

The following discussion is a record of various observations made during the process of preparing the concept maps on RAAP. All of these observations support the concept map as a powerful communications tool.

Three observations are made based on the fact that each expert brings a different perception of RAAP into the interviews. Throughout all of the mapping exercises, one thing became very clear. The experts defined RAAP in terms of their specific backgrounds and from their perspective. Experts approach the problem based on their backgrounds. Col Rothrock looked at it from the theoretical level of information processing. Mr Papagni, Mr Converse and Lt Fye centered their discussions around the process and the hardware. Col Kline's view was from operation's need for support in information processing and the advantage of RAAP in this problem domain. Maj Harrison's point of view came from the operational intelligence field. He was very concerned about how RAAP would interface intelligence with operations and accomplish the intelligence functions. Mr Allen took a totally different view by describing RAAP as a planning system that is mission driven. This makes perfect sense since Mr Allen is the Soviet expert and deals in-depth with the mission assessment portion of RAAP. Finally, Col

Suter took the approach: "If I were the commander, how would I want the decision aid to support me?" (Suter, 1987).

From these varied perceptions come the first observation. It recognizes the fact people do have differences, but still the series of maps show a high level of conceptual agreement. This phenomenon demonstrates that a universal understanding of basic RAAP concepts does exist among the experts.

The second observation substantiates the basis of the overlay process. The many perceptions produced a variety of maps which emphasize different parts of the RAAP concept, but each expert identified most of the same basic concepts. This made the overlaying of maps an easy process. When most of the experts agree on the basic concepts and link them in similar manners, confidence is high that that concept is key.

The final observation made from the variety of perceptions deals with the transfer of understanding to others. Difference in background and development of thought patterns do not alter the transfer of understanding. Linkages may be different and organization of the concepts may be radical from map to map but the basic understanding of the concept still comes through. For example, contrast the maps of Mr Papagni and Col Rothrock.

The strong background of scientist/engineer produces a set of maps that show the powerful influence of systematic analysis and process. Especially noteworthy is the way Mr Papagni described the process. He has it organized in his mind as a flow of inputs, data bases, processors, and outputs. This approach is quite different from that of Col Rothrock. Yet, the overall concept of RAAP is the same and many of the linkages reflect similar understandings. The educational value of both sets of maps for the novice reader enhances the transfer of information and eventual understanding.

Finally, one noteworthy incident was observed that supports the value of the maps as communications tools and transfers of understanding. After completing the second interview with Mr Allen, Maj Harrison entered the room and looked at the map that was still on the board from the interview. Maj Harrison was able to quickly read and identify a mistaken concept Mr Allen had of the Air Tasking Order (ATO). After a few questions and some explanations, Maj Harrison suggested changes in the map that would more correctly depict the function of the ATO in managing assets.

This incident substantiated two propositions of the concept mapping technique. First the incident showed the ease of readability that is inherent in a concept map. Maj Harrison could easily read and pick out the

191

understanding depicted by the map. This action of Maj
Harrison is evidence that a transfer of understanding
took place. Secondly, it showed that two individuals,
having different beliefs about a concept, could quickly
identify and discuss the issue by reviewing the map.
After an agreement is reached, appropriate changes to
the map occur which shows the corrected understanding.

These were just a few of the many observations
made that support the power of concept mapping as a
communications tool.

7.60 Conclusion:

This chapter has recorded the application of concept
mapping to a large problem area. Its goals were to
bring about a transfer of understanding about the basic
concept and to help identify key decision elements in
the various decision processes. The chapter explained
why RAAP was chosen as the test bed problem area and
gave some background as to why the USAF is very interested
in RAAP. The experimental procedure was outlined and
results reported in detail along with the entire series
of concept maps.

In conclusion, this experiment has shown that concept
mapping can act as an aid to pick out key kernels, help
enhance understanding between individuals and do these

things on a variety of conceptual levels. Recommendations
regarding the results of this experiment are expressed
in the final chapter.

Chapter 8

Results, Recommendations, and Conclusions

8.00 Introduction:

This chapter discusses the overall findings and results obtained from applying concept mapping to the task of problem definition and kernel identification. Based on these comments, recommendations for future research with concept mapping is presented for the technique development and application. Recommendations are also presented for the future work yet to be done on RAAP and where concept mapping may assist.

8.10 Findings and Results:

The main objective of this research effort was to develop a user oriented tool (concept mapping) for problem definition and kernel identification during the design phase of a DSS. The second objective was to develop a procedure for using this tool in the adaptive design approach. The two sections below record the findings and observations from each of these objectives.

8.11 Concept Mapping as a Tool:

Through the observations made during the many experiments, the findings can be broken down into five separate areas. First, concept mapping demonstrated its ability

to transfer understanding between individuals. This was especially noteworthy where more than one person was involved in the construction of the DSS or defining the problem. The fact that concept maps transfer understanding is also why they are an excellent teaching tool in education.

The second finding is that concept maps identify inconsistencies and misconceptions. If a person is erratic in his/her explanation of the problem by using different concepts and illogical or multiple links, then these inconsistencies are readily seen in the maps. The person can then concentrate on the actual meaning and form the proper understanding. In other words, the expert stabilizes the meaning. If in a group setting, one of the members has a misconception about some part of the problem, it will be seen by the others on the concept map. The members can then help the individual attain the correct understanding and eliminate the misconception.

The third and fourth findings are the most important. Basically, concept mapping works. It is shown in the many examples presented in this paper that the concept maps: 1) capture a human's understanding of a specific problem space and 2) capture his/her decision process elements. This process can produce a reasonably complete description of the problem space. It creates both a

perceived definition of the problem and a list of tasks and events that make up the individual's perception of the decision process. Understanding depicted in these maps is easily transferred to others by 'negotiating the meaning'.

The last finding is the forum for 'negotiating the meaning' that concept mapping provides to the DSS design team. Concept mapping provides a forum for discussion and evaluation. Using the concept maps to capture their understanding of the problem space and elements of the decision process gives an easy-to-read format that is simple to manipulate as perceptions change. The design team members identify and rank the 'importance' of the elements in the decision process. Once they have the rankings and initial system requirements, evaluation criteria can be developed to ensure the design supports the kernels.

8.12 The PDP as an Integrator:

Three key observations were made from the two experiments using the PDP approach. First, the designers had an orderly approach to guide them through the analysis and design phases of the adaptive design. Each time they complete a step or an evaluation in the PDP, the next action was clearly identified. Second, the criteria for the evaluation of the system requirements were much

easier to derive. The evaluation had a purpose: the need to support cognitive processes which were described by the concept maps. The evaluation also had guidance. The guidance came from the kernels identified as the key decision elements that required the support of the DSS. Thus the criteria derived ensured the system design supported the cognitive process and was built around the key kernel(s).

The last observation was the increased confidence the design team members had on the system requirements. Using the PDP enhanced the design of the system to support the cognitive processes of decision making. The concept mapping tool aided in the identification of the kernels. The feature charts and storyboards developed the system requirements based on the kernels identified and the evaluation kept the design on the right track. All three steps made for a set of initial system requirements that were believed to describe a DSS that really did support the decision maker.

The examples and personal experience of the author led to the belief that the Problem Definition Process is a viable method of developing and maintaining the system requirements of an evolving DSS. The steps contained in the three phases of the PDP have produced two interesting and successful designs and prototypes. The more DSS designers experiment and work with the order and iteration

197

of the steps, the easier it seems for them to determine the requirements and alterations needed by the system.

8.20 Recommendations:

All of the recommendations presented below are for further research and study. The recommendations are broken into three categories. The first group looks at proposals for improving or enhancing the concept mapping technique. These are mostly nice to have ideas. They came from the fact that current concept mapping is a lot of paper and pencil work that is tedious and repetitive. The second group of proposals looks at further studies that would apply to concept mapping in different arenas. The third and final group of proposals suggests ways that the PDP could be enhanced, used, and evaluated in different ways.

8.21 Technique Enhancements:

There are three areas recommended for future study that could improve the ability of analysts to perform the concept mapping technique.

8.211 Harness the power of Automation:

Tools such as the Macintosh with MacDraw need to be explored as aids to concept mapping. These tools could be used to initially build the maps in the interview,

store the maps, make quick changes, formalize a map for presentations, and perform 'What-ifs' with the links and hierarchial arrangements. A study could also look at the peripherals to the computer, such as: larger screens, light pens, multiple colors. Software enhancements could include a study on the value of animating the concept maps. This animation would be the evolution of the concept map as it was constructed. The study would explore the value of the animation in transferring and negotiating meaning.

Automating the maps would allow the maps to be 'overlaid'. This would mean matching key concepts from different experts and physically laying one map over the top of the other. With the maps stored in the computer the manipulation of concepts would be trivial. The differences in linkages and meanings would be highlighted. The areas of agreement would also be highlighted and further justify the evaluation of concepts as key kernels in the problem.

One final recommendation for follow-on study is to build a portable tutorial program to teach the designers. This tutorial should include all of the lessons in Appendices A and B as well as a complete walk-through of the DSS development with hands on experience. The lesson would be targeted for the user, so he can design his own systems. Basically, it takes the middleman out of the DSS develop-

ment. This would leave the professional DSS designer
the time for consultations and larger projects.

8.22 <u>Concept Mapping Applications</u>:

There are four areas of study that could be continued
based on the application of concept mapping to problem
definition.

8.221 <u>Apply to more Problems</u>:

Concept mapping needs to be applied to a wider
range of problems. This thesis effort concentrates
on the problem definition for DSS development. Concept
mapping can be applied to any problem domain that requires
the problem solver to define and describe the problem.
However, procedures need to be established and experiments
performed to prove that concept mapping can be applied
to any problem domain.

8.222 <u>Concept Mapping and later stages of DSS Development</u>:

Further research is needed in the later stages
of DSS prototype development. What role do concept
mapping, storyboarding, and feature charts play in the
maturing development stages of a DSS? Does concept
mapping help dampen the volatile effects of major changes
in system requirements?

200

8.223 Follow up with the RAAP problem:

There are two areas for continued research in RAAP. First, the full set of concept maps need to be reviewed again by the experts and a general consensus established. After the agreement of terms, descriptions, definition and process elements, a list of kernels needs to be developed. This list of kernels can then be evaluated and ranked in order of importance, feasibility, etc. This action would result in a setting of research goals and justification for financial and political support.

The second emphasis would be in developing a briefing tool out of the combined concept map of the problem definition. This map would become a finely tuned communication tool for use by the Air Staff and others. The inherited ability of concept maps to present information in an easy-to-absorb manner would make the presentations to novices much more understandable. After all, concept mapping is an educational tool for negotiating meaning and transfer understanding.

8.224 Apply CM to the USAF Acquisition System:

Further research is needed to find if a concept mapping technique is feasible in building a management scheme. Specifically, can concept mapping be used by the Air Force Systems Command to manage adaptively designed systems? What would be the procedure? What evaluation

criteria would be used to compare the many kernels within a system? What evaluation criteria would be used to compare similar but different systems?

8.23 PDP Enhancements:

Almost the exact same recommendations for enhancing the concept mapping technique can be said for the enhancement of the PDP. Automating the feature chart and storyboard steps would also aid the designer in the process of determining the system requirements. A drawing board, on which s/he could quickly create the feature charts and storyboards, modify, rearrange and save them, would be a big time saver as well as a big boost to creativity.

Evaluation criteria on the human engineering aspects of the DSS man-machine interface could be built into the drawing board. A system of this nature could alert the designer to a variety of faults or recommend a better idea. The system might offer some of the following information.

1) The printing is too small to read.

2) The colors are too difficult to distinguish

3) The DSS should have an attention-getter.

   Example: Flashing light - red in color.

8.30 Conclusions:

This paper has explored a broad range of topics and issues. First, the decision maker's environment was described. This description showed the world as a mass of fused communications bombarding the decision maker constantly. From this onslaught of information, he must identify that a problem exists and then attempt to define it in full detail so a DSS, if applicable, can be developed.

Second, the theoretical foundation was laid for why concept mapping would work. The way the mind stores information and the way concept maps capture information was shown to be consistent. Based on this fact, meaning and understanding would be represented much more effectively than with any other method of capturing knowledge.

The next two presentations were 'how-to's'. The concept mapping tool was shown with two self-paced lessons and helpful hints for interviewing. The PDP was then introduced and explained step by step. All of these steps and lessons were designed for two reasons. The first reason was to establish a standard approach to the problem of determining the system requirements for a DSS using concept mapping. The second reason was to teach the reader and future designer a successful way of designing and building a DSS.

Finally, the paper presented eight months of exercises

where concept mapping was applied. A broad variety of problems was sought out and experiments were run. The successes, small and large, were all recorded.

Although concept mapping is a simple tool to use, it is powerful in its ability to define problems and identify kernels in a problem space. Some further trials and experimentation with the method of applying the tool need to be done. But the theoretical foundation and its current success points to a new approach to understanding problems.

APPENDIX A:

Introductory Lesson to Concept Mapping

An Introduction To:

CONCEPT MAPPING

LESSON A

Prepared by Capt. M.R. McFarren
AFIT/EN GST-87J May 1987

Concept Mapping

WELCOME to Lesson A ... the first of a two part introduction to Concept Mapping.

This lesson is self-paced. Read and follow the instructions on each of the following charts. The lesson will guide you through the terms and basic ideas of Concept Mapping.

206

Concept Mapping

STOP HERE!

Get: * Paper
       * Pencil

You'll need them for notes and responses to the exercises.

Concept Mapping

Look at these two lists of words.

Dog	Raining
Car	Playing
Chair	Washing
Tree	Thinking
Cloud	Thunder
Book	Birthday Party

What is different about the two lists?

Concept Mapping

On your paper describe how the two lists differ.

Concept Mapping

The two lists are different in many ways.

The main difference is the group on the left is a list of object words while the group on the right is a list of EVENT words.

Concept Mapping

This list is a list of OBJECT words.

Dog

Car

Chair

Tree

Cloud

Book

Concept Mapping

An object is anything that can be seen, touched or otherwise sensed.

Exercise:

Lift the flap on the right. On your paper describe or draw a picture of what comes to mind when you read the word:
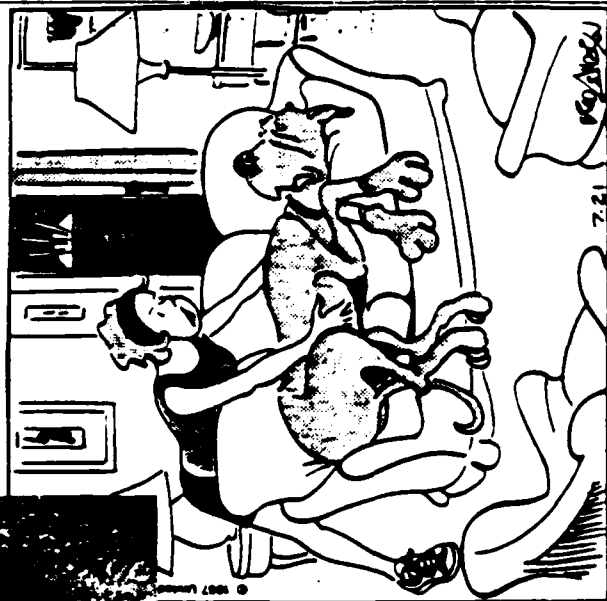
DOG

Concept Mapping

When you read the word 'DOG' a mental image came into your mind. This image could be a picture of a dog or an experience you've had in the past with a dog.

Concept Mapping

Chances are the mental image you described or drew is different than anyone elses.

For Example: was your image or description of a 'DOG' exactly like one of these?

Concept Mapping

Concept Mapping

Although all of these images are are different they are all correct. The word DOG is a label given to a concept. So, all of these pictures are examples of the concept 'DOG'.

Concept Mapping

This list is a list of EVENT words.

Raining

Playing

Washing

Thinking

Thunder

Birthday Party

Concept Mapping

An EVENT is a thing that happens. It is an action that takes place.

Exercise:

Lift the flap on the right.
On your paper describe or draw a picture of what comes to mind when you read the word:

PLAYING

Concept Mapping

When you read the word 'PLAYING' another mental picture came to mind.

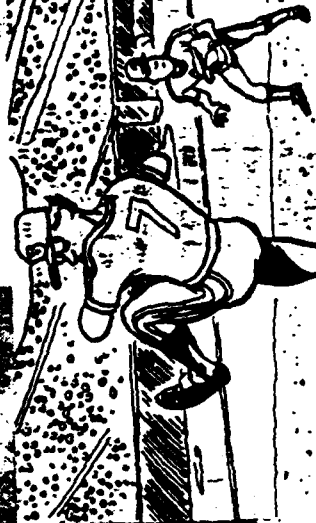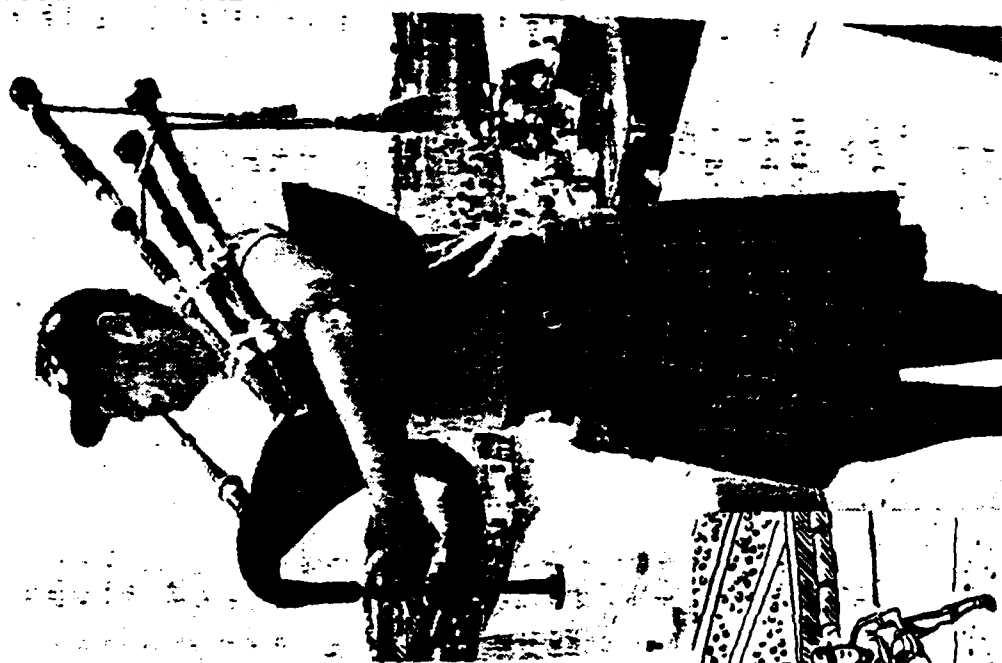This picture again came from your past personal experiences.

Concept Mapping

The mental picture made by the event 'playing' is different from the mental picture made by an object word. 'Playing' shows or describes an action. Read your description.

Doesn't it describe an action or happening?

Is it the same as these other images?

Concept Mapping

Concept Mapping

Again all of these images and descriptions are different. But, all are recalled by the word 'PLAYING'. The word 'PLAYING' is a label given to a concept. So all of these mental images are examples of the concept 'PLAYING'.

Concept Mapping

CONCEPTS are the mental images recalled

by the labels given to them.

Concept Mapping

We have just seen two examples of a single label creating many different mental images.

How then do you know that another person understands you when you use the word 'DOG' or 'PLAYING'?

Concept Mapping

You Don't!

Words are labels for concepts. Each of us learns the same words but acquires our own unique mental images through personal experiences. Therefore, we have trouble understanding each other because our concepts are never quite identical.

Concept Mapping

Review the following list of words.

Are

Where

The

Is

Then

With

Concept Mapping

Describe the mental image(s) that came into your mind when you read any of the above words.

Concept Mapping

You're Right!

None of these words recall any mental images. These words are not concepts. They are LINKING words.

Concept Mapping

LINKING words are used together with CONCEPT words to construct sentences that have meaning.

Concept Mapping

Example:

'Sky' and 'Blue' are CONCEPT words. When linked together with a LINKING word like 'is' they combine to form a specific meaning. The sentence

... SKY IS BLUE. ...

transfers a meaning.

Concept Mapping

You can take these three lists and make up several sentences which have specific meaning.

Examples: Dog is running.

Clouds are thundering.

Write down other combinations from these lists.

Concept Mapping

Sentences can contain many concepts linked together. These sentences attempt to convey specific understanding to the receiver. To understand the sender, the receiver needs to be able to identify the KEY concepts in the message.

Concept Mapping

Depending on the message, there can be many KEY concepts. Some concepts will be more important than others to the message.

Concept Mapping

Read the following paragraph. List the KEY concepts. If you see some concepts more important than others make two lists. One list is for the KEY concepts. The other is for those concepts that are less important.

Concept Mapping

According to the kinetic theory, a gas consists of infinitely small independent particles, moving randomly in space and experiencing perfect elastic collisions. This theoretical description is of an imaginary gas called an 'ideal gas'.

(Metcalfe, 1966:126)

Concept Mapping

Compare your list(s) of KEY concepts with this list.

Kinetic Theory

Gas

Particles

Random Movement

Space

Elastic

Collision

Ideal Gas

Concept Mapping

Did you agree?

If not, why do you think
we differed?

Concept Mapping

Before leaving Lesson A let's REVIEW what we've learned about concepts.

1) Concepts are mental images created in our minds.

2) These mental images are either OBJECTS like 'car' and 'deck', or EVENTS like 'running' and 'jumping'.

3) Concepts are connected by LINKING words to form sentences that have meaning.

4) By studying messages, KEY concepts can be identified.

238

APPENDIX B:

Storyboard and Evaluation of a

Decision Support System

STORYBOARD AND EVALUATION
# OF A
DECISION SUPPORT SYSTEM

Submitted To: Lt. Col. Valusek

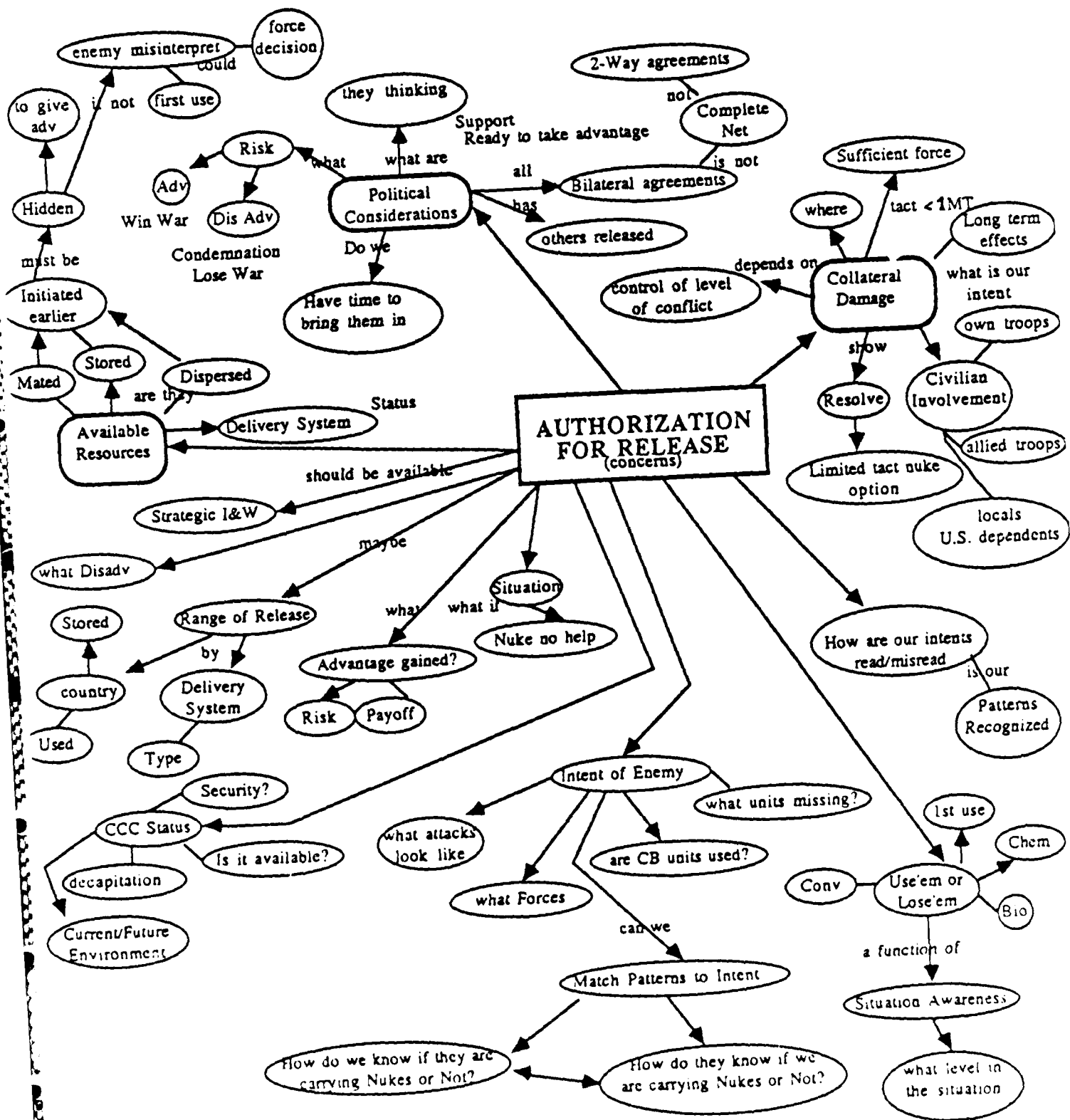By: Capt Bivins and Capt McFarren

20 February 1987

STORYBOARD OF A
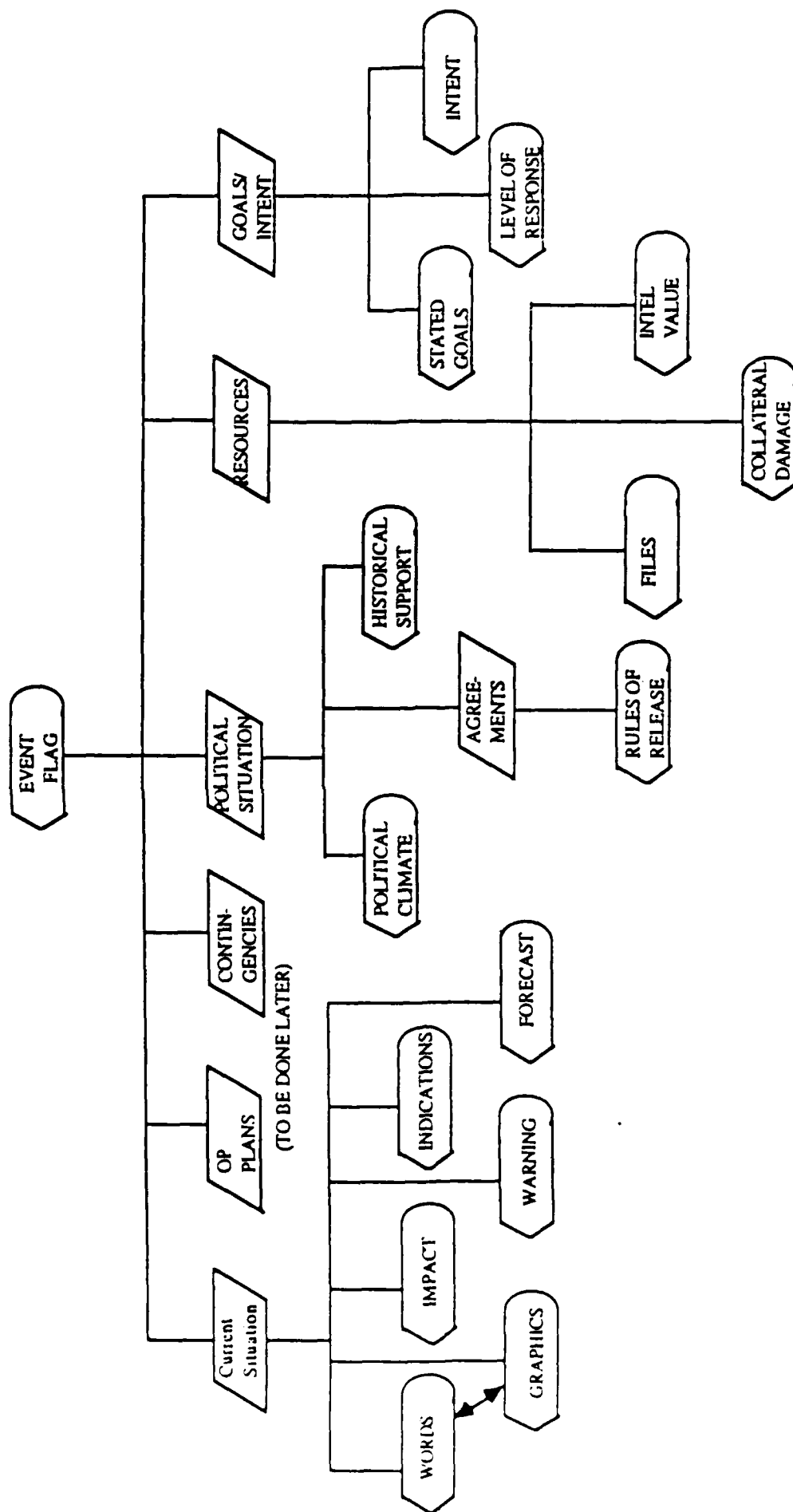# COMMAND AND CONTROL
DSS

Introduction

This paper contains the storyboards of the DSS for the command and control of
theater nuclear weapons. The storyboards are meant to be the basic displays that a decision
maker would see in a theater command post faced with the decision of when to authorize
the release of theater nuclear weapons. The level of the DM that this storyboard is designed
for is the highest level in the theater (CINCEUR or equivalent). This set of storyboards
would give the commander the "big" picture of the situation, climate, resources,
constraints, and timing required to make the decision to release nuclear weapons. The
storyboards were created by conducting a "problem definition." First a "concept map" was
done for the problem, then a "task analysis", a feature chart, the storyboards, and finally
the evaluation of the DSS. All of these steps lead to the identification of kernels, two of
which were identified during the "concept mapping" and are highlighted on the concept
map. The next few pages show the results of the "concept mapping" and "feature chart."
The "problem definition process" is shown below.

Problem Definition

Feature Chart   Kernel

Flag   Concept Task   Data   Storyboard   Eval
        Map   Analysis Flow

Time
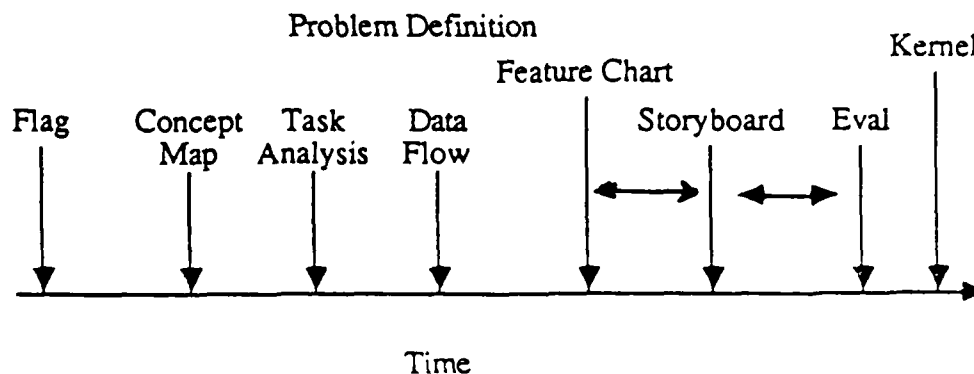
CONCEPT MAP

FEATURE CHART

EVENT NOTIFICATION WINDOW

- This storyboard is the window which would appear to let the decision maker know that an event of some importance has occurred. This window can appear on any screen that the DM sees and at any level in the DSS. Because the DM will not want to always respond immediately to an event, the window asks him if he wants to change screens or continue. Under some circumstances (an event of imperative nature) the screen will change automatically to the screen containing the changed information.

- The spectrum of events which can occur from least critical to most critical are:

  — Important

  — Serious

  — Grave

  — Imperative

- As mentioned, the DSS does not give the DM a choice when the event is imperative. The EVENT message will flash 5 times and then the DSS will switch to the EVENT/INDICATIONS menu.

- Other first line messages which can appear are: "A series of events of", "A series of indications of", and "An indication of."

243

An EVENT of

IMPORTANT

consequence has occured.

Do you wish to investigate further?

YES   NO

CONTROL OF DSS DISPLAYS

- This storyboard shows the various modes of control the DM has over the DSS. He will have five full-screen monitors over which he can display information.

- This storyboard would have a menu which contained all the various displays the DM could use to assist in his decision making.

- Of special interest is the control the DM has over who gets the information he is seeing displayed. In early phases of a crisis when the survivability of the command and control system is high, the DM would probably choose not to send all of the information and displays he is receiving to all of his subordinate units. However, when the situation heats up he may elect to send all of the information to lower units because of the likeliness of command, control, and communications being lost with subordinate units. This can be done automatically by selecting the appropriate option.

DISPLAY SELECTOR

1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5

DESCRIPTION OF EVENT

GRAPHICAL REPRESENTATION OF EVENT

INDICATIONS RECEIVED

IMPACT ASSESSMENT OF EVENT/INDICATION ON CURRENT SITUATION

FORECAST OF NEXT POSSIBLE EVENT

REQUEST LINE

Automatically forward all event data to subordinate units

ENABLED   DISABLED

Situation Political Op-plan Contingencies Resources Goals/Intent

SITUATION

- This storyboard gives a listing of events that are occurring and the time they are occurring. The display can be split into two screens with one side being text and the other side a graphic display of the area and the event which is occurring.

- Text Controls

  - Scroll DM can scroll listing of events forward or backward.

  - Display DM can call-up Graphic (Map) on right or leave only text (Automatically splits screen into two parts).

  - Suppress DM can show only events of interest and suppress all others.

  - GIWIF is a menu for other screens (Graphics, Indication, Warning, Impact, Forecasts) coming from the EVENT MENU. This allows the DM to move laterally at will.

- Graphic Controls

  - Zoom Gives the DM the ability to increase or decrease the resolution on the map.

  - Scroll Can scroll manually in any of 4 directions one at a time.

  - Options Various physical structures can be shown on the map (roads, topography, and buildings).

  - Program DM can program the map to "follow the movement of a unit and keep the unit in the center of the display.

  - Data Unit identification. Specific data on units selected by the mouse.

  - Time A time can be loaded in and the display will reflect the future situation through simulation.

247

SYMBOL
LINE
MODES
FORD

TIME	EVENT
0030	51ST BN ARMORED CHECK POINT C-8, 10-82
0031	FLIGHT F243 RETURNED
0032	51ST BN ARMORED FIRED UPON LOCATION .5 KM N C-8

SCROLL BUILD PROGRAM WARNINGS

OPTIONS INDICATIONS FORECASTS

TIME ZOOM DATA GRAPHIC IMPACT

SCROLL DISPLAY SUPPRESS WARNING
GRAPHICS INDICATION FORECASTS
IMPACT

SITUATION POLITICAL OP-PLAN CONTINGENCIES RESOURCES GOALS

IMPACT

- This DSS display gives a word description of the event's impact and the confidence level of that impact.

- The decision maker can point to any entry under the IMPACT heading and the DSS will display more detailed information about that event and the impact assessment. This data can include the time of the assessment, the time before the impact is felt, areas which will be affected by the event, and any actions or events which may intervene to reduce or eliminate the impact of the event.

WARNING

- This DSS display answers the questions: What gave the warning?, How reliable is the system which gave us the indications and warning (I&W)?, and What are the I&W which led up to this point?

- The CURRENT HISTORY sub-heading gives a time series listing of the warnings which led to the current situation. This feature allows the DM to look for and determine patterns in the I&W information.

- The PREVIOUS HISTORY sub-heading gives a time series listing of the warnings that occurred in the past to bring the DM to the same or similar situation. An asterisk indicates past warnings that occurred beyond the point that the current DM finds himself. This feature alerts the DM for possible warning indications that might occur in the future. This is a pattern recognition or non-pattern recognition tool. The DM would know that the other side is switching their "play book" if the asterisk indications never occur but some other indications occur instead.

251

WARNING SYSTEM

RELIABILITY

0 . . . . 50 . . . . . 100%

1. - - - - - - - -

2. - - - - - - - -

3. - - - - - - - -

Current History

1. - - - - - - - -

2. - - - - - - - -

3. - - - - - - - -

Previous History

1. - - - - - - - -

2. - - - - - - - -

3. - - - - - - - -

* 4. - - - - - - - -

* Most likely the next EVENT/INDICATION based on past experience

Situation Political Op-Plan Contingencies Resources Goals/Intent

INDICATIONS

- This DSS display lists the set of indications that were received which led to the current situation.

- The flow of logic that links a specific indication to the warning is outlined under the LOGIC sub-heading.

- Other indications that would support the assessment of the current situation are listed under the SUPPORTING INDICATIONS sub-heading.

- Additional detail on any entry under any sub-heading can be obtained by pointing to the entry and clicking with a mouse.

253

LOGIC

INDICATIONS

1.

2.

SUPPORTING INDICATIONS   INDICATION : 1

1.

2.

3.

254

FORECAST

- This DSS display gives the DM a look at the possible outcomes of his actions or next event to occur if no actions are taken.

- The storyboard lists the Indications and Warning (I&W) that if occur, increase the probability of the forecast. This feature alerts the DM to look for specific I&W.

- This storyboard gives the confidence level assessment of the forecasted events.

- The DM can gain more detailed information about the NEXT PROBABLE EVENT entry by pointing to it and clicking with the mouse. Some of the detailed information which may be displayed are the timing of the next event, the areas of impact, the I&W collection means from which the event has been forecast, and a detailed discussion of the confidence level assessment. This data will be presented in a pop-up window on the FORECAST display.

255

CONFIDENCE
0...50...100%

NEXT PROBABLE EVENT   WARNINGS   INDICATIONS
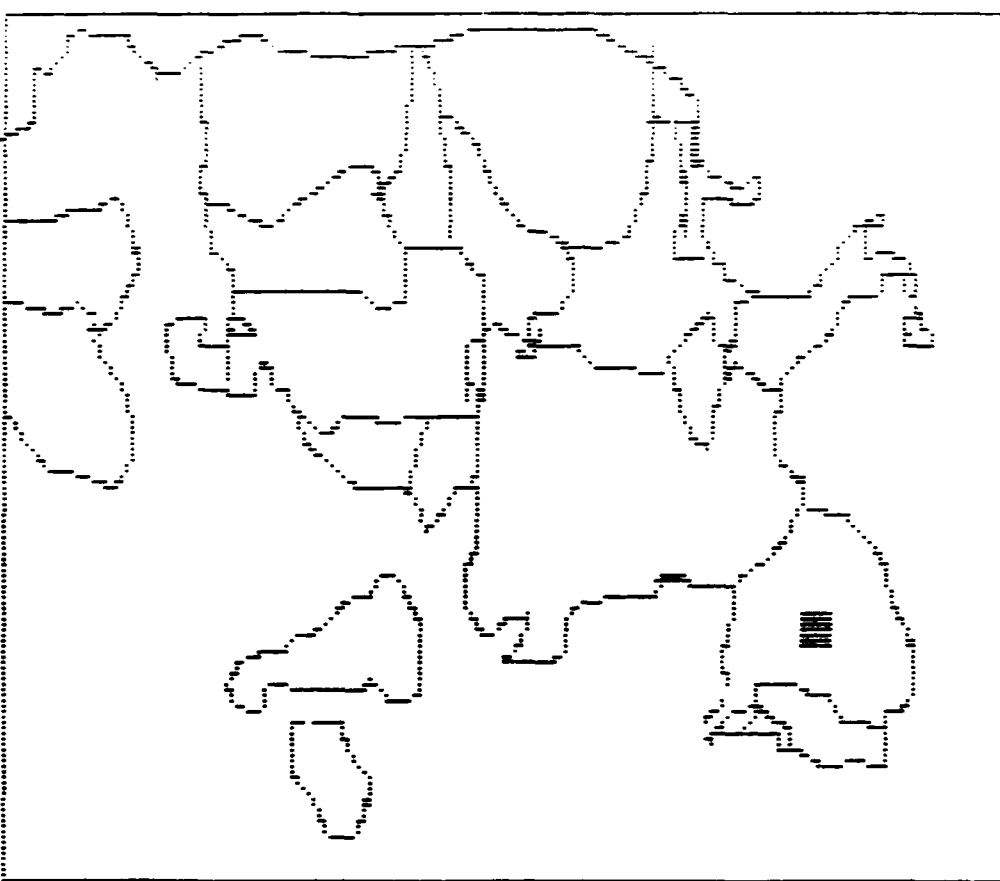
1.

2.

3.

Situation Political Op-plan Contingencies Resources Goals/intent

POLITICAL SITUATION

- This storyboard introduces the political risk assessment of using theater nuclear weapons. This assessment is based on the

    POLITICAL CLIMATE and PAST SUPPORT of each country towards the theater partners.

- The menu then allows the DM to choose among POLITICAL CLIMATE, HISTORICAL SUPPORT, INTERNATIONAL

    AGREEMENTS.

- This display is a menu where the DM can select the country of interest by placing the cursor on the country and clicking with

    the mouse.

POLITICAL SITUATION

SELECT COUNTRY

SPAIN

SELECT INFO SCREEN

POLITICAL CLIMATE

HISTORICAL SUPPORT

INTERNATIONAL AGREEMENTS

SITUATION POLITICAL OP-PLAN CONTINGENCIES RESOURCES GOAL

POLITICAL CLIMATE

The political climate of each country is shown as a continuum from NON-SUPPORTIVE to SUPPORTIVE. This storybourd

also shows political attitudes toward conventional as well as nuclear conflict.

SPAIN

POLITICAL CLIMATE

Non-Supportive   Supportive

CONVENTIONAL THEATER

CONVENTIONAL HOMELAND

NUCLEAR THEATER

NUCLEAR HOMELAND

HISTORICAL SUPPORT

The past support of each country towards theater policies is reflected in expenditures for theater defense and level of financial commitment

The % Defense Spending GNP, % Defense Spending NATO are displayed as follows:

   Baseline is the requested amount (Baseline shown in red).

   Black line is country's actual outlay at the current time.

The last chart shows how many troops are committed "on the books" to the UN versus how many show up when tasked.

AGREEMENTS

... board allows the DM to quickly determine if a bilateral agreement has been signed between a country desiring to

... ar weapons and the country in which the weapon will be detonated. The DM can also get a quick assessment of

... circumstances which both countries have agreed would warrant the use of nuclear weapons.

The DM can view this set of circumstances by clicking in the matrix cell corresponding to the two countries of interest.

The set of conditions which could be viewed from this storyboard include feelings on collateral damage, the time needed to

... release authority from the country in which the weapon will be detonated, any target exclusions, and generally

... of importance in the bilateral agreement.

HISTORICAL SUPPORT IN DEFENSE POLICY

SPAIN

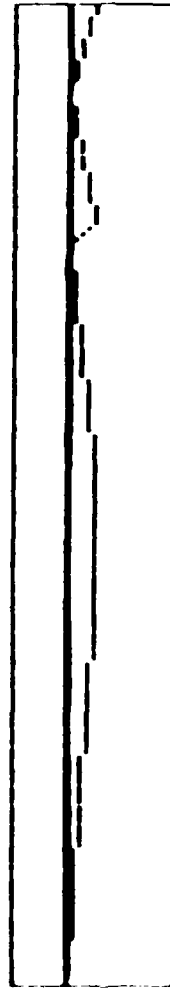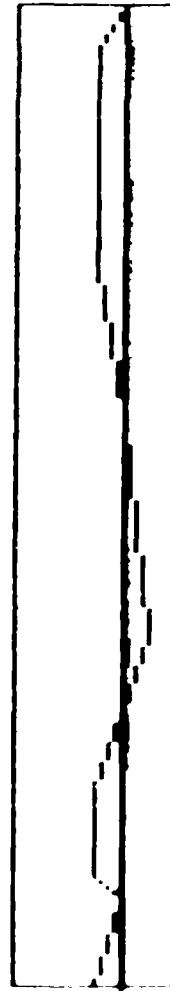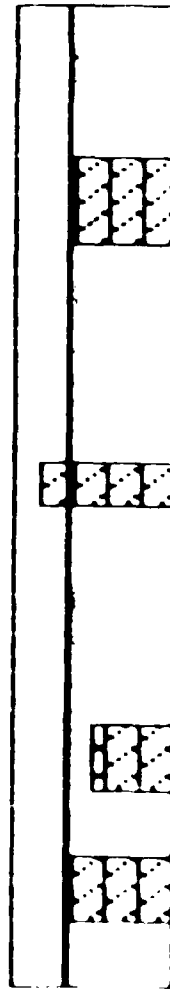% Defense Spending GNP — Time

% Defense Spending NATO — Time

Troops Assigned UN Duties — Time

Troops Deployed UN Duties — Time

Situation Political Op-Plan Contingencies Resources Goals/Intent

INTERNATIONAL AGREEMENTS - NUCLEAR

	England	France	West Germany	United States	Denmark
England	X	NO	YES	YES	NO
France	YES	X	NO	YES	NO
West Germany	YES	NO	X	YES	NO
United States	YES	YES	YES	X	YES
Denmark	NO	NO	NO	YES	X

Situation Political Opt-Plan Contingencies Resources Goals/Intent

RULES OF RELEASE

- This DSS storyboard basically spells out for the decision maker the "Rules of Engagement" which could be known as "Rules of Release."
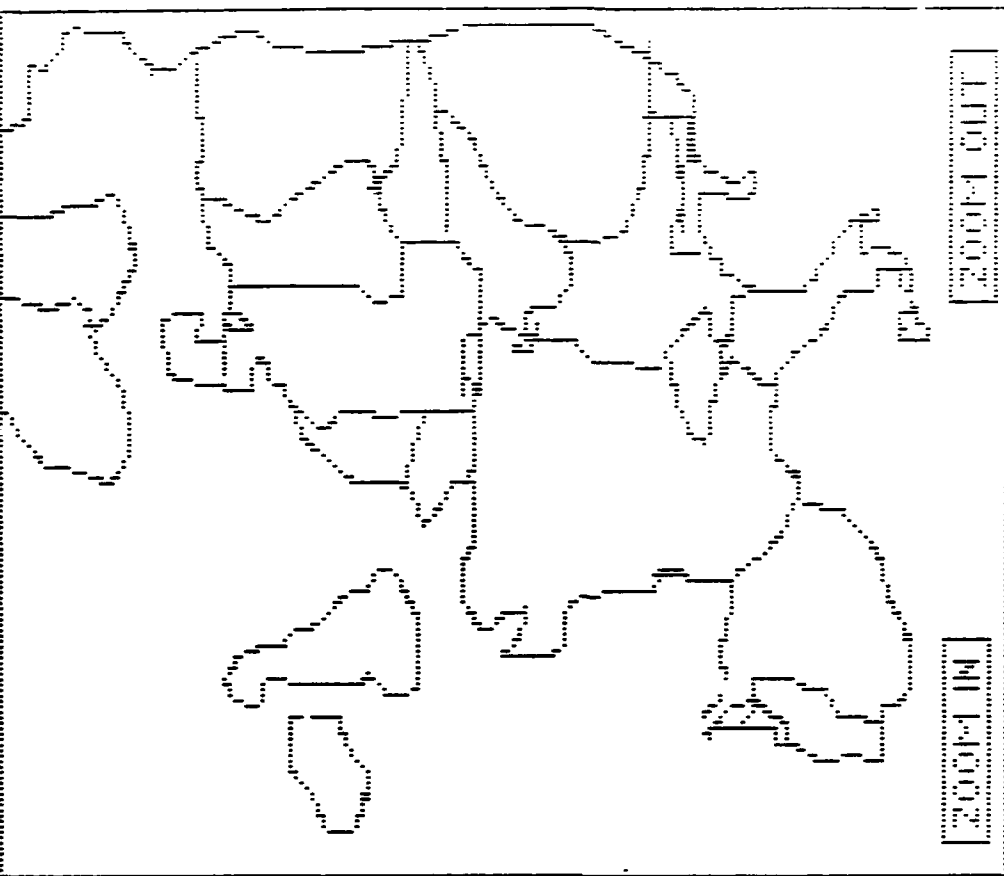
"RULES OF RELEASE"

FRANCE/ENGLAND

1. _____

2. _____

3. _____

4. _____

Situation Political Op-plan Contingencies Resources Goals/Intent

266

STATUS FILES

- Files containing the numbers, types, and location of all nuclear weapons in the theater can be accessed and displayed.

  — The file will contain data which is flashing if that piece of data has changed since the last time the DM opened that file to review the data.

  — By clicking on the flashing data, the DM can see what the previous data entry was before it changed.

- Under the PROJECTED USE sub-heading, all the files contain data which reflect what the status of the weapons (location, dispersal, arming) will be at different points of time in the future (1hr, 6hr, 18hr, 24hr,...) based on simulation.

- PROJECTED LOSS files contain loss information in the same format as the PROJECTED USE files.

- The map of the theater displays the data in color-coded format (BLUE or RED). The screen can display both BLUE and RED resource status.

- A ZOOM IN or OUT capability exists so that the DM can point to an area or a unit which he wants more detailed information about. The capability exits to increase the resolution of the map and display text or numerical data about a unit or weapon.

COLLATERAL DAMAGE

- On the map of the theater, the projected collateral damage areas can be displayed. These areas can either represent projected areas of damage if weapons haven't been released yet or they can represent actual areas of damage if nuclear weapons have been released.

- The option WEATHER allows the DM to see the major weather activity which could affect collateral damage. This weather information will usually consist of wind patterns and areas of precipitation. A change in the direction or intensity of winds or the beginning or increase in precipitation can affect both the fallout pattern and its intensity.

- The map can be made to select patterns of radiation intensity above safe levels for humans (200 rad) at 1hr, 12hr, 36hr, 10 days, and 30 days. This feature also supports simulated patterns due to projected nuclear detonations as well as patterns from actual detonations.

- By clicking on menu items under the sub-headings AREAS OF IMPACT, LEVEL OF DAMAGE, and SIGNIFICANCE OF DAMAGE detailed information will be displayed about that item in text and numeric format.

The display can show BLUE, RED, or a combination of collateral damage.

INTELLIGENCE VALUE

- Using a RAAP approach, resource status for both sides will be analyzed and correlated to give estimates of the current situation. The situation will be shown as a continuum from NORMAL DAY-TO-DAY readiness to NUCLEAR WEAPONS have been RELEASED.

- Historical events which have occurred when the resource status of either side have matched the current situation will be displayed. This feature can be used by the decision maker to drawn inferences about possible future events from resource levels. This correlates to the "pattern recognition" of the RAAP approach.

- The BLUE and RED intelligence value of resource status can be displayed on two separate screens, or for better comparison the screens can be displayed on a split screen to given the DM a quicker comparison between the two side's resources.

271

INTELLIGENCE VALUE

PAST EVENTS with RESOURCE PATTERN

1. - - - - -
2. - - - - -
3. - - - - -
4. - - - - -
5. - - - - -

RESOURCES SHOW INTENT

BLUE

EXECUTED

RELEASE
AUTHORITY

RELEASE
REQUEST

ALERT

NORMAL

Situation:Political:Op-Plan:Contingencies:Resources:Goals/Intent
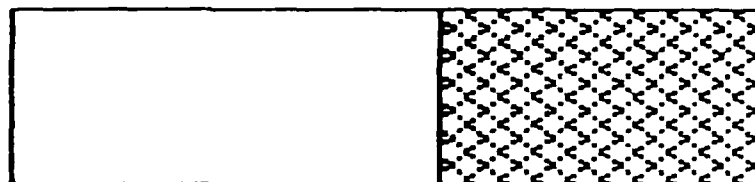
272

INTELLIGENCE VALUE

RED

RESOURCES SHOW INTENT

PAST EVENTS with RESOURCE PATTERN

1. - - - - -
2. - - - - -
3. - - - - -
4. - - - - -
5. - - - - -

EXECUTED

RELEASE AUTHORITY

RELEASE REQUEST

ALERT

NORMAL

Situation Political Op-Plan Contingencies Resources Goals/Intent

STATED GOALS

- This display gives the stated theater objectives and goals under a broad range of scenarios. Amount of detail under specific goals can be changed by pointing to a specific entry under any sub-heading and clicking with the mouse.

- The current level of intensity and DEFCON are displayed to remind the DM which set of stated goals is currently applicable. By allowing the decision maker to have access to the entire range of goals and objectives, the DM can start to formulate plans early when the intensity of the current situation changes.

- This DSS display gives the DM the flexibility to make plans on what the stated goals will be if the current situation continues along some path and reaches a new level of intensity. The plans may even be formulated by taking a mix of the goals under more than one sub-heading.

274

STATED GOALS   Current Status DEFCON [ ]

                                Day-to-day

                                Crisis

                                1._____

                                2._____

                                3._____

                                Nuclear War Imminent

                                1._____

                                2._____

Day-to-day   Nuclear Weapons Used

1._____   1._____

2._____   2._____

3._____

4._____

Increased Tension

1._____

2._____

3._____

4._____

Situation Political Op-Plan Contingencies Resources Goals Violent?

275

LEVEL OF RESPONSE

- The level of response can be displayed for BLUE, RED, or both sides simultaneously using a split screen

- The current response posture is displayed as reversed-out text and that section of the screen is flashing

- The most current and important Indications and Warning (I&W) that have been received are displayed. If the DM wants more detailed information about any particular I&W entry he can go to that section and point and click with the mouse. This would allow him to gain information about the I&W such as its confidence assessment and the timing of the I&W

- The overall assessment of the situation from the I&W is displayed as reversed-out text and that portion of the screen is flashing. Confidence assessment of the overall level of response is also displayed.

276

Level of Response

Current Response Posture

Preemptive

Launch on Warning

Launch on Attack

Launch on Impact

NO Launch

Current Response Posture

Preemptive

Launch on Warning

Launch on Attack

Launch on Impact

NO Launch

Indications and Warnings Received

Preemptive Strike launched

Tactical Warning Received

Attack Indicated

Confirmed Impacts

1. - - - - -
2. - - - - -
3. - - - - -
4. - - - - -
5. - - - - -

CONFIDENCE

——— High

——— Low

INTENT

... an display for either side, the actual versus perceived intent of actions.

... differences in actual intent versus perceived intent are displayed as a function of UNINTENTIONAL or BY ...

... The DIFFERENCE feature can be used by decision makers who wish to better exploit the command, ... communications environment.

... of intent is displayed.

... to any DIFFERENCE entry with the mouse and click to get more detailed information about the ... i.e. area of impact, degree of impact, and possible future impact on theater operations.

INTENT

RED

Confidence
low   high

BLUE

Intent of Actions
1. ---- ----
2. ---- ----
3. ---- ----
4. ---- ----

As perceived by other side
1. ---- ----
2. ---- ----
3. ---- ----
4. ---- ----

Differences: UNINTENTIONAL   BY DECEPTION
1. ---- ----   1. ---- ----
2. ---- ----   2. ---- ----
3. ---- ----   3. ---- ----

Situation Political Op-plan Contingencies Resources Goals/Intent

INTENT

RED

Confidence

low   high

BLUE

Intent of Actions

1. _ _ _ _ _ _ _ _
2. _ _ _ _ _ _ _ _
3. _ _ _ _ _ _ _ _
4. _ _ _ _ _ _ _ _

As perceived by other side

1. _ _ _ _ _ _ _ _
2. _ _ _ _ _ _ _ _
3. _ _ _ _ _ _ _ _
4. _ _ _ _ _ _ _ _

Differences: UNINTENTIONAL   BY DECEPTION

1. _ _ _ _ _   1. _ _ _ _ _
2. _ _ _ _ _   2. _ _ _ _ _
3. _ _ _ _ _   3. _ _ _ _ _
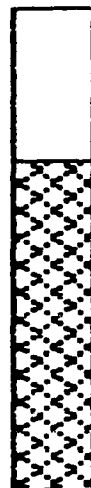
Situation Political Op-plan Contingencies Resources Goals/Intent

X. ANNOTATED BIBLIOGRAPHY

Adams, James L. Conceptual Blockbusting (Third Edition). Reading, Massachusettes: Addison-Wesley Publishing Company, Inc., 1986.

Adams, Capt (USA) William G., Student GST 87M. Personal interviews. AFIT, Wright-Patterson AFB OH, 22 October 1986 through 1 March 1987.

Adelman, Leonard, Fredrick W. Rook, and Paul E. Lehner. "User and R&D Specialist Evaluation of Decision Support Systems," IEEE Transaction on System, Man, and Cybernetics, 15 (3): 334-342 (May/June 1985).

AFIT 1985-1987 Catalog. Course Catalog. USAF ATC Air University, Air Force Institute of Technology, Wright-Patterson AFB OH, Volume XX, Number 1, 1985.

Allen, John G., Director of Engineering. Personal interviews. Lica Systems Inc., Fairfax VA, 30 March through 1 April 1987.

Anderson, David R. and others. An Introduction to Management Science: Quantitative Approaches to Decision Making. St Paul MN: West Publishing Co., 1976.

Bivins, Capt Robert L., Student GST 87M. Personal interviews. AFIT, Wright-Patterson AFB OH, 5 January through 20 February 1987.

Busemeyer, J.R. "Decision Making Under Uncertainty. A Comparison of Simple Scalability, Fixed-Sample, and Subsequent-Sampleing Models," Journal of Experimental Psychology, 11: 538-564 (1985).

Checkland, Peter. "Achieving 'Desirable and Feasible' Change: An Application of Soft System Methodology," Journal of Operations Research Society, 36 (9): 821-831 (1985).

Clements, Capt Donald W., Student GST 87M. Personal interviews. AFIT, Wright-Patterson AFB OH, 14 October 1986 through 17 December 1987.

Cohen, Marvin S., Bryan B. Thompson and James O.Chinnis, Jr. <u>Design Principles for personalized Decision Aiding: An Application to Tactical Air Force Route Planning</u>, Sep 84 -- Mar 1985. Report RADC-TR-85-140. Decision Science Consortium, Inc., Falls Church VA, July 1985 (Rome Air Development Center, Griffiss AFB NY).

Converse, Lenord E., Manager, Advanced Sensor Explotation Group. Personal interviews. Rome Air Development Center, Griffith AFB NY, 2 April through 3 April 1987.

Correll, John T. 'Machines That Think,' <u>Air Force Magazine</u>, <u>69</u> (7): 70-75 (July 1986).

Davis, G. B.. 'Strategies for Information Requirements Determination,' <u>IBM System Journal</u>, <u>121</u> (1): 4-30 (1982).

Eden, Colin and David Sims. 'Subjectiviey in Problem Identifcation,' <u>Interfaces</u>, 11 (1): 68-75 (February 1981).

Eden, Colin. 'Problem Construction and the Influence of O.R.,' <u>Interfaces</u>, 12 (2): 50-60 (April 1982).

-----. 'Perish the Thought,' <u>Journal of Operations Research Society</u>, 36 (9): 809-819 (1985).

Edwards, Ward and others. 'What constitutes 'A Good Decision'? A Panel Discussion among Ward Edwards, Istvan Kiss, Giandomenico Majone and Masanao Toda,' <u>Acta Psychologica</u> ,<u>56</u>: 5-27, Elsivier Science Publishers B.V. (North-Holland), (1984).

Einhorn, Hillel J. and Robin M Hogarth. 'Prediction, Diagnosis, and Causal Thinking in Forecasting,' <u>Journal of Forecasting</u>, 1: 23-36 (1982).

Fye, 2Lt Glenn, Engineer, Tactical Sensor Fussion. Personal interview. Rome Air Development Center, Griggith AFB NY, 2 April through 3 April 1987.

Gentner, Dedre. and Albert Stevens. <u>Mental Models</u>. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers, 1983

Glaser, Robert. 'The Role of Knowledge,' <u>American Psychologist</u>. 39 (2): 93-104 (February 1984).

Gowin, D. Bob & Novak, Joseph D. Lecture materials -
Improving College Teaching. Cornell University,
Ithaca NY, June 1982.

Grechanik, Capt Jeffery W. and Paul E. Trapp, Student
GST 87M. Personal interviews. AFIT, Wright-Patterson
AFB OH, 14 October 1986 through 1 March 1987.

Haltwanger, J. and M. Waldman. "Rational Expectations
and the Limits of Rationality. An Analysis of Hetero-
geneity," American Economic Review, 75: 326-340 (1985).

Handgraaf, Capt Darrel L. Entity-Relationship Model
vs. Extended Semantic Heirarchal Model for Conceptual
Modeling. MS Thesis. Naval Postgraduate School,
Monterey CA, June 1986 (AD-A171 930).

Harmon, Paul. and David King. Expert Systems: Artificial
Intelligence in Business. New York: John Wiley &
Sons,Inc., 1985.

Harrison, Maj Herbert., Personal interviews. INYX,
HQ USAF, Pentagon, Washington D.C., 30 March through
1 April 1987.

Hira, H. and Mori, K. "Customer-Needs Analysis Procedures:
C-NAP," Requirements Engineering Environments, edited
by Y. Ohno. North-Holland Publishing Co., 1982.

Hogarth, Robin M. Generalization in Decision Research:
The Role of Formal Models, (no date). University
of Chicago, Graduate School of Business, Center for
Decision Research. IEEE Transactions on Systems,
Man, Cybernetics, in press.

Hutchins, D.K. "Managing System Creation," IEE Proceedings,
133 (A 6): 343-354 (September 1986).

Keen, Peter G.W. and Scott Morton, Michael S. Decision
Support Systems: An Organizational Perspective.
Reading Massachusetts: Addison-Wesley Publishing
Co., 1978.

Kline, Col Timothy E., Chief, XOXID. Personal interviews.
XOXID, HQ USAF, Pentagon, Washington D.C., 30 March
thorough 1 April 1987.

Klinger, Daniel E. "Rapid Prototyping Revisited," Datamation,
32: 131-132 (15 October 1986).

Kopf, Capt Thomas J., Student GST 87M. Personal interviews.
AFIT, Wright-Patterson AFB OH, 10 November 1986 through
1 March 1987.

Larkin, Jill and others. "Expert and Novice Performance
in Solving Physics Problems," Science,208: 1335-1342
(June 1980).

Mahmood, Mo A. and Jeanette N. Medewitz. "Impact of
Design Methods on Decision Support Systems Success: An
Empirical Assessment," North Holland Information
and Management, 9: 137-151 (1985).

Massie, Joseph L. and Douglas, John. Managing - A Contempor-
ary Introduction (Third Edition). Englewood Cliffs,
NJ: Prentice-Hall, Inc.,1981.

Mathis, Maj Jon W., Student GST 87M. Personal interviews.
AFIT, Wright-Patterson AFB OH, 25 February 1986 through
30 March 1987.

Meador, C. Lawrence, Martin J. Guyote, and Peter G. W. Keen.
"DSS in Organizations: Setting Priorities for DSS
Development," MIS Quarterly, 8 (2): 117-127 (June
1984).

Metcalfe, H. Clark and others. Modern Chemistry. New
York: Holt, Rinehart, and Winston, Inc., 1966.

Konsynski, Benn R. and Jay F. Nunamaker. "Plexsys: A
System Development System," Advanced System Development/
Feasibility Techniques, edited by J.Daniel Couger,
Mel A Colter, and Robert W. Knapp.

Minsky, Marvin. The Society of Mind. New York: Simon
and Schuster, Inc., 1986.

Morris, William T. Decision Analysis. Columbus, Ohio: Grid,
Inc., 1977.

Mylopoulos, John and Hector J. Levesque. "An Overview
of Knowledge Representation," On Conceptual Modeling,
edited by Michael Brodie, John Mylopoulos, and Joachim
Schmidt. New York: Springer-Verlag, 1984.

Orr, Major George E. Combat Operations C^3I: Fundamentals
and Interactions. Maxwell AFB, AL: Air Univeristy
Press, July 1983.

Papagni, James, Manager, RAAP program. Personal interviews.
Rome Air Development Center, Griffith AFB NY, 2 April
through 3 April 1987.

Quade, E.S. and Boucher, W.I. editors. <u>Systems Analysis</u>
<u>and Policy Planning: Applications in Defense</u>. New
York: Elsevier North-Holland, Inc., 1977.

Rivard, Suzanne and Sid L. Huff. "User Development
of Applications: A Study of Model Success". Association
of Computing Machinery (ACM 0-89781-156-3/85/005/0081)

Robinson, Lt Col James. Lecture Materials distributed
in TACT 6.70, Systems Analysis and Defense Planning.
School of Engineering, Air Force Institute of Technology
(AU), Wright-Patterson AFB OH, January 1987.

Rothrock, Col John E., Chief, INYX. Personal interviews.
INYX, HQ USAF, Pentagon, Washington D.C., 13 January
through 1 April 1987.

Rouse, W.B. and R.M. Hunt. "Human Problem-solving in
Fault and Diagnosis Tasks," <u>Advances in Man-Machine</u>
<u>Systems Research</u>. edited by R. Rouse. Greenwich
CT: JAI Press, 1984.

Sage, A. "Behavioral and Organizational Considerations
in the Design of Information Systems and Processes
for Planning and Decision Support," <u>IEEE Transactions</u>
<u>on Systems, Man, and Cybernetics</u>, 11 (9): 618-638
(1981).

Saxena, K.B.C. and Kaul Mohan. "A Conceptual Architecture
for DSS Generators," <u>North Holland Information and</u>
<u>Management</u>, 10: 149-157 (1986).

Schank, Roger C. with Peter G. Childers. <u>The Cognitive</u>
<u>Computer</u>. Reading, Massachusettes: Addison-Wesley
Publishing Company, Inc., 1984.

Schneider, Maj William L., Student GST 87M. Personal
interviews. AFIT, Wright-Patterson AFB OH, 28 October
1986 through 1 March 1987.

Seagle, John P. and Belardo Salvatore. "The Feature
Chart: A Tool for Communicating The Analysis for
a Decision Suport System," <u>North Holland Information</u>
<u>and Management</u>, 10: 11-19 (1986).

Simon, Herbert A. <u>The Sciences of the Artificial</u> (Second
Edition). Cambridge, Massachusette: The MIT Press,
1985.

Shirasago, Dale T., Student GST 87M. Personal interviews.
AFIT, Wright-Patterson AFB OH, 30 October 1986 through
1 March 1987.

Sowa, J.F. Conceptual Structures - Information Processing in Mind and Machine. Reading, Massachusettes: Addison-Wesley Publishing Company, 1984.

-----. "Conceptual Graphs for a Data Base Interface," IBM Journal of Research and Development, 20 (4): 336-357 (July 1976).

Sprague, Ralph H. Jr. and Carlson Eric D. Building Effective Decision Support Systems. Englewood Cliffs, NJ: Prentice-Hall Inc., 1982.

Sprague, Ralph H. Jr. and Watson, Hugh J. editors. Decision Support Systems: Putting Theory into Practice. Englewood Cliffs, NJ: Prentice-Hall Inc., 1986.

Suter, Col Moody (Ret), Consultant. Personal interview. E-Systems, Garland Division, Dallas TX, 1 April 1987.

Valusek, John R. and Dennis Fryback. "Information Requirements Determination: Obstacles Within, Among, and Between Participants," University of Wisconsin, Madison Wisconsin, (1985).
(ACM 0-89791-156-3/85/005/0103)

Ware, Hugh C. The 1984 Measures of Effectiveness (MOE) for C3I Evaluation Symposium: Proceedings and Analysis Volume III. Contract F19628-84-C-0001. The Mitre Corporation, Bedford Mass, December 1984.

Wohl, Joseph G. "Force Management Decision Requirements for Air Force Tactical Command and Control," IEEE Transactions on Systems, Man, and Cybernetics, 11 (9): 618-638 (September 1981).

Woolsey, Gene. "The Fifth Column: On System Acceptance," Interfaces, 16 (3): 55-59 (May-June 1986).

Yadav, Surya B. "Determining an Organization's Information Requirements: A State of the Art Survey," Data Base, 14 (3): 3-20 (1983).

Yasdi, Ramin. Formal Representation of a Conceptual Knowledge Model for a Database Based Expert System, University of Stuttgart, Azenberg Str. 12, D-7000 Stuttgart 1. (1985) (ACM 0-89791-156-3/85/005/-0011),

VITA

Captain Michael R. McFarren was born on 25 February 1953 in Warsaw Indiana. He graduated from Warsaw Community High School in Warsaw, Indiana, in 1971 and attended Purdue University from which he received a Bachelor of Science in Chemistry Education in May 1976. Upon graduation, he received a commission in the USAF through the ROTC program. He was employed as a chemistry teacher and football coach for Sullivan School Corporation, Sullivan, Indiana, until called to active duty in September 1977. He complete Initial Qualification Training for Minuteman III/CDB system in January 1978. He then served until June 1982 as a missile launch officer and weapon system instructor in the 321st Strategic Missile Wing, Grand Forks AFB, North Dakota. While on assignment in North Dakota, Capt McFarren graduated From the University of North Dakota, Minuteman Education Program, with Masters degree of Business Administration, in December 1980. In June 1982 he was assigned as an instructor to Air Force ROTC, Detachment 520, Cornell University, Ithaca, New York until entering the School of Enginering, Air Force Institute of Technology, in September 1985.

Permanent address: 300 Boys City Drive
                    Winona Lake, Indiana 46590