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An Integrated Plan for Human Performance Enhancement in C^2 Operations

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In an effort to devise a long range plan for research into the human performance aspects of (C2) the ARI sponsored a C^2 research planning project involving experts from both industry and academe. Its purpose was to generate a 10-year plan consisting of a series of integrated, deficiency-driven research programs to help the Army improve C^2 systems performance. ~~The project required~~ pre-workshop assignments and workshop activities were designed to aid the consultants in identifying human performance deficiencies in the C^2 operational (over)

environment, and then to help them select a subset of the most critical deficiencies on which to focus the next 10 years of research. The pre-workshop and workshop activities also involved the identification of technologies from cognitive, social and organizational psychology and from the human factors and artificial intelligence research communities which might be developed and applied most profitably to upgrade each deficient area. The conduct and results of this planning project are documented in this report.

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Keywords include: Battlefield automation, C2 human performance enhancement, Distributed C2, Expert systems, and Decision support.

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FOREWORD

This document represents the work of many people. It is, of course the product of deliberations among the five consultants selected for this project. But even more so, it is the product of the dedicated efforts of the project staff exemplified by the contributions of Drs. M. Donnell and M. Archer and Ms. R. Ely. Of special note are the additional efforts, beyond the call of duty, of Dr. M. Samet of Perceptronics Corporation and Dr. J. Zeidner of George Washington University. Both of these gentleman contributed more than their consultant agreements required. All conference participants and their affiliations are listed below.

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EXECUTIVE SUMMARY

"I can assert for land warfare that the day will soon be gone when massed formations of armored vehicles will be able to swarm over the surface of the earth, trailing behind elaborate logistic trails. Instead we are going to have to move toward something like distributed force, meaning that in order to provide protection we will have to disperse more broadly and thoroughly than ever before, and thus confuse the enemy as to which elements of the target array before them are particularly significant as a threat."

(LTG Paul F. Gorman, 1981)

General Gorman's comment recapitulates the Army's concept of future warfare in the Middle European theater of the 1990's where decentralized command and control will provide the "nervous system" of the "distributed force." In order to prepare for the combat environment of the 1990's, the C^2 systems community is presently developing advanced and innovative hardware and software while the C^2 human performance community is asking the hard questions relative to C^2 functions, procedures, staffing, and decision aiding. This paper reports on one attempt to formulate those questions in a manner which will assure their resolution. This effort is based on the assumption that if you ask the question precisely and accurately the answer will be more reliable and valid.

The Army Research Institutes' Systems Research Laboratory gathered together a panel of experts in various aspects of the C^2 problem. Some are experts in the technology issues while others are highly knowledgeable regarding C^2 requirements, functions, tasks, and procedures. The expert panel was supported by three ARI scientists and two SAIC representatives. The basic purpose of the group was to develop an integrated plan for human performance enhancement in C^2 operations for the 1990's.

This planning was accomplished by first briefing the experts and developing structured "assignments" tailored for each. These assignments were designed to tap the specific expertise of each panel member. After the resulting material was returned and assimilated by the support team, the research themes resulting were used to organize a 3-day workshop during which the experts expanded and integrated their viewpoints regarding both C^2 technologies and C^2 needs. Following the workshop, the established needs and technologies, C^2 doctrine and budgeting information were integrated to produce this report.

The major feature which distinguishes this approach to C^2 planning is the very careful attempt to link all recommended approaches to C^2 human performance enhancement to bona fide, C^2 requirements derived from the projected combat environment. This environment will demand more of its combatants than ever before. Our force must take the initiative in all engagements in order to retain independence of action, it must have the agility in organization and leadership to act faster than the enemy, it must act in synchronization to maintain a unity of purpose while part of a "distributed force," it must understand the depth of the battle in space and time and be capable of decentralized operation in order to take advantage of fleeting opportunities. Fighting outnumbered demands some advantage--C^2 will be our force multiplyer.

With these requirements in mind the group derived a set of five general deficiencies in C^2 human performance which, when resolved would support a more effective C^2 system. These deficiencies are listed in Table ES-1. At the same time these deficiencies were being deduced, the experts representing the technology community were suggesting hardware/software approaches to the resolution of these problems. These solutions varied in complexity, feasibility, and cost. However, their intuitive validity as a solution to a deficiency was the major criterion upon which each was selected. The technologies suggested by the experts appear in Table ES-2.

Once these deficiencies and technologies had been agreed to as representative (but certainly not exhaustive) of the two major dimensions of C^2 human performance enhancement, they were opposed in a matrix format as in Figure ES-1. This format was used to poll the experts on the potential efficacy of each technology to reduce each deficiency. The results were integrated by the support team and used to derive a series of research programs. Several other candidate technologies were suggested, however, they were selected based on the results of the polling. Two of these were

Table ES-1.

HUMAN PERFORMANCE DEFICIENCIES IN C^2 OPERATION DERIVED FROM COMBAT REQUIREMENTS

The projected combat requirements for initiative, agility, depth, synchronization and decentralization result in several deficiencies in the performance of the human component of future C^2 systems. Resolution of these deficiencies requires upgrades in user capability relative to the following areas.

1. Future battle managers, faced with the complexity and time constraints of the 1990's combat environment, will not be able to assign targets with the quickness and precision necessary to seize and retain independence of action. (Refers to the requirement for Initiative)

2. Because of the numerous "pockets of conflict" on the integrated battlefield, the C^2 staff will be unable to analyze the battle situation quickly or accurately enough to generate effective options or plans. (Refers to the requirement for Agility)

3. Given the compressed time frame and extended geography of the AirLand Battle, the C^2 staff will be unable to generate, select, and integrate battle plans with sufficient speed to optimize the deployment of limited forces. (Refers to the requirement for Depth)

4. Because of the need for distributed combat power on the integrated battlefield, the commander will have difficulty communicating his plans and objectives quickly or accurately enough to maintain a unity of effort throughout the force. (Refers to the requirement for Synchronization)

5. Given an enemy attack in depth, the commander will be unable to allocate his dispersed resources with sufficient accuracy and timeliness to put them into advantageous tactical positions. (Refers to the requirement for Decentralization)

Table ES-2.
HUMAN PERFORMANCE TECHNOLOGIES FOR ENHANCEMENT OF
C^2 OPERATIONS ORDERED BY "EFFECTIVENESS," "MATURITY," AND FEASIBILITY

Technology	Definition
1. Distributed information aids	Distributed information processing/displays, which support simultaneous decisionmaking e.g., electronic mail with confirmation/feedback loops
2. Low-level expert systems and decision support algorithms	Decision protocols based on the rules used by human experts; procedure aids, artificial memory, information access aids
3. Soldier machine interface optimization	Human factors engineering analysis, design, and assessment of the point of interaction between soldiers and computer
4. Cognitive modelling	Analysis of expert problem-solving behavior and reconstitution of these elements into mathematical symbols and decision support algorithms

HUMAN PERFORMANCE ENHANCEMENT TECHNOLOGIES ORDERED BASED ON
- MATURITY
- FEASIBILITY
- EFFECTIVENESS

HUMAN PERFORMANCE DEFICIENCIES IN DC^2 OPERATIONS

THERE IS A NEED FOR IMPROVED:	DISTRIBUTED INFORMATION AIDS	LOW LEVEL EXPERT SYSTEMS AND DECISION SUPPORT ALGORITHMS	SOLDIER MACHINE INTERFACE OPTIMIZATION	COGNITIVE MODELLING AND SIMULATION
DECENTRALIZED BATTLE MANAGEMENT AND TARGET ASSIGNMENT	H	H	H	H
SITUATION ANALYSIS AND DISTRIBUTED DECISION SUPPORT	H	H	H	H
INFORMATION MANAGEMENT IN SUPPORT OF OPTION GENERATION AND BATTLE PLANNING	H	H	H	M
ELABORATION AND COMMUNICATION OF MISSION OBJECTIVES	H	N/A	H	N/A
COMBAT RESOURCE ALLOCATION AND REALLOCATION	H	H	M	M

LEGEND:

H = HIGH VALUE
M = MID VALUE
L = LOW VALUE
N/A = NOT APPLICABLE

Figure ES-1. INTEGRATION OF PRIORITIZED DEFICIENCIES WITH RANK ORDERED SOLUTION TECHNOLOGIES high level expert planning systems and automated sensor monitoring. The programs resulting were characterized by thematic statements and listed in Table ES-3.

The listing in Table ES-3 obviously reflects some attempt at priority setting. The rank ordering of the themes was based on several factors, the most important being the implied impact of the deficiencies to which it relates. The second factor was the "globalness" of the program, i.e. how much of the C^2 mission it encompasses, and the third was the sequencing of C^2 functions (situation assessment preceeds option generation preceeds force allocation).

We believe that C^2 human performance enhancement is the most cost-effective, near-term approach to optimization of C^2 systems for the 1990's. We further believe that the research programs and the plan for their implementation developed by this group provide a feasible and conservative approach to the development of these enhancements. It is the sincere hope of our group that the upgrades derived from this effort will result in a force of such effectiveness so as to obviate the battle we are planning to win.

Table ES-3.

RESEARCH THEMES REORDERED RELATIVE TO THEIR PLACES IN AN OVERALL PLAN

1. Enhanced battle management and target assignment through the exploratory development of low-level expert systems/decision aids based on the cognitive modelling of the battle management process.

2. Enhanced battle management and target assignment in a decentralized environment through the advanced development of distributed information technologies and the optimization of soldier machine interfaces.

3. The enhancement of tactical situation analysis in a distributed decisionmaking environment through the exploratory development of low level expert systems based on cognitive modelling of the situation analysis process.

4. The enhancement of tactical situation analysis in a distributed decisionmaking environment through the advanced development of distributed information technologies, soldier-compatible computer interfaces and DBMS software.

5. Optimizing the generation, selection, and integration of tactical plans and options through the exploratory development of low-level expert systems and soldier-compatible planning systems.

6. Interactive generation and selection of tactical plans and options through the advanced development of distributed information technologies and optimized soldier machine interfaces.

7. Optimizing the validity of combat resource allocation/reallocation decisions through the advanced development of low-level expert systems accessed via soldier-compatible distributed information interfaces.

1.0 INTRODUCTION

The command and control (C^2) of tactical units is an area of long standing concern within the military. Predictions of future battlefield scenarios from both current Airland Battle doctrine and developing Army 21 concepts have revitalized, with a new sense of urgency, the Army's commitment to seek more extensive command and control capabilities. Defined as "the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission" (JCS Pub. 1), command and control involves the coordination of information and people to facilitate correct, timely decisionmaking and implementaion. Thus, many of the limitations in command and control systems can be characterized as human performance issues to be addressed under the rubric of behavioral science research.

The human performance technologies, however, not only encompass a variety of research topics relevant to C^2, but include many types of researchers in many different environments, each with a diverse set of goals and objectives. Consequently, this research discipline as it has been applied to C^2 has become disjointed, and often fails to gain direction and focus from the real needs, or deficiencies, that exist in C^2 systems today. Moreover, there is little cross-fertilization of research ideas and findings among the various content areas, between the basic and applied sectors, and between Army and contractor research efforts. Hence, the Army needed an overall, long-term research plan to coordinate and draw upon the many elements within the field of human performance enhancement. The objective of the plan was to develop a coherent line of research on human performance issues in C^2 with both scientific and military payoff. Such a plan also would serve to communicate to the Army sponsors of C^2 research, and to the various Army management and implementation personnel, the future directions and goals for C^2 performance enhancement.

1.1 METHODOLOGY

In an effort to devise a long-range plan for research into the human performance aspects of C^2, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) sponsored a C^2 Research Planning Project involving experts from both industry and academe. The purpose of the project was to generate a 10-year plan consisting of a series of integrated, deficiency-driven research programs to help the Army improve C^2 systems performance. The project required pre-workshop assignments and workshop activities designed to aid the consultants in identifying human performance deficiencies in the C^2 operational environment, and then to help them select a subset of the most critical deficiencies on which to focus the next 10 years of reserch. The pre-workshop and workshop activities also involved the identification of technologies from cognitive, social, and organizational psychology and from the human factors and artificial intelligence research communities which might be developed and applied most profitably to upgrade each deficient area.

After the conference, SAIC personnel reduced and analyzed the contributions of the consultants and developed an approach for integrating these contributions into a series of research programs. The programs were then rank ordered based on the impact of the deficiency and the feasibility of its relevant technologies. Prioritized research programs were integrated into a 10-year research plan. The programs and the plan are described in the following sections.

2.0 A RESEARCH PROGRAM FOR HUMAN PERFORMANCE ENHANCEMENT IN ARMY COMMAND AND CONTROL

2.1 THE PLANNING APPROACH AND RATIONALE

2.1.1 The Planning Approach

The research plan proposed herein contains a series of research programs to be carried out during the 1985-95 time-frame. These programs are the culmination of all of the thoughts presented primarily in the consultants' pre-workshop analyses of the C^2 problem and in the 3-day workshop attended by the consultants and by ARI and SAIC scientists. When taken together, these programs represent an integrated, deficiency-driven approach to human performance enhancement in the distributed command and control environment of the 1990's and beyond.

A flow chart of the process by which the research programs were developed is contained in Figure 2-1. The figure represents a "top-down" deficiency driven approach which begins with a definition of the C^2 environment and operational characteristics, including tactics, strategies, and scenarios proposed in the Airland Battle 2000 doctrine and Army 21 concepts. From this analysis, several operational requirements of a C^2 systems were derived. Requirements refer to the attributes which must reside within tactical C^2 systems in order to support successful battle management given the integrated battlefield environment. The next step in the process was to determine which requirements are currently being met by the C^2 systems in place today and to isolate those that are deficient in terms of the performance of the human component. Those deficiencies most consequential to the effective functioning of command and control then became the focus for formulating specific research questions. The next step in the process was to propose various technologies that could be applied in each area of human performance deficiency in order to answer the research questions. The marriage of a deficiency with relevant solution technologies represents a research program designed to yield solutions to specific C^2 problems.

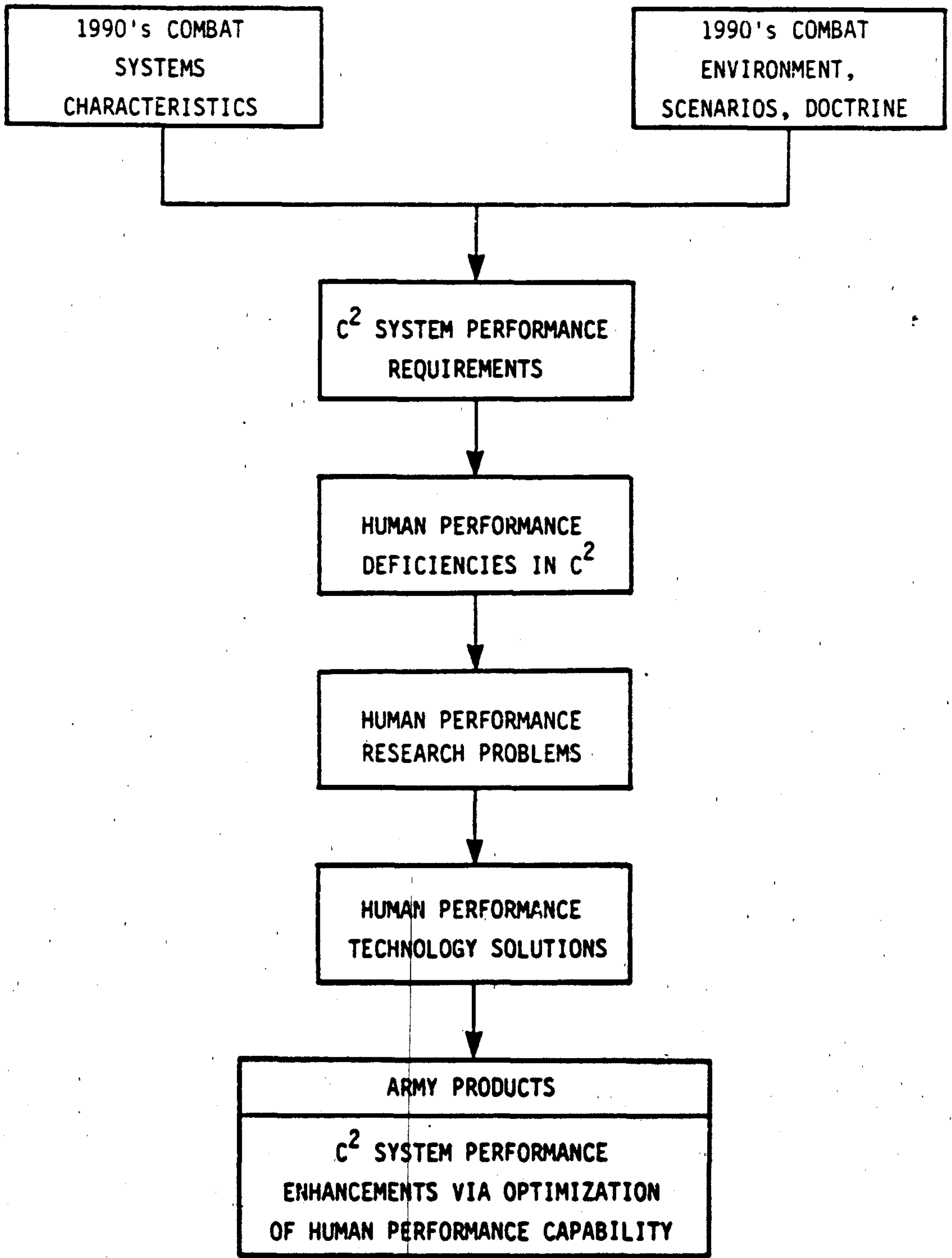


Figure 2-1. RESEARCH PROGRAM DEVELOPMENT PROCESS

2.1.2 The Rationale for C^2 Enhancement Programs Derived From C^2 Systems Requirements on the Battlefield of 1990's

Before discussing the elements of the research planning process and the research programs which are the result of this process, it is necessary to provide a description of the battlefield environment (as shown in Figure 2-1) within which the tactical C^2 systems of the 1990's must function. Following this description of the environment we will derive several combat operational requirements for such a C^2 system and develop a defensible "audit trail" between those requirements and the human performance deficiencies which are the "drivers" of the research plan.

The Army's perception of the battlefield of the 1990's is reflected by Army Pamphlet 525-5 entitled "The AirLand Battle" and by later interpretation contained in a document entitled "Army 21." In August 1982, AirLand Battle 2000 was reissued with substantial revision. This time it was expanded by the addition of Functional Area concepts developed by the TRADOC proponents. The second edition was first presented at the 1982 AUSA Symposium on AirLand Battle 2000.

Since then, there has been a significant effort underway by HQ DA and TRADOC to develop a parallel joint operational concept with the Air Force. This effort, titled "Focus 21," has progressed slowly and has precipitated a reappraisal of some of the basic AirLand Battle 2000 ideas. A revision of the original concept is in process, tentatively titled "Army 21," but is not expected to be completed until the end of 1984.

Regardless of the subtle changes which may result from "Army 21" the current concepts of warfighting in the integrated environment of the 1990's are well identified and can be safely used to forecast operational concepts and the battlefield environment of the timeframe 1995-2015.

The essence of AirLand Battle doctrine is an aggressive, dynamic, flexible use of the modern forces of warfighting with reliance on the competence and initiative of soldiers and their leaders. Agressor strategy will demand an integrated battle (i.e. nuclear, biological, chemical, and conventional) be fought at greatly increased depths of distance and time with a coordinated employment of forces never before attempted. The Air

Force has a key role in the execution of this doctrine and an integrated AirLand team is essential for success.

The success of AirLand Battle doctrine is based upon gaining the initiative quickly and using that advantage to divide and defeat the enemy in small contained pockets of conflict. Combat power must be focused to provide force where it will have the greatest impact on the battle at the most advantageous time.

There are four guidelines which must be adhered to in order to succeed on the AirLand Battlefield: initiative, synchronization, agility, and depth.

According to FM100-5, "Initiative implies an offensive spirit in the conduct of all operations. The underlying purpose of every encounter with the enemy is to seize or to retain independence of action. To do this we must make decisions and act more quickly than the enemy to disorganize his forces and to keep him off balance."

The basic capabilities of our soldiers and leaders provide the edge in this area, and education and training can do much to leverage that advantage. Effective command and control is the channel through which this initiative must be applied to assure the successful conduct of the AirLand Battle. In order to make these decisions more effectively, a commander requires valid information at some optimal level of detail at the correct time. Supporting this requirement is the overall purpose of an effective C^2 system.

According to FM100-5, "Synchronization ... results from an all-pervading unity of effort throughout the force. Every action of every element must flow from understanding the higher commander's concept."

This means teamwork at every level, from soldiers to Combined Arms Teams to Joint Task Force operations. It means that all aspects of combat power engaging the enemy must be integrated toward achieving the same objective. In order to function on a battlefield in which synchronization is tantamount to survival, the Army requires a C^2 system that provides decentralized commanders/planners with instantaneous "shared perceptions" of the battle situation. A unity of effort can only be supported in an organization that is knowledgeable of and committed to the objectives of the force as a whole.

Agility, according to FM100-5, "requires flexible organizations and quick-minded, flexible leaders who can act faster than the enemy" and the key to agility is rapid decisionmaking and execution. We must have timely, accurate intelligence, and properly interpret and convert it into usable, understandable operations orders which can be executed by maneuver and firepower before the enemy has had time to react to the same situation. Because we must fight outnumbered, there will be more emphasis on movement and maneuver on the battlefield. Warfighting will be increasingly decentralized and independent, yet based upon a common plan. Linear battle lines are giving way to a mobile, fluid confrontations almost analagous to many-on-many dog fights. The terms "360° battle" and "pockets of conflict" are often used to describe the predicted conflict situation.

In order to achieve a critical mass of combat power without the overpowering numbers of men and machines enjoyed by the Warsaw Pact, it is necessary to have a "force multiplyer." C^2 is our "ace in the hole." With effective C^2, commanders can move battalion task forces around the battlefield like chess pieces. The analogy holds even further if we require that C^2 systems of the 1990's store information as to the strengths and weaknesses of each of the task forces and of the task force commanders. The battlefield environment will drive the C^2 systems into providing shared information to disparate commanders based on some shared cognitive model of the battle itself. The C^2 systems must also provide the division commander with very rapid generation and evaluation of "moves" for each of the battalions under his command. In addition, flexibility on the battlefield of the 1990's will require that the C^2 system supports extremely rapid combat resource allocation/reallocation decisions. The C^2 system must aid the commander and his subordinate in "running excursions" to determine what the battle outcome would be if he allocated combat power to one pocket of conflict instead of another.

FM100-5 states that, "Depth ... refers to time, distance, and resources," and goes on to say, "Momentum in the attack and elasticity in the defense derive from depth. Commanders need to use the entire depth of the battlefield..."

This principle is based upon delaying, disrupting, or defeating the enemy before he can join and overwhelm friendly forces with his superior numbers. It requires that the C^2 system predict/project in time and prepare friendly forces for our success in that battle.

In order to project the battle ahead in time, the C^2 system would be required to assimilate vast quantities of friendly and agressor combat information including numbers, armament, position, terrain, weather, etc. It also suggests that the C^2 system be guided by an expert system (high or low level) which would peruse and integrate these data in regard to decision rules distilled from many interviews with successful Army tacticians. C^2 systems which include some level of artificial intelligence will certainly be required to determine where in time and space to allocate resources of various capabilities in order to disrupt or redirect an enemy penetration.

Depth also refers to staying power and the ability to wage continuous combat, to high morale and alertness, and to proper employment of reserves to regain the initiative and win.

2.1.3 The Future of C^2

The same precepts and principles described above for AirLand Battle doctrine apply to the general concept of future warfare. The key to this evolution is the changing world political environment and its implications for the military and the battlefield environment. The major implications for the military in general and for C^2 in particular are:

- Forces must be prepared to fight anywhere. Forces must be more flexible and deployable.

- Forces must win the land battle. The purpose of military operations must be to win.

- Parity of forces must be maintained through quality of weapons, reliance on C^2 technology, tactics, leadership, and national will.

- Avoid high combat losses by seeking victory through maneuver, deception, and attacking the enemy's will to continue.

- Initial battles are increasingly critical because they have the potential to be so devastating that political settlements may be sought early.

- Strategic mobility through high technology C^2 is vital to all of the above since the U.S. must have the means to deploy, reinforce, and sustain forces worldwide to meet those objectives.

The essence of these statements is that we will be engaged in a "style of waging war in which agility, deception, maneuver, firepower, and all other tools of combat are used to face the enemy with a succession of dangerous and unexpected situations more rapidly than he can react to them." In order to do this we must prevail in C^2 technology. This requires an integration of the full capabilities of seeing, understanding, deciding, and doing on the battlefield, and it must be in a time cycle sufficiently faster than the enemy's that he is limited to reacting to our actions and deprived of the initiative. Effective C^2 is the major avenue to achieving this capability.

It is always much easier to levy requirements than it is to offer approaches to their resolution. However, in this case, a converging pair of trends, technological, and doctrinal, does establish the framework for describing the information management systems of the early 1990's. Accelerating advances in the development of very compact, very powerful, and very fast computer systems virtually guarantee that every weapons platform or vehicle can have on-board processing capacity exceeding that which was available in all but the largest laboratories a few years ago. Reliable communications gear, using spread spectrum and frequency hopping techniques to avoid interception and interference, will allow these multiple processors to be netted together for realtime exchange of data.

The underlying assumption driving both technological and doctrinal developments is that data/information/knowledge is a vital element in the battlefield equation. Unless we know in near realtime when and where to move, and when and where to apply our relatively limited firepower, then improvements in mobility and firepower will be of little benefit on the future battlefield.

While the optimistic technological projections of powerful on-board processing linked by advanced communications would seem to ensure that the necessary knowledge will be available for successful control and utilization of our mobility and firepower, this "knowledge resource" must be carefully managed if it is to provide an advantage rather than a disadvantage. As the processing and communication capacity increases, choke-points in information flow and distribution will develop. Individuals will become overloaded beyond their capacity to process and communicate and will fall back on rough rules-of-thumb to select out information. This is where the tactical C^2 system as enhanced by the proposed R&D efforts is a key factor.

Figure 2-2 illustrates the various sources of information that would constantly be coming to a tactical commander in such a "knowledge rich" situation. Essentially, the commander would be receiving information on a variety of different outside channels, any one of which could potentially require his full attention at a given time. In addition, the commander would need to monitor various displays of friendly force disposition at the same time. At the same time, the commander will be receiving constant updates on the overall battlefield situation from such capabilities as an All Source Analysis System (ASAS), perhaps downlinked through a Very Intelligent Surveillance and Target Acquisition (VISTA) system. Finally the commander will be receiving commands or answering queries of higher echelon commanders, while directing and communicating with his subcommanders.

One approach to this problem is to increase the skill level of the operators of future battlefield information systems through selection and training. A complementary approach proposed in this plan is that of developing an active, adaptive, "intelligent" C^2 system to relieve the commanders' burdens and reduce information overload.

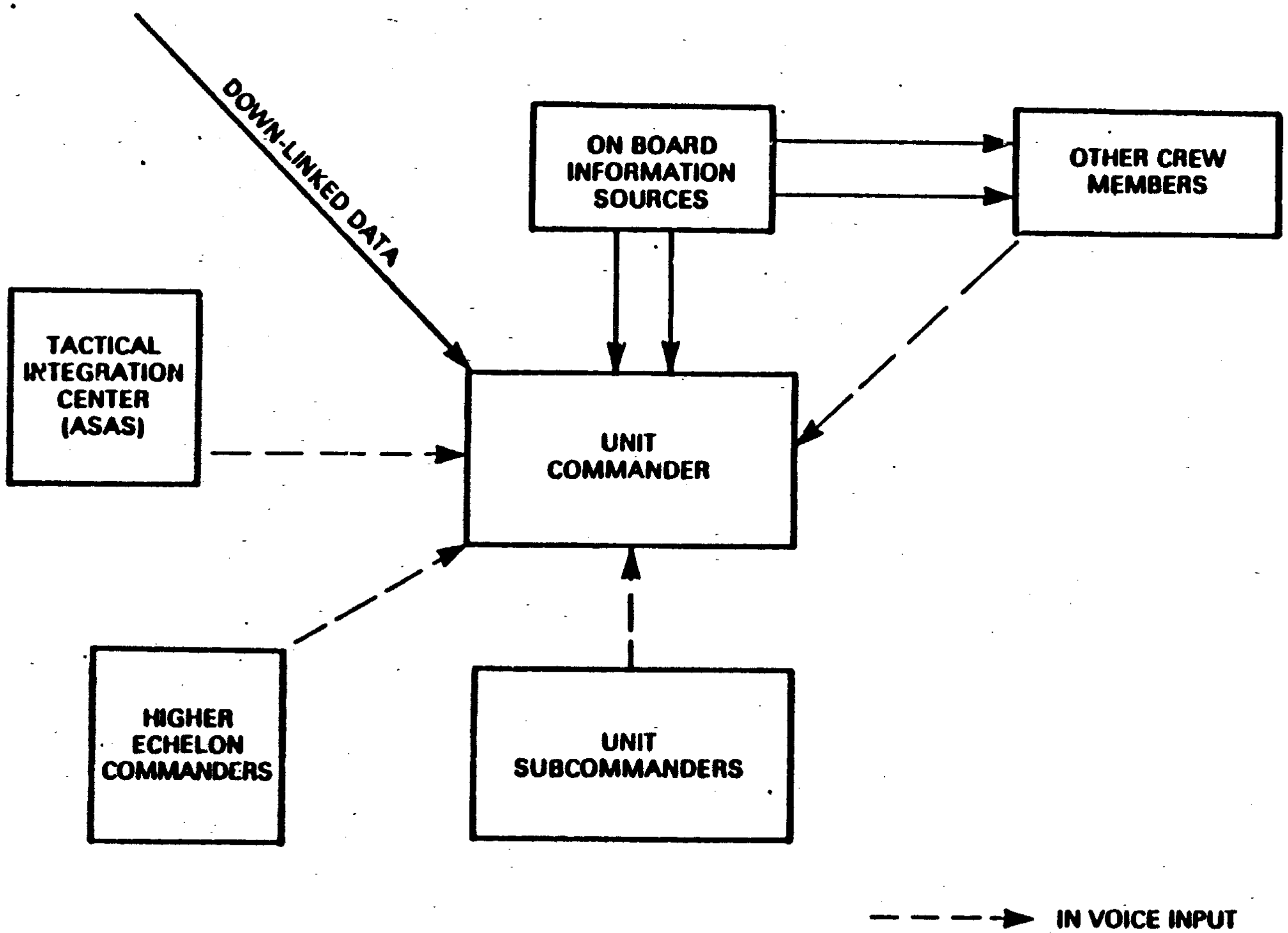


Figure 2-2. UNIT COMMANDERS INFORMATION SOURCES WITHOUT "INTELLIGENT" C^2 SYSTEM

An intelligent C^2 system can be designed which will provide only the necessary information to an operator. It will use Artificial Intelligence techniques to capture and apply expert users' rules for what information to share with whom, when it is needed, and how it sould be displayed.

An intelligent C^2 would further alleviate the information overload problem by providing a single adaptive channel through which much of the tactical and status information would flow. This Soldier Machine Interface (SMI) would be intelligently adaptive in both the manner in which it selects and condenses information, and in the format it selects for display. Specifically, ASAS-derived or other correlated data, non-voice communication by higher echelons, down-linked data, sensor outputs, and system status outputs would all be "filtered" through the SMI, which would determine the necessary information to display to the commander via expert rule-based protocols. The SMI would condense that information and present it in a format (e.g., graphic) that results in optimal information transfer to the commander as a function of the situation and the individual's needs. In effect, the intelligent SMI functions as a "roll-your-own" display which provides the "mission manager" with decision support information in time to be valuable for effective tactical command and control.

All of the above discussion supports the derivation of five fundamental combat requirements which C^2 systems of the 1990's must support. These C^2 system requirements are listed and defined below.

Initiative - Taking the offense in all actions to seize or retain independence of action.

Agility - Developing flexible organizations and leadership designed to act faster than the enemy.

Depths - Attacking the enemy at the heart of his war-fighting capability by planning ahead, striking deep, and preserving momentum and elasticity.

Decentralization - Dispersion of valuable C^2 and combat resources to protect them from the enemy and to maneuver them into advantageous tactical positions.

Synchronization - Maintaining a unity of effort throughout the force by understanding and responding to the commander's concept.

2.2 THE ELEMENTS OF THE RESEARCH PLAN

Our approach to constructing a C^2 research plan requires the integration of three major categories of information. The first and by far the most important category contains the deficiencies which the research is designed to resolve. The deficiencies must be derived from the combat requirements which are unresolved by current knowledge. The C^2 requirements in turn must be deduced from the battlefield environment in which the system must function. The latter two steps have been described previously and the delineation of deficiencies remains.

The second piece of the puzzle is the category of solution approaches. In the case of tactical C^2, these approaches are mostly technological and are derived from a review and extrapolation of the current state of the art in the field of information management. The final category of information is more subtle. These are the enabling technologies, i.e. those techniques and methodologies which support the application of a solution technology to a specific deficiency. These categories will be discussed briefly. Then we will consider integration of the elements and illustrate this process with exemplary research programs.

2.2.1 Human Performance Deficiencies in C^2 Operations

Deficiencies are defined for purposes of this paper as requirements which remain unresolved by application of proven solution approaches. The deficiencies to be stated are derived directly from the combat requirements placed on a C^2 system that must operate on the integrated battlefield of the 1990's. These requirements are characterized by such descriptors as flexibility initiative, synchronization, depth, decentralization, high mobility, etc. The deficiencies which follow are a distillation of the consultants' pre-conference assignments, the minutes of the C^2 planning conference, doctrine and guidance from military manuals, and the author's experience. They are presented in Table 2-1 as determined by expert opinion.

Table 2-1.

HUMAN PERFORMANCE DEFICIENCIES IN C^2 OPERATION DERIVED FROM COMBAT REQUIREMENTS

The projected combat requirements for initiative, agility, depth, synchronization and decentralization result in several deficiencies in the performance of the human component of future C^2 systems. Resolution of these deficiencies requires upgrades in user capability relative to the following areas.

1. Future battle managers, faced with the complexity and time constraints of the 1990's combat environment, will not be able to assign targets with the quickness and precision necessary to seize and retain independence of action. (Refers to the requirement for Initiative)

2. Because of the numerous "pockets of conflict" on the integrated battlefield, the C^2 staff will be unable to analyze the battle situation quickly or accurately enough to generate effective options or plans. (Refers to the requirement for Agility)

3. Given the compressed time frame and extended geography of the AirLand Battle, the C^2 staff will be unable to generate, select, and integrate battle plans with sufficient speed to optimize the deployment of limited forces. (Refers to the requirement for Depth)

4. Because of the need for distributed combat power on the integrated battlefield, the commander will have difficulty communicating his plans and objectives quickly or accurately enough to maintain a unity of effort throughout the force. (Refers to the requirement for Synchronization)

5. Given an enemy attack in depth, the commander will be unable to allocate his dispersed resources with sufficient accuracy and timeliness to put them into advantageous tactical positions. (Refers to the requirement for Decentralization)

These deficiencies are certainly not the only ones in C^2 operations, however, they are representative of major problems in C^2 operations which can be solved by the application of human performance enhancement technologies.

2.2.2 Human Performance Enhancement Technologies

The technologies which are listed and defined in Table 2-2 are a result of the painstaking literature search carried out during the pre-conference work assignments consultants who represented the "technology" community. These technologies will be applied to the deficiencies in Table 2-1 in order to establish research and development objectives.

2.2.3 Integration of Human Performance Deficiencies and Solution Technologies

There are many approaches to application of candidate solutions to human performance deficiencies. After considering several, we chose to array the deficiencies and technologies in their respective rank orders along the two axes of a matrix as shown in Figure 2-3. This approach enables us to inspect each of the 20 possible intersections (cells) that result from crossing four technologies with five deficiencies. Upon inspection of each cell the author has asked... "how valuable is this technology in resolving this deficiency." For example, it was the opinion of the author that distributed information technology would be extremely valuable to the improvement of decentralized battle management. Therefore, an "H" was placed in the cell representing the interaction of these two elements. In a similar manner each of the 20 cells was analyzed and marked. This rating scheme represents only one informed opinion and it is certain that other experts would come up with other rating results. However, it is our belief that the ratings have resulted in feasible research programs which when executed will reduce the deficiencies to which they are applied. It is recommended that before these programs are accepted for execution, the cells in this matrix be analyzed by a group of experts in the field of military science (ORSA), cognitive psychology, computer science, and artificial intelligence. The combined ratings across all judges should then be used to check the validity of the research programs contained in this paper.

Table 2-2.
HUMAN PERFORMANCE TECHNOLOGIES FOR ENHANCEMENT OF
C^2 OPERATIONS ORDERED BY "EFFECTIVENESS," "MATURITY," AND FEASIBILITY

Technology	Definition
1. Distributed information aids	Distributed information processing/displays, which support simultaneous decisionmaking e.g., electronic mail with confirmation/feedback loops
2. Low-level expert systems and decision support algorithms	Decision protocols based on the rules used by human experts; procedure aids, artificial memory, information access aids
3. Soldier machine interface optimization	Human factors engineering analysis, design, and assessment of the point of interaction between soldiers and computer
4. Cognitive modelling	Analysis of expert problem-solving behavior and reconstitution of these elements into mathematical symbols and decision support algorithms

HUMAN PERFORMANCE ENHANCEMENT TECHNOLOGIES ORDERED BASED ON • MATURITY • FEASIBILITY • EFFECTIVENESS / HUMAN PERFORMANCE DEFICIENCIES IN DC^2 OPERATIONS — THERE IS A NEED FOR IMPROVED:	DISTRIBUTED INFORMATION AIDS	LOW LEVEL EXPERT SYSTEMS AND DECISION SUPPORT ALGORITHMS	SOLDIER MACHINE INTERFACE OPTIMIZATION	COGNITIVE MODELLING AND SIMULATION
DECENTRALIZED BATTLE MANAGEMENT AND TARGET ASSIGNMENT	H	H	H	H
SITUATION ANALYSIS AND DISTRIBUTED DECISION SUPPORT	H	H	H	H
INFORMATION MANAGEMENT IN SUPPORT OF OPTION GENERATION AND BATTLE PLANNING	H	H	H	M
ELABORATION AND COMMUNICATION OF MISSION OBJECTIVES	H	N/A	H	N/A
COMBAT RESOURCE ALLOCATION AND REALLOCATION	H	H	M	M

LEGEND:

H = HIGH VALUE
M = MID VALUE
L = LOW VALUE
N/A = NOT APPLICABLE

Figure 2-3. INTEGRATION OF PRIORITIZED DEFICIENCIES WITH RANK ORDERED SOLUTION TECHNOLOGIES

2.2.4 The Research Programs Resulting From the Matrix Analysis

Given the 10-year time frame and limited resources for the C^2 enhancement research effort only the high value (H) cells were used in the development of the research programs which follow. Since the programs would be deficiency driven, it was decided that three technologies at most could be applied to one deficiency within a program. Therefore, technologies were regrouped according to their similarities and applied to each of the five deficiencies. The results of this reallocation of technologies is shown below.

Deficiency	Number of Hi Value Techs	Number of Research Programs Resulting
• Decentralized battle management	4	2
• Situation analysis	4	2
• Option generation, selection, and battle planning	3	1
• Elaboration and communication of objectives	2	1
• Combat resource allocation	2	1

The number of programs for each deficiency reflects the number of technologies which were considered "highly valuable" to its resolution.

Following this analysis the research programs were established by relating the deficiency and the highly applicable technologies in a thematic statement. This statement provides a scientific "short hand" which can then be used to generate research questions, hypotheses, and research objectives. From these objectives, the research tasks (projects) can be derived and their expected results and the utility of these results can be discussed. Finally, based on the foregoing information, a planner would be able to estimate time and resource requirements for implementation of the program.

The research themes are presented in Table 2-3 and are followed by a series of exhibits which discuss each of them in some detail.

In order to facilitate the description of these programs several short cuts have been taken. Each of the programs requires a research, simulation and/or training facility for its execution. In addition, each program requires the analysis of cognitive processes underlying the C^2 human performance deficiencies being resolved. Finally, all of the programs also require that their solutions be translated into Army policy, doctrine, and tactical training if the deficiencies are to be resolved.

In the interest of brevity these "generic" research and development issues will be discussed once, prior to the specific program descriptions.

2.2.4.1 Establishment of a Research and Development Facility for the Enhancement of Human Performance in C^2. In order to execute the experimental research programs described in the following sections the Army needs a dedicated C^2 research and development facility. Past experience has shown us that attempts at "piggy-backing" human performance research onto in-progress simulation exercises does not provide us the necessary control of variables. Another problem with this situation and with "naturalistic" approaches such as observation of field exercises is the matter of subject selection. Lack of control over the variables and the selection of subjects leads to research findings that are irrelevant at best, and dangerously misleading at worst. Therefore a "center," or facility, dedicated to the enhancement of human performance in C^2 operations is a necessary condition for the resolution of human performance deficiencies. The key subtasks supporting the establishment of a C^2 human performance research laboratory (HPRL) include:

- Establishment of a HPRL development plan
- HPRL concept definition
- HPRL user requirements analysis
- HPRL hardware, software, functional, and procedural specifications

Table 2-3.
RESEARCH PROGRAM THEMES

- The enhancement of tactical situation analysis in a distributed decisionmaking environment through the advanced development of distributed information technologies, soldier compatible computer interfaces and data base management software.

- The enhancement of tactical situation analyses in a distributed decisionmaking environment through the exploratory development of low-level expert systems based on cognitive modelling of the situation analysis process.

- Interactive generation and selection of tactical plans and options through the advanced development of distributed information technologies and optimized soldier machine interfaces.

- Optimizing the generation, selection, and integration of tactical plans and options through the development of low-level expert systems and soldier-compatible planning systems.

- Optimizing the validity of combat resource allocation/reallocation decisions through the advanced development of low-level expert systems accessed via distributed information interfaces.

- Enhanced battle management and target assignment in a decentralized environment through the advanced development of distributed information technologies and the optimization of soldier machine interfaces.

- Enhanced battle management and target assignment through the exploratory development of low-level expert systems/decision aids based on the cognitive modelling of the battle management process.

- Selection, procurement, and integration of HPRL hardware
- Coding, testing, and integration of HPRL software
- Development of HPRL users' manual and procedures.

The C^2 HPRL should represent the total C^2 process, commencing once correlation and fusion of data have been completed and running through the issuance of orders, whereupon the entire process recommences. The laboratory must possess flexible data bases, simulations, and displays. It must have embedded within it an ability to conduct observations on C^2 processes and decisions as well as experiments testing specific hypotheses. In general, it should assume that it has available to it those fused and correlated data which will be resident in the tactical databases of the early 1990's.

The HPRL should be capable of supporting the study and enhancement of processes and decisions in the following areas of C^2:

1. Generation and analysis of orders of battle (OPFOR AND BLUEFOR)
2. Situation analysis and the estimate of the situation
3. OPFOR intentions, capabilities, and probable actions
4. BLUEFOR plan and option generation, evaluation, and selection (including outcome projection)
5. BLUEFOR resource allocation, target assignment, and battle management/coordination
6. BLUEFOR tactical objective communication and explanation (to lower echelons).

The Division Commander and his staff should be the primary focus of the research. However, the HPRL requirements analysis should make it clear what changes would be required to refocus the lab at the next higher or lower echelon. An ability to graphically portray and analyze terrain and transportation route data, as well as the location, identity, and status of BLUEFOR and OPFOR elements is considered essential, as is the ability to simulate a distributed C^2 processing environment. Finally, the HPRL should be flexible enough to support training experiments and tests of new concepts in C^2 aiding and C^2 staff reorganizations.

2.2.4.2 Analysis of Cognitive Processes Underlying Major C^2 Functions. Before any meaningful research on the enhancement of human performance in tactical C^2 can be done, current procedures and techniques must be understood as clearly as possible. The first step is to perform an analysis of the various cognitive and behavioral tasks that must be performed to arrive at a clear perception of a tactical situation, generate, select, and integrate solution options, communicate those options, and allocate forces to implement them. Along with this, the essential elements of information needed to support tactical analysis must be determined, and some indication of the relative usefulness of different kinds of information must be provided. This can best be captured by collecting scenario-driven opinions of experts in tactical C^2 and observing their performance in laboratory-based simulations.

The second step of the analysis would be to determine what activities in the C^2 process are amenable to aiding through low- and high-level expert systems and other forms of decision aids.* A taxonomy of the types of activities that can be supported through each form of aiding technology should assist in this process (see Figure 2-4).

The final step in the process is to conduct cost benefit analysis. Given that a particular task could be aided through a specific technology, an analysis of payoff, feasibility, acceptability, risk, and cost must be performed for each candidate expert system or other type of decision aid. These analyses should be folded into a total cost-benefit analysis where each potential aid can be compared with all other potential aids to support Army decisions regarding aid selection.

* For the purposes of this discussion, low-level expert systems (LLES) refer to those expert systems designed to enhance the user's ability to review and access the data relevant to the required decision as well as those that lead the user through systematic generation and consideration of the decision options. LLES's leave the actual decision to the user. High level expert systems seek to automate the entire decision process.

DECISION PROCESSES	STEPS IN THE ESTIMATE	METT-T FACTORS
PERCEIVE	Mission Analysis	Mission
	Area of Operations Analysis	Terrain
	Enemy Situation Analysis	Enemy
	Own Situation Analysis	Own Troops
PLAN	Relative Combat Power Analysis	
	Define Enemy Capabilities	Enemy
	Define Own Courses of Action	Own Troops
DECIDE, INFORM, DIRECT	Analysis of Opposing Courses of Action	Time
	Comparison of Own Courses of Action	Time
	Decision	

Figure 2-4. DECISION PROCESSES IN THE ESTIMATE OF THE SITUATION

2.2.4.3 Supporting the Translation of Technical Findings into Solutions that the Army Can Implement: The Enabling Technologies. Before the Army can implement HPRL solutions it is necessary to briefly consider the concept of enabling technologies. These represent solution approaches suggested by the consultants which could not be classified according to the rules we established. They are approaches which could, in their own right, offer solutions to many of the human performance deficiencies. However, more importantly, they are pervasive in their value since the application of any solution technology to a human performance deficiency requires their inputs. They could also be considered as "support" technologies. Just as combat troops require combat support such as artillery and air cover, implementation of solution technologies requires support to assure that they get the job done.

The three pervasive enabling technologies which resulted from the conference were: human performance measurement, organizational development/job design, and training/proficiency maintenance.

- Performance Measurement. In order to fully define deficiencies in C^2 systems performance and to assess the efficacy of various technologies to resolve those deficiencies, we must be able to measure performance. Consequently, all research programs must involve, or rely on, the development of valid and reliable measures of performance effectiveness.

- Organization and Job Design. The introduction of any new solution technology into an organizational system requires attention to organization-wide and job-specific changes that must be made to accommodate smooth transition to the use of that technology. Also, we must consider team aspects of distributed decisionmaking.

- Proficiency Maintenance. Users must learn how to cope with new changes to the C^2 operational environment. They must be trained to use the new technologies, to deal with new organizational structures, and to respond to new procedures.

Although research and development of these technologies was not the original charge to this planning effort, we believe it urgent that the implications of these disciplines to be integrated into all research programs carried out as a result of this planning effort. With this overview of "generic" research tasks and program themes in mind, we will now consider the illustrative research programs that were constructed from the matrix in Figure 2-3.

Exhibit 1.0

IMPROVED TACTICAL SITUATION ANALYSIS VIA OPTIMIZED COMPUTER INTERFACES AND DATABASE MANAGEMENT SOFTWARE

1.1 THE RESEARCH THEME

The enhancement of tactical situation analysis in a distributed decisionmaking environment through the advanced development of distributed information technologies, soldier-compatible computer interfaces and database management software.

1.1.1 The Research Question

One of the major demands placed on any Command and Control (C^2) system is the ability to arrive rapidly at an accurate estimate of the tactical situation. In an environment involving physically distributed decisionmakers and the rapid, flexible use of mobility, how can human performance research aid the staff officers charged with assessing the tactical environment to become more effective in their decisionmaking? This research program is designed to help meet this increased need by developing soldier-compatible computer interfaces, Database Management Software (DBMS), and distributed information technologies.

1.1.2 Research Objectives

In order to address this question above, this program is designed to support five distinct, but interdependent research objectives. Therefore, the program should:

- Provide a complete task and information needs analysis
- Develop a prototype testbed and an experimental paradigm for studying situation analysis, along with appropriate measures of effectiveness and performance (MOE and MOP)
- Employ this testbed and experimental paradigm to optimize a soldier-compatible computer interface for tactical situation analysis

- Develop a soldier-compatible database management system to meet the needs of tactical situation analysis

- Develop distributed information technologies to help assure that physically distributed decisionmakers can accurately and rapidly exchange their impressions of the tactical situation.

1.2 RESEARCH TASKS

The objectives above may be advanced through the implementation of a series of highly interrelated tasks described below which are preceeded by the development of the C^2 HPRL, the conduct of a cognitive task analysis, and the consideration of appropriate enabling technologies.

1.2.1 Task 1: Optimizing the Soldier Machine Interface

The speed and accuracy of tactical situation analysis depends, to a great extent, on the effectiveness of the soldier machine interface (SMI). The profitable areas for research on the SMI for tactical situation analysis involve: human factors in workstation design, display design, the use of graphic symbology, interactive communication, and development of adaptive and intelligent user interfaces. These areas are elaborated in the following sections.

Subtask 1a: Human Factors in Workstation Design

The physical characteristics of the computer workstation may have marked effects on performance. While some research on human factors in workstation design does exist, further research is needed, especially in the demanding environment of C^2 operations. Some of the major areas to be investigated include the effects of CRT size, resolution, brightness, contrast, and flicker rates, and testing alternate modes of input (e.g., light pens, touch panels, "mice," etc.). While verbal, natural language input may be desirable, we believe that too much basic research must still be done to include verbal input in this phase of research. However, audio computer output, including spoken words, may be useful, especially for alert messages.

Subtask 1b: Display Design

The way tactical information is displayed by the computer may have a major influence on the speed and accuracy of situation estimation. Overload may be reduced by two basic approaches: simplifying the display so that less information is presented, or presenting the information in ways that make it easier to understand. Research on improving information presentation should include the use of selection overlays, alphanumeric vs. graphic displays, windowing and scrolling, and methods for highlighting and separating information (e.g., brightness, blinking, screen position, reverse video, and color). In a series of experiments, subjects could be given control over display features and their preferences for data presentation formats examined, especially for as a function of subject experience.

Subtask 1c: Symbology

Much of the information needed for assessing tactical situations may best be presented graphically in the form of maps and overlays. Conventional symbology, however, lacks richness in detail, is not visually distinctive enough for rapid identification, and does not lend itself to computer generated graphics displays. A new set of graphic symbols, based upon information needs of tactical situation analysis developed in this research program, should be developed and experimentally evaluated.

Subtask 1d: Interactive Communication

The way soldiers communicate with their computers can also have an important impact in the speed and accuracy with which they complete their situation estimates. Areas to be investigated should include: menu design and structure, the use of function keys, formats and prompting for command and data entry, use of on-line documentation and help messages (including how these requirements change with experience), and error handling. Studies of error handling should cover error messages, increasing error toleration, and computer logging of user errors, along with analysis of operator errors and how error management may be customized for users of differing skill and ability levels.

Subtask 1e: Adaptive and Intelligent User Interfaces

A final approach to optimizing the soldier machine interface involves customizing it to the individual user, and making the interface smarter. Software should be developed to allow the interface to adapt to the preferences of each user. While advanced artificial intelligence (AI) applications are beyond the scope of this research project the data gathered may be directly applied to making more intelligent interfaces. Estimates of information importance may be used to allow the computer to prescreen incoming information using if/then rules, immediately displaying and highlighting the most critical while saving less critical information for routine management.

1.2.2 Task 2: Develop Soldier-Compatible Database Management Software

The development of a soldier-compatible database management system (DBMS) for tactical situation analysis goes hand-in-hand with developing soldier-compatible computer interfaces. The DBMS is used to input, organize, store, and retreive the data needed for making an estimate of the tactical situation. Soldiers will utilize the DBMS via the soldier-compatible interface, therefore many problems are similar for both subsystems. The DBMS should be developed using guidelines generated by SMI studies, and the SMI reserch may well utilize prototype data sets from the DBMS development task. Several activities are required to optimize DBMS interaction. They are described briefly below.

Subtask 2a: Organization and Classification of Data

The great quantity of data necessary for estimating the tactical situation must be properly organized and classified to facilitate analysis. Preliminary data selection and organization may be based on previous studies of information needs and preferences. Research should then be conducted to determine how this data is used by decisionmakers. Knowledge regarding which data tend to be used most often, what kinds of data are most likely to be used together, and what level of aggregation are most often used should be incorporated into the DBMS, as reflected in the database design and structure, data display formats, and menu design and structure. It is expected that any system developed will permit both hierarchical and relational database management.

Subtask 2b: Command and Query Language Syntax

The ease with which data can be entered and accessed is not only dependent on its organization, but also dependent upon the syntax used by the DBMS. One major approach to improving this syntax involves ongoing error analysis in addition to standard experimental trial of alternate command structures. Logging and analysis of errors should reveal where and when the most problems are encountered, and focus further development efforts there. Additional research should examine syntax preferences for novices vs. experienced users, and the flexibility to meet their different needs should be incorporated into the DBMS software.

Subtask 2c: Pre-Processing of Data

Some of the information processing load on the individual decisionmaker may be reduced by proper pre-processing of data. This preprocessing should be developed to include correlation of data from divergent sources, automatic aggregation and classification of newly input data, and pre-screening of incoming data coupled with automatic presentation and highlighting of critical data.

Subtask 2d: Distributed Data Systems

The use of the DBMS in a distributed environment places additional demands upon it. An analysis of who needs access to what information, at what frequency, and for how long must serve as the basis for partitioning of the dataset. Data input also poses a problem in a distributed environment, not only must the integrity of the dataset be protected from errors, but it must also be able to correlate conflicting data from multiple sources. In addition, research must be conducted as to how and when distributed users must be informed of recent additions and changes to the dataset.

1.2.3 Task 3: Development and Application of Distributed Information Technology

A major problem of distributed decisionmaking is ensuring that physically remote personnel can clearly and accurately exchange their ideas concerning the tactical situation. To do this, it is important to assure that they have a similar understanding of the situation estimate and share a basic set of background information. Without shared perceptions and reasonably consistent cognitive models of the tactical situation it becomes impossible for distributed decisionmakers to accurately communicate and arrive at consistent, integrated tactical decisions. Several aspects of this problem are discussed in the following sections.

Subtask 3a: Communications in a Distributed Network

The primary way to insure accurate shared perceptions is to facilitate communication between the decisionmakers. Studying distributed communication and shared perceptions will require the capability of having multiple users work simultaneously on the same representative tactical situation estimate, as well as having a means of monitoring the flow of information between the users and methods for comparing their final perceptions.

The major approach to communication in most distributed networks involves the use of electronic mail (EM) to transmit alphanumeric messages. In developing an EM system, primary concerns include the ease of composing and editing the message as well as the ease and flexibility of routing the composed message to its destination(s). Key issues to be studied involve the tasking and communication structure used for tactical situation analysis. Another major issue is the relative effectiveness of electronic mail compared to verbal (audio) communications and full audio visual communications.

Subtask 3b: Improving Distributed Information

Several other approaches to improving shared perceptions require research. The use of graphic information transfer may be less prone to errors than alphanumeric messages. This will entail the development of improved and standardized graphic symbology. Methods for highlighting critical elements of messages, and for message recipients to provide feedback, also need to be developed.

A final approach to improving shared perceptions involves the investigation of the types of cognitive models which different individuals apply to the analysis. Different people often exhibit different types of cognitive styles in decisionmaking and the possibility of fitting one's cognitive style to the demands of different tasks should be investigated. It may be that the establishment of cognitive models/styles is susceptible to training and experience. Experience and proper training on standard ways to approach a tactical situation analysis may help ensure that a common frame of reference is employed by different decisionmakers.

1.3 RESEARCH IMPLEMENTATION

1.3.1 Research Products

Each of the five research tasks will produce needed and immediately useful products. Generic Task A will develop a flexible testbed and experimental procedures for assessing proposed enhancements. Generic Task B will produce an authoritative inventory of the cognitive and behavioral tasks and information required for tactical situation analysis. Task 1 will produce a prototype computer interface for tactical situation analysis, optimized for soldier compatibility. Task 2 will develop a complimentary database management system, integrated with, and optimized like, the soldier-compatible interface. The last task will develop a concrete set of techniques to facilitate the rapid and accurate exchange of tactical assessments.

1.3.2 Utility of the Research Products

The products of this research are of fundamental importance to any attempt to automate C^2 systems. The task and information needs assessment is vital for defining the scope of any such system, and will be extremely valuable to any agency needing a comprehensive systematic structure to support C^2 personnel selection, proficiency assessment, operational analysis, or teaching C^2 doctrine. The testbed developed in Task 2 will have the flexibility not only to conduct the subsequent research in this program, but to readily adapt to investigate a wide variety of C^2 problems such as new needs development and C^2 training via simulation and gaining. The soldier-compatible interface, DBMS, and shared perception technologies will provide an integrated prototype of a working, soldier-compatible, advanced C^2 automation system designed to meet the growing need for speed and accuracy in tactical situation analysis.

1.3.3 Suggested Timeline for the Program

This research program should run for 5 years and its individual tasks should be integrated as shown in the illustrative schedule below:

<u>Generic</u>

Task A - HPRL Planning and Development: 18 Months

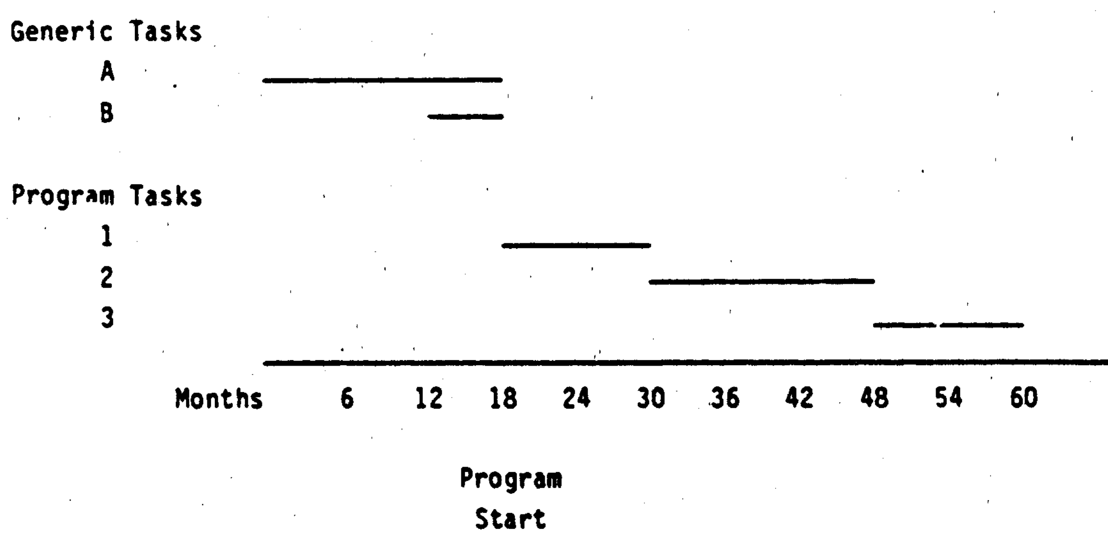
Task B - Cognitive Task and Information Needs Analysis: 6 Months

<u>Specific</u>

Task 1 - Optimize Soldier Machine Interface: 12 Months

Task 2 - Soldier-Compatible DMBS: 18 Months

Task 3 - Distributed Information Technology Development: 12 Months



1.3.4 Estimated Personnel Resources

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program Specific	1	Optimize Soldier Machine Interface	30-48
	2	Develop DBMS	30-48
	3	Develop Distributed Information Technology	42-60
	Total		264-372

Exhibit 2.0

IMPROVED TACTICAL SITUATION ANALYSIS USING LOW-LEVEL EXPERT SYSTEMS

2.1 THE RESEARCH THEME

The enhancement of tactical situation analysis in a distributed decisionmaking environment through exploratory development of low- and high-level expert systems based on cognitive modelling of the situation analysis process.

2.1.1 The Research Question

The overall question to be addressed by the proposed research program concerns the relative efficacy of various forms of decision aids in enhancing the cognitive and behavioral processes required to generate the estimate of the situation in a distributed tactical environment. Therefore, the purpose of the proposed research is to determine whether the process of developing the Estimate of the Situation (ES) can be enhanced through the use of low- and/or high-level expert systems.

2.1.2 Research Objectives

In order to accomplish this goal, several objectives must be met by the research program. These objectives are listed below and will be employed as guidelines and evaluation criteria to keep the program on track. In order to answer the research questions the program must:

- Provide an input-process-output model of the approach to developing the estimate of the situation (ES)
- Develop appropriate low- and/or high-level decision aids
- Evaluate the efficacy of the decision aids.

The objectives above will drive the integrated series of research tasks described in the following paragraphs. The tasks described here are preceeded by the development of a C^2 human performance research laboratory, the conduct of a cognitive task analysis, and the consideration of appropriate enabling technologies.

2.2 RESEARCH TASKS

2.2.1 Task 1: Provide ES Development Model

Developing the ES requires the collection and analysis of relevant information within the limits imposed by the information and the time available. The ES is typically employed to select a course of action for accomplishing the current tactical mission or task. The ES requires a thorough consideration of the mission, enemy, terrain and weather, troops available, and time (METT-T), as well as other relevant factors. Each decision process has individual steps associated with it and the factors of METT-T are relevant to these steps.

Each of the five decision processes, i.e. perceive, plan, decide, inform, and direct (or whatever processes are determined as critical to developing the ES), should be separately modelled as should each of the steps in each process. This reductionistic approach to the modelling process should continue to a sufficient level of detail so that the lowest level activity meets certain predefined limitations on time required, information that must be managed, and cognitive load. The distributed nature of databases and other information sources, as well as the personnel taking part in the process, must also be fully represented.

2.2.2 Task 2: Develop Appropriate Low-/High-Level Decision Aids

The first step in this activity is to develop a generic software tool capable of aiding/automating those processes and decisions which are key to tactical C^2 (processes derived from generic cognitive task analysis). The tool should support a number of the decision analyses, operations research, and computer science algorithms (especially artificial intelligence e.g., rule-based expert system) that would be likely to be required. The tool should possess readily manipulable database management and graphical data display capabilities. This tool should minimally be able to support those prototype process/decision aids being developed, and forethought should be given to the specific C^2 process/decision aids likely to be designed and implemented.

As a proof of concept and feasibility demonstration, the tool will be used to develop several (at least three) prototype process/decision aids which will operate on hardware and software within HPRL and which will be readily transferable to Army C^2 systems once operational. The data feeds to these aids should be representative of those which will be available in the real world but they need not have the same level of fidelity. The tactical focus of these prototype aids should be determined on the basis of their feasibility and the importance of the process/decision task being aided. They should be chosen from at least three of the six areas of C^2 identified in Section 2.2.4.1 preceeding.

It will then be appropriate to utilize the Generic Process/Decision Aid Development Tool (GP/DADT) to develop a number of specific C^2 process/decision in each of the six areas of C^2 identified earlier during generic HPRL development. In addition, the several (at least three) prototype process/decision aids developed above should at this time be "institutionalized" into the HPRL.

2.2.3 Task 3: Evaluate the Effectiveness of the Decision Aids

This task is designed to test hypotheses concerning the relative value/cost-effectiveness of various decision-aiding approaches to upgrading the estimation of the tactical problem. This would require the researchers to develop the chosen aids, develop a simulated C^2 environment in which to embed the aids, and to evaluate the aids through a series of experiments where the major independent variables are user expertise, scenario types, time pressure, and aided versus unaided performance. At least one low-level expert system, one high-level expert system, one decision analytic aid, and one operations research aid should be developed. While aiding technologies may be combined in a single product, the aids to be developed, the environment, and the experiments must all emphasize the distributed nature of the ES preparation process.

Hypotheses to be tested will focus primarily on aided and unaided performance of activities involved in ES preparation involving different forms of distributed environments, different levels of user expertise and proficiency, and different tactical environments and scenarios. The dependent variables will include the completeness, accuracy, and timeliness of the ES products. MANOVAs of objective data will be the primary form of statistical analyses utilized while subjective preference ratings of the aids will also be gathered from subjects for comparison to the objective performance data.

2.3 RESEARCH IMPLEMENTATION

2.3.1 Research Products

The products of the program will include: 1) a process model of ES preparation emphasizing human cognitive/decisionmaking activities, 2) a comparison of aiding technologies to the activities actually involved in the ES preparation process, 3) several (3-4) AI-based and other forms of decision aids, 4) a research environment to support diagnostic evaluation with emphasis on distributed activities, and 5) evaluation operational test and of the effectiveness of the developed aids.

2.3.2 Utility of the Research Products

The research products above will provide a useful model of the ES preparation process which when validated can support analytic research. The research program will also provide a valuable assessment of technologies which, when compared to their cost, will aid in the selection and application of these technologies to the ES preparation process. The C^2 HPRL, which results from the program, will support future development and testing of similar decision aids and, in addition, may be the basis for future selection and training systems. Finally, the program will provide not only specific evaluations of several decision aids, but also an assessment of the feasibility of an empirical approach to selecting, designing, and developing decision aids for the ES preparation process.

2.3.3 Suggested Timeline for the Program

The research program could run for 5 years. The individual tasks that should be performed are indicated below:

Generic

Task A - Develop HPRL: 18 Months

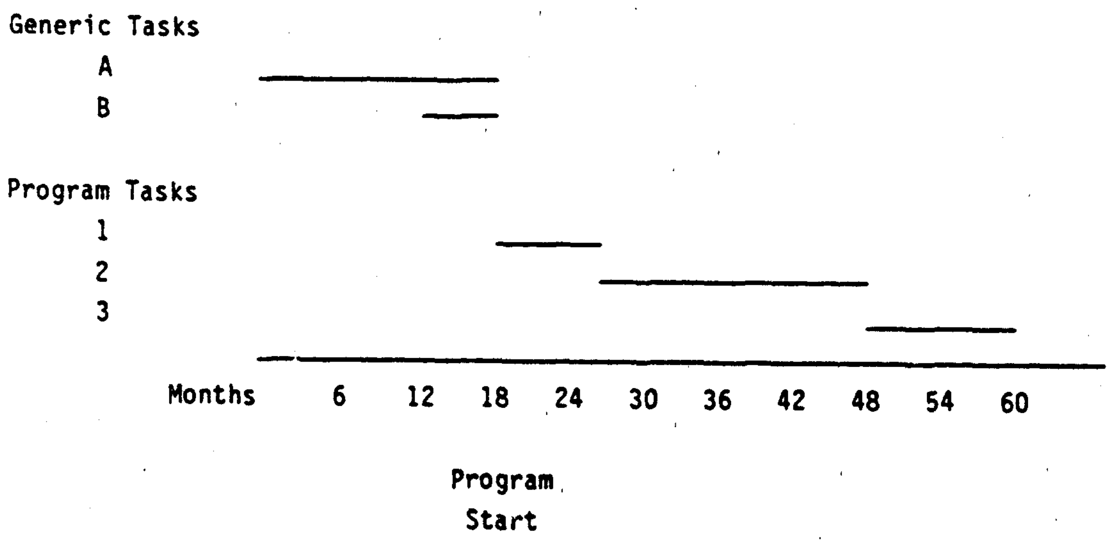
Task B - Analyze Cognitive Processes: 6 Months

Specific

Task 1 - Develop Process Model: 9 Months

Task 2 - Develop Appropriate Low-/High-Level Decision Aids: 21 Months

Task 3 - Evaluate Aids: 12 Months



2.3.4 Estimated Personnel Resources

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program Specific	1	Develop Process Model	42-60
	2	Develop High-/Low-Level Decision Aids	108-150
	3	Evaluate Effectiveness of Decision Aids	54-72
	Total		366-498

Exhibit 3.0

IMPROVED TACTICAL PLANNING VIA DISTRIBUTED INFORMATION

3.1 THE RESEARCH THEME

Interactive generation and selection of tactical plans and options through the advanced development of distributed information technologies and optimized soldier machine interfaces.

3.1.1 The Research Question

Being able to rapidly generate high quality tactical plans and options as a result of accurate analysis of the situation is a key factor in successful Command and Control (C^2) decisionmaking. The quality of the plan finally decided upon depends a great deal on the quality of the options from which the plan was constructed. Therefore, in an environment involving physically distributed decisionmakers and the rapid flexible use of mobility, the question for human performance research is how to enhance the staff officers' ability to devise and communicate tactical plans and options from which to construct the OPLAN and OPORDER. This research program is designed to optimize soldier machine interfaces and develop distributed information technologies, then to apply these tools to enhance the generation of tactical plans and options.

3.1.2 Research Objectives

In order to find out how to enhance soldier's planning and option generation, this program set out four distinct, but interdependent research objectives. The program should:

- Develop a prototype testbed and an experimental paridigm for studying tactical planning and option generation along with appropriate measures of effectiveness and performance (MOE and MOP)

- Provide a task and information needs analysis which will be used as the basis for subsequent tasks

- Employ this testbed and experimental paridigm to develop a soldier-compatible computer interface for the generation of tactical plans and options

- Develop distributed information technologies to help assure that physically distributed decisionmakers can accurately and rapidly communicate their plans and options.

3.2 RESEARCH TASKS

The objectives listed above may be implemented through the series of integrated tasks already described in the preceeding programs. The difference is that these activities are now focused on option generation and planning rather than situation analysis. Rather than repeat the description of activities in program 1, we need only to reconsider the selection and integration of cognitive activities from the generic task analysis. This will result in the selection of tasks relevant to the option generation/planning function. These tasks will become the focus for the SMI optimization and distributed information analysis to be conducted in accordance with previous descriptions.

3.3 RESEARCH IMPLEMENTATION

3.3.1 Research Products

Each of the four major tasks in this research program will produce useful products. The first will produce analyses of the tasks and information flow necessary for generating valid tactical plans and options. The second task develops an experimental approach (along with the appropriate MOP and MOE) and a prototype test bed for evaluating different methods of enhancing the generation of tactical plans and options. Task 3 will produce tested design concepts and a working prototype for a soldier-compatible computer interfacing to optimize developing tactical plans. Task 4 utilizes this interface to develop a system for communicating plans, options, and approaches to help ensure that the plans are interperted correctly by physically distributed personnel.

3.3.2 Utility of the Research Products

The products of this research program will provide practical methods to respond to the need for greater speed and quality in generating tactical plans and options. The analyses of the tasks performed and information required by tactical planners not only provide a framework for subsequent research, but can be used directly to encourage more systematic development of C^2 doctrine and training. Developing a testbed and an experimental paradigm for scientifically evaluating different approaches to enhancing plan generation not only provides the tools necessary for performing Tasks 3 and 4, but also will provide a flexible capability for future research on this aspect of command decisionmaking. The prototype C^2 systems and techniques developed in Tasks 3 and 4 will produce empirically tested C^2 decision aids designed to meet the need for better and faster ways to develop and communicate tactical plans and options in a distributed environment.

3.3.3 Suggested Timeline for the Program

This research program should run for 2.5 years, and its individual tasks should be integrated as shown in the illustrative schedule below.

Generic

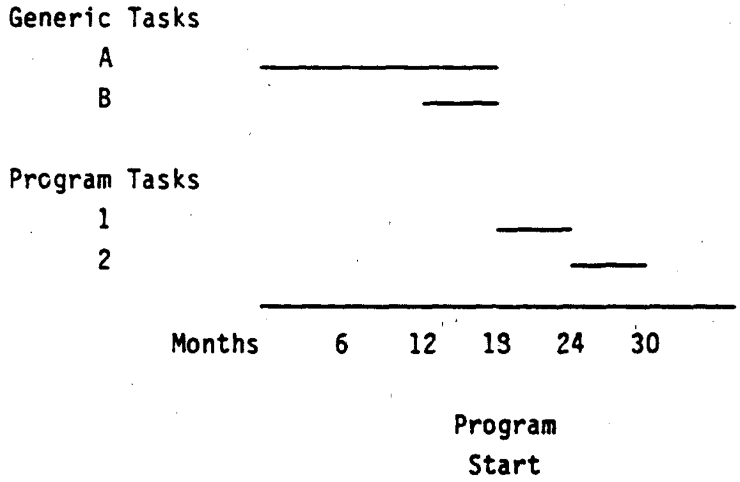
Task A - HPRL Planning and Development: 18 Months

Task B - Cognitive Task Analysis: 6 Months

Specific

Task 1 - Optimize SMI: 6 Months

Task 2 - Apply Distributed Information Technologies: 6 Months



3.3.4 Estimated Personnel Resources

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program Specific	1	Optimize SMI for Option Generation	9-18
	2	Apply Appropriate Distributed Information Technologies	9-18
	Total		180-252

Exhibit 4.0

IMPROVED TACTICAL PLANNING VIA LOW-LEVEL EXPERT SYSTEMS

4.1 THE RESEARCH THEME

Optimizing the generation, selection, and integration of tactical plans and options through the development of low-level expert systems and soldier-compatible planning systems.

4.1.1 The Research Question

The generation of valid tactical options and plans is critical to the performance of combat operations. Because of the importance of this task, as well as its complexity, it deserves high priority for computer-based aiding of human performance. In the past, little research attention has been paid to supporting and improving creative task performance as required in option generation and planning tasks.

Although sophisticated Artificial Intelligence (AI) approaches to aiding option generation and planning have been proposed, it appears that the most promising aiding techniques to be applied over the next few years will be based on low-level expert system technology. These aids will help the commander assess, organize, and utilize information relevant to the option and plan generation processes. The overriding research question here revolves around the optimization of the design and configuration of an "intelligent interface" between man and machine that encourages a greater degree of human creativity and performance effectiveness with respect to tactical option and plan generation.

This intelligent interface represents the point of exchange or transaction between the person and the machine. In other words, it is getting relevant user inputs into the computer and getting useful output (information) from the computer that effectively guides and stimulates the users' thought processes. Stated differently, the research question focuses on the development and application of innovative structured models (i.e. low-level expert systems) that: appropriately configure and integrate tasks for the user; that select, organize, and display task-related information; and that guide the user in productive interactive procedures. Overall, the goal of this type of system is to support the more creative aspects of human performance such as option and plan generation.

4.1.2 Research Objectives

In order to address the question above, this program is designed to support four distinct yet interdependent research objectives. Therefore, in addition to providing an HPRL and conducting cognitive task analysis, a program to optimize tactical planning through application of low-level expert/planning systems should:

- Analyze the tactical planning process for user needs and information flow requirements in support of system design
- Develop a prototype low-level expert planning aid (LLEPA)
- Provide for performance-based formative and summative evaluation of the planning aid.

The central hypothesis which should be tested by a program based on the above objectives is that a low-level expert system can be developed which will significantly aid user performance in the generation of tactical options and plans. It can be further hypothesized that performance improvements with the LLEPA will be observed in both the efficiency of the option generation process, and in the quality of final plan.

4.2 RESEARCH TASKS

The technical approach for testing the research hypothesis requires these integrated tasks; the development, and evaluation of a computer-based LLEPA for supporting the generation of tactical options and plans. These tasks, in turn, rest on the presence of an HPRL and the conduct of a cognitive task analysis. These activities have been described previously.

4.2.1 Task 1: Develop a Prototype LLEPA

The figure below provides an illustration of what the components of a low-level expert planning aid might look like.

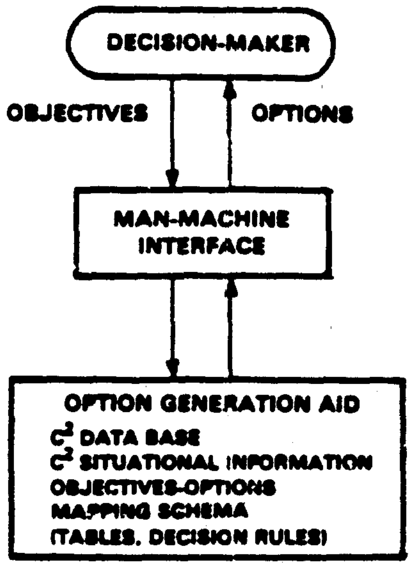


Figure 4-1 Components of Option Generation Aid

Once an option-generation problem is recognized and defined through analysis, the user together with the LLEPA could specify general goals and guidelines and then enumerate all specific objectives and constraints that would be expected to influence the ultimate selection of a particular option. The LLEPA could then organize and appropriately display, in a timely fashion, the information previously elicited from the user (e.g., existing options and specific objectives, evaluation criteria, historical data, etc.) so as to prompt the user to further generate additional options for consideration. Overall, the LLEPA could be employed to help the user to widen both the problem and the solution space--that is, in this case, to increase the number of plausible options to be considered. Then, when it is time to select an option, the user and LLEPA could evaluate and narrow down the avilable options. Based on the foregoing analysis the LLEPA would allocate information processing and decision functions between the human and machine in a manner that optimizes the use of their respective strengths and compensates for their respective weaknesses.

4.2.2 Task 2: Provide Performance-Based LLEPA Evaluation

The technical approach for evaluating the effectiveness of the LLEPA should be performance-based and include the capability for directly linking the manner in which the system is employed to solve a given problem to the quality of output resulting from its use. In this manner, the effects of LLEPA use on task-related performance can be clearly identified. Furthermore, by modelling the interactive protocols resulting from LLEPA use by "good" vs. "poor" users, specific guidelines can be derived for how the system may be used most effectively in a given tactical situation. These guidelines can then be applied in further evaluations/validations of LLEPA system effectiveness. This task-oriented performance-based approach requires some objective measurement of systems-use to be programmed into the LLEPA software to determine when, how, and to what extent subjects actually use the various aiding features of the system.

4.3 RESEARCH IMPLEMENTATION

4.3.1 Research Products

The main product resulting from this effort will be easy-to-use computer software programs, and accompanying user guides that interactively aid users in the generation of tactical options and plans. The software system should be generic in nature so that it can accommodate a variety of tactical applications and situations. The research products will also include performance studies that evaluate the effects of system use on human performance in the generation of options and plans.

4.3.2 Utility of Research Products

The utility of the products to be developed here will be manifested in a number of ways: (1) the aiding principles, models, and processes will advance the state-of-the-art for low-level expert system development; (2) the tactical option-generation and planning aids will themselves offer significant improvements in command and control performance; and, (3) these aids will contribute together with other tactical performance aids in an integrated decision support system for tactical command and control. Overall, the aiding of option generation and plan development is a critical preliminary step on which subsequent command and control functions are based (e.g., option selection and evaluation, plan execution, etc.).

4.3.3 Suggested Timeline for the Program

The execution of this program will benefit from the work accomplished in prior research efforts, hence the time and resources required are smaller. The major tasks to be undertaken and approximate time boundaries for the tasks are itemized below:

Generic

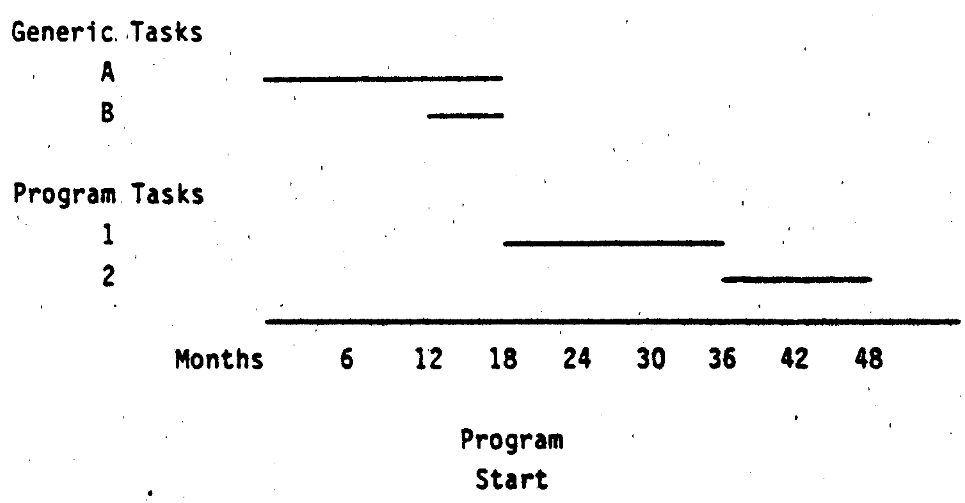
Task A - HPRL Planning and Development: 18 Months

Task B - Cognitive Task Analysis: 6 Months

Specific

Task 1 - LLEPA Model Development: 18 Months

Task 2 - LLEPA Evaluation and Refinement: 12 Months



4.3.4 Personnel Resources/Level of Effort Per Year

Successful accomplishment of this research project will require the pooled efforts of cognitive psychologists, human factors specialists, tactical experts, systems analysts, and computer programmers. The number of Professional Staff Years (PSY) needed for this program will depend upon the specific scope of work to be undertaken, however, a reasonable estimate for a meaningful research and development program might be a level of effort of approximately 5 PSY per year over a period of 2-years (making a total of 12 PSY.

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program	1	LLEPA Prototype Development	84-120
Specific	2	LLEPA Evaluation, Refinement	30-48
	Total		276-384

Exhibit 5.0

COMBAT RESOURCE ALLOCATION VIA LOW-LEVEL EXPERT SYSTEMS

5.1 THE RESEARCH THEME

Optimizing the validity of combat resource allocation/reallocation decisions through the advanced development of low-level expert systems accessed via distributed information interfaces.

5.1.1 The Research Question

The allocation and apportionment of combat resources, as well as their reallocation in response to dynamic changes in the tactical situation, are critical to the performance of military operations on the integrated battlefield. Because of the importance of this tactical decision task, and because of its dynamic nature and cognitive complexity, it deserves high priority for computer-based aiding of human performance. In the past, research and development efforts have focused on the implementation of sophisticated models (based on operations research, dynamic programming, decision theory, etc.) for processing and analyzing data relevant to resource allocation decisions. Little work, however, has been done on the problem of how to optimally structure and present the resource allocation/ decision environment to the tactician so as to enhance human judgment, information processing and decisionmaking. Furthermore, since tactical resource allocation decisions are usually made in a multi-person environment, intelligent interfaces must be designed to allow cooperating users to appropriately communicate information with others in the decision network.

The specific research questions associated with aiding resource allocation performance are many, including how the task/problem domain can be decomposed (partitioned), worked upon by individuals, and then reassembled (aggregated) in a shared environment. Given this complex problem, the use of low-level expert models appears promising. These models would be configured to help users structure and perform resource allocation tasks by appropriately selecting, manipulating, displaying, and communicating relevant information. This information would involve mission objectives, doctrine, resources, constraints, situational factors, etc. In addition, the goal of the system would be to offer on-line guidance to users in the nominal procedures of resource allocation.

5.1.2 Research Objectives

In order to address this extremely complex question, it is necessary to generate several hypotheses and from them derive the objectives of this effort. The main hypothesis for this research program is that a low-level expert system can be designed and developed which will significantly aid performance on combat resource allocation and reallocation problems in a multi-person environment where information and tasks are shared. It is further hypothesized that performance improvements will be observed for command groups who use the aid to make resource allocation/reallocation decisions. These improvements are expected in the validity, reliability, and timeliness of the resource allocation process and in the quality and effectiveness of allocation decisions.

Therefore, the objectives of this effort are to; conduct a task analysis of the resource allocation process, and develop a conceptual model, design, specify, and develop the software that emulates this model and empirically evaluate the prototype system on a multipurpose C^2 testbed.

5.2 RESEARCH TASKS

The technical approach for testing the research hypothesis requires the design, development, and evaluation of a computer-based aiding system for supporting resource allocation/reallocation that takes advantage of a distributed information interface concept. The technical approach also assumes the existence of a C^2 human performance research laboratory and the prior conduct of a generic analysis of cognitive processes supporting C^2 functions.

5.2.1 Task 1: Simulate Resource Allocation Process

A reasonable approach will be to first develop, test, and refine a single-user system that has the capability to <u>simulate</u> the presence of other users within a distributed decision network. That is, while working with the rudimentary system to be developed, the user's interface could display information and perceptions which seem to originate from other users who are simultaneously participating in the resource allocation problem session. In truth, other users would not be present, but their hypothetical inputs/outputs could be communicated via the "shared" interface. In such a manner, an additional source of task analytic information can be obtained concerning how relevant data might be communicated and shared in a true multi-person network.

5.2.2 Task 2: Develop a Conceptual Model of Tactical Resource Allocation and Software Systems to Support It

The technical approach should concentrate on the design of an intelligent interface for managing information processing in resource allocation tasks. This interface should be compatible with the mental models and procedures used by experts in resource allocation tasks. The focus should be an optimal model for organizing, presenting, and representing the key information needed for prudent resource allocation decisions.

5.2.3 Task 3: Empirically Evaluate and Refine the Prototype System

The technical approach for evaluating the effectiveness of the aiding system should be performance-based, with the capability of directly linking the manner in which the system is used to allocate resources with the quality of output resulting from that resource allocation session. In other words, formative and summative evaluation techniques are both required. Particular attention should be paid to how users access and utilize (as inputs to their own decision processes) the interactions and perceptions "communicated" by "others" through the simulated group environment.

Through this approach, the effects of system use on task-related performance can be clearly identified. Futhermore, by empirically modelling the interactive protocols of "good" resource allocations, specific guidelines can be derived for how the system may be used most effectively in a given problem situation. These guidelines can then be applied in future evaluations/validations of system effectiveness. This task-oriented, performance-based approach requires some degree of system-use measurement to be programmed into the software to determine when, how, and to what extent users actually employ the various features of the intelligent interface.

5.3 RESEARCH IMPLEMENTATION

5.3.1 Research Products

The main product resulting from this effort will be easy-to-use computer software programs and accompanying user guides that interactively aid users in tactical resource allocation/reallocation problems. The software system should be generic in nature so that it can accommodate a variety of tactical applications and situations. The research products will include performance studies that evaluate the effects of system use on human performance in resource allocation tasks.

5.3.2 Utility of Research Products

The utility of the products to be developed here will be manifested in a number of ways: (1) the aiding principles, models, and processes will advance the state-of-the-art for low-level expert system development; (2) the tactical resource allocation aids will themselves offer significant improvements in command and control performance; and, (3) these aids will contribute together with other tactical performance aids in an integrated decision support system for tactical command and control. Overall, the aiding of resource allocation/reallocation is critical to the performance of other command and control functions (e.g., option selection and evaluation, plan execution and monitoring, etc.).

5.3.3 Suggested Timeline for the Program

The major tasks to be undertaken are similar to those in Program 4.0 and approximate time boundaries for the tasks are itemized below:

<u>Generic</u>

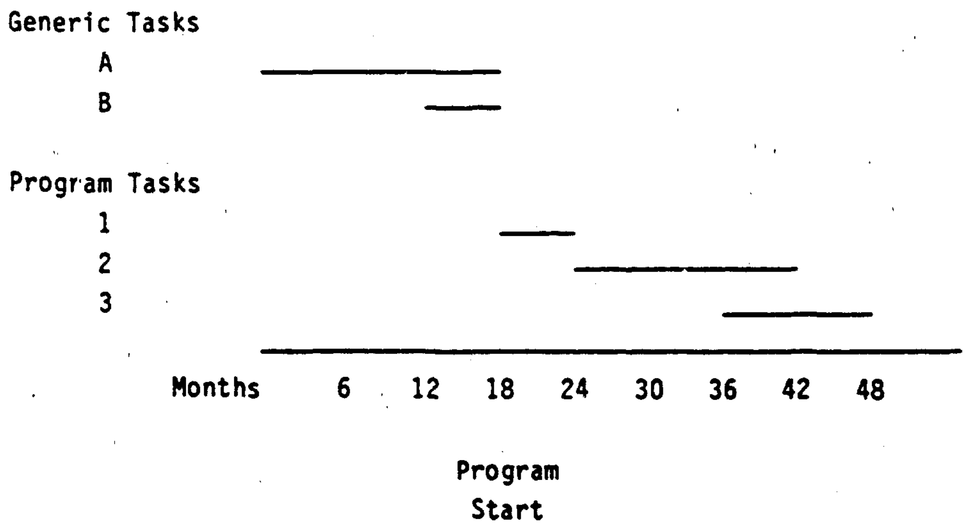
Task A - HPRL Planning and Development: 18 Months
Task B - Cognitive Task Analysis: 6 Months

Specific

Task 1 - Simulate Resource Allocation Process: 6 Months

Task 2 - Model and Software Development: 18 Months

Task 3 - System Evaluation and Refinement: 12 Months



5.3.4 Personnel Resources/Level of Effort Per Year

Successful accomplishment of this research project will require the pooled efforts of cognitive psychologists, human factors specialists, tactical experts, systems and operations analysts, and computer programmers. The number of Professional Staff Years (PSY) needed for this program will depend upon the specific scope of work to be undertaken, however, a reasonable estimate for a meaningful research and development program might be a level of effort of approximately 7 PSY per year over a period of 4 years (making a total of 28 PSY).

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program Specific	1	Analyze Resource Allocation Process	18-36
	2	Model and Software Development	96-132
	3	System Evaluation and Refinement	42-60
	Total		318-444

Exhibit 6.0

ENHANCED BATTLE MANAGEMENT THROUGH OPTIMAL DISTRIBUTION OF INFORMATION

6.1 THE RESEARCH THEME

Enhanced battle management and target assignment in a decentralized environment through the advanced development of distributed information technologies and the optimization of soldier machine interfaces.

6.1.1 The Research Question

The general research question addressed here is how the development of innovative interface designs and communication software will enhance battlefield management tasks, such as target assignment, in a decentralized or distributed decisionmaking environment.

Recent advances in microcomputer-based local area network (LAN) capabilities, and reduced costs of these systems have made distributed computer environments increasingly attractive as a tool for tactical information processing and decisionmaking. However, there are very few theoretical assumptions or empirical results to explain how these decentralized battle management groups will work effectively. Although several relevant studies have been conducted in the domain of experimental social psychology, these experiments have employed primitive interface technology and have typically involved very simplified and constrained tasks. We must therefore learn more about the potential and actual effects of distributed decision systems using a testbed based on modern computer architectures (i.e. configurations of users).

Many research questions arise, of which only a few are enumerated here: How should goals, tasks, and responsibilities be distributed among individual decisionmakers who are cooperating in the performance of a common task? What types of information communication protocols among individuals should be automated by the system? How can shared perceptions be mediated on common or similar situation displays? How can individual outputs and decisions be aggregated across a distributed group? etc. In general, structural and functional principles must be determined toward optimizing information flow and cooperative tasking procedures in distributed command and control environments.

6.1.2 Research Objectives

In order to address these questions several hypotheses have been generated. These hypotheses will in turn generate the objectives of this program. The general hypothesis behind this research program is that intelligent software can be developed to constructively coordinate and enhance battle management decisionmaking among a decentralized (distributed) command group. It is hypothesized that significant improvements in command decisionmaking can be obtained with appropriate system architectures that configure users and mediate information exchange and display (i.e., shared user perceptions) in optimal ways. Performance enhancements are anticipated in the speed, efficiency and quality of decisionmaking.

The objectives derived from these hypotheses are threefold: analyze the battle management/target assignment function; design/specify, and develop the appropriate decision aid; and evaluate the aid on a generic battle management simulator.

6.2 RESEARCH TASKS

The technical approach for testing the research hypothesis requires the design, development, and evaluation of a computerized distributed network for simulated command and control information processing and decisionmaking. The design of the system should focus on distributed information technologies, and it should permit flexible manipulation of different distributed architectures and communication protocols. This program assumes that the research facilities exist and that a generic cognitive task analysis has been completed.

6.2.1 Task 1: Develop a Conceptual Model of Battle Management and a Software System to Support It

This task should concentrate on the design of an intelligent interface for managing combat information in support of the overall battle management function. This interface should be compatible with the cognitive models and decision rules used by expert military tacticians in conducting battle management tasks. The focus of this task should be an optimal model for organizing, presenting, and communicating the key combat information necessary for productive yet effective battle management. This model must support the basic combat function of a battalion task force on an integrated battlefield: move, shoot, live to fight again.

Once the analysis is complete software should be designed, specified, and developed to support the assumptions and processes inherent in the analytical model. This software should reside on a generic C^2 simulator and testbed designed to accommodate and evaluate any C^2 related software system.

6.2.2 Task 2: Empirically Evaluate and Refine the Prototype Battle Management Aid

The technical approach for evaluating the effectiveness of different distributed decisionmaking architectures should be a performance-based approach, with the capability of directly linking the impact of different distributed architectures on the quality of decision output. One way of doing this is to present command problems to groups working in a true multiperson distributed environment. These groups will be allowed to assume a variety of different architectures, and the impact of these configurations will be mapped onto corresponding measures of decision performance.

Through this approach, the effects of different distributed architectures on task-related group performance can be clearly identified. Furthermore, by empirically determining the configurations (i.e. the different architectures assumed) of groups that perform best on command decision tasks, specific guidelines can be derived for how individual users in a decision network might should structure themselves in given tactical problem-solving situations. These guidelines can then be applied in further evaluations/validations of system effectiveness. This task-oriented, performance-based approach requires some degree of system configuration measurement to be programmed into the networking software to assess and determine changes in effectiveness as a function of the various system architectures assumed.

6.3 RESEARCH IMPLEMENTATION

6.3.1 Research Products

The main products resulting from this effort will be principles and guidelines for designing and configuring distributed networks of command groups who perform battle management tasks. These principles and guidelines will be general in nature so that they may be applied in a variety of tactical applications and situations. In addition, software will be created for demonstrating and evaluating different distributed networking concepts and architectures in a simulated command and control environment. The research products will also include performance data evaluating the effects of different system architecture on group performance in battle management tasks.

6.3.2 Utility of the Research Products

The utility of the products to be developed here will be manifested in a number of ways: (1) the aiding principles, shared perception models, and processes will advance the state-of-the-art for computer-based distributed decisionmaking environments; (2) the conceptual aiding framework developed for this program will be generally applicable to several other tactical command and control domains; and (3) this framework will offer one important building block toward the development of an integrated decision support system for tactical command and control. Overall, because of rapid changes in available computer-based hardware configurations, understanding of the actual and potential effects of distributed architectures on tactical decision performance will carry significant utility across many emerging research problem areas.

6.3.3 Suggested Timeline for the Program

The major tasks to be undertaken and approximate time boundaries for the tasks are itemized below:

Generic

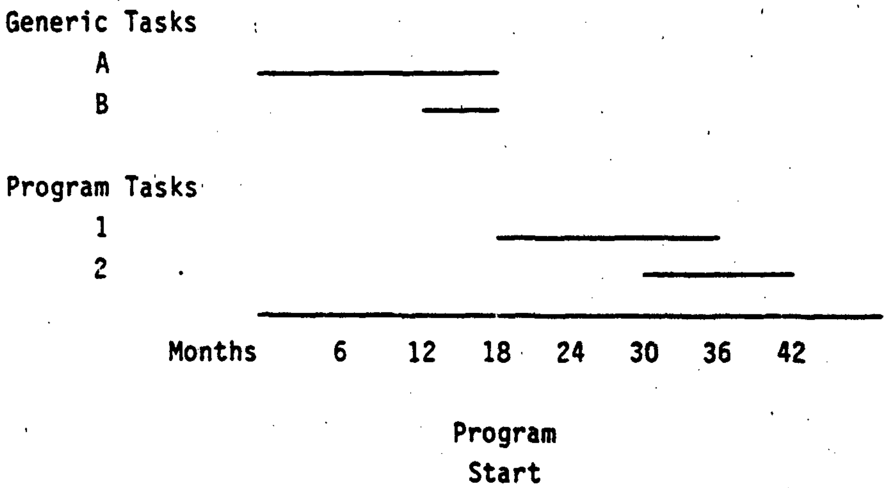
Task A - HPRL Planning and Development: 18 Months

Task B - Cognitive Task Analysis: 6 Months

Specific

Task 1 - Battle Management Model and Software Development: 18 Months

Task 2 - System Evaluation and Refinement: 12 Months



6.3.4 Personnel Resources/Level of Effort Per Year

Successful accomplishment of this research project will require the pooled efforts of cognitive and experimental psychologists, human factors specialists, tactical experts, systems and operations analysts, and computer programmers. The number of Professional Staff Years (PSY) needed for this program will depend upon the specific scope of work to be undertaken; however, a reasonable estimate for a meaningful research and development program might be a level of effort of approximately 10 PSY per year over a period of three and a half years (making a total of 35 PSY).

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program	1	Battle Management Model and Software	162-204
Specific	2	System Evaluation and Refinement	84-120
	Total		408-540

Exhibit 7.0

ENHANCED BATTLE MANAGEMENT THROUGH THE DEVELOPMENT OF LOW-LEVEL EXPERT SYSTEMS/DECISION AIDS

7.1 THE RESEARCH THEME

Enhanced battle management and target assignment (BMTA) through the exploratory development of low-level expert systems/decision aids based upon cognitive modelling of the battle management process.

7.1.1 The Research Question

Can the BMTA processes and products be enhanced through the applications of high- and low-level expert systems and decision-analytic aids which are based upon (logically derive from) modelling of the cognitive processes underlying the battle management function?

7.1.2 Objectives of the Research Program and Hypotheses to Be Tested

The objectives of this integrated research program are as follows:

- Analyze the BMTA function and conceptually model its processes
- Review aiding technologies, select appropriate generic tools and match with BMTA aiding opportunities
- Develop specific aids for most cost-effective matches
- Develop simulated BMTA environment and experimental protocols for evaluation/refinement of selected aids.

The primary hypothesis to be tested during these experiments will be: Do the aids lead to superior performance? The independent variables will include (1) aided vs. unaided, (2) skill level of the user(s), (3) the nature of the sceanario(s), (4) the aspect of the BMTA process being aided, and (5) the time requirements imposed on the user, as well as others. The dependent variables will include various objective and subjective measures of individual and group performance, including indirect measures of probable battle outcomes resulting from the decisions rendered.

7.2 RESEARCH TASKS

The program will be organized around four program-specific research tasks, each of which corresponds to a different objective. It is assumed that a facility for the study of C^2 human performance exists and that a generic cognitive task analysis has been completed.

7.2.1 Task 1: Model BMTA Functions and Tasks

Modelling the BMTA activities should be based on an input-process-output representation of the total BM process with added emphasis on the Target Assignment subprocess, in particular. A multi-level decomposition of the processes into tasks, subtasks, sub-subtasks, activities, etc. must occur. Approximately seven levels of modelling, should be attempted. However, modelling should stop when the level has been achieved where the number of inputs is manageable and the output(s) can be achieved through a well-defined set of steps which are also limited in number. The processes one identifies in developing the required Functional Model should be a combination of simple data management and manipulation, tasks as well as higher order human cognitive and judgment tasks. The key here is to develop a modelling taxonomy such that BM and TA aiding opportunities can be readily recognized and identified. In addition this supports other activities including: matching tools to opportunities, developing aiding concepts, and evaluating resulting aids. In short, the process to be aided through high- and low-level expert systems and decision analytic and operation research types of decision aids must be readily understood through these models.

7.2.2 Task 2: Review Aiding Technologies, Select Tools and Match to BMTA Opportunities

Studying available aiding technologies and identifying and/or developing generic aiding technology tools should take optimal advantage of similar efforts that have been performed in prior programs. The orientation should be one of developing a guide to decision aiding technologies and tools based on the needs of the user community. This guide would identify the strength and weaknesses of each technology, the conditions under which it is valuable, the required hardware and software, the effort and risks typically involved, and other key factors about the technologies and tools that will assist the matching of tools to aiding opportunities. Therefore, the matches will be based on the comparison of user requirements to aiding techniques. During this project one might also develop generic tools which are known to be of value in developing decision aids.

The task of identifying BMTA aiding opportunities, matching technology tools to aiding opportunities, and developing/evaluating/selecting aiding concepts must be performed by a combined team of technologists and military operations experts. As an exploratory development program, we want there to be a proper blend, or high and low risks, in aid development. We want to emphasize aiding of those activities that are most critical to the BMTA processes. We also want to use a technology only where it is best suited. There are a number of other criteria that should be formally modelled and considered as part of the decision aid evaluation and selection process.

7.2.3 Task 3: Develop Specific BMTA Aids for Most Cost-Effective Matches

The task of developing the AI, OR, and DA tools and developing a computerized, simulated BMTA environment (to be used for aid evaluation) are, of course, the crux of the entire research program. Both of these tasks will require thorough design activities prior to embarking on development activities. To the extent possible, the aids should mold directly into the existing processes and environment and not force changes in them unless it is readily accepted by operational experts that the changes are for the best and will be acceptable to the user community.

7.2.4 Task 4: Evaluation/Refinement of Selected Aids

The simulated BMTA environment must be as representative as possible of the real environment and data sources of today, as well as anticipate the environment and data sources of tomorrow (1990-2000). this testbed will be developed as an extension and modification of the similar efforts described in previous research programs.

Designing and preparing evaluation experiments and experimental materials and conducting those evaluations is the final key element of the total program. Not only must the evaluations be experimentally sound, but they must also be aimed at producing the necessary subjective evaluations by the user community that, if positive, will rapidly lead to advanced development.

7.3 RESEARCH IMPLEMENTATION

7.3.1 Research Products

The key products of the exploratory R&D program are as follows:

- A process model identifying the low- and high-level tasks and activities of the BMTA processes and leading to the identification of aiding opportunities

- A thorough study of AI, DA, and OR aiding technologies and tools, with possible development of several generic tools, as well as a matching of these technologies and tools to aiding opportunities

- A computerized, simulated BMTA environment

- A number of aiding concepts for the BMTA processes

- Several decision aids (AI, DA, and OR) for the BMTA processes

- A refined approach to decision aid evaluation in a simulated environment and actual evaluations of the developed aid.

7.3.2 Utility of the Research Products

The utility of the products will be significant in the enhancement of BMTA performance. The process model alone could lead to refinement and revision of BMTA processes. The technology study would be useful in many similar research endeavors and the aiding opportunities, opportunity/

technology matches, and aiding concepts could be the basis for continued exploratory R&D in the BMTA process aiding arena. The aids themselves could prove worthy of advanced development while the simulated BMTA environment in which they are tested could be used to support the development and evaluation of similar aids, and other types of systems for use in the BMTA environment. Finally, the general approach to aid evaluation developed for this program should be useful for other similar types of exploratory R&D endeavors.

7.3.3 Suggested Timeline for the Program

The BMTA enhancement program should run 5-years with a possible 1-year option to cover the development of new technologies unforeseen at the start. The four program-specific tasks below are somewhat independent and could, therefore, be overlapped.

<u>Generic</u>

Task A - HPRL Planning and Development: 18 Months

Task B - Cognitive Task Analysis: 6 Months

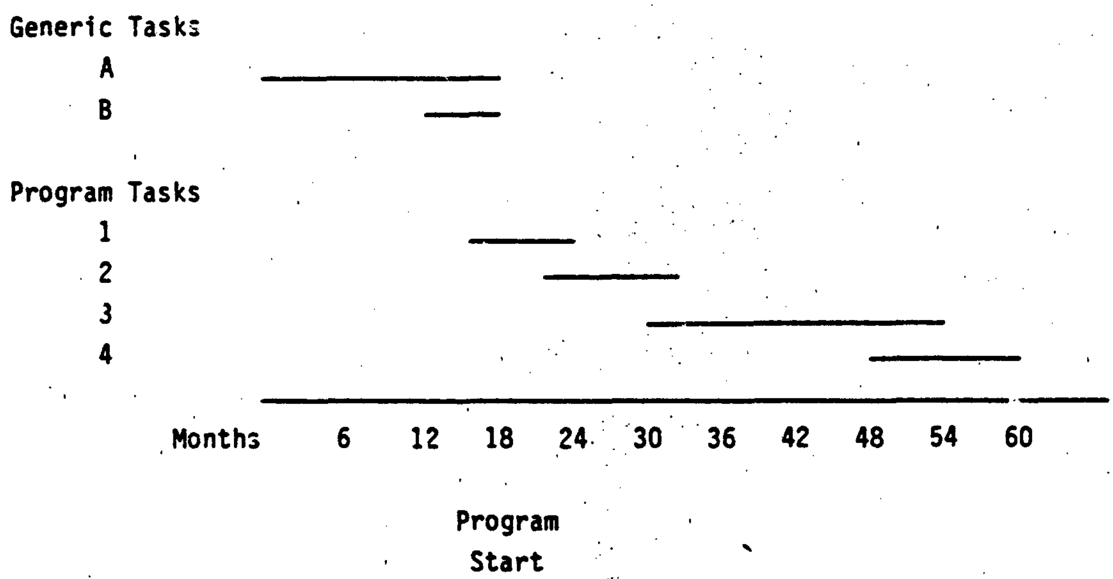
<u>Specific</u>

Task 1 - BMTA Model Development: 9 Months

Task 2 - Technology Review, Selection, and Opportunity Comparison: 12 Months

Task 3 - Specific BMTA Aiding Development: 24 Months

Task 4 - Evaluation/Refinement of Selected BMTA Aids: 12 Months



7.3.4 Estimated Personnel Requirement

The task team for this project should consist of cognitive/experimental psychologists, computer scientists, AI specialists, and military operations experts. Total level of effort should be 43 person years.

	Tasks		Resources in PMM
Generic	A	HPRL Planning and Development	132-168
	B	Cognitive Task Analysis	30-48
Program Specific	1	Modelling of BMTA Process	42-54
	2	Technology Review and Selection	66-84
	3	BMTA Aiding Development	132-168
	4	Evaluation/Refinement of BMTA Aids	84-120
	Total		486-642

3.0 INTEGRATION OF THE RESEARCH PROGRAMS INTO A COMPREHENSIVE PLAN FOR C^2 OPERATIONS ENHANCEMENT

3.1 INTRODUCTION

"I believe that it is possible, looking into the future, to conclude that, almost certainly, a technologically advanced combatant in future warfare will be able to see all elements of an opposing force in real time, and will have at his disposal, firepower means for reaching out to strike throughout the depth of the opponent's warwaging apparatus from his theater forces all the way back to his strategic reserves. Some naval officers have found it reasonable to say, vis-a-vis naval warfare, that it will be difficult if not impossible to steam around the seas with forces centered on a large-decked carrier, with protective rings of specialized air and submarine defense ships around that carrier. Some air officers have found it possible to say that we will have to find alternatives to the operation of air forces from large fixed airfields, whereon aircraft are processed for high sortie generation rates on something like an assembly-line basis. I can assert for land warfare that the day will soon be gone when massed formations of armored vehicles will be able to swarm over the surface of the earth, trailing behind elaborate logistic tails. Instead we are going to have to move toward something like "distributed force," meaning that in order to provide protection we will have to disperse more broadly and thoroughly than ever before, and thus confuse the enemy as to which elements of the target array before them are particularly significant as threat. Our tactical dispositions will have to confront our foe with a large complex of target elements, each of which is potentially able to deliver punishing firepower, and each element of which could be capable of developing the intelligence requisite to the accurate delivery of that firepower."

(LTG Paul F. Gorman, 1981)

The research programs discussed in the last chapter are all aimed at implementing general Gorman's approach, i.e. multiplying the capability of our "distributed force" by enhancing C^2 operations through the reduction of human performance deficiencies. Each of the programs would indeed be of benefit if it were conducted by itself. However the integration of those programs into a rational structured research plan will enable the cross talk and technology transfer among programs which will reduce cost and time and increase the effectiveness of all solution approaches. This approach to integrated research planning is discussed below. However, research plans per se will not get the job done. We also need a development plan which considers the facilities, politics, and management mechanisms necessary to assure that research solutions get implemented. These issues are discussed as recommendations in Section 4.0.

3.2 INTEGRATION OF PROPOSED PROGRAMS INTO A COHERENT PLAN FOR C^2 RESEARCH

The first step in the integration process is to reorder the research programs so that the most serious deficiency, met with the most feasible and effective technologies, is done first. Such a reordering has been accomplished by the author and is reflected in Table 3-1. This reordering is based not only on efficacy of the research within each program but also on the sequencing/"globalness" of each C^2 function represented. For example battle management is the "largest" C^2 function. It encompasses situation analysis, option generation, option selection, etc. Therefore, if research on battle management is conducted first, it provides valuable insight to all subsequent programs dealing with "smaller" C^2 functions. Still another dimension analyzed in the reordering process was sequence. In other words, situation analysis is done prior to option generation, which is done before option selection, and so on. The logic here is intuitive, i.e. investigate the process from the top down. If we know what the process and products of situation analysis are then we have valuable inputs to the aiding of option/plan generation.

Once the reordering has been accomplished it is a simple matter to establish an overall time line for the research plan since we already have estimates of time for each program. These programs are placed against a 10-year time line in Figure 3-1. The figure shows that the most "global"

Table 3-1

RESEARCH THEMES REORDERED RELATIVE TO THEIR PLACES IN AN OVERALL PLAN

1. Enhanced battle management and target assignment through the exploratory development of low-level expert systems/decision aids based on the cognitive modelling of the battle management process.

2. Enhanced battle management and target assignment in a decentralized environment through the advanced development of distributed information technologies and the optimization of soldier machine interfaces.

3. The enhancement of tactical situation analysis in a distributed decisionmaking environment through the exploratory development of low level expert systems based on cognitive modelling of the situation analysis process.

4. The enhancement of tactical situation analysis in a distributed decisionmaking environment through the advanced development of distributed information technologies, soldier-compatible computer interfaces and DBMS software.

5. Optimizing the generation, selection, and integration of tactical plans and options through the exploratory development of low-level expert systems and soldier-compatible planning systems.

6. Interactive generation and selection of tactical plans and options through the advanced development of distributed information technologies and optimized soldier machine interfaces.

7. Optimizing the validity of combat resource allocation/reallocation decisions through the advanced development of low-level expert systems accessed via soldier-compatible distributed information interfaces.

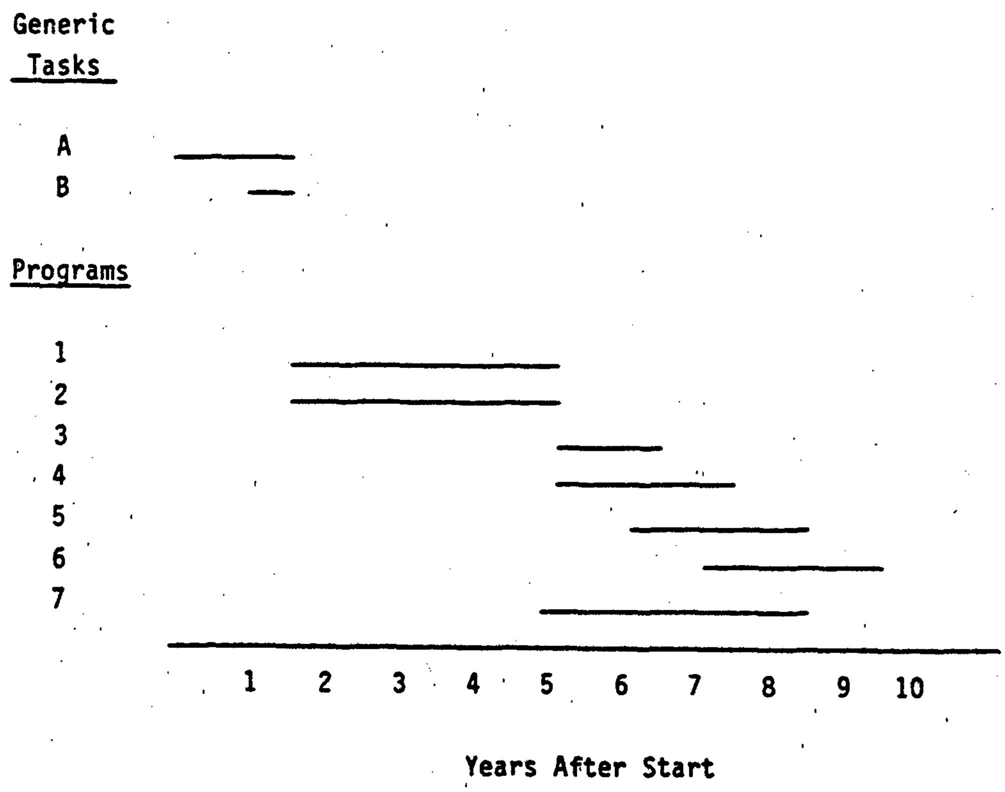


Figure 3-1. RESEARCH PROGRAMS FOR THE NEXT 10 YEARS

research programs are accomplished in parallel during the first 4 years. In addition the most direct/simplistic program is accomplished in order to support the higher order functions of the battle management program.

Research programs are paired during the 10-year period so that separate contractors, or separate in-house and contractor teams can work on the same deficiency from different technological orientations. The first orientation is the more risky, but perhaps more powerful approach, which combines expert system development with cognitive modelling (e.g., programs 1, 3, 5). The second orientation is less risky but is directed more at symptons rather than causes. This is the approach of combining distributed information technology with SMI optimization and DBMS software development. This approach is reflected in programs 2, 4, 6, 7.

The integration fostered by parallel implementation of these two approaches to each deficiency provides a greater payoff over the 10-year period. One advantage is the use of two teams working in parallel with constant cross feed. Another advantage is avoidance of self-fulfilling prophecies which occur when a researcher generates his own requirements. The most obvious advantage of using two orientations conducted by two teams is that all the research can be done in 10 years.

4.0 CONCLUSIONS/RECOMMENDATIONS

One major issue to be discussed here is the fact that all of the information upon which all of this planning was based, came from scientists. Indeed there was much thought given to systematic capture and analysis of expert opinion, to the establishment of rating dimensions, to the rational opposition of technologies and deficiencies, and most important to the derivation of deficiencies from combat requirements driven by the integrated battlefield of the 1990's. This of course is light years beyond the usual planning process whose inputs include "lots of coffee, several stubby pencils, and two smart guys sitting around a table."

Nevertheless, the work described in this report still represents the opinions and biases of a small, albeit select, group of experts. It is our recommendation that the first step in the implementation of this research plan be to assess the validity of the deficiencies, technologies, the research programs and the planning process itself. This could be done by applying some of the decision support algorithms discussed in the programs to new data collected from a much broader/deeper sample of C^2 experts. The multi-attribute utility approach, multi-dimensional scaling, and pareto-optimallity techniques are all applicable to the prioritization and planning process. It is suggested that the front end of any implementation effort conducted as a result of this plan provide for a reassessment of the validity of the research programs contained in this report.

A second major issue is the actual implementation of the research programs. A recommended approach is described in the following sections.

4.1 RECOMMENDED APPROACH TO THE IMPLEMENTATION OF THE INTEGRATED RESEARCH PLAN

As mentioned earlier the research programs themselves are merely academic exercises unless they are viewed in the context of some structured, systematic approach to their implementation. To construct such an approach, four basic components are necessary, a C^2 research facility, a generic analysis of the cognitive processes underlying C^2, the programs of research already described, and a means by which the solutions can be applied to real world C^2 problems. This systematic implementation of the research programs should be conducted at a site near the Army's center for command and control and should be supervised by the Army Research Institute through a team of cognitive psychologists, military ORSA specialists, and computer scientists. Such an implementation effort could be well under way in 5 years as illustrated by the exemplary tasks and schedule described in the following paragraphs.

The overall objective of the effort to be described is to establish a facility with which to enhance the performance of C^2 personnel. The basic assumption here is that enhancement of operator performance will provide a cost-effective approach to upgrading C^2 system performance. This objective can be implemented by carrying the series of tasks below.

4.1.1 Task 1: Establish and Refine Short, Mid-Range, and Long-Term Objectives for C^2 Human Performance Enhancement

During this activity scientists should collect, review, and integrate all pertinent literature dealing with human performance deficiencies in C^2. This document is one source, others include Army manuals, research reports, after-action reports, and personal experience. Objectives should be distilled and used to finalize a development plan for actually carrying out the research described earlier in this paper. It is suggested that the overall C^2 research facility (referred to in this paper as the HPRL) have multiple purposes to include:

- Serving as a research laboratory
- Serving as a training simulator
- Providing a testbed for new C^2 concepts.

4.1.2 Task 2: Develop Rudimentary C^2 HPRL

In order to demonstrate that the 10-year research effort will provide relevant products it is advisable to produce a rudimentary version of the HPRL and use it to try out all the activities suggested in this implementation plan. In addition, the rudimentary HPRL should be used to develop a specific solution to one of the C^2 human performance deficiencies mentioned earlier. This activity should consist of design, development, integration, utilization, and testing of the rudimentary C^2 HPRL. In addition, the solution resulting from this effort should be tested and training for its use undertaken. It is suggested that a specific battle management decision aid be chosen as the first product.

4.1.3 Task 3: Upgrade the Rudimentary HPRL to Version 1.0 Capability

In this task, the rudimentary HPRL will be upgraded to a level of capability sufficient to carry out the BMTA research program described as Exhibits 6 and 7. Using the research objectives of these programs and the technologies suggested, upgraded HPRL, functional, and design specifications should be prepared. Necessary hardware, software, and staffing will then be developed to meet the research objectives. The Version 1.0 C^2 HPRL will then be integrated, component by component, and iterative testing will begin. Testing should proceed from the component to the subsystem and finally to the system level. As the hardware and basic software are completed, additional, more sophisticated software should be developed and installed. Suggested software packages should include: a "very smart" system manager to allow for flexibility in the number and type of subjects operating in the HPRL, and a generic process/decision aid development tool (GP/DADT) with which to construct specific solutions to C^2 human performance deficiencies.

4.1.4 Task 4: Conduct Generic Analysis of the Cognitive Processes Fundamental to C^2

The objective of this activity should be to provide an empirically derived taxonomy of cognitive tasks. This taxonomy can serve as a baseline against which to measure the effectiveness of decision aids and can provide a theoretical context within which to understand the interactions of C^2 functions. Once accomplished, this task analysis could be the foundation of all subsequent research program whose goal is to break down a C^2 function, determine where it's deficient, fix the deficiency, and reconstruct.

4.1.5 Task 5: Conduct a Research Program to Enhance Battle Management Through the Specific Application and Evaluation of Appropriate Human Performance Technologies (see Themes 1 and 2, Table 3-1)

During this task, specific solutions to the research questions posed in Themes 1 and 2 should be developed. These solutions could include decision aids, expert systems, training modules, better human engineering of visual displays, or some combination of these. Any solution should then be evaluated first for effectiveness relative to increased speed and accuracy of C^2 decision, and then with regard to cost and feasibility. The evaluation of any research program should include a cost-benefit analysis module based on multi-attribute utility theory or some equally appropriate model. (It should be noted that any of the research programs described could be done here.)

4.1.6 Task 6: Identify the Technical Social and Organizational Impact of C^2 Enhancement Options Derived from the Research and Develop Approaches to Minimize Negative Effects as the Solution Is Implemented

This task is extremely important since this is generally where research programs break down. The world's best solutions are only valuable if the Army chooses to implement them. It is the responsibility of the scientists and managers of this effort to ensure that the C^2 enhancement options which result from the research be practical with regard to the Army user community. This task should include interviews, focus groups, telephone surveys, or whatever techniques are appropriate to involve the user in decisions regarding the packaging of C^2 enhancement options. If the user has some "stake" in the product he'll help to assure its acceptance.

4.1.7 Task 7: Institutionalize the C^2 HPRL as an Army Center for the Enhancement of Human Performance in C^2

This is also a major step, although not strictly a technical effort. At this time, HPRL scientists and managers should be supporting policy making with regard to the establishment of a permanent center for research, training, testing, and simulation concerning C^2 human performance issues. By this time in the effort, one major C^2 human performance deficiency will have been resolved and the impacts of implementing the solution will have been minimized. The "demonstration" is concluded and the basis for a permanent center has been established.

4.1.8 Continued Research into C^2 Human Performance Deficiencies

Once the center has been established additional research programs can be conducted as described in Exhibits 1-5. The center can also serve as a testbed to determine the effectiveness of decision aids or C^2 concepts invented elsewhere. The center would also be used to develop training programs for C^2 personnel and to begin research to develop selection techniques based on decisionmaking capability. As an indication of the direction of future efforts the following issues are raised:

Of the four guidelines for success in the Airland Battle--initiative, synchronization, agility, and depth--the achievement of depth, in terms of a multi-dimensional understanding of the battlefield, is of the most considerable importance to the quality and effectiveness of the decisionmaking team. In an "Intelligent" Command and Control System of the future, the intelligence will derive from its ability to deliver only necessary and pertinent information to an operator. The provision of apt and timely information takes place when the system can itself decide what information to share with whom, when it is needed, and how it should be displayed. Central to the success of this whole approach is the question of how the system and its operators can determine whether particular knowledge is, in fact, shared. Indeed, whether the requirement is for the system to generate a message for transmission to its operator(s), or whether it is for operators to communicate with each other via the system, the production of <u>shared</u> knowledge is not guaranteed by merely encoding and sending the message, neither is it assured by requiring the sender to note that the message has been attended to by the recipient(s). Whatever its method of encoding, the meaning of any message is not guaranteed to be understood as it was intended unless a mechanism exists to test the way that it has been taken by its recipient.

This problem worsens when we consider what is encoded in messages (circa 2000) that may be either textual or graphical. In the distributed command post where each operator is involved with a different command and control function, it is not appropriate to assume that there is a one-to-one correspondence between a message and its interpretation. Each recipient of any given message is an operator who has his own perspective, purposes, and priorities; each, therefore, must necessarily interpret what is ostensibly the same piece of information in quite different ways. What is being interpreted in these cases is not the meaning of a message, but rather, the implication(s) of a particular message for a particular operator, coming at a particular time, from a particular sender.

If a command and control system is to be truly intelligent, then it must do more than merely allow message passing: it must be able to understand the roles, situations, and information requirements of its distributed operators sufficiently to detect when an ambiguity (i.e. a breakdown in understanding) is occurring and how to focus it for resolution between sender and recipient. Resolution may manifest as a simple clarification of a command (e.g., better explanation of target assignment), or in the case of distributed tactical situation analysis, resolution of conflict may lead to an innovative act or perception that serves to increase the force initiative. The power of an intelligent system lies in this capacity to identify the areas of ambiguity where the command team's decisionmaking effort should be focused, and to expose the nature of ambiguities so that they may be addressed promptly. Therefore, future research in the C^2 HPRL could be designed:

- To provide informational needs analyses for each of the command and control deficiencies that has been identified as requiring the application of a shared perception technology
- To develop an inventory of shared perception/understanding technologies
- To provide guidelines to show which shared perception method is appropriate to which kind of command and control deficiency.

4.2 IMPLEMENTATION TIMELINES AND RESOURCE ALLOCATIONS

Although we've already discussed milestones and budget for the seven research programs suggested in this paper, it may also prove worthwhile to view the implementation plan in the same manner. Figure 4-1 shows how the tasks discussed in Section 4.1 could be implemented within a 5-year time frame. This period would also include the implementation of one major research program. That would leave the other research programs to be accomplished in the succeeding 5 years. This approach provides the Army with an established center for C^2 human performance enhancement that has proven itself in all aspects, rather than 5 years worth of research reports which no Army user would read. We suggest trading additional research studies for the establishment of a facility with which to collect data later on.

The philosophy above also results in a more reasonable, easily defensible expenditure of funds. Rather than showing Army users a shelf of reports they will see a useful enhancement facility that they can employ as necessary. A suggested allocation of resources for C^2 HPRL development through the first 5 years is shown in Table 4-1. The overall level of effort for the 5-year program is approximately 56 professional man years.

In closing, we believe that C^2 human performance enhancement is the most cost-effective approach, in the near term, to substantial upgrades in the efficiency and utility of current and planned C^2 systems. We further believe that the research programs and strategies for their implementation presented in this report provide an eminently feasible approach to C^2 human performance enhancement. It is our sincere hope that our efforts will prove to be of value to the Army and that the conflict we are planning to win will never be fought.

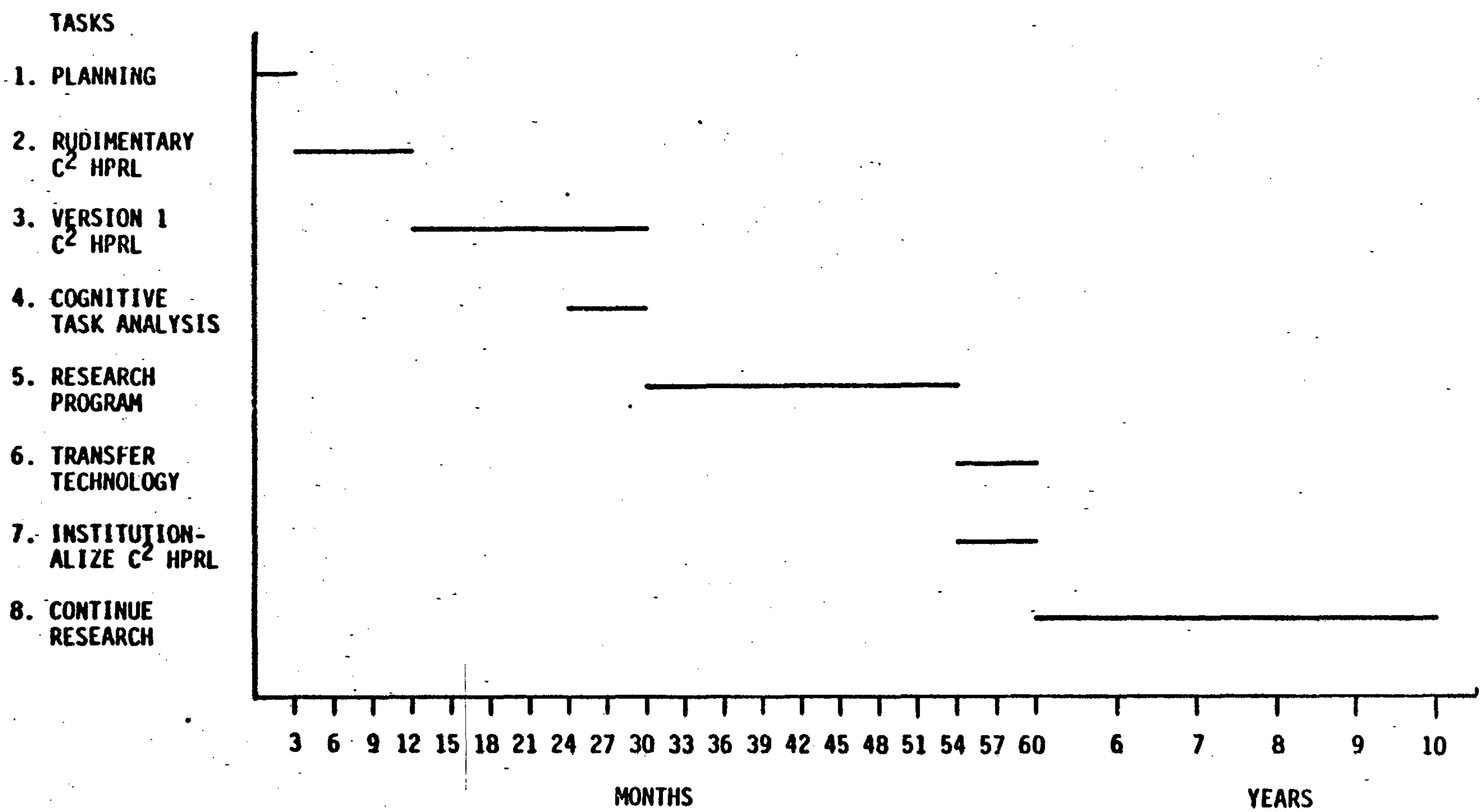


Figure 4-1. A TIMELINE FOR AN INTEGRATE C^2 HUMAN PERFORMANCE ENHANCEMENT PROGRAM

Table 4-1.
PERSONNEL RESOURCE ALLOCATIONS FOR
IMPLEMENTATION OF C^2 HPRL BY YEAR

PMM/YEAR

TASK	1	2	3	4	5	TOTALS
1. Planning	1-15					9-15
2. Rudimentary C^2 HPRL	66-84					66-84
3. Version 1.0 C^2 HPRL		72-96	36-48			108-144
4. Cognitive Task Analysis			33-42			33-42
5. Research Program Conduct			84-96	162-192	84-96	330-384
6. Transfer Technology					33-42	33-42
7. Institutionalize C^2 HPRL					36-48	36-48
TOTAL	75-99	72-96	153-186	162-192	153-186	615-759

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