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ABSTRACT

This is the second annual report of the Army Research Institute's (ARI) basic research program. It describes the current focus of the program and the individual research efforts sponsored within each of the four principal thrust areas: ability assessment; instructional technology; cognitive processing limitations; and intelligent systems. In addition, this volume surveys prior years of this effort, outlining the changing size and scope of the program and some of the more significant accomplishments from 1972 to 1984: (1) leader match for army training; (2) decision making in diagnostic skills; (3) cognitive learning strategies; (4) problem complexity and troubleshooting strategies; (5) computer adaptive testing; (6) methodology for intelligent computer adaptive instruction; (7) identification of research needs for human factors; (8) human components in combat simulation; and (9) discrete levels of human capacity in defense forces readiness and combat. A nine-page bibliography, arranged by topical areas, of all research completed from 1972 to date is included. Two indexes provide access by principal investigator and research organization. (PN)

Basic Research

Behavioral and Social Sciences

U.S. Army Research Institute
1984 Annual Report — Office of Basic Research

The U.S. Army Research Institute
for the Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, Virginia 22333

Contents

Foreword

ARI is an applied research organization dedicated to helping the Army solve people-related problems—problems of selecting, assigning, training and equipping soldiers to optimize their combat effectiveness. Applied research requires a bedrock of scientific knowledge provided by basic research, both in terms of techniques or methodologies and of data. Without this adequate scientific underpinning, applied research is subject to trivial exploitations of technology, or worse, to be constantly driven only by technology.

ARI's basic research program is our springboard to the future. Through this program we can develop the research capability to solve military problems of the next decade and beyond. This program is our opportunity to nurture the field of behavioral science, broadly defined. It allows us to work with our colleagues in the more basic research areas to bring forth new scientific developments and breakthroughs in our various fields of specialization.

ARI is dedicated to scientific and technical excellence and to making the future happen sooner. The basic research program is one of our prime vehicles for this. The efforts of this program, conceived within ARI and executed by external research institutions, advance behavioral science and contribute to the growth of ARI's scientific domains.

Edgar M. Johnson
Technical Director, ARI

Introduction

This is the second annual report of ARI's basic research program. It describes the current focus of the program and the individual research efforts sponsored within each of the thrust areas. In addition, this volume surveys prior years of this effort, outlining the changing size and scope of the program and some of the more significant accomplishments. A complete bibliography, arranged by topical areas, of all research completed from 1972 to date is included.

This program consists of basic research efforts which are deemed to be both of outstanding scientific merit and of critical importance in assuring ARI's ability to conduct future applied research on problems of the operational Army. Throughout the years, we have received unstinting and invaluable assistance in shaping its direction and in casting the critical questions to be asked by our colleagues in the field. To all of you whose insights and scientific acumen make such a program viable, my sincerest thanks.

Robert M. Sasmor, Director
Office of Basic Research

ARI—Programmatic and Organizational Overview

The Army Research Institute

The Army Research Institute for the Behavioral and Social Sciences, informally known as ARI, is a field operating agency reporting to the Deputy Chief of Staff for Personnel. It includes civilian scientists and military personnel, as well as administrative and technical support personnel. Complementing the headquarters and principal research center in Alexandria, Virginia, are seven field units and six scientific coordination offices. ARI's assigned Army mission is to maximize combat effectiveness through research on the acquisition, development, training and utilization of soldiers in military systems. ARI research, primarily in the behavioral and social sciences, helps the Army to recruit and retain the best people by developing a scientific understanding of soldiers and the tasks they perform. The understanding of human behavior — a continual subject of investigation for ARI scientists — leads to a better matching of soldiers to Army jobs, improved equipment designed with the soldier in mind, and better trained soldiers and units. This understanding is applied to maximize individual and organizational effectiveness in light of modern battlefield tactics that rely on increasingly advanced equipment and technological systems.

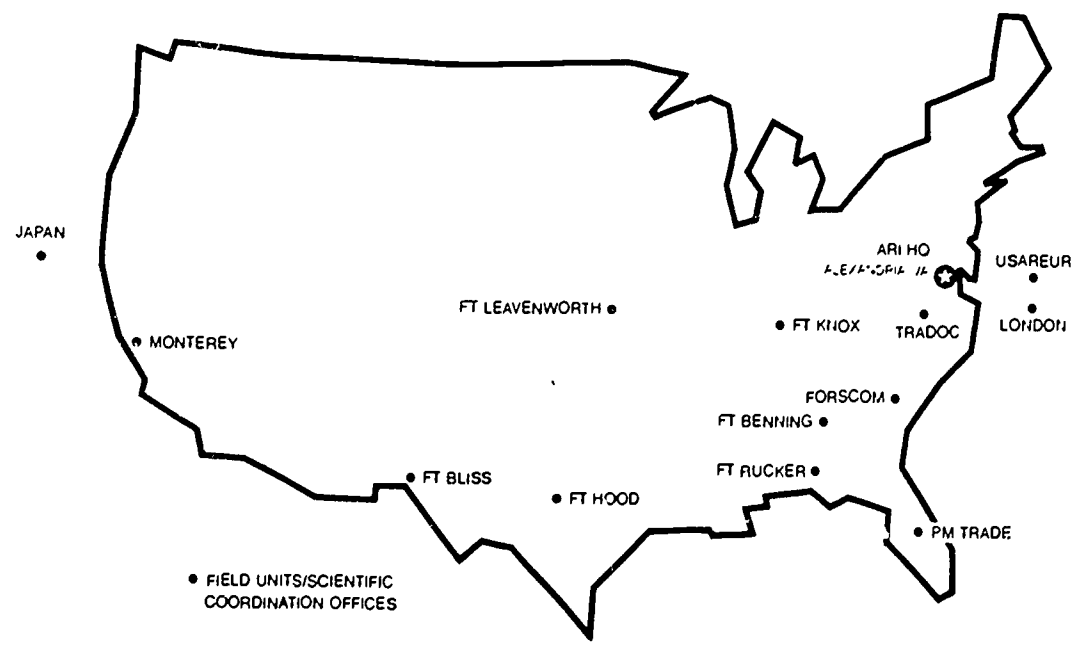
ARI within the Army Research Community

ARI is one of some 25 laboratories operated by the Army. ARI traces its beginning and the advent of military psychology to a meeting of experimental psychologists at Harvard University in 1917. They gathered to discuss how psychology and the application of scientific methods could support national defense. This group was incorporated into the Army and during World War I developed the first mass screening instruments, which were used for draftee selection. It was reactivated during World War II.

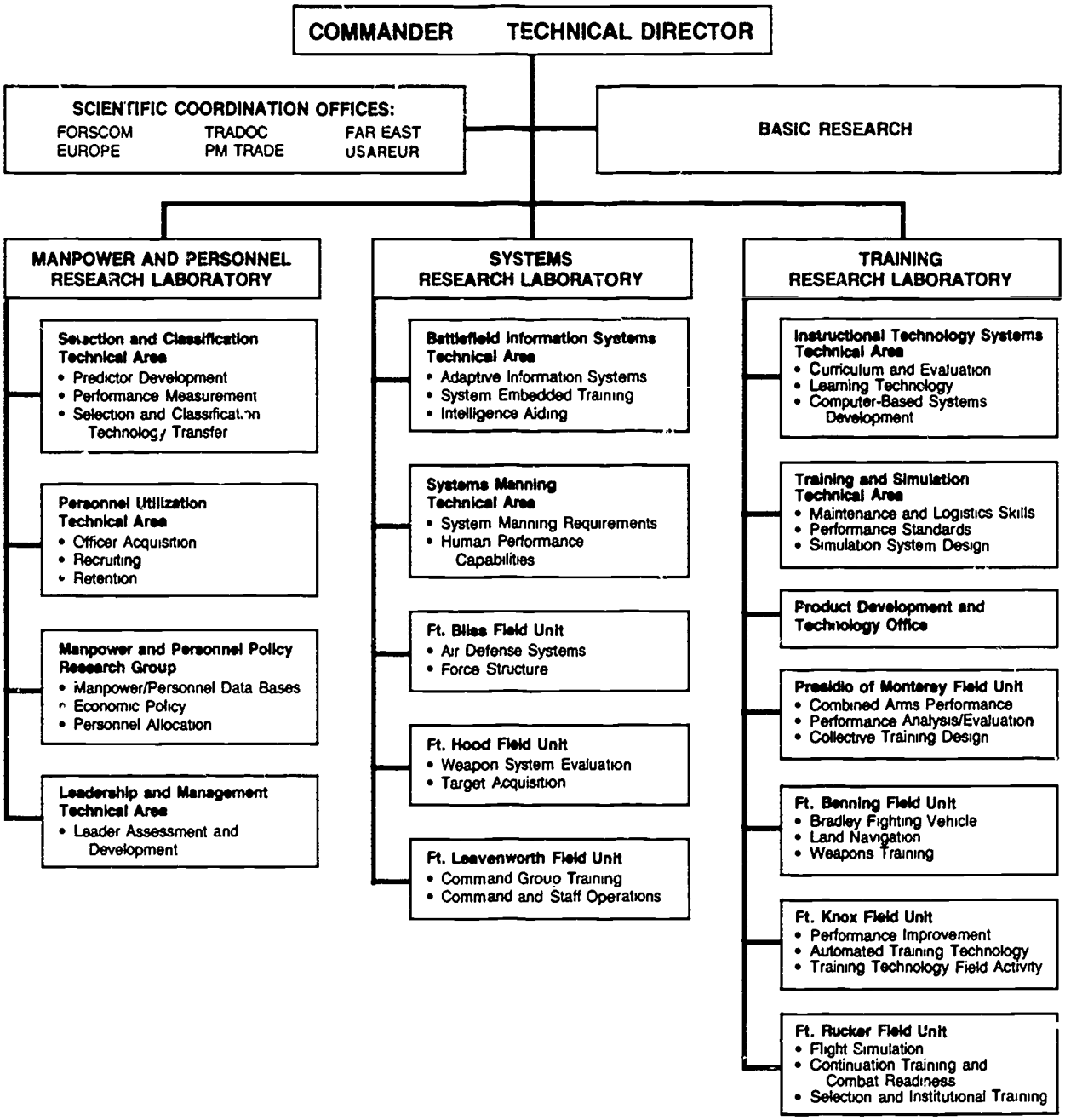
From 1943 on, the group underwent a variety of organizational changes, and addressed problems in such areas as soldier selection and job matching. As the Army experienced more complex situations, the mission of this group gradually expanded until it included research on initial selection of soldiers, job matching, retention, training and design guidelines for ensuring that the increasingly complex systems being brought into the Army were compatible with human capabilities. In October 1972, the Chief of Research and Development within the Department of the Army brought ARI officially into being with this expanded mission.

Today ARI is the Army's principal center for research on the human component in all aspects of Army activities and systems. Applying state-of-the-art concepts and methods of the social and behavioral sciences, ARI scientific and technical staff help to solve current Army problems and to make future problems more manageable. ARI research improves Army effectiveness by finding the best ways to man the force and equip the men and women who continually meet the challenge of national defense. The research psychologist and human factors specialist do this by applying scientific procedures to the selection of the best soldiers, making the optimal match between the available human resources and Army job requirements, training effectively, and equipping soldiers with weapons systems designed to complement their human capabilities.

ARI Locations



Organizational Structure of the Army Research Institute



Organization and Research Structure

ARI's core program falls into three major areas: manpower and personnel research, systems research, and training research. Three specialized laboratories associated with each technical area execute the research. The Office of Basic Research conducts a program that cuts across all three areas. Subordinate technical areas and field units fit into ARI's three-laboratory structure with current efforts aligned so that specific research thrusts are pursued by the field unit or technical area with the best available resources. Working with troops in the field not only permits ARI's scientists to apply research results, but it also provides them an opportunity to learn firsthand the research needs of the Army.

Manpower and Personnel Research Laboratory

The Manpower and Personnel Research Laboratory focuses on designing and developing methods to improve the process of recruiting, selecting, assigning and retaining Army personnel. Related efforts seek to improve the effectiveness of military organizations, particularly through analysis of Army organizational structure, management and leadership, and the dynamics of unit cohesion.

Systems Research Laboratory

The Systems Research Laboratory conducts research on how to realize optimum performance from Army personnel who operate or interface with the new systems entering the Army inventory. Modern psychological concepts of human perception and cognition are applied to the design of computerized systems and the procedures for their use. The capabilities and limitations of human performance, as well as the people-related aspects of system design, affect Army efforts to design, develop and field equipment which people can easily operate and maintain.

Training Research Laboratory

The Training Research Laboratory, drawing on existing theories of learning, motivation, cognition, measurement and evaluation, continuously examines and refines, through research and development, the training methodology and practices employed by the Army. Current research seeks to identify the specific skills required for successful performance in the Army and ways to improve the basic skills of marginal performers in order to increase their chances for successful Army careers. Training research also is developing more cost-effective training methods through simulation and training devices.

Office of Basic Research

The Office of Basic Research conducts the basic research program, intended to fill gaps in the existing scientific methodology and data base. These gaps, if not addressed, would hamper or preclude ARI's ability to conduct its applied research programs three years or more in the future. Basic research is implemented primarily through contractual efforts with the academic community. At the present time there are some 60 contracts, based on unsolicited proposals from different universities or organizations in the United States. In addition, a small number of efforts are supported within the European, Middle Eastern, and Far Eastern research communities. This program is conducted independently of the applied research, but follows the same general programmatic lines as the three major ARI laboratories.

Research Program Development

Research and development in the Army is primarily hardware oriented and is based on developing systems to meet specific needs. It progresses through successive steps beginning with developing concepts and basic data, followed by testing of system prototypes and, finally, testing of related support systems. Within the Army research community this progression includes the following levels:

- Basic Research (6.1 funding)—concerns research on theory and new techniques and methodologies
- Exploratory Development (6.2 funding)—uses basic research results and tests their applicability in specific areas
- Advanced Development (6.3 funding)—focuses on pilot testing of subsystems or total systems
- Engineering Development (6.4 funding)—concerns development of prototypes

As part of the overall Army research program, ARI's efforts follow the same sequence. Unlike hardware development, however, research in the human component is non-system specific. Moreover, the research process is much more iterative than with hardware development; applied research often encounters unanticipated obstacles that lead back to basic research questions, which in turn, when answered, allow a more optimal applied solution to be developed.

Army priorities have practical implications for the way ARI develops its research program, which is necessarily broad and multi-faceted. ARI's current program of applied research consists of four congressionally-defined funding categories:

- Manpower and Personnel
- Education and Training
- Training Devices
- Human Factors in Systems

A complete description of this program is contained in the 1984 ARI Annual Report. An overview of the basic research program at ARI, including its organization and development, is presented in the next section.

Basic Research Program at ARI

Office of Basic Research

Basic Research at ARI is managed by the Office of Basic Research. It focuses on the future. The mission of the Basic Research Office is to create a cumulative behavioral science knowledge base on which to build new technologies for improving the effectiveness of Army personnel and to expand the scope of the underlying scientific base. While the search for these technologies is driven by Army needs, their development often results from significant breakthroughs by pioneering researchers. Because of this, the basic research program is designed to involve innovative civilian scientists in research relevant to the Army. The findings of relevant new research supported by the program ultimately could produce high pay-off solutions to projected problems in the operational Army.

Background

The Army's involvement in basic research can be traced back to the 1960s and Project THEMIS, the first Army-wide effort to provide a broad and continuing base of support for academic research considered vital to the national defense. Although there had previously been some support for selected basic research projects, THEMIS offered the stable financial base necessary to ensure continuing involvement of the academic research community in basic research oriented to the military. The behavioral science portion of the program was jointly sponsored by the Army Research Office, Highland and the Army Personnel Research Office, an early predecessor of ARI.

By 1972, the Army had four separate programs of basic research, each associated with an Army organization already conducting applied research. Through maintaining this close association between basic and applied research efforts, the Army fosters the transfer of basic research findings into more advanced stages of research. This enables basic research findings to have a direct impact on procedures and systems embedded within the functional, operational Army.

The four programs of basic research, as currently structured, are:

- Physical and Mathematical Sciences—sponsored by the Army Research Office at Durham, North Carolina, a part of the Army Materiel Command, the Army's materiel development agency. In any given year this program accounts for approximately 75 percent of the Army's basic research (6.1) effort.
- Medical Science—sponsored by the Deputy Surgeon General for Research and Development, and accounting for approximately 12 percent of the Army's 6.1 efforts.
- Civil Engineering—sponsored by the Deputy Chief of Engineering for Research and Development and accounting for approximately 8 percent of the Army's 6.1 efforts.
- Behavioral and Social Science Research—jointly sponsored by the Human Engineering Laboratory (Aberdeen Proving Grounds) and ARI and accounting together for approximately 5 percent of the Army's 6.1 effort.

Basic Research at ARI: 1972-1984

When ARI was established in 1972, the basic research program was executed in three portions, each managed by a separate unit within the newly formed organization. Basic research in military sociology, training and motivation was conducted through the Motivation and Training Laboratory. Basic research in human factors, including symbology and some initial research on decision processes, was carried out by the Systems Research Laboratory. Basic research on more global issues was executed through the Office of the Technical Director. While the separate efforts reflected technical excellence, and most showed promise for transition to advanced or applied research, the basic research program as a whole lacked an integrated thrust.

As a first step in this direction, all basic research efforts were consolidated within the Technical Director's office. In 1974, the $1.5 million budget for basic research constituted approximately 6.6 percent of ARI's total $22.2 million budget. In order to maximize the benefits of the small budgetary resources available to the program, a two-tiered system was established to review all proposed basic research endeavors prior to funding. A committee of bench scientists performed a peer review to determine the technical excellence of each basic research effort. Following this review, an executive committee, composed of senior ARI management, then assessed the relevance of each effort to future applied research. This group made recommendations to the Technical Director. Both review groups rotated members, and the review process encompassed the entire scope of the Institute's research interests. The executive committee was chaired by a representative of the Technical Director, responsible for long-range planning at the Institute. Through this representative, it was possible to ensure that the basic research program was integrated with the Institute's future plans.

In 1978, ARI management initiated the next in a series of moves to sharpen the programmatic focus of the Institute's basic research efforts. At that time, there was growing commitment among senior Army management to develop and institutionalize techniques for organizational effectiveness within the Army. Acknowledging that commitment, ARI management set aside a fixed portion (between 25 and 30 percent)

of the year's basic research funding to support appropriate underlying theoretical research in that area. This was the first time that a deliberate management strategy was imposed on the basic research program.

Throughout the 70s, a period of rapid technological change, the need for basic research grew significantly. To meet this need more effectively and still remain within the strict budgetary limitations imposed on the program, ARI established, in 1981, a separate Office of Basic Research, reporting directly to the Technical Director. Simultaneously, programmatic emphasis was focused on major thrusts with a new one beginning each fiscal year. Though not excluding other promising efforts, this focus has ensured adequate support to areas deemed most vital to ARI's future applied research programs. In FY81 the program focused on Analysis of Cognitive Ability; in FY82 on Instructional Strategies; in FY83 on Intelligent Systems (Artificial Intelligence Applications). In FY84 the emphasis was on broadening and consolidating these thrusts.

Selected Accomplishments 1972-1984

These examples represent selected accomplishments of the basic research program during the past twelve years.

Leader Match for Army Training

This effort validated Fiedler's Contingency Model of Leadership Effectiveness for officer training and led to the development of an Army-specific syllabus and instructional manuals. The manuals have been adopted by TRADOC, ROTC and are in use throughout the Army ROTC.

Decision Making in Diagnostic Skills

This research developed general decision strategies for all equipment trouble-shooting regardless of complexity. This effort also elaborated these strategies in a computer based, context-free, non-equipment specific diagnostic task, which was shown to improve performance on specific equipment repairs. This project provided the basis for a new training approach now in use at the Army Signal School, Ft.Gordon.

Cognitive Learning Strategies

This research tested the relative effectiveness of various learning strategies for different learning situations and determined which were optimal for certain tasks. It also established that these learning strategies could be taught to students. Following this, an instrument for diagnosing students' entry level learning strategies and deficiencies was developed and fielded. The diagnostic test, the Learning and Study Strategy Inventory (LASSI), has received wide acceptance within the education/training community, and the assessment results are being utilized by ARI's Training Research Lab in planning and executing advanced development on specific Army problems.

Problem Complexity and Troubleshooting Strategies

This project addressed the problem of transfer of training from simple to complex problems, a major obstacle to practical applications of training techniques. The major finding was that problem practice in an unfamiliar context led to strategies which transferred to other contexts if problems were of similar size or scope. To transfer problem solving strategies to considerably larger and more complicated problems in other contexts, practice on intermediate size problems was needed. This finding led to the solution of underlying problems in developing training programs for transferable strategies. The results are being utilized in ARI's applied training development program.

Computer Adaptive Testing

Current tests of an individual's knowledge within a given domain are inflexible, give relatively little information and are easily compromised. Procedures for developing a large item pool and selecting appropriate items tailored to an in-depth probe of a given individual's knowledge were developed. The result is individually tailored, faster, less easily compromised tests, which provides a more accurate assessment of the individual's actual knowledge. This tri-service supported basic research effort subsequently underwent field validation, also under tri-service support (6.4).

Methodology for Intelligent Computer Adaptive Instruction (ICAI)

This research represents a first step in developing truly adaptive and individually tailored computerized instruction. The system developed consists of a Competency Model of what the student should know; a Performance Model, representing the student's current state-of-knowledge; an Instruction Monitor, which can compare the two and determine the next sequence in the teaching program; and dialogue facilitation to improve interaction between system and student. The result is the first instructional system capable of custom tailoring its program to the needs and abilities of the individual student without intervention. These results provided the basis for initiating ARI's applied research on applications of ICAI.

Identification of Research Needs for Human Factors (Committee on Human Factors, National Research Council)

Human factors research is being increasingly driven by advances in technology rather than programmatic-

ally organized research considerations. To reverse this situation, a tri-service funded committee was established under the auspices of the National Research Council. The committee's purpose is to delimit and define target areas for human factors research so that the findings can be incorporated into the design of future Army systems. The 1983 report has helped to structure the areas and specific research needs for human factors military support for the coming decade. Six areas so identified and currently being explored are:

- Human Decision Making
- Eliciting Expert Judgment
- Supervisory Control Systems
- User-Computer Interaction
- Population Group Differences
- Applied Methods

The Committee continues to function and has proven an invaluable asset to the Services by continuing to redefine the expanding frontiers of the field.

Human Components in Combat Simulation

Existing combat simulation models for officer training do not take human actions into account, a problem sufficiently serious to have warranted Army Science Board review and concern. This effort reviewed existing combat models to identify: (1) explicit and implicit human interactions in their modeling, and (2) the sensitivity of simulated battle results to assumptions concerning such actions and interactions. Three points of maximal sensitivity in simulated combat models were identified, and the specific parameters involved were identified. This led to an applied research effort to develop the necessary information to implant into such models so that they will serve as more realistic aides for future officer combat training.

Discrete Levels of Human Capacity in Defense Forces Readiness and Combat

Based on initial research measuring different levels of abstract conceptual ability, ranging from the most concrete to the most abstract, and also determining that the requirements for more abstract, longer term thinking increase as one goes up the organization, including military organizations, training requirements for new senior level executives were explored. Specifically, the requirements for and impact of discrete levels of conceptual ability on different levels of organizational command, leadership development, senior military staffing, officer efficiency, and information, communication and control process were explored. Overall impact on readiness and combat performance was assessed. Additionally, analysis of anticipated work requirements a decade hence yielded a different overall pattern of skill requirements, with a radically different organizational staffing structure. These results feed directly into a Department of the Army Task Force on General Officer/Senior Executive Service Development.

Basic Research Program Development

The basic research program is organized and developed along lines parallel to the applied research interests of ARI: manpower and personnel, education and training, and the human element in Army systems. The Basic Research Office analyzes the Army's needs in these areas, particularly as revealed in MAAs (Mission Area Analyses) and related documents. It then determines how they might be met through new knowledge or application of emerging knowledge and technology. The Office plans and executes a progam of basic research aimed at filling perceived gaps in the knowledge and technology base required for the execution of future exploratory and advanced development research programs. Proposed projects are evaluated primarily in terms of their relevance to the perceived needs for supporting future applied research, their scientific merit, potential payoff and their synergistic impact on other work being supported. In order to ensure that basic research efforts are properly integrated into the overall program, the Office participates in the long-range planning of the exploratory and advanced development research programs.

Current Programmatic Scope

ARI's current program in basic research must anticipate the Army's needs 20 years from now and beyond. Projections of the Army in the year 2000 and beyond suggest that there will be fewer people and that they will be of more diverse quality and makeup. Training time will increase, as will the cost of training. Increasingly sophisticated equipment and heightened dependence upon computer driven systems seem certain. The potential for data overload with information paucity, both in operations and maintenance, appears high. Looking toward future military encounters, the Air Land Battle 2000 envisions compressed time, information overload, and a distributed battlefield with fewer people but with an increased span of control.

These projections have implications which, if taken seriously, impose many new requirements on the Army of the future. More accurate and faster methods for assessing abilities and skills will be needed. The Army will have to increase the individual's ability to learn and to operate at more abstract conceptual levels. Soldiers will have to be trained in multiple skills through faster, less costly and more generic training. All of this must occur with a lower ratio of trainers to trainees. Further

increased reliance on simulation appears imperative. In the area of computer aids, the Army must acquire devices capable of machine processing of information in real time; problem solving for maintenance, planning and decision making; distributed information processing and decision making; and group decision making. Command and control networks will be needed for information sharing in planning and decision making.

These projections into the future, and the requirements they will impose on the Army, set the stage for the research trends of today. The next generation of applied research will have to emphasize information handling and engineering using computers. Most of these probably will be small, high speed and portable. To develop this technology, the Army needs to know how humans process information and what are the necessary and sufficient minimal conditions for information processing. To explore, develop and blend these two lines of inquiry is the challenge for ARI's program in basic research. To meet this challenge, the basic research program currently is focused in four principal areas:

- ability assessment
- instructional technology
- cognitive processing
- intelligent systems

Brief introductions to these areas of focus, and descriptions of ARI's current and recently completed basic research projects in these technical areas, are provided in the following section of this report.

FY84 Basic Research Program Summary

Basic Research Area: Ability Assessment

The problem of assessing and measuring the innate abilities and the acquired skills and knowledge of individuals is one of critical importance to the Army. This bears on individuals entering the Army as well as those already in the service. Basic research in this domain centers on two major thrusts: Assessing Cognitive Capability and Assessing Specific Knowledge and Skills.

Assessing Cognitive Capability—The focus of this thrust is to find improved methods of assessing the cognitive skills and abilities which individuals possess. Within this thrust, new approaches to measuring the innate intellectual abilities of individuals are being examined. The development of new methodologies, for measuring intelligence of individuals is of primary importance to the Army. Of greatest concern are methods to develop testing procedures that will provide more detailed information and a more definitive profile of an individual's abilities.

That individuals function at different levels of conceptual abstraction is a well known fact. Research in abstract conceptual ability is attempting to define these different levels of abstract conceptual ability and to measure an individual's current level of functioning. Research also is seeking to determine whether individuals can be trained to go from one level of abstract conceptual functioning to a higher one, and if so, how. Within this thrust is included basic research to explore the concept that learning time can serve as a measure of potential.

Assessing Specific Knowledge and Skills—The problem of measuring an individual's level of attainment after skill training remains a constant concern within the military. Newly developed measurement techniques using computer adaptive testing show promise, but the validity and test-retest reliability of such computer adaptive testing require further research.

Within this thrust is basic research in the area of nonverbal skills assessment. Despite the visual display capabilities inherent in computer adaptive testing, much of the current testing focus is on verbal cognitive skills. The problems of testing nonverbal skills, such as spatial and manual abilities, remain to be addressed.

Current Research:

Components of Verbal Intelligence
Sternberg/Yale University

This research is part of Sternberg's attempt to develop a new functional definition of 'intelligence' and a culture-free test for it, based upon the way in which individuals process information of different types in various situations. In this study, the processes by which individuals determine the meaning of text and the meaning of unknown words based on context is being investigated. This information will allow for better prediction and diagnosis of an individual's level of verbal intelligence and for training of those persons deficient in verbal comprehension skills. Sternberg is conducting the study using an approach that borrows from a wide range of methodologies new to the intelligence research field. Using this integrated approach, he is focusing on two basic questions relevant to the Army's needs: (1) what are the kinds of cues people use in learning word meanings from context, and (2) what are the processes and the knowledge base on which such cue utilization draws. Both the reading passages used in the study and the decisions asked of subjects are of a 'real world' nature, relating to the types of materials found in newspapers, magazines, and technical texts and manuals. This research is being cosponsored with the Office of Naval Research.

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Human Problem Solving in Complex Dynamic Environments
Rouse/Georgia Institute of Technology

This project focuses on skills relevant to problem solving in complex, computerized, change monitoring systems. Problems arising in such systems, whether in communication, transportation, or manufacturing, require user or operator intervention, and an increasing demand is being placed on human intelligence and resourcefulness as the systems grow more complex. This study addresses four questions: (1) what cognitive skills are used in the diagnosing of a problem and its correction, (2) what cognitive skills are used in coordinating these two tasks, (3) can training improve these skills, and (4) what measures of problem complexity are best suited for predicting skill requirements in such tasks. Rouse has designed a simplified, abstract network control scenario as the first phase of the study, and will manipulate relevant variables as the study progresses. As specific skills relevant to such system problem-solving are identified, training will be developed for those skills, and more productive supervisory control procedures for problem solving in human-computer interactive systems in dynamic environments will begin to emerge.

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Training for Cognitive Complexity
Streufert/Yale University

The goal of this study is to enable the Army to select the best available person for a complex task and adequately train him or her for it. It is becoming apparent that current measures of intelligence and level of trained skill are not adequate predictors of performance with respect to jobs that are highly complex in terms of cognition — jobs that, for example, require a large amount of strategic planning. More information is needed to determine how information is processed; how ideas, thoughts, and object perceptions are associated; and how plans are made. This study addresses two specific questions: (1) to what degree training in cognitive complexity can be successful, and (2) which training procedures can be most successfully applied across the broadest spectrum of tasks. Further, as part of this effort, Streufert aims to develop a reliable technique for measuring an individual's current level of cognitive complexity functioning.

Operators' Internal Models of Complex Dynamic Systems
Wickens/University of Illinois

This project is investigating the process by which individuals create internal representations of complex, dynamic systems. Every individual who is charged with operating a complex human or technological system, from the supervisor of a nuclear plant to the commander of a military unit, at some point develops a mental representation of how that system functions. This representation, at whatever level of sophistication, makes it possible for the operator to control the system and detect failures when they develop. Unfortunately, little is known about how this cognitive process works — knowledge that could help reduce the number of accidents or miscalculations caused by shortcomings on the part of operators by finding ways to help them develop more functional models faster. Wickens is working with subjects in a variety of systems in which operators' control and decision making are complicated by an extensive set of variables that are not deterministic — such as the military commander who must anticipate enemy movements in order to direct his own unit.

The Meaning and Function of Military Experience
Fiedler/Washington University

It is generally accepted that prior military job experience is desirable for most military command assignments, yet little is known definitively about the rela-

tion between experience and leadership performance. This study attempts to identify (1) what military officers mean by experience, (2) what elements they consider important in judging the quality of an individual's experience, and (3) how various elements in an individual's work history contribute to leadership performance. Fiedler is basing his data on the personnel records and questionnaire responses of the 100 or so Army officers acting as subjects. Each subject's superiors and peers also will be asked to evaluate him or her in terms of leadership performance. With the resulting information, the Army should be able to better predict how officers will function in certain positions following promotion, and what training will improve their performance.

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Dynamic Personnel Job Management Modeling
Charnes/University of Texas

The purpose of this project is to extend the current personnel job management model to account for personnel reactions to team scenario changes. Personnel job management modeling is a method of determining whether an individual is compatible with a specific team scenario. It aids in selecting the right individuals for the right jobs. However, current personnel job management modeling is static and does not account for personnel reactions to change in team scenario conditions. The extended model will incorporate individual flexibility, adaptability and efficiency responses to dynamic, or changing, situations. It will provide a more realistic basis for predicting individual-team scenario compatibility and improve personnel planning and personnel utilization.

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Basic Research Area: Learning and Instruction

In an era of rapidly changing technology and soaring training costs, the need to develop more rapid and efficient methods and systems for providing instruction for training and retraining is of paramount concern to the Army. Research in this domain is categorized in three major thrusts: Instructional Strategies, Computer Based Instruction and Expanding Learning Skills.

Instructional Strategies—To improve the Army's instructional systems, basic research in individual learning strategies seeks a better understanding of the methods by which individuals acquire, process, and incorporate new information. Related research in analytic reasoning strategies also is underway. As individuals become more proficient in solving particular types of analytic problems, it appears that they discard the linear paradigm by which they were taught to approach such problems. Experts talk about approaching such problems in terms of their perception of "correctness" or the "pattern" of the situation. A better understanding of this expert approach will lead to the design of more efficient strategies for teaching such skills.

Computer Based Instruction—ARI sponsored research has demonstrated the feasibility of using computer based instruction (CBI) to develop psychomotor skills. Further research is needed to develop CBI procedures for training psychomotor skills and for determining optimal schedules for such training. Research is also needed on the types of situations and constraints under which such training can be accomplished and to develop suitable criteria for performance measurement in the area of psychomotor skills. For the training process to succeed, easy and reliable performance measures are essential. Research in this area is laying the groundwork to convert computer based instruction into individually tailored, interactive instructional systems — that is, it is the precursor to intelligent computer adaptive instruction (ICAI) systems.

Expanding Learning Skills—Recent research suggests that the perceptions behavioral scientists have of the ability of individuals to learn may have been more narrow than reality indicates. Basic research in this area is seeking to overcome the so called "natural limitations" long believed to be inherent in humans' ability to learn. Further, follow up on new findings in the area of "split brain" learning seeks to explore the phenomenon of right brain versus left brain learning and its implications for Army instructional systems.

Current Research:

Training in How to Learn
Weinstein/University of Texas

In this study, Weinstein is focusing on training individuals in how to learn. At a time when technology is demanding more of recruits in order to achieve proficiency in their area of specialization, their basic learning abilities must be improved. In addition, studies have shown that some soldiers in the current cohorts come to the service poorly equipped to learn. Given these facts, it is important for the Army to develop ways of increasing the effectiveness of its training programs. One approach is to instruct students in the use of particular learning strategies, i.e., techniques for organizing and interpreting new information. In this study, Weinstein is trying to: (1) identify individuals who can benefit from instruction in learning strategies, (2) evaluate the needs and entry level knowledge of individual learners, and (3) develop instruction targeted at individual deficits and characteristics. This research also is studying the cost-effectiveness of various learning strategies so that the Army will be able to devise and implement the most cost-effective training programs.

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Instructional Design Based on Problem Solving Behavior
Steinberg/University of Illinois

Steinberg is investigating the methodological differences between novices and experts confronted with situations that involve deductive reasoning. In the Army, as elsewhere, there is a pressing need for people who can solve problems requiring deductive reasoning, such as diagnosing a medical condition or a technological malfunction. These are problems that cannot be solved by applying a fixed set of rules in a prescribed order. Schools have not been able to effectively teach problem-solving techniques of this kind, partly because so little is known about the deductive reasoning process. This research seeks to identify effective deductive problem solving techniques to determine whether these techniques can be taught, and whether an individual's deductive reasoning capabilities can be assessed prior to assignment and training.

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Macroprocesses and Adaptive Instruction
Tobias/City University of New York

The objective of this study is to provide instructional systems designers with information on the procedures used by different individuals for the cognitive processing of instructional information. Although there has been a great deal of research on the relation between students' achievement and teachers' observable instructional techniques, there has been little research on how differences in individuals' cognitive processing affect achievement. This study will investigate whether differences between instructional methods are reflected in the level of achievement when they provoke different macroprocesses in students. Accordingly, defining the different macroprocesses and instruction which are optimal for various types of material and individuals should lead to more effective instructional systems.

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Cooperative Learning: Impact on the Acquisition of Knowledge and Skills
Dansereau/Texas Christian University

Dansereau's study will provide empirical data to support the growing interest in students learning by interacting with one another. The project uses pairs of students learning scientific texts in a cooperative fashion. Dansereau is attempting to: (1) determine the effects of various cooperative learning strategies on the acquisition of academic knowledge and skills; (2) evaluate the impact of individual differences in such things as status, prior knowledge, and cognitive style on cooperative learning; (3) explore ways to facilitate transfer from cooperative to individual learning; and (4) investigate how cooperative learning activities relate to various memory and text processing theories. These results also will provide insight into improving future interactions between students and computer instructional systems by allowing for the incorporation of such cooperative approaches into future computer based instructional systems.

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The Relationship of Simulator Fidelity to Task and Performance Variables
Allen/George Mason University

Allen is seeking to establish whether greater physical and/or functional similarity (fidelity) between simulators and real systems increases the effectiveness of training and, if so, to what extent. He also is determining minimal fidelity guidelines for training simulators in an effort to optimize the relationship between simulator fidelity and transfer of training, and cost in training simulator design. Currently, simulators which have less resemblance to the real system are thought to offer extensive advantages over real system "twin" models. They can assist the trainee through feedback and cues, and are generally more flexible in the number of skills for which they can train. In addition, they are significantly less expensive, may provide for quicker transfer of training, and can substantially reduce training hazards. However, there is a lack of hard evidence to substantiate and measure these proposed advantages, and no guidelines exist defining minimal fidelity. This research is attempting to address both of these problems.

Individual and Task Differences in Understanding and Using Instructions
Smith/Bolt, Beranek & Newman, Inc.

This study focuses on the process of how people understand instructions. The success of a modern military force depends in large measure on the capabilities of the individuals who have to operate, maintain and repair its equipment. Unfortunately, as technology has become more complex, the written instructional manuals used by Army personnel have frequently proven to be inadequate. Many of the difficulties associated with developing instructional manuals can be attributed to the lack of data on how people understand instructions for performing a task or procedure. Smith is studying: (1) what types of instructions result in optimal understanding and performance for different types of tasks; and (2) how individuals with different levels of cognitive ability understand and execute written instructions. These findings will provide a basis for improving the design of military training documents and guidelines for determining what types of jobs certain people can be most effectively trained to perform. This research is being co-sponsored with the Office of Naval Research.

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Individual Difference Effects in Human-Computer Interaction
Ambardar/Northeastern Illinois University

This study focuses on the problem of providing access to computerized information in a way most compatible with the cognitive style of the individual user. It is Ambardar's hypothesis that efficiency in accessing information can be increased if individual differences in cognitive style are taken into account in designing human-computer interfaces. To test this hypothesis, Ambardar is employing a four-step research plan: (1) Those characteristics of cognitive style most likely to affect interface features will be identified; (2) A simulated interface will be used to study these interactions within the context of real-life information retrieval; (3) A non-simulated interface will be substituted; (4) The research results will be verified by evaluating the cognitive styles of users of existing computer systems. If the hypothesis is borne out, the research results will provide substantial input to design guidelines for compatible human-computer interfaces, a major problem in developing "user friendly" computerized systems.

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Test of the Stabilization-Error Theory of Retention
Jones/Pennsylvania State University

The purpose of this project is to enable the Army to minimize skill loss through more effective training. To minimize skill loss, training processes must be designed and structured in accordance with individual retention

capabilities and must compensate for skill loss over time. In this study, Jones is evaluating the stabilization-error theory of retention and developing a framework for understanding individual differences in retaining skills. The stabilization-error theory suggests a method for analyzing the optimal point in training for maximum retention and provides a means to predict the retention capabilities of individuals. The framework developed by Jones will serve as a guide for grouping individuals with equal retention capability for training. In addition, it will serve as a design tool for adjusting the length and level (structure) of training to ensure acceptable performance over time.

Memory and Learning Strategies

R. Bjork/University of California, Los Angeles

A common way in which human memory breaks down, particularly in rapidly changing military situations, is through a failure to update efficiently, particularly when confronted with information overload. This research is exploring ways to code information and to sequence it in such a way as to aid the updating process and thereby enhance retrieval at a later time. It is known that successful retrieval of information from the human memory, as in a test, makes the subsequent retrieval of that information on a later occasion far more likely. This effort is investigating the mechanism or mechanisms through which this retrieval of information enhances the strength or accessibility of that information in one's memory. Several different control processes under investigation show promise in overcoming difficulty in retrieval from long-term memory and may constitute a means of overcoming "natural limitations" in human memory.

The Effect of Guided Imagery and Internal Visualization on Learning

Meier/The Center for Accelerated Learning;
Caskey/Texas Tech University

This effort examined the effects of mental imagery on short-term and long-term retention of learning materials. Meier and Caskey found that presenting learning material through mental imagery leads to higher achievement both on tests of immediate recall and of long-term retention. This improvement was reflected across various demographic groups, academic majors, socio-economic backgrounds, and levels of ability. Meier and Caskey's research has provided Army trainers with a significant new basis for enhancing learning, particularly in tasks requiring the rote memory of sequential data.

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Reading Competencies and Practices

Guthrie/International Reading Association

The purposes of this investigation were (1) to construct measures of reading competencies that are frequently needed in an occupational environment, and (2) to describe the influence of the components of reading practice on these competencies based on the conceptual framework of ethnographic psychology. Guthrie found that traditional tests of reading competency may not be adequate measures of competency, particularly of those competencies required in a military or occupational environment. It appears that sustained activity of reading leads to improvement of particular means of processing written language to fulfill the goals of the processor. Depending upon one's purpose in reading, different levels and types of competency are attained. Moreover, there is a high correlation among specific practices and specific competencies. As a result, practices of reading may be intimately tied to competencies for reading and may actually be construed as their origin.

These findings have significant relevance to the Army. The volume of printed materials supporting military systems has increased substantially in recent years. Not surprisingly, the amount of time a recruit spends engaged in reading is also on the increase, as is the difficulty of the material due to the high technology involved. This has raised concern about how to react to reports of soldiers' reading competency and the reliability of the tests for assessing reading competency relevant to a soldier's military occupational specialty (MOS). Guthrie's work forms the basis of a new and significant approach to determining the extent of functional illiteracy and taking appropriate corrective measures.

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Novice Strategies for Comprehending Technical Texts

Larkin and Dee-Lucas/Carnegie-Mellon University

Despite the obvious and growing need for reliable and effective ways of transmitting technical knowledge to novice learners, little is known about how readers understand technical prose. Studies of technical knowledge structures have generally focused on the more stable and well-defined structures of experts, whereas studies of reading strategies and learning from text have focused on narrative (story-like) rather than technical expository text. Larkin and Dee-Lucas are investigating how novice learners comprehend technical texts. The research is examining the nature of comprehension strategies used by novices and how these strategies influence what is learned from technical texts. The focus is on the extent to which novices use

and modify their "normal" comprehension processes in developing strategies for organizing and integrating technical information. The classes of strategies under investigation are attentional strategies, organizational strategies, inferential processes and information reduction strategies. This effort is intended to yield a basic understanding of these processes that might be used by text designers and instructors of novices to produce more reliable and effective text instruction. The results will indicate how technical texts for novice learners should be designed. The results may also suggest instructional strategies for improving novices' understanding of these texts.

Roles of Information Feedback in Motor Skill Training

Schmidt and Shapiro/
University of California, Los Angeles

This research is investigating how information feedback functions to aid learning. Information feedback in the form of knowledge of results is generally regarded as one of the most important variables for complex skill learning. Scientific understanding of how this type of information feedback operates is limited because researchers have generally failed to separate the temporary performance effects from the relatively permanent learning effects. As a result, the role of feedback of knowledge of results in learning is relatively unclear. Drawing upon the results of their previous research, Schmidt and Shapiro hypothesize that knowledge of results has a particularly strong guidance role but not necessarily an equally strong learning role. During acquisition, behavior is powerfully guided by knowledge of results, often to the detriment of future performances where such knowledge is lacking (and to the detriment of learning), because learners may come to rely too heavily on it. The goal of this research effort is to extend this earlier knowledge using far more practice and more complex tasks, and to examine issues not only for learning but also for long-term retention and transfer. This research is attempting to provide a new more effective basis for structuring real-world practice sessions with respect to the delivery of information feedback.

Basic Research Area: Cognitive Processing Limitations

The Army is entering an era in which larger, more rapid, and increasingly sophisticated computer-driven information processing systems are proliferating. As a result of this increasing reliance on such systems, the study of the limitations on human cognitive processing and what can be done to compensate for these limitations is of critical concern to the Army. Research in this domain is organized in three major thrusts: Man-Machine Integration, Information Overload and Decision Making.

Man-Machine Integration—The overriding concern in the area of man-machine integration is to develop design guidelines to ensure that future systems are compatible with human use. Especially important is the development of guidelines for optimal allocation of tasks between the human user and the computer, taking advantage of the unique skills of both.

Information Overload—As automated systems provide individuals with more and more information, the need grows for a theoretical structure to determine how best to package information for different types of settings, situations, and tasks. Approaches for packaging and presenting information which will alleviate the overload condition, under various levels of operating load and time pressure, need to be developed.

Decision Making—Efforts are underway to reach a greater understanding of the decision making process, especially regarding organization of information. Basic research is needed to address how individuals organize and use information in making a decision and the ways in which they weight the validity and importance of incoming information relevant to that decision. In addition, future systems probably will require decision making by groups of varying sizes, composed of individuals at some distance from one another. These individuals may or may not share a common data base, either in part or in whole. Basic research on procedures for group decision making and for determining the need for shared data bases is required. In regard to decision making *per se*, it is now known that even experts are subject to systematic bias of which they are unaware. Identification of these types of bias and development of methods to deal with them is critical. Additional research is needed to determine how decision makers are affected by factors such as uncertainty regarding the total situation or the validity of specific inputs.

Current Research:

Information Processing Using a Structured Framework

Sage/University of Virginia

The purpose of this research is to develop procedures that are useful as aids to enhance human information

processing with specific relevance to Command, Control and Communication Information systems. The central goal is to develop a structured information processing framework, based on logical reasoning, that will allow identification of various forms of cognitive bias in information formulation, analysis, and interpretation. An ancillary, but equally important, goal is to develop debiasing procedures to avoid the various forms of cognitive bias. One result of the research will be an evaluated structured framework for information presentation in systems which will help to alleviate users' cognitive biases.

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Procedures for Learning to Interact with a Computer Based Information System
Foss/University of Texas

The goal of this study is to provide an accurate model of how the novice acquires understanding of a computer based system. Foss is testing the hypothesis that the novice learns the process by which the system operates more quickly when presented with an appropriate metaphor (conceptual model), from which he can make predictions about the behavior of the system in unfamiliar situations. Foss is also studying how the sequence and amount of information presented on command languages affects learning. In addition, he is examining how acquiring the metaphor and learning the commands compete for the limited "cognitive resources" of the learner. The findings will permit the development of better guidelines for the design of instructional and operational procedures for computer based information systems.

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Methodology for Assessing Organization of Information
Hock/Florida Atlantic University

This research involves the development of a methodology to investigate and measure the size of the functional units in which visually presented information is processed by humans. Previous research on human memory has shown that information about the frequency of events is coded automatically, with little influence from the individual's levels of intelligence and education. In this research, Hock is seeking to identify functional units of processing by determining whether subjects accurately monitor the frequency of occurrence of the units under investigation. In addition to addressing some fundamental issues in visual search, selective attention, conceptual abstraction, and pattern recognition, this research offers the possibility of enhancing understanding of how individuals assimilate information concerning the likelihood of events and contingencies between events in various situations. Overall, the research offers promise for developing a method to organize visual information more efficiently in large information collection and retrieval systems, while imparting contingency information to the user — information of vital importance often overlooked.

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Quantification of Risk Assessment
Wallsten/University of North Carolina

This research represents an attempt to apply quantitative values to judgments at high risk in real world situations which parallel those occurring in military operations. It is an attempt to determine how human decision makers assess risk and to provide a common, objective, quantified vocabulary for such use. This research is a unique attempt to study the process of experts' subjective valuations of real world risk situations and to quantify this procedure. The goal is to provide a stable basis for communication and understanding among two or more individuals, or systems, assessing risks in complementary or overlapping situations.

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Human Factors Steering Committee
Deutsch/National Research Council

ARI, the Office of Naval Research, and the Air Force Office of Scientific Research, later joined by NASA, established the Human Factors Steering Committee to explore basic research needs for human factors. This resulted from concern that the field was being so forcefully driven by developments and changes in technology that significant programmatic issues were being overlooked. There was also concern that basic research in the area of human factors was becoming too fragmented and lacked a programmatic overview. The committee consists of 12 rotating experts in various areas of the human factors field. The report issued by the committee at the end of the second year has had a distinct impact on the development of basic research in the field, not only within government laboratories, but also in the academic and business community. Because of the high return on the small investment, the committee has been retained and is exploring and attempting to define certain areas of critical concern to military systems such as supervisory control situations, and simulation device fidelity requirements.

Conditions Associated with Interference Between Processing Demands in One Cerebral Hemisphere
Green/Georgia Technology Research Institute

This study focuses on the "interference" that occurs when one side of the brain must both process a stimulus and make a response to the stimulus, as occurs in the processing of large amounts of complex and competing visual information, a situation often encountered in military tasks. How successful an individual is in performing such a task depends in large measure on whether or not the task itself causes interference between stimulus processing and response control within the same cerebral hemisphere. A stimulus appearing in the left visual field, for example, will project to the right hemisphere; likewise, movement of the left hand is controlled by the right hemisphere — hence the possibility of interference between stimulus processing and response control. The objective of this study is to identify conditions that enhance performance when stimulus processing and response control originate within one hemisphere, as well as when they originate in separate hemispheres. Identification of the conditions under which interference occurs will allow task design that takes such effects into account. For instance, visual displays for tasks with a high level of interference could be designed so that stimuli initially project to the hemisphere not controlling the response. The findings also will provide an understanding of how rapid visual information processing is accomplished and help to resolve contradictory findings in the existing experimental literature.

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Meanings of Non-Numerical Probability Phrases
Wallsten/University of North Carolina

This project, conducted in two parts, focuses on the frequent use of such phrases as "probably," "very likely," and "possibly" as a barrier to effective communication on the battlefield. As previous research has demonstrated, the meaning of such phrases varies widely depending on the person speaking, the person being spoken to, and the particular circumstances involved. The first purpose of this study is to develop and validate techniques for quantifying an individual's understanding of a given phrase in a given context. This is being done through computer controlled experiments in which subjects are asked to make judgments about the relative likelihood of an event, based on a numerical and nonnumerical description of it. The second phase of the study will investigate the effects of context and individual characteristics on the understanding of these phrases. Wallsten will conduct experiments similar to those in the first phase to ascertain the answers to such questions as: (1) Do people with different kinds of training systematically use probability words differently? (2) Do the words have different meanings when applied to positive and negative events? (3) How do modifiers such as "very" or "not" affect meaning? (4) Does the choice of phrase depend on the amount of information supporting the judgment? The results will be particu-

larly useful to the Army in training future decision makers and in instructing them on how to communicate effectively with one another.

Aiding the Human Decision Maker Through Knowledge Based Sciences
Sage/University of Virginia

This project involved the planning and conducting of a workshop that will include representatives from three different disciplinary areas: artificial intelligence, decision analysis, and cognitive science. In attempting to make improvements in cognitive functions such as judgment, decision making, planning, and resource allocation, the Army tends to receive conflicting advice from individuals representing different professional perspectives. During the workshop, individuals involved in these three areas, each with its own set of research objectives and development priorities, will explore commonalities and differences. Among the specific topics that will be addressed are problems relating to battlefield management; intelligent automation; Command, Control and Communication Information systems design; maintenance and maintainability of equipment; and other human-machine interface systems. The problems within these areas are many and varied, including incomplete knowledge, conflicting information, ambiguity, changing environments, differences in user experience, and irrelevant data. However, the knowledge-based sciences have created an equally large array of opportunities with respect to the development of information systems. These opportunities will be explored by workshop participants to the end of making consensus recommendations towards the goal of increased efficiency of the human component in Army systems.

Constraints on Access: Costs and Benefits
Franks and Bransford/Vanderbilt University

Learners acquire knowledge through instruction so that it can later be accessed when it becomes relevant. Inadequacies in learning, problem solving, and decision making often stem not from a lack of relevant knowledge, but from a failure to access knowledge that was acquired previously. This research investigates factors affecting the degree to which, and, more importantly, how people become aware of the relevance of previously acquired knowledge for such tasks as problem solving, learning, and decision making. Franks and Bransford will also investigate both negative and positive implications (cost-benefit effects) associated with access to previously acquired information.

Cognitive Processing
E. Bjork and Kaye/
University of California, Los Angeles

This research project is assessing basic components of nonverbal intellectual ability including spatial ability and memory. One component of spatial ability appears to involve switching one's attention, independent of eye movements, to different locations in the visual field in order to process large amounts of briefly presented information. While components of this ability may represent innate automatic responses, people may vary in their ability to utilize cues as to how they should manipulate their attention for optimal visual processing. In this case, it may be possible to train the strategies that will enable efficient allocation of attention to different spatial locations. Further, since this ability may be related to skills of mental rotation, the discovery of ways to train efficient attention switching may generalize to many types of nonverbal spatial problem solving. EEG/Polygraph equipment is being used to monitor the underlying neural components of attention switching behavior.

A second element of this effort addresses the updating capability of human memory, that is, one's ability to keep memory current. Without such a process, people would quickly become overwhelmed by the massive amounts of information they must process and remember each day. When memory updating breaks down, there is a reinstatement of interference owing to previously learned but no longer current information. Using a pupillometer as an independent measure of cognitive activity, Bjork and Kaye hope to isolate the specific conditions that result in breakdowns of this valuable updating process. The isolation and discovery of such conditions should provide possible solutions for problems created by information overload.

The Role of Data and Feedback Error in Inference and Cognition
Doherty and Tweney/Bowling Green State University

Increasingly, decision makers utilize information provided by computers to make judgments, predictions, inferences, and decisions. This trend raises concern, particularly in military settings, about the consequences of errors in the information provided to decision makers. This new research explores the impact on inferencing behavior of errors introduced through a system failure which produces data unrelated to the true state of the information. While the role of uncertainty has been explored by psychologists, there has been virtually no work on uncertainty created by errors in the information provided to the subject by the environment. This effort addresses this area through manipulation of the amount and nature of the error in the environment on a trial by trial basis and through observation of the effects on several measures of performance in inference and prediction tasks.

Assessment of Relation Between Asymmetry in Cerebral Hemisphere Arousal and Perceptual Asymmetry
Green/Georgia Institute of Technology

Recent research suggests that asymmetry in the relative arousal of the two cerebral hemispheres may be an important factor in explaining individual differences in a wide range of behaviors. Green is investigating a new approach for assessing individual differences affecting human performance. She has hypothesized that individual differences in perceptual asymmetry may be related to individual differences in asymmetry of cerebral hemisphere arousal. If this is so, simple behavioral measures for assessing perceptual asymmetry can be used to make valid inferences regarding asymmetry of cerebral hemisphere arousal. This effort is attempting to quantify the relation between asymmetry of hemispheric arousal and perceptual asymmetry. Research also will focus on identifying other correlates of arousal asymmetry. The overall goal is to identify behavioral correlates of arousal asymmetry that can be used for purposes of personnel assessment.

Basic Research Area: Intelligent Systems

Much of the work pursued under the three domains previously discussed concerns the methods by which individuals process information. In contrast, research carried out within this domain is exploring issues related to the machine processing of information under various tasks. This area deals with applications, and, in some cases, extensions of techniques initially developed in the artificial intelligence and cybernetics communities to problems in behavioral science research. The four major thrusts within this domain are Knowledge Representation, Learning, Problem Solving and Planning.

Knowledge Representation—ARI supports a program of basic research in the field of knowledge representation. One of the major underlying problems of many large scale systems is determining how to collate and organize information for future use and the appropriate categories and mechanisms for retrieving it at the needed time. Research on human knowledge has resulted in a variety of knowledge structures: hierarchies, networks, schematic representations, prototypes, lists and rule-based systems. A critical issue is what kinds of representations are most appropriate for various knowledge domains and purposes.

Research is needed on methods of knowledge transfer, from one expert or a variety of sources, into a comprehensive system. Methods of coding, collating, organizing, storing and retrieving need to be developed. Research is also needed on flexibility of knowledge representations, representing dynamic information, and inclusion of value information or weighting in knowledge bases.

Research is underway on knowledge creation. People use existing knowledge as the basis for generating new information, through inferential, deductive or inductive processes. This little understood subject requires intensive investigation.

Learning—A primary focus of research within this area is methods for initially creating new data bases from discrete information and for incorporating new information into an existing data base. This latter topic applies both to information from the outside environment and to internally generated input based on the experience of an individual user or the system itself. Finally, although it is well known that new tasks often are learned by extrapolation from previous learning experiences, or through analogies, basic research is needed to explore the mechanisms by which humans accomplish this kind of learning and how these mechanisms could be incorporated into machine programs.

Problem Solving—The development of computerized aids for problem solving is of great interest to the Army, and ARI supports basic research in the methods and procedures used to solve problems. These include procedures of iterative branching techniques used in heuristic problem solving; rule based problem solving;

goal directed problem solving; the nonlinear approach often used by experts; and the inductive approach whereby individuals reason backward from fragmentary, less than perfect pieces of evidence to determine an underlying scheme, purpose, or reason. It is anticipated that, in the future, some Army problems will require rapid solutions from two or more individuals physically removed from each other who may not have access to identical data bases. The types of network controls and mechanisms that will be necessary for such distributed group problem solving and the extent of data based redundancy required in such situations are of concern.

Planning—Research is underway in the area of structured planning, particularly into the rules and procedures used to plan for ill defined future scenarios. ARI also supports research on how planners generate new goals, modify goals, and create alternate goals. Most current planning systems are limited in that they incorporate fixed goals which are incapable of changing. This research aims at providing more adaptive planning systems in the future.

ARI supports research to develop methods for incorporating the user's value judgments into machine system planning operations. Experienced planners or decision makers often incorporate subjective value judgments into their planning and decision-making processes which they cannot verbalize but which often turn out to be valid. To date, automated systems do not possess such capabilities.

Research also is underway on constraint modification and development of alternatives. Current planning systems have constraints built into them when they are initiated. However, constraints often differ according to level of importance, and some may be modified by human users during operations. To date little research has addressed how the ability to change constraints can be provided and under what conditions changes should be allowed. Additional areas of support include distributive planning, in which experts in different subject matter areas are geographically removed from each other; generic planning, to develop systems capable of producing plans for different subsets of related areas or situations; and meta-planning, or planning for planning.

Current Research

An Intelligent Personal Aid for Planning and Decision Making

Azad Madnie/Perceptronics, Inc.

The objective of this project is to develop and demonstrate the feasibility of low-cost portable decision aids that can function in battlefield decision environments. In the 1990s and beyond, military commanders will have responsibilities created by technology that are far different and more extensive than those of their predecessors. Rapidly, and under chaotic conditions, they will have to integrate intelligence information, use innovative techniques to avoid detection and to counter advanced sensor systems, and direct multi-functional resources to meet the enemy threat. Specifically, Madnie will: (1) design an interactive decision aid for the elicitation, evaluation, and selection of options in battlefield command tasks; (2) develop a user interface for this system which appropriately presents the critical psychological and situational variables in the problem solving process; and (3) implement the decision aid using off-the-shelf personal microcomputers and hardware.

Complex Decision Making

Pask/Concordia University

The primary objectives of this project are to combine two systems developed to train military personnel in decision making, and to pilot test the combined system. After the research, the experimental software will be transferred to ARI for applied research efforts. Sufficient laboratory work will have been done to warrant the use of these systems, and further research then can be most expeditiously conducted in-house. Previous efforts have led to the development of two man-machine operating systems: (1) the Team Decision System (TDS), a complex space environment simulation system in which a mission is presented and cooperation among decision makers is required; and (2) THOUGHT-STICKER, a system that can elicit, accept, manipulate and output statements of plans and strategies in training or operational situations. It is envisioned that the combined system will be used for representing decision-making products such as strategies and tactics, and for providing assistance to the decision process. Little is required in terms of new hardware; display devices such as simple graphics boards will be incorporated when necessary as the experiment proceeds, and these will be made compatible with existing ARI systems.

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Retrieval of Knowledge Through Algorithmic Decomposition
Slovic, Lichtenstein, Fischoff/Decision Research, Inc.

In this study, the research team will examine the effectiveness of various strategies for retrieving knowledge from memory. The study has three objectives: (1) to learn more about how people store and recall information, (2) to study the effectiveness of aids based on algorithmic decomposition for knowledge retrieval, and (3) to explore the relation between accuracy and subjective confidence in tasks involving factual estimates. The algorithmic decomposition being investigated is a three-step method of information processing in which an individual first decomposes or breaks down a primary question into several sub-questions; then estimates answers to the sub-questions; and finally recomposes the answers to the sub-questions, using a rule, or algorithm, to arrive at an answer to the original question. Knowledge gained of how human experts do this is a first step in incorporating similar procedures into future, real-time, computer driven systems.

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Information Processing Organizations with Acyclical Information Structures
Levis/Massachusetts Institute of Technology

The inherent complexity of the Army's Command, Control and Communications Information systems has seriously strained the capabilities of the human organizations that use the systems. The high cost associated with systems, the time lag between inception and prototype testing, and the system complexity itself make it impossible to design systems on a trial-and-error basis. It is critical, therefore, to make an accurate assessment of the characteristics of the user organization early in the design process, so that the organization is not forced to adapt to the use of an inconvenient system. Levis is addressing the problem of developing an organizational model that reflects the actual decision structure (what types of decisions are made at what levels) and information structure (who has access to what type of information) in order to facilitate the design of a compatible information processing system. It is expected that this research will have significant applications for other organizations with interacting decision makers who (1) must use an information gathering and processing system to make decisions, and (2) may have overlapping areas of responsibility and, in some cases, different sets of data.

Semi-Automatic Synthesis and Refinement of Knowledge
Michie/University of Edinburgh

Researchers at the University of Edinburgh have recently developed computer programs that are able to learn inductively following exposure to examples. In this project, Michie is studying whether machine syntheses of concepts might enable experts in a particular domain to extend their mental grasp into previously inaccessible areas by incrementally conceptualizing a complex problem and domain for them in an interactive mode. More explicitly, this research proposes to build into the machine system, judgmental rules which experts use but which they cannot clearly explicate. Once these are transferred to the machine, the machine system can use them to help the human decision maker to extend his or her understanding of extremely complex situations. The study will explore the possibility that such programs can be developed, and then develop procedures to measure the "knowledge" contained in the machine syntheses programs, by applying quantitative values to the "goodness" of the judgmental material contained in the system.

Development of a General Contingency Planner: Phase II
Lehner/PAR Technology Corporation

The overall objective of this research effort is to develop and test a general purpose planner that can solve adversarial planning problems in a variety of domains. It is a continuation of a previously conducted effort, "Planning under Adversity": The Development of a Contingency Planner, referred to as CP/x. The current effort focuses on developing language and approaches for adversarial planning, multiple goal planning, multi-agent planning, and, perhaps most impor-

tantly, real-time planning for corrective action as situations develop or change. This area of automated planning is of the highest priority for the Army and supports long-range planning for Air-Land Battle 2000.

Adaptive Human/Computer Interface Using Expert Profiles
Williges/Virginia Polytechnical Institute

This research effort will investigate critical issues in the design of an adaptive human/computer interface using on-line expert profile generation procedures. As more and more people with different levels of computer skills interface with computers, the need for adaptive interfaces has grown. An adaptive interface is capable of tailoring dialogue to the characteristics of the user, his/her level of experience, and the task configuration.

The objective of this research is to develop automated systems which use expert approaches to aid the novice in developing his/her own unique approach to the problem domain, but which do not force the user to use the "experts' " problem solution. The advantage to such a system is that the user would optimally have developed his/her own approach and so would be better prepared to deal with real situations which do not confirm exactly to the conditions under which the expert(s) solved the problem.

This effort will refine the expert profile methodology, develop procedures for adaptive model building, and incorporate expertise into an adaptive assistant for aiding novice users of computer systems. The results of this research will provide a broader understanding of critical components of intelligent interfaces which are tailored to individual users of complex computer-based systems.

The Assessment of Knowledge: Theory and Algorithms
Falmagne/New York University

Falmagne and his colleagues are attempting to design and implement efficient computer algorithms for assessing the knowledge individuals have of a specific body of information. This effort entails developing an appropriate formal language and an abstract theory specifying the structure of the possible states of knowledge in a population of subjects. In this research, a field of knowledge is conceptualized as a large set of questions or problems. The knowledge state of any individual is the particular subset of all the questions that he or she can solve. Not all sets of questions are states of knowledge, and the set of possible states is constrained rather than open ended. An efficient algorithm for the assessment of knowledge takes advantage of the structure of the possible states, and identifies each such state by a list of test-questions, together with their responses. An algorithm is efficient if, on the average, these lists tend to be short, so that the assessment can be fast. Probabilistic algorithms are considered which (1) allow for possible errors in the assessment and (2) take into account the fact that the possible states of knowledge may not be equally distributed in the population.

Distributive Problem Solving: Adaptive Networks with a Computer Intermediary Resource
Lyman/University of California, Los Angeles

The thrust of this effort is to design optimal architectural configurations for distributed problem solving protocols based on cognitive and artificial intelligence principles. Advances in hardware technology, by reducing the size and cost of computer components, are making distributed system architectures economically feasible. A distributed group of problem solvers incorporating in real time common computational aids and data bases for command and control systems becomes realizable. Lyman is exploring the man-machine issues critical to achieving efficient distributed problem solving systems. These include the availability of techniques and compatible protocols for data sharing; collaborative information exchange; and models to control, guide, and coordinate the problem solving process. The objective of this effort is to gain a fundamental understanding of the structure and dynamics of the problem-solving process when it includes multiple interacting inputs and outputs from interfaced humans and distributed computer systems. Little is known about the principles for guiding the design of architectures for such systems, and this research is seeking a broader understanding of computer based, intermediator models that are adaptive to the requirements of generic as well as specific problem solving situations.

Diagnosis and Remediation in the Context of Intelligent Tutoring Systems
Sleeman and Hess/Stanford University

Computer assisted instruction (CAI) shows considerable promise as a cost-effective means of individualizing instruction, especially for military training. Most existing systems individualize instruction only to a limited extent. This is accomplished through pacing, branching, and feedback governed by errors on a closed set of questions. A more advanced form of CAI will require the ability to deal flexibly with students' errors and misconceptions. Artificial intelligence (AI) techniques can provide a basis for such individualized tailoring by inferring a model of the students' understanding, along with an explicit knowledge of the subject domain. Successful integration of both will provide the basis for an intelligent tutoring system that is capable of using a specific teaching operation in immediate response to a student's error. The specific focus of this research is to develop inference models of students' developing comprehension of a given subject domain and to do this across multiple domains, looking for generalizable tech-

niques. These domains are algorithmic domains, domains which are inherently non-deterministic, and domains which are conceptual. In two of these areas, Sleeman and Hess will use the inferred models to develop a system capable of intelligent individualized interaction with the student.

Automatic Concept Formation in a Rich Input Domain
Lebowitz/Columbia Univeristy

Computer systems that process and store large amounts of information can operate more effectively, both in terms of storage and retrieval, if they automatically create new concepts from their input. This research attempts to create a domain-independent computer system that will take large amounts of information about a given area, identify important concepts in that area, use these concepts to store the information in memory, and be able to answer questions about the data. Efforts will focus on the problems of comparing examples to form new concepts as well as on how to determine which examples to compare. Most existing research in artificial intelligence has consisted of supplying programs with examples of specified concepts and having the programs determine definitions of those concepts. In real-world problems, the crucial concepts to be learned—those that best help explain and organize information about the domain—are not pre-supplied; rather it is necessary to identify these concepts in a stream of very complex input data. This research will build on previous work of Lebowitz in order to construct an information system, largely domain-independent, that accepts a large quantity of facts about a given area, uses generalization techniques to derive important concepts, and uses these concepts to organize the information in an intelligent fashion.

Technical Documentation: The Computer Solution of Word Problems
Charniak/Brown University

This research is investigating the representation and use of "common sense knowledge" in computer understanding of language and problem solving. To date, Charniak's research in artificial intelligence has been primarily concerned with the construction of programs which can understand natural language and solve problems within a single domain. These efforts stem from observations that language comprehension and problem solving, which encompass aspects of knowledge engineering, have similar knowledge requirements. This project will extend the research from attempts to understand simple problems to an attempt to find a small set of problem-solving techniques, or even a single semantic representation, that will suit many different domains. The system to be developed will be based upon a unified set of programs for deductive information retrieval, syntactic parsing, and "low level" problem solving, as well as a single "frame" representation.

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