Technical Report 474

BIBLIOGRAPHY: ARI RESEARCH ON COMMAND AND CONTROL (1970-80)

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U. S. Army

Research Institute for the Behavioral and Social Sciences

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This bibliography was prepared as a reference to research publications in the command and control area by the U.S. Army Research Institute. Publications are divided into research areas and are listed in chronological order within each area. The major research categories are: system operations and aids; information processing and presentation; surveillance, reconnaissance, and target acquisition; command staff simulation and gaming; and exploratory research and supporting technology. An author index is included.

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Technical Report 474

BIBLIOGRAPHY: ARI RESEARCH ON COMMAND AND CONTROL (1970-80)

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February 1981

Command and Control

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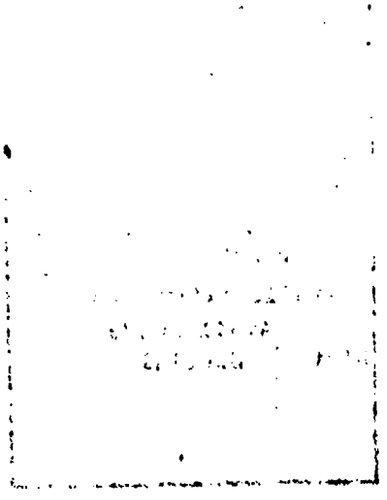

FOREWORD

This bibliography has been prepared as a convenient reference to recent research publications in the command and control area by the U.S. Army Research Institute (ARI). Research in this domain currently is conducted primarily by the Human Factors Technical Area, Alexandria, and the Fort Leavenworth Field Unit. Publications have been divided into a set of convenient areas of research and are listed in chronological order within each area.

In early 1979, the variety of documentation types was reduced to the Research Report, Technical Report, Research Note, and Working Paper. Several earlier types of reports appear in this bibliography. The various ARI documentation types are distinguished by the primary intent of the report, as follows:

Research Reports describe completed research studies or programs which contribute directly to the solution of Army human factors problems. Reports are distributed to their sponsors, research and operational facilities in the Department of Defense and to interested civilian agencies and educational institutions. Research Reports are deposited in the Defense Technical Information Center (DTIC) and the National Technical Information Services (NTIS) for public retrieval. (Called Technical Research Reports 1941-1973.)

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Research Notes report contract research of immediate interest to an important but very small audience. Copies are not printed for formal ARI distribution, but may be obtained from DTIC and NTIS.

Working Papers, for limited distribution only, present technical information of interest within ARI or as interim or partial report to specific agencies supported by ARI. Distribution is generally restricted to ARI and sponsor personnel.

Research Problem Reviews, 1958-1979, were special reports to military management, generally prepared in response to questions raised by operating agencies when early answers were needed. Distribution was primarily to operating agencies with a direct interest in the content, but copies of many may now be obtained through DTIC and NTIS. Discontinued in 1979.

Research Memorandums, 1951-1979, were informal reports on technical research problems and methodological developments relating primarily to in-house technical operations. Distribution of these publications was

generally limited to personnel engaged in research for ARI, but copies of many may now be obtained from DTIC and NTIS. Discontinued in 1979.

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Preliminary reports which have not been revised and edited for publication because of the recency of the research have been identified as Draft. Additionally, reports which were not formally published either because of changing requirements, small specialized audiences, or urgency of other efforts also have been identified as Draft. Draft reports are primarily of immediate interest to sponsors as well as to future research efforts, and their distribution is generally limited to personnel engaged in research for ARI and to direct sponsors of that research.

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CONTENTS

I. GENERAL

General

Ringel, S. J., Baker, J. D., Strub, M. H., and Kinsinger, L. L. Human factors research in command information processing systems--Summary of recent studies. Technical Research Report 1158, July 1969. (AD 694 347)

The present report provides a synopsis of research accomplished from March 1966 to July 1969 in close liaison with the Command Systems Field Branch established in USAREUR in September 1967. It includes principal findings and their application to the enhancement of human performance in the Seventh Army Tactical Operations System (TOS) and facilitation of man-machine interaction in relation to total system effectiveness. Studies completed prior to this period are described in BESRL Technical Research Report 1145, "Human Factors Research in Command Information Processing Systems," March 1966.

Baker, J. D. Acorns in flower pots/psychologists in the field. Report of the Sixteenth Annual Army Human Factors Research and Development Conference. U.S. Army Air Defense Center and Fort Bliss, TX, 20-22 October 1970, pp. 22-47. (Available from American Psychological Association, Journal Supplement Abstract Service, MS No. 191.)

This paper addresses itself to the problem of establishing a linkage between laboratory experimentation and applied research and development. It describes a situation wherein a laboratory-linked field-unit approach was taken to bridge the gap. The vehicle for the field research portion of the effort was the United States Army's Tactical Operations System (TOS). A general description and broad overview of the system's operations is included. A common framework for both the laboratory and field-unit research was developed and used. Some representative studies that were conducted in the field are described.

Discussion centers on the use of human factors research to improve system design and the problems of introducing laboratory findings into real-world operations.

Baker, J. D. Human performance research in military information systems: Quo fuimus et quo vadimus? In Walraven, P. L. and Bernotat, R. (Ed.). Proceedings of the Twelfth Defense Research Group Seminar on the Optimum Balance Between Man and Machine in Man-Machine Systems. Utrecht, The Netherlands, NATO Report DS/DR(73)375, May 1973.

The 1969 NATO Defense Research Group (DRG) Seminar on the Design of Equipment for Effective Utilization (held at Mondello, Italy) had identified a number of recurring key problems in man-machine design. Among these were (a) how to get the results of research being done applied; (b) motivation as a variable, and the absence of this concept in the human factors field; (c) the need to restructure design procedures to include the user; (d) the failure to consider the dynamics of interpersonal behavior in complex man-machine systems; and (e) the question of identifying and defining relevant criteria.

General

This paper describes some research which addressed these problem areas. It attempts to identify some critical aspects of these questions which remain unanswered, and it suggests what some of the future developments in man-machine systems are likely to be.

Andrews, R. S. Human processes in battlefield information systems. In Thrall, R. M., Tsokos, C. P., and Turner, J. C. (Eds.), Proceedings of the Workshop on Decision Information for Tactical Command and Control. Airlie House, Airlie, VA, 22-25 September 1976. Houston, TX: Robert M. Thrall and Associates, 1977.

The vehicles for decision information for Army tactical command and control are often identified as battlefield information systems. For the foreseeable future, human processes will be an integral part of such systems and must be attended to as explicitly as the computer technology if significant advances in system capability are to be achieved. This concept and its implications are developed in this paper. First, an attempt is made to define the Army problem. Then some of the relevant variables are discussed with respect to how their effects might be measured, whether solutions are intuitively obvious, and, finally, how advanced computer technology holds both promises and pitfalls in aiding the decision process.

Bonder, S., Cherry, W. P., and Farrell, R. L. A framework for identifying human research needs in command and control. Research Note 80-5, March 1980. (AD A082 011)

This effort developed a framework to assist in identifying human factors research areas in command and control (HF/C^2) which are of importance to the Army. It is a systems-oriented framework that considers HF/C^2 activities needed to assist in developing Army systems and NH/C^2 knowledge required/available to generate a menu of potential HF/C^2 research needs by type of research (Application Demonstration, Applied Research, and Exploratory Research). The framework also provides information as to when the research output will be of first use to the Army.

II. SYSTEM OPERATIONS AND AIDS

Staff Organization and Operations
Decision Support
Decision Support: Graphic Aids
Information Requirements
Information Management
Intelligence Information Processing
Intelligence Data Evaluation

Staff Organization and Operations

Modisette, B. R., Michel, R. R., and Stevens, G. W. Initial strategies for the Tactical Operations System (TOS) support of the command and control process. Volume 1: Overview of TOS operations. Technical Report TR-78-A15, June 1978. (AD AC58 324)

The impact of the Tactical Operations System (TOS) on the procedures, personnel, and skill requirements for affected staff elements at Army division, brigade, and battalion command posts is discussed. Changes to the current TOS design that would enhance its usefulness to staff users are identified and defined. The results of this research provide basic source material useful for determining TOS training requirements and providing the rationale for detailed investigation of the feasibility and utility of proposed system enhancements.

Modisette, B. R., Michel, R. R., and Stevens, G. W. Initial strategies for the Tactical Operations System (TOS) support of the command and control process. Volume 2: Description of TOS functions for division elements. Technical Report TR-78-A16, June 1978. (AD A061 155)

This report provides an element-by-element discussion of the TOS functions described in Volume 1 of this series.

Modisette, B. R., Michel, R. R., and Stevens, G. W. Initial strategies for the Tactical Operations System (TOS) support of the command and control process. Volume 3: Description of TOS functions at brigade and battalion. Technical Report TR-78-A17, June 1978. (AD A061 103)

This report provides a discussion of TOS functions for brigade and battalion command posts, paralleling Volume 2 of this series.

Decision Support

Erickson, J. M., and Levit, R. A. Development and application of a decision aid for tactical control of battlefield operations: Bibliographic sort of the decision-aiding literature. Research Memorandum 73-3, December 1973. (AD A082 950)

A bibliography on decision aiding and decisionmaking in man/computer systems was selected primarily from post-1960 research literature. Selections met at least one of the following criteria: (a) contained a working decision aid in a man/computer decisionmaking environment; (b) contained a model of decisionmaking from which an aid could be derived; (c) contained useful information on tactical information processing; and (4) contained useful information on methodological aspects of decision aiding in man/computer contexts. The literature is presented in four ways: alphabetically by first author, alphabetically by author within year of publication, alphabetically by keyword, and alphabetically within each of 17 classifications.

Levit, R. A., Erickson, J. M., and Heaton, B. J. Decision style measurement and decision support software specifications. Unpublished Technical Report, March 1977.

This report includes the computer printouts of the software specifications for the decision aid discussed in Technical Reports TR-77-A2 and TR-77-A3. The report is available for inspection at ARI headquarters in Alexandria, Virginia.

Levit, R. A., Alden, D. G., Erickson, J. M., and Heaton, B. J. Development and application of a decision aid for tactical control of battlefield operations: A conceptual structure for decision support in tactical Operations Systems. Technical Report TR-77-A2, March 1977. (AD A040 606)

A by-product of future automated tactical systems is proliferation of data to be organized and analyzed. To help cope with this problem and bring about an efficient man-computer interface, an evaluation of the decision-aiding literature was undertaken. Special emphasis was placed on those aids which might be useful in tactical systems and could be implemented in ARI's laboratory simulation of an automated tactical operations center.

Levit, R. A., Alden, D. G., Erickson, J. M., and Heaton, B. J. Development and application of a decision aid for tactical control of battlefield operations: A preliminary evaluation of a decision support complex in SIMTOS. Technical Report TR-77-A3, March 1977. (AD A040 563)

The present research provided a preliminary evaluation of a decision support complex designed for use in a simulated tactical operations system (SIMTOS).

Ten participants were divided into two groups. One group used the decision aid throughout the simulated defensive scenario while the other group

did not. Both groups participated in the same G3 planning and combat activities.

The general results showed that the concept of a decision support complex is a sound one. ARI is continuing to utilize the decision support complex in further studies of tactical decisionmaking.

Levit, R. A., Heaton, B. J., and Alden, D. G. Development and application of decision aids for tactical control of battlefield operations: Decision support in a Simulated Tactical Operations System (SIMTOS). Technical Report 77-A13, December 1977. (AD A050 889)

In an experiment designed to evaluate the effectiveness of an automated decision support system on tactical information processing and decisionmaking performance, 25 experienced Army officers played the role of Division G3 in the Simulated Tactical Operations System (SIMTOS). Results of the evaluation demonstrated that the concept of decision support is sound, although specific measures of tactical performance were insensitive to player actions. The decision support complex increased players' ability to interact effectively with SIMTOS and increased their satisfaction with the system. Further development of automated decision support for tactical decisionmaking is warranted.

Cooper, G. E., Moore, M. H., and Halpin, S. M. MOVANAID: An interactive aid for analysis of movement capabilities. Technical Paper 305, October 1978. (AD A064 276)

A computer-drive interactive aid for movement analysis, called MOVANAID, has been developed and is described in this report. The aid, which has been designed to be of assistance in the performance of certain Army intelligence processing tasks in a tactical environment, can compute fastest travel times and paths through road networks for military units of various types, as well as fastest times in which simultaneous maneuvers of certain types can be completed. Military situations in which the aid might be useful are discussed, and the manner in which users interact with the aid is described. Details about the analytic basis upon which the aid has been constructed, together with a discussion of the method in which the aid has been computer-implemented, are also given. Ideas for ways in which the capabilities of the aid can be extended are discussed.

Kibler, A. W., Watson, S. R., Kelly, C. W., III, and Phelps, R. H. A prototype aid for evaluating alternative courses of action for tactical engagement. Technical Report TR-78-A38, November 1978. (AD A064 275)

This technical report describes a decision-aiding technique developed to assist division-level commanders and their staffs in choosing among alternative courses of action for tactical engagement. By employing principles of multi-attribute utility assessment methodology, a two-level model consisting of five general categories (terrain, own forces, enemy forces, weather, and risk) and 24 factors was developed and implemented on an IBM 5100 computer. In applying the decision aid, the user is required to score

each of the alternative courses of action on each factor and to assign a weight indicating the importance of each factor in discriminating among the alternatives. A simple algorithm is used to calculate a weighted score for each course of action, the highest score being an indication of the preferred course of action. A sensitivity analysis provides a measure of the robustness of the scores and weights assigned by the user.

The aid provides a means of encouraging detailed consideration of all factors bearing on a tactical choice, a method for integrating subjective assessments of decision factors, and a means of explicitly communicating results of the decision process.

Parrish, R. N., and Stevens, G. W. Development of data processing strategies for potential applications in the Tactical Operations System and other tactical data systems. Research Note 80-33, February 1979.

This report describes research performed by the System Development Corporation (SDC) to develop improved procedures/data processing methodologies for forecasting battlefield personnel attrition and for reporting logistics status. Two active Army divisions provided information vis-a-vis how the two lattermentioned functions are now performed manually. This information provided the basis for the development of a data processing strategy concept which, if implemented in an automated tactical data system, should greatly improve the accuracy and timeliness with which the functions addressed can be performed. An experiment conducted with Command and General Staff College students confirmed that the timeliness and accuracy of the target functions would be significantly improved.

Hoblitzell, C. M., and Phelps, R. H. Computerized procedures guide: Decision aid for evaluating Enemy Courses of Action (ENCOA). Working Paper HF 80-7, January 1980.

This paper provides guidelines for use of a computer implementation of the aid described in Kibler, A. W., TR-78-A38, Decision Support.

Hoblitzell, C. M., and Phelps, R. H. Manual procedures guide: Decision aid for evaluating Enemy Courses of Action (ENCOA). Working Paper HF 80-8, January 1980.

This paper provides guidelines for use of a manual (i.e., noncomputerized) version of the aid described in Kibler, A. W., TR-78-A38, Decision Support.

Parrish, R. N., Stevens, G. W., and Stewart, S. R. A resource planning aid for assessing the personnel and logistics implications of tactical operations. Research Report 1295, November 1980.

This report describes the research performed by the System Development Corporation (SDC) to develop data processing techniques to enhance the performance of personnel administration and logistics functions at corps and

subordinate echelons. The research focused on administrative/logistics functions that relate directly to tactical command and control. European and CONUS Corps provided principal sources of data used to isolate Resource Planning as the function most needing support. A conceptual job aid was then developed to support the area under investigation and tested using a modified CGSC scenario to determine feasibility. An evaluation briefing on the methodology was prepared, in concert with CACDA and ARI, and was presented to staff officers in the European Theater to determine its ability to fulfill the needs of the user. The major finding of the evaluation is that the methodology is needed and should be considered for implementation in European Theater.

Phelps, R. H., Halpin, S. M., and Johnson, E. M. A decision support framework for decision aid designs. Technical Report 504, in press (January 1981).

A Decision Support Framework is presented (Figure 1) which serves two purposes: first, to organize and integrate various decision aids according to their function, and secondly to provide the decision aid designer with a systematic context in which to develop decision aids as well as examine which aspects of the decision problem would most benefit from decision aiding. The main components of the framework are discussed in detail with Army intelligence decision-making examples: (1) analysis of the decision requirements; (2) development of decision aids to provide the decisionmaker with information as well as tools for evaluating, weighting, and integrating the information to make a decision; and (3) evaluation of the success of the decision aids in leading to a logical, rational decision.

Decision Support: Graphic Aids

Bowen, R. J., Feehrer, C. E., Nickerson, R. S., and Triggs, T. J. Computer-based displays as aids in the production of Army tactical intelligence. Technical Paper 258, February 1975. (AD A007 819)

Man-machine interactive computer-based display techniques were evaluated for their automatic data processing (ADP) applications in combat intelligence. Analysis of a tactical exercise helped conceptualize and formulate display formats and procedures for tactical intelligence production. Methods are suggested for transposing military exercises into data base structures which support computer-generated situation displays. Concepts of mass and movement analyses using interactive displays are developed. ADP problems of software, memory, and information organization are considered. Implementation of a prototype system will validate the analytic methods developed here and explore other techniques which capitalize on the combination of the computer's ability to generate complex displays and the analyst's control of specific displays to be generated.

Moses, F. L., and Vande Hei, R. P. A computer graphic-based aid for analyzing tactical sightings of enemy forces. Technical Paper 287, January 1978. (AD A049 578)

Computer and computer-driven graphics are being explored for potential utilization by the battlefield staff. One such effort is designed to assist in detecting patterns by replacing manual plots of sightings with flexible computer graphic techniques and associated algorithms. An interaction of the analyst with these displays and algorithms for analyzing sightings forms the basis for the present evaluation of a battlefield interpretation aid.

Questions were asked about direction, speed of movement, and changes in location of battlefield activity in a classical division attack scenario. Six "aided" participants derived answers by specifying activity on a graphic display from which the computer calculated distances, speeds, etc. Six "unaided" participants derived answers from the displays without the use of computerized calculations. Responses in the aided condition were substantially more accurate than responses in the unaided condition. Measures of time did not meaningfully discriminate between the conditions. Accuracy results suggest that analyst-controlled computerized algorithms should be used for determining enemy patterns for computer graphic displays of sightings. The aid could be improved by better adaptation to equipment, thorough training, and design refinements. However, results are sufficiently promising to suggest provision for accommodating mass/movement and related temporal/spatial analysis algorithms in requirements documents.

Irving, G. W., Farrell, L. M., and Lindquist, G. Modeling of tactical events by interactive graphics: Approach, interface design, and system design. Technical Report TR-78-A40, February 1978. (AD A064 324)

The potential role for computer graphics in interactive tactical modeling was investigated using a four-color vector graphics display. The display

enabled a user to define terrain features, order of battle, and the movements and actions of units. Interactive devices included a light pen, track ball, and function keyboard. The model emphasized tactical planning, although similar techniques could be used for tactical analysis. A simplified intelligence planning task was developed to demonstrate the concept of graphics modeling. In it, an intelligence performance model simulated the detection and classification performance of patrol units. A movement/terrain model guided user-postulated movements of units, and probability algorithms determined performance of units. The research showed that graphic simulations defined by the user can be developed to help conceive and evaluate potential combat activity.

Irving, G. W., Farrell, L. M., and Lindquist, G. Modeling of tactical events by interactive graphics, Volume 2: Software documentation and algorithms (Appendixes). Technical Report TR-78-A40, December 1978.

Volume I, TR-78-A40, described a procedure for defining Army tactical models on a four-color vector graphics display for intelligence collection planning and intelligence data analysis. The models defined by a user at the display consist of representations of terrain, order of battle for opposing forces, movement and actions of opposing forces, and movement of friendly intelligence collection units.

Volume II contains the algorithms used in the models and computer program listings of all software developed.

Schechterman, M. D., and Levi, L. R. Dynamic displays for tactical planning. Volume III: Software documentation. Research Note 80-9, December 1979.

Volume III of the three-volume set contains detailed documentation of computer software used to support research on two-sided, user-controlled, dynamic wargaming. The current volume is intended for systems programmers/technical personnel who are interested in specifics of implementation. Complete program listings are provided. Volume I, ARI Research Report 1247, provides a functional description of the research for Army users of the concepts. Volume II, ARI Technical Report 455, is intended for specialists in research and development of interactive graphics for battlefield applications.

Walsh, D. H., Rebane, G. J., Levi, L. R., and Schechterman, M. D. Dynamic displays for tactical planning. Volume 2: Technical description. Technical Report 455, December 1979.

Volume II of the three-volume set is a technical description of an exploratory application of computer graphics with animation capabilities for two-sided, user-controlled, dynamic wargaming. This description is intended for readers with specialized interests in research and development of interactive graphics for battlefield applications. The project emphasizes that a battlefield planner/analyst can work in harmony with computer graphics to structure and analyze battlefield situations.

Preliminary procedures were developed that allow noncomputer personnel to create battlefield situations on displays and to assess changing events using dynamic replays and computer calculations of possible outcomes. Special displays allow the planner to see how terrain affects unit mobility and combat effectiveness. In addition, the use of dynamic replays of events and likely engagements helps the planner to interpret time and space relationships within scenarios. The aid has potential for allowing rapid evaluation of "what if?" battlefield questions.

Rebane, G. J., Walsh, D. H., Moses, F. L., Schechterman, M. D., and Levi, L. R. Dynamic displays for tactical planning. Volume I: User oriented description. Research Report 1247, April 1980.

Volume I of a three-volume set describes an exploratory application of computer graphics with animation capability for two-sided, user-controlled, dynamic wargaming. The description is intended for Army managers, command staffs, and other potential users of the concepts. The project emphasizes that a battlefield planner/analyst can work in harmony with computer graphics to structure and analyze battlefield situations.

Preliminary procedures were developed that allow noncomputer personnel to create battlefield situations on displays and to assess changing events using dynamic replays and computer calculations of possible outcomes. Special displays allow the planner to see how terrain affects unit mobility and combat effectiveness. In addition, the use of dynamic replays of events and likely engagements helps the planner to interpret time and space relationships within scenarios. The aid has potential for allowing rapid evaluation of "what if?" battlefield questions. Volume II, ARI Technical Report 455, is intended for readers with specialized interests in research and development of interactive graphics for battlefield applications. Volume III, ARI Research Note 80-9, contains detailed documentation for systems programmers/technical personnel who are interested in specifics of implementation.

Information Requirements

McKendry, J. M., Wilson, R. C., Mace, D. J., and Baker, J. D. Application of a method for determining information requirements in a field Army. Technical Paper 247, August 1973. (AD 767 262)

The Army is developing a number of automatic information systems to expedite tactical staff operations in the field, by providing vital information to staff officers in sufficient detail at appropriate times. The research presented here provided techniques and data for more effectively evaluating one of these systems, the Tactical Operations System (TOS) in the Seventh Army in Europe, and its user information requirements.

General interest patterns were found to be almost exclusively a function of the staff element in which a person served. G2 and G3 personnel required the greatest variety of information, CBRE the least. There was general agreement on which items were most important within each staff element, and general disagreement between staff elements, which indicates that the specific interest patterns for each element should be viewed separately in determining staff information requirements.

The methodology and techniques employed here for determining user information requirements are capable of producing criteria for measuring how thoroughly information is disseminated in a given system. Beyond this immediate use, such methodology and techniques could prove useful for generating staff/user information requirements for a variety of Army tactical data systems, which in turn could influence data base structure and display design.

Strub, M. H., and McConnaughey, P. Tactical planning (offensive and defensive) minimum essential information requirements. Research Memorandum 74-7, October 1974. (AD A076 726)

This research identified minimum essential information requirements for offensive and defensive tactical planning. The basis of identification was the number of officers requesting the information during the course of offensive or defensive scenario play. While the controlled environment of the experiment placed some restrictions on the generalizability of the requirements identified, the results reflect a body of information items consistently requested by experienced Army officers. The hierarchical structure of the data base permitted the delineation of these requirements by category and level of detail. The information should serve as a basis of comparison and synthesis with information requirements identified by other means, such as surveys and ad hoc analytic groups.

Mace, D. J., and Baker, J. D. Information requirements in a field Army. Working Paper HF-80-1, November 1979.

As automated Command and Control systems became more prevalent in the early 1970's the need for an accurate description of tactical information requirements increased. A survey questionnaire containing 61 of the information items most frequently disseminated in 7th Army exercises was administered to 86 senior staff officers of 7th Army's Corps and Divisions.

Information Requirements

The respondents were asked to indicate the items most important to their elements' mission and to indicate the level of information detail required. Results identified items of specific interest to individual staff elements, as well as items and groups of items of common interest to two or more staff elements. The level of detail required was essentially the same for all echelons and higher than the field manual recommendations for all echelons.

Strub, M. H. Tactical planning (offensive and defensive) information requirements: Comparison of survey questionnaire and laboratory exercise data. Working Paper HF-80-2, November 1979.

This research attempted to assess the validity of defining command staff information requirements by means of a survey questionnaire. Predictions concerning the type, amount, and detail of information required in two division-level tactical scenarios, obtained by questionnaire, were compared with information requested by officers actually playing these two scenarios in the role of G3. Results showed that predictions based upon opinions of experienced personnel in a desk setting (such as those obtained by the questionnaire) did well for the types of information required, although there was a tendency to assume that much greater levels of information detail were required than were actually used. This finding is consistent with previous research. The results indicate that if a determination of minimum information requirements is critical the requirements are better obtained through the use of Tactical Exercise Simulators than by introspective techniques.

Information Management

Saalberg, J. J., Miller, J. R., Friesz, T. L., and Keegan, C. A. Exploratory examination of purge techniques. Technical Report 77-A21, November 1977. (AD A047 354)

The problem of overload in tactical information systems can be reduced by purging--freeing a tactical data base of useless, redundant, outdated, and incorrect information. This report analyzes the role of information in decisionmaking and examines techniques for identifying a decisionmaker's information needs. Current purging procedures and division level informational needs for land combat are reviewed and potential criteria developed for identifying information essential for task performance in the Division Tactical Operations Center. Rules, techniques, and operative procedures are suggested which can be employed to manage and control TOS data.

Human Factors Technical Area, Fort Leavenworth Field Unit, TOS Manager's Office, and Vector Research, Inc. Guidelines for information management for the Tactical Operations System (TOS): Provisional Standing Operating Procedures (SOP). Working Paper HF 79-01, May 1979.

Preliminary results of the project described in Research Report 1228 were used to establish a provisional SOP for information management within TOS. This SOP is outlined in this paper.

Vector Research, Inc. A design/decision aid for the Tactical Operations System (TOS). Working Paper HF 79-02, May 1979.

As described in Research Report 1228, an aid was developed to support analyses of information flow in TOS and similar systems. This paper describes the mathematical basis of the aid.

Geiselman, R. E., and Samet, M. G. Information summarization in a corps-level scenario. Technical Report 385, October 1979. (AD A078 021)

This research obtained data to develop guidelines for summarizing TOS message content, particularly tactical intelligence data. Sixteen staff officers were asked to read a description of a tactical scenario and to examine 30 enemy situation data messages describing the beginning of an enemy border crossing and attack. Each officer's task was to summarize the tactical information contained in the messages in preparation for a 3-minute briefing of the G2. The 16 handwritten summaries were typed and evaluated by five military raters.

Vector Research, Inc., and Perceptronics, Inc. Information management for the Tactical Operations System (TOS). Research Report 1228, October 1979. (AD A081 974)

This executive summary presents synopses of three items resulting from the first phase of a project to establish guidelines for a Standing Operating

Procedure (SOP) for managing information at the division level within the Tactical Operations System (TOS), an automated staff-operations information system. Two research products were developed, a provisional SOP and a TOS design/decision aid model. ARI Technical Report 385, the third item, presents the qualities found to be characteristic of a "good" summary of battlefield intelligence information.

Blum, R. W., Callahan, C., Cherry, W. P., Kleist, D., Touma, G., and Witus, G. Information management for an automated battlefield command and control system: Executive summary. Research Report 1249, May 1980.

This executive summary presents synopses of seven documents produced in the second phase of a project to develop information management concepts and procedures for automated battlefield command and control (ABCC) systems. ARI Research Report 1248 describes considerations in and procedures for the management of contemporary ABCC systems. ARI Technical Report 458 presents an analysis of procedures for the extraction, summarization, and presentation of critical information.

ARI Research Note 80-12 describes an analysis of information flow in the Tactical Operations System (TOS), an example ABCC system. ARI Research Note 80-13 describes the mathematical model used in the information flow analysis. ARI Research Notes 80-14 and 80-15 describe the operation programming of the computer programs implementing the model. ARI Working Paper HF-80-XX discusses design issues associated with the emerging All-Source Analysis System (ASAS) concept.

Callahan, C., Blum, R. W., Witus, G., and Graulich, M. Guidelines for managing the flow of information in an automated battlefield command and control system. Research Report 1248, May 1980.

This report documents research directed toward the development and evaluation of guidelines for Standing Operating Procedures (SOP) for managing information flow in automated battlefield command and control systems. This research was performed during the second phase of a project to develop information management concepts and procedures for tactical operations systems. Three stages of SOP guideline development are discussed: (1) identifying critical problems; (2) developing candidate management procedures to address the critical problems; and (3) evaluating the efficacy and side effects of the candidate procedures.

Cherry, W. P. All source analysis system: Design issues. Research Report 1250, May 1980.

Experience with the development of battlefield automated systems, e.g., TSQ-73, TACFIRE, CS_3, and TOS, has not been uniformly satisfactory. Schedules have slipped, costs have increased, and performance standards have been difficult to achieve. A significant reason for this is that these command and control systems operate in a process which is highly variable, dependent upon individuals, and not completely understood. However, problems have also arisen with the interfaces among these systems and between the systems

and other components of the total command and control process. Paramount among these problems is the fact that existing communications will not support input, output, and exchange of data. This particular problem is further complicated by the dynamics of radio-electronic combat on the modern battlefield requiring high levels of resistance to jamming and intercept.

The ASAS system currently envisioned provides capacity but not coverage nor communications sufficiently adequate to fulfill its mission. It is possible that coverage and communication problems will be solved before the ASAS is fielded. The primary problems in the ASAS/ECS^2 interface stem from a lack of understanding of commanders' information needs and their relative values. Beyond this, problems with communications and interfaces among the components of the ECS^2 system will continue to pose a major stumbling block to successful systems development, both for the ASA, and the ECS^2 as a whole.

Samet, M. G., and Geiselman, R. E. Guideline development for summarization of tactical data. Technical Report 458. May 1980.

The present study was conducted to validate and expand the generalizability of a set of guidelines for summarizing tactical message content, and to develop guidelines for conducting a manual purge of a message file. Thirty-two Army staff officers studied a scenario and 30 enemy-situation-data (ESD) messages describing an enemy defensive operation. Their task was to summarize the tactical information in the form of an intelligence briefing. Half the officers were supplied with three general guidelines to follow in preparing the summary: "(1) provide an interpretation of the data, (2) give a dynamic portrayal, and (3) use conversational style." After the summarization task, the participants were asked to delete 15 of the 30 messages and to rank-order those retained on the basis of importance. The 32 summaries were evaluated by seven military raters in terms of quality of content, interpretation, accuracy, organization, and style.

The raters judged the summaries prepared with the aid of the guidelines to be significantly "better" summaries on an overall evaluation scale and on four of five qualitative scales, and potent positive effects were revealed for all three guidelines. The 10 summaries that received the highest overall evaluations were used in a procedure to derive a general suggested outline for describing the message content (Geiselman & Samet, 1979). The outline structures information according to levels of importance, ranging from a description of immediate enemy threat and intentions to details about support units. The purging-task data also revealed general levels or clusters of messages upon which guidelines could be based for reducing the size of ESD files by different amounts.

Witus, G., Blum, R. W., and Meerschaert, M. Analysis of information flow in the Tactical Operations System (TOS). Research Note 80-12, May 1980.

Witus, G., Blum, R. W., and Graulich, M. Description of the Tactical Operations System information flow model. Research Note 80-13, May 1980.

Witus, G., Meerschaert, M., and Kleist, D. User's manual for the Tactical Operations System analysis package. Research Note 80-14, May 1980.

Information Management

Witus, G., Meerschaert, M., and Kleist, D. Programmer's manual for the Tactical Operations System analysis package. Research Note 80-15, May 1980.

The four reports listed here describe various aspects of an analysis of the Tactical Operations System (TOS). The research effort evolved from previous work to develop a design/decision aid (DDA) for the evaluation of alternative information management policies. The original DDA model was concerned exclusively with the Division Computing Center. The effort expanded to encompass both the distributed processors--the Tactical Computer Systems and Tactical Computer Terminals--and the supporting communications. The resulting model not only provides a tool for the analysis of TOS and its component parts, but also has the potential for application to other distributed command support systems with a central node and data base.

ARI Research Note 80-12 describes the results of an analysis of the Tactical Operations System (TOS) communications subsystem performed in the second phase of a project to develop information management concepts and procedures for automated battlefield command and control systems.

Research Note 80-13 describes a mathematical model of the Division Tactical Operations System (DIV TOS).

Research Note 80-14 provides instructions for the use and operation of a computer program package for the analysis of the Tactical Operations System (TOS).

Research Note 80-15 discusses the programming details of the computer program package for the analysis of the Tactical Operations System (TOS). The program computer code is included.

Intelligence Information Processing

Bowen, R. J. Survey of military opinion on tactical Order of Battle: Supporting data and commentary. Unpublished Consulting Research Memorandum, January 1974.

A four-phase questionnaire and interview program was conducted to support a review of the state-of-the-art of Order of Battle (OB) published as Technical Paper 265. The four phases consisted of: structured interviews with 14 OB specialists at the U.S. Army Intelligence Center and School; a questionnaire emphasizing Combat Effectiveness completed by 12 former G2/S2's and intelligence operations officers; a questionnaire focused on Combat Effectiveness completed by 23 former G3/S3's and field commanders; and informal discussions with former senior field commanders on the subject of Combat Effectiveness. Detailed summaries of each phase of this program are presented with supporting commentary.

Bowen, R. J., Feehrer, C. E., Nickerson, R. S., and Triggs, T. J. Computer-based displays as aids in the production of Army tactical intelligence. Technical Paper 258, February 1975. (AD A007 819)

Man-machine interactive computer-based display techniques were evaluated for their automatic data processing (ADP) applications in combat intelligence. Analysis of a tactical exercise helped conceptualize and formulate display formats and procedures for tactical intelligence production. Methods are suggested for transposing military exercises into data base structures which support computer-generated situation displays. Concepts of mass and movement analyses using interactive displays are developed. ADP problems of software, memory, and information organization are considered for a prototype system to validate the analytic methods developed here.

Bowen, R. J., Halpin, J. A., Russell, P. T., and Staniforth, B. J. Tactical Order of Battle: A state-of-the-art survey. Technical Paper 265, October 1975. (AD A018 368)

This report provides a state-of-the-art survey of tactical Order of Battle (OB) intelligence, concentrating on the division OB section and based on official documentation, authoritative reference material, and the results of an informal questionnaire and interview program with experienced combat intelligence and operations personnel. The survey includes: historical development of OB; role, function, and operations of the division OB section; examination of the OB factors; and the results of a brief survey of military opinions on OB. OB analysis requires more varieties of detailed information processing than any other single area of combat intelligence. However, the procedures and techniques available are not standardized or well developed, and the OB section tends to provide historical reference information rather than current intelligence. Specific findings and recommendations are presented after each section of the survey.

Intelligence Information Processing

Coates, E. N., and McCourt, A. W. A questionnaire-based analysis of Order-of Battle elements. Technical Paper 271, January 1976. (AD A021 956)

On a questionnaire administered primarily to field grade officers, 1,258 respondents rated the value to them of the eight elements of tactical Order of Battle (OB) intelligence and of the 95 components of these elements. Respondents evaluated how essential each element or component would be to their job in each of four scenarios describing different levels of war, and also rank ordered the elements and the components within each element.

Respondents agreed generally on the relative values of OB elements; ratings of usefulness followed consistent patterns which were confirmed by the forced rankings. Intelligence on enemy Disposition was consistently rated the most valuable in all four conditions of war: enemy Strength, Composition, Combat Effectiveness, and Tactics were also considered crucial. The perceived value of Logistics intelligence increased with increasing intensities of war, while that of Tactics and Training was greatest in low-intensity conditions. Military Intelligence branch officers valued every element except Training more highly than Combat Arms officers did while Combat Arms officers consistently valued every element more than support branch officers did. The results provide the basis for further examination of intelligence requirements and priorities in intelligence collection, production, and dissemination under various conditions of war.

Johnson, E. M., Spooner, R. L., and Jaarsma, D. The perception of tactical intelligence indications by intelligence officers. Technical Paper 278, April 1977. (AD A040 350)

As part of an effort to provide improved techniques and methods for intelligence collection planning and intelligence analysis, an experiment was conducted to assess the effectiveness of traditional tactical intelligence indications for the analysis of conventional military operations. Forty-six captains in the Intelligence Officers Advanced Course each assumed the role of staff officer in a G2 section of an Infantry Division conducting a mobile defense in north-central West Germany. Each officer estimated the probability that each of 49 separate indications listed in Field Manual 30-5, Combat Intelligence, would occur, given the aggressor's known course of action. Each indication was evaluated with four separate courses of action--Attack, Defend, Delay, and Withdraw. The estimates made by individual officers were highly reliable. However, the variability in the estimates made by different officers for the same indication was extremely high, with an average range of estimates greater than .7 on a 0 to 1.0 scale. The logic underlying clusters of related indications could not be clearly identified for any of the four courses of action. The findings reveal that current indications of conventional military operations are either poorly understood or intrinsically inadequate for use in contemporary intelligence operations, or both.

Johnson, E. M. The perception of tactical intelligence indications: A replication. Technical Paper 282, September 1977. (AD A046 954)

This research replicates an earlier experiment which showed that tactical intelligence indications, as currently used, are of doubtful effectiveness.

In the replication, 28 intelligence specialists (primarily from the 163d Military Intelligence Battalion) each assumed the role of an intelligence analyst in a G2 section of an infantry division conducting a mobile defense in north-central West Germany. Each individual estimated the probability that each of the 49 indications of conventional military operations listed in Field Manual 30-5, Combat Intelligence, would occur, given a known aggressor course of action. Each indication was evaluated with four separate enemy courses of action--Attack, Defend, Delay, and Withdraw. Variability in the estimates made by different individuals for the same indication was extremely high (greater than .7 on a 0-1.0 scale in both experiments). Only 12 indications were perceived by this group and 19 by the previous group as effective discriminators of the course of action with which they are doctrinally associated. Estimates made by officers and enlisted men in the replication did not differ significantly, nor did estimates made by intelligence specialists in the present research differ significantly from those made by student officers previously. Findings confirmed that current indications of conventional military operations are either poorly understood or intrinsically inadequate for use in contemporary intelligence operations, or both.

Moses, F. L., and Vande Hei, R. P. Computer graphic-based aid for analyzing tactical sightings of enemy forces. Technical Paper 287, January 1978. (AD A049 578).

See the listing for this reference on p. 13 of this report.

Stewart, S. R. Utility of automation of Order of Battle and Target Intelligence data for intelligence analysis. Research Report 1194, September 1978. (AD A065 458)

To help determine user requirements for a Tactical Operations System (TOS), software packages were evaluated for potential inclusion as requirements for a prototype TOS. The first of these packages--automated Order of Battle (OB) and Target Intelligence (TI) files--was evaluated in the present study. A series of intelligence tasks was accomplished by two groups, each consisting of 10 subjects qualified as intelligence analysts. Both groups worked with a basic simulated TOS. The experimental group had access to automated OB and TI files; the control group used OB and TI files in manual form. Automation of the files significantly increased both the accuracy and the completeness with which intelligence requirements were accomplished but did not increase the speed of completion of those requirements.

Katter, R. V., Montgomery, C. A., and Thompson, J. R. Cognitive processes in intelligence analysis: A descriptive model and review of the literature. Technical Report 445, December 1979. (AD A086 451)

This descriptive model of cognitive processes in intelligence analysis was developed as part of an "Investigation of Methodologies and Techniques for Intelligence Analysis." The approach to constructing the model is based on the investigation of analytical processing in two types of single source analysis (SIGINT and IMINT), subsequently generalizing to multisource

analysis. For the purposes of this investigation, intelligence analysis was defined as a spectrum of analytical and judgmental activities involved in the processing and production of intelligence, where particular individuals may devote more or less time to different aspects of such activities according to their individual roles in the intelligence cycle.

This report contains a detailed review of selected aspects of current psychological literature, as well as the cognitive model which is based on that literature and on investigation of the IMINT and SIGINT production models. The cognitive model and the literature review focus on how information is processed, stored and retrieved from memory, evaluated, and integrated to form intelligence. The model has general applicability to the full spectrum of intelligence processing activities.

Katter, R. V., Montgomery, C. A., and Thompson, J. R. Human processes in intelligence analysis: Phase I overview. Research Report 1237, December 1979. (AD A086 503)

This report provides an overview of the results of an "Investigation of Methodologies and Techniques for Intelligence Analysis." The goal of this study was to develop a framework for understanding human processes in intelligence analysis. An understanding of these processes will be useful during the development or evaluation of training procedures, doctrine, and system requirements for automated support to analysts.

The approach taken in this project was a parallel development of intelligence production models and a cognitive model of intelligence analysis. The Imagery Intelligence (IMINT) Production Model (ARI Research Report 1210) developed under this project and an existing Signals Intelligence (SIGINT) Production Model were used as the basis for developing a generic model of intelligence production, described in this overview. The generic production model includes a description of the hierarchical flow of intelligence data, tasking, etc., as well as a listing of critical variables influencing analysis. A detailed review of the psychological literature described in ARI Technical Report 445, combined with the production models, led to development of a descriptive model of cognitive processes described in this overview. This overview also explores some of the implications of the cognitive model for training developments, system development, and organizational control of intelligence production. The cognitive model will be extended and these implications will be examined in greater detail during Phase II of this project.

Intelligence Data Evaluation

Baker, J. D., McKendry, J. M., and Mace, D. J. Certitude judgments in an operational environment. Technical Research Note 200, November 1968. (AD 681 232)

This report describes human performance research conducted at the ARI Field Unit in Europe in connection with early development of the experimental Tactical Operations System (TOS). Major focus was placed upon the certitude judgment process within the TOS. In the intelligence cycle, G2 spot reports include subjective estimates of information expressed in a standard rating form. All messages (N = 2,039) filed by two divisions of one corps during the 7-day field exercise were examined for presence of the required ratings of reliability of the source and accuracy of the information being sent. Assessment was made of the quantitative and qualitative improvement that could be expected under operating conditions within a computerized TOS. Observations during the field exercise revealed: (1) G2 spot reports constituted 70% of all messages; (2) omission of the required source reliability and accuracy ratings occurred in 50% of the spot reports (attributed, in part, to unavailability of standard report forms); (3) reliability and accuracy ratings were noticeably interdependent (distributions of the values indicated that senders tended to assign high scale values to ratings); (4) analysis of the rating scales revealed the source reliability scale to be unidimensional and the accuracy scale to be multidimensional. Findings point to substantial increase in quantity of certitude data available for decisionmaking at all levels of command by introduction of the automated TOS.

Johnson, E. M. Numerical encoding of qualitative expressions of uncertainty. Technical Paper 250, December 1973. (AD 780 814)

Judgments of the probable accuracy of intelligence data and products are integral to the intelligence process. Accurate communication of the uncertainty implicit in these judgments is essential to the effective production and utilization of intelligence. Twenty-eight subjects, 14 U.S. Army enlisted men and 14 extension college students, numerically encoded on a 0 to 100 scale each of 15 probability phrases in each of 3 sentence contexts. The 15 phrases systematically covered a wide range of probabilistic meaning and the 3 sentence contexts involved a weather forecast, a prediction of personal success, and an intelligence report. There were no significant differences in the encoding of probability phrases into numerical equivalents among the 3 sentence contexts, between enlisted personnel and college students or as a function of age, sex, or educational level. Subjects were relatively consistent in their own encoding of given phrases, but differed, often radically, from other subjects. Cluster analysis of the numbers assigned by subjects indicated an underlying asymmetric probability scale comprised of a small number of intervals. Further research should investigate the use of standardized lexicons with a small number of expressions or the direct use of numerical scales. Numerical scales appear to be the most promising and would facilitate the use of the tools of probability theory and decision theory in intelligence analysis.

Samet, M. G. Subjective interpretation of reliability and accuracy scales for evaluating military intelligence. Technical Paper 260, January 1975. (AD A003 260)
(Also, Quantitative interpretation of two qualitative scales used to rate military intelligence. Human Factors, 1975, 17, 192-202.)

This report is part of a broader effort to investigate human performance in judgmental tasks and to determine ways of improving such performance, particularly as it affects data input to tactical intelligence information processing. The research reported here assessed the adequacy of source-reliability and information-accuracy rating scales for conveying intelligence information.

Intelligence officers completed an original set and a replication of paper and pencil tasks which measured their attitudes toward and knowledge about the scales; recorded their judgments as to which report in each of 100 pairings of reports with different joint accuracy and reliability ratings was more likely to be true; asked them to estimate the probability that a report with a specific reliability rating would also carry a specific accuracy rating, and vice versa; and had them assign numerical values representing the probable truth of reports with given levels of reliability, of accuracy, and reliability-accuracy combinations. About one-fourth of the subjects treated reliability and accuracy as independent dimensions; the majority treated reliability as highly correlated with accuracy, and their judgment of a report's truth was influenced more strongly by its accuracy rating. Numerical (probabilistic) interpretations of scale levels were consistent within individuals but varied widely between them. Development of a new scale is suggested. The scale should require the assignment of a quantitative value which would reflect the likelihood of a report's being true and be based on all available information including the reliability of the source.

Halpin, S. M., Moses, F. L., and Johnson, E. M. A validation of the structure of combat intelligence ratings. Technical Paper 302, August 1978. (AD A061 568)

This is a validation of a previously derived four-dimensional descriptive structure for evaluating the quality of combat intelligence data. Fifty-six officers in the Intelligence Officer's Advanced course were split into two groups; one group rated 40 messages from the Battle of the Bulge scenario used in the original research, and the second group rated 40 messages from a scenario based on a hypothetical mid-intensity European conflict. Each message was rated on 50 rating scales previously used, as well as on four new scales based on the findings of the previous research. Factor analyses of the results showed that the structure of ratings within both scenarios is basically the same as that derived from the enlisted analysts. Two concepts, Truth and Relevance/Importance/Threat, were major factors in the evaluation of intelligence information in all cases. Two of the new scales, "True" and "Predictable," reflect the Truth dimension, and the other two new scales, "Important" and "Relevant," represent the Relevance/Importance/Threat dimension. The structure of intelligence information quality validated in the present study is not well represented by the current ratings of Information Accuracy and Reliability of Source. A new Accuracy

scale could capture a major portion of the variance in quality ratings, and the other new scales evaluated here provide a basis for further development of supplementary ratings.

Miron, M. S., Patten, S. M., and Halpin, S. M. Determination of the structure of combat intelligence ratings. Technical Paper 286, September 1978. (AD A060 321)

Unpublished appendixes--A: Test materials. B: Discriminant analysis. C: Scale factor analyses. D: Report factor analyses. E: Multiple regression analyses. F: Reports text. G: KWIC. H: Frequency. I: Tagging. J: Factor analyses of tagged categories and report content.

Previous research has indicated that ratings of tactical intelligence data on the dimensions of accuracy and reliability are inadequate to convey the analysts' perception of the quality of the data. Forty messages derived from 28th Infantry Division files for the Battle of the Bulge were rated by 55 enlisted intelligence analysts on each of 50 scales, including the current Accuracy/Reliability scales. These ratings were factor-analyzed to determine the underlying judgment structure. Three basic dimensions emerged, tentatively labeled Accuracy, Relevance, and Directness. Both the current scales are closely related to the Accuracy dimension. The stability of these three dimensions remains to be evaluated. The implications of this judgment structure for quality ratings of combat intelligence data merit further exploration.

Phelps, R. H., Halpin, S. M., Johnson, E. M., and Moses, F. L. Implementation of subjective probability estimates in Army intelligence procedures: A critical review of research findings. Research Report 1242, March 1980.

This paper examines one area which appears to degrade the quality of tactical intelligence: the formulation and expression of uncertainty in both the intelligence estimate and the evaluation of information contained in spot reports. Two interrelated issues are examined: (1) current doctrinal procedures (FM 30-5) for both spot report data evaluation and the expression of uncertainty in the intelligence estimate as well as research on the current use and problems with these procedures; and (2) implementation of numerical subjective probability estimates to express uncertainty as an alternative to the present methods.

Using current procedures, uncertainty is expressed by verbal probability phases (e.g., possible, unlikely) in the intelligence estimate and by a 7-point rating scale based on verbal phases in spot report data evaluation. Available research clearly shows that such verbal probability phrases are extremely ambiguous in interpretation. The use of numerical subjective uncertainty in the intelligence estimate and data evaluation. While some questions still remain concerning the details of training and implementation, our current state of knowledge provides a sufficient base to begin incorporating subjective probability estimates into Army doctrine as well as practice.

Intelligence Data Evaluation

Use of numerical subjective probability estimates is anticipated to decrease the ambiguity in communicating intelligence estimates and in evaluating spot reports. Once numerical probabilities have been incorporated into intelligence procedures, an additional advantage will be the ease with which numerical estimates can be compared among personnel, overtime, or used as inputs for automated decision aids.

III. INFORMATION PROCESSING AND PRESENTATION

Human-Computer Interaction: General
Data Entry
Data Entry: System Simulation (MANMODEL)
Data Organization
Data Retrieval
Graphic Displays
Symbology
Topographic Products and Procedures

Human-Computer Interaction: General

Granda, T. M. An application of human factors concepts to an interactive computerized personnel record-keeping system. Research Report 1233, January 1980. (AD A083 160)

This report describes a "hands-on" demonstration that illustrates how human factors principles can be applied to the design of the human-computer interface and the operational procedures of an interactive, real-time Army personnel record processing system. The Standard Installation/Division Personnel System (SIDPERS) was identified as a typical record-processing system suitable for conversion to an interactive computer system. Four SIDPERS transactions (Duty Status, Departure, Arrival, and Grade Change) were selected as representative tasks for demonstrating the application of behavioral principles. The demonstration was programmed on the PLATO (Programmed Logic for Automatic Teaching Operation) system.

The demonstration focused on the interactions between the computer and both an experienced and an inexperienced processing clerk of a unit. The demonstration also displayed interactions between a unit supervisor and the computer and between SIDPERS personnel and the computer. The demonstration capabilities included error detection and correction, definition of terms, variable input format, and efficient information retrieval.

The hands-on demonstration clearly showed the advantages of an interactive system designed for the user: reduction in processing time and number of errors per transaction, accommodation to users with differing needs and levels of skill, and increased user satisfaction.

Ehrenreich, S. L. Design recommendations for query languages. Technical Report 484, in press (November 1980).

The existing human factors literature on query languages is both sparse and scattered. This paper seeks to collect and review that literature. The first section of the paper introduces the subject of query languages. In the second and third sections, the topics of natural and formal query languages are respectively discussed. These two types of query languages are reviewed with the objective of determining their potential for expanding the population of computer users. The fourth section considers some general issues pertinent to both types of query languages. These issues include the ability of people to deal with logical quantifiers, the user's concept of data organization, mixed initiative dialogues, and the use of abbreviations. Methods for experimentally evaluating specific query language features and research on person-to-person communication are also discussed here. To focus the findings reported in the preceding sections, the fifth section summarizes the implications of the research performed to date. Next, the sixth section presents possible new research which would be of value to the designers of Army tactical information systems. The paper concludes with two appendixes. Appendix A discusses human factors review papers concerned with the design of interactive systems. Appendix B presents a compendium of design recommendations directed toward the system designer.

Data Entry

Baker, J. D., Mace, D. J., and McKendry, J. M. The transform operation in TOS: Assessment of the human component. Technical Research Note 212, August 1969. (AD 697 716)

Of concern in this study were the human factors problems involved in transforming free-English G3 message texts into rigidly defined format in preparation for user interaction with TOS. In the experiment, 47 simple messages were given to 14 individuals familiar with TOS or G3 operations, or both. Half the men (job-aid group) used an aid devised by the ARI investigators, and half (standard group) used a "menu" type listing of available formats in performing the required task of selecting an appropriate format for each message. Time taken to complete the task and also degree of confidence in the selection made were recorded. Findings showed a mean time of approximately 50 seconds for message reading and format selection. Average error rate in format selection was 22%. No significant difference was obtained in performance with the job aid over t it with the "menu" type listing. Messages of different types and subject m er differed in error rate of format selection. Mean expressed certitude of correctness in format selection was almost the same for both groups. Time and error rate data, together with other factors such as screening for applicability to TOS, correction of errors, and translating more complex tests led to the conclusion that the transformation process is potentially a major problem in the experimental TOS. Results provided baseline data for comparative study of future performance and suggested some approaches to training and alternative methods for the transform process.

Strub, M. H. Evaluation of man-computer input techniques for military information systems. Technical Research Note 226, May 1971. (AD 730 315)

The present publication describes speed and accuracy evaluations of four configurations of procedures for inputting information into a semi-automated information processing system. Sixty USMA Prep School enlisted men were given an experimental task requiring each to translate 35 free-text messages into computer-acceptable terminology. Accuracy and speed of two input procedures were each compared under two conditions of verification. In one procedure, the subjects translated the incoming message onto a paper format before transcribing on a CRT screen (off-line). In the other procedure, the message was transcribed directly on the CRT screen (on-line). In the unverified condition, two men translated the same message, compared their translations, and resolved differences before entering the information into the data base. Performance results under the four experimental conditions were also compared with a similar 7th Army TOS procedure in which a message is translated onto a paper format and the unverified message is copied on the CRT screen by the UIOD (user input-output device) operator.

In the present experiment, data input accuracy was significantly increased when free-text messages were translated directly on the CRT screen rather than first filled out on paper formats (11.2% error vs. 14.8%). Input speed was practically the same under both methods. When two operators

checked each other's translation before inputting to the data base, error was reduced by one-third (10.3% vs. 15.7%), but the procedure required one-third more time (6.81 min. vs. 4.98 min.). Either procedure was an improvement in accuracy over the work method used in the TOS. The present study strongly suggests that incoming messages should be translated directly on the CRT screen. Direct CRT input would reduce error while eliminating paper formats and need for UIOD operator transcription. Findings further suggest that, when time and personnel permit, messages should be verified for consistency before entering the information into the data base.

Nawrocki, L. H., Strub, M. H., and Cecil, R. M. Error categorization and analysis in man-computer communication systems. IEEE Transactions on Reliability, 1973, R-22, 135-140.

This paper briefly examines traditional approaches to human reliability and presents a technique which permits the system designer to derive a mutually exclusive and exhaustive set of operator error categories in a man-computer system. These error categories are defined in terms of process failures and provide the system designer with a qualitative index suitable for determining error causes and consequences. The technique is demonstrated, and the utility of the resulting error categories is evaluated in the context of two studies on a military information processing system. The paper concludes with a brief discussion of detectable and nondetectable errors and a suggestion for determining the impact of errors on ultimate system goals.

Sidorsky, R. C. Alpha-Dot: A new approach to direct computer entry of battlefield data. Technical Paper 249, January 1974. (AD 774 841)

The purpose of the present study was to determine the suitability of the five-key Alpha-Dot keyboard for source data automation of battlefield information. The Alpha-Dot system is a coding technique that enables people to input data using familiar shapes in a form that is also directly compatible with computers and other binary data processors. The technique can be used as the basis for a number of devices and procedures for the two-way communication of information between man and machine. Ten enlisted personnel entered both free form and formatted versions of simulated enemy situation spot reports. Learning time as well as rate and accuracy of data entry using the Alpha-Dot keyboard was compared to operator performance using a standard typewriter.

The results indicate that no special skill is required to operate the device. All of the trainees were able to input messages satisfactorily after 2 or 3 minutes of instruction. Learning time for skilled operation is very short. Nine of the 10 trainees memorized the character set within 1½ hours of practice and were then able to transmit messages without reference to the guide chart. Rate of data entry compares favorably with the standard keyboard. After less than 5 hours of practice, free text messages were entered at 60% of each trainee's standard keyboard rate. However, formatted (TOS type) messages were transmitted at a rate equal or exceeding that of the standard keyboard. Uncorrected errors were nil with both keyboards.

Data Entry

The Alpha-Dot technique appears to have potential as a means to increase the speed, accuracy, and flexibility of input of battlefield data by frontline observers. Functional specifications for a militarized field operable unit will be developed following field tests of a prototype unit.

Strub, M. H. Automated aids to on-line tactical data inputting. Technical Paper 262, February 1975. (AD A010 350)

In an automated information system the input operator must rapidly and accurately convert free text information into computer-readable format while entering it into the data base.

This report describes and evaluates a computer-assisted message inputting (CAMI) aid designed to provide useful additional formatting instructions to operators.

Both a full format and an experimental checklist format were used with the CAMI CRT and with a handbook of instructions and sample formats to input scenario-type messages. Subjects were 60 enlisted men divided into five groups, one for each of the experimental conditions plus one using only the handbook and blank-screen CRT. Speed and accuracy were measured. Speed did not differ significantly among the four experimental conditions, but the fifth unaided condition was significantly slower. No significant differences in accuracy appeared. However, over 80% of the total input errors were discovered to be types of error which are not detectable by present automated error-checking routines.

Alderman, I. N. Tactical data inputting: Research in operator performance and training. Proceedings of the Second National Symposium on the Management of Data Elements in Information Processing. Washington, D.C.: NBS/ANSI, 1976.

The Army development of battlefield information systems established a need for research on improved integration of human tasks and computer operations. This paper reviews selected studies on the data entry process. The allocation of functions/tasks for data entry and the development of job and training aids are related to human performance and to the effectiveness of the system as an aid to the user.

Fields, A. F., Maisano, R. E., and Marshall, C. F. A comparative analysis of methods for tactical data inputting. Technical Paper 327, September 1978. (AD A060 562)

Nearly all information in tactical operations systems is input manually. Two problems that arise when manually inputting data are (a) the introduction of errors in translating information into computer format and (b) the introduction of a bottleneck in total system response time. Therefore, alternative methods of inputting data for accuracy and speed should be evaluated.

Data Entry

Four methods were examined for speed and accuracy in inputting tactical messages concerning enemy activity into an Army computer format. The methods were (a) typing--the user types the appropriate codes into a message format; (b) typing with an error corrector--the computer automatically attempts to correct common spelling and/or typing errors; (c) menus--the user indicates which of the legal entries is desired from a list; and (d) typing with autocompletion and an English option--the user must type only sufficient characters to uniquely identify the item, using either the appropriate code or its English definition.

Thirty-two enlisted persons representative of the class of military personnel who might serve as input device operators input one of four sets of nine messages using each inputting method.

The use of menus was the most accurate inputting method. For users of limited experience (1 day of inputting), there were no differences in speed among the inputting methods.

Consideration should be given to the adoption of menus in tactical operation systems with a menu override option for experienced users. The use of an error corrector, autocompletion, or an English option is probably not warranted unless operational use shows a specific need for such an aid.

Nystrom, C. O., and Gividen, G. M. Ease of learning alternative TOS message reference codes. Technical Paper 326, September 1978. (AD A061 697)

To interact with a tactical data processing system such as the DEVTOS or TOS^2, action officers and user input-output device (UIOD) operators must correctly enter a message reference code. The senior author had participated in recommending that DEVTOS' letter-letter-number (LL#) codes be replaced by LLLL message reference codes for the forthcoming TOS^2 system, predicting in effect that the LLLL codes would be easier to learn. To confirm or disprove this prediction, 40 officers and 20 enlisted personnel were employed to learn one or the other of the code sets. Seated individually at a computer terminal, the learner was shown message category titles and action names. The learner entered the message reference code, transmitted it, and received feedback as to the correctness or incorrectness of his input, plus the correct code.

The error rate associated with the learning of the LLLL codes was less than half that associated with the learning of the LL# codes (13% versus 29% for EM working on the G2 message codes; 11% versus 21% for officers on the same G2 message codes; and 7% versus 15% errors for officers working on G3 message codes). The LLLL codes were learned in about 60% of the total time required by the LL# codes. Analysis of error rates by character position revealed that the old code's numeric character and arbitrary second letter were large sources of error. Several characters in the LLLL code produced undesirably high error rates; the reasons for this and possible corrections were usually obvious.

Data Entry

Gade, P. A., Fields, A. F., and Alderman, I. N. Selective feedback as a training aid to on-line tactical data inputting. Technical Paper 349, November 1978. (AD A061 789)

Training as Message Input Output Device (MIOD) operators was given to 53 Army enlisted personnel under one of four training methods that were based on different instructional strategies. Performance of each participant was assessed during training and under one of two operational configurations of the Tactical Operations System (TOS).

Results showed that the response-sensitive training strategy was effective in reducing training time without loss of performance accuracy during transfer-testing. None of the training methods significantly reduced the amount of undetected errors that enter the system through manual data entry.

Sidorsky, R. C. Source data automation via the Alpha-Dot tablet: A feasibility study. Working Paper HF-79-07, June 1979.

A study was done to test the feasibility of using a "tablet" type inputting device in conjunction with the Alpha-Dot system for data entry of military information. Sixty-six enlisted men, typical of the potential users of the device, participated in the study. Participants were given hard-copy, self-instruction Alpha-Dot training booklets. After completion of these, participants were given test booklets on the Alpha-Dot system, similar to the training booklets. Participants were then instructed on the use of the tablet device and given a series of Alpha-Dot characters to input using the device. Almost all participants showed positive transfer of training from the paper booklet training to the tablet device. Participants were able to enter an average of 22.4 characters per minute (cpm) during the test booklet phase. For the tablet device the mean was about 20 cpm. The results indicate that with extended training, data entry levels of 60-75 cpm could be obtained with the tablet device.

Mace, D. J., Harrison, P. C., Jr., and Seguin, E. L. Prevention and remediation of human input errors in ADP operations. Technical Report 395, August 1979. (AD A081 730)

This report classifies types of human errors made while entering data into automatic data processing (ADP) systems. Input error causes, effects, and prevention are discussed specifically in terms of tactical ADP systems for automated battlefield information systems. The multi-attribute utility measurement approach described here provides a method for evaluating costs and benefits of different error-reduction techniques.

Alderman, I. N., Ehrenreich, S. L., and Bindewald, R. Recent ARI research on the data-entry process in Battlefield Automated Systems. Research Report 1270, in press (November 1980).

This paper reviews ARI research designed to improve the data entry process. The first and second sections of the paper describe the data entry

process in general and in the context of a specific battlefield automated system, the Tactical Operations System (TOS). Because it was used as an exemplar of the data entry process, TOS played an important role in the development of improved data entry procedures. The third section reviews the findings and conclusions of the many ARI research projects concerned with data entry. Among the areas covered in ARI's research program are:

a. How to format and display data entry information.
b. What safeguards can be developed to reduce the number of operator errors made and/or accepted by the system.
c. What kinds of operator job aids can be developed to improve performance.
d. How to improve operator training.
e. How to make the system's message codes easier to use and more memorable.
f. How to improve the design of keyboards.

The fourth section of the paper reports on efforts to analyze the cause of operator errors. This section also discusses the development of a simulation of the data entry process. The simulation is intended to facilitate system design by permitting the inexpensive evaluation of alternate data entry procedures. The fifth section presents a general discussion of the problems that have been encountered by the ARI research program. Also included here is a discussion on how this program might be improved in the future. The final section of the paper summarizes the operational implications of ARI's research results.

Data Entry: System Simulation (MANMODEL)

Baker, J. D. Quantitative modeling of human performance in information systems. Ergonomics, 1970, 13, 645-664. (Also Technical Research Note 232, June 1972.) (AD 746 096)

This publication summarizes an approach toward developing a general information system model which focuses on man and considers the computer only as a tool. The ultimate objective is to produce a simulator which will yield measures of system performance under different mixes of equipment, personnel, and procedures. The model is structured around three dimensions: (1) data flow and processing, (2) task analysis, and (3) outside sources of variation in the system. Five basic functional areas represented in the model are screening incoming messages, transforming messages to computer format, inputting messages, assimilating data displayed, and deciding on courses of action based on information obtained. The impact of human performance in the model is reflected in measures of system performance (thoroughness of information and responsiveness to the user need) and quality of information (completeness and accuracy).

Siegel, A. I., Wolf, J. J., and Leahy, W. R. A digital simulation model of message handling in the Tactical Operations System: I. The model, its sensitivity, and user's manual. Research Memorandum 73-5, November 1973. (Also Technical Report TR-77-A-23, October 1977.) (AD A047 104)

The results of research into implementation of a quantitative model of human performance in information systems are presented. The principal efforts were to: (1) define the most influential psychosocial variables inherent in the mission of interests, (2) incorporate these into a logic for a digital simulation model, and (3) develop a computer program reflecting this model. The Tactical Operations System (TOS) for which the model was developed is described, and model features involving predictive capability and system effectiveness measurements are presented. The results of a series of model sensitivity tests under a variety of parametric input conditions are reported.

Leahy, W. R., Lautman, M. R., Bearde, J. L., and Siegel, A. I. A digital simulation model of message handling in the Tactical Operations System: III. Further extensions of the model for increased interaction. Research Memorandum 74-11, August 1974. (Also Technical Report TR-77-A25, October 1977.) (AD A047 105)

The present report is the last in a series of three which describe the inner working of MANMODEL, a simulation of the U.S. Army Tactical Operations System (TOS). MANMODEL yields measures of system performance under different mixes of equipment, personnel, and procedures. Sensitivity tests of MANMODEL have been successfully completed and are reported here. Formal validation of MANMODEL as a predictor of performance is discussed as a logical next step in its evolution.

Data Entry: System Simulation (MANMODEL)

Siegel, A. I., Wolf, J. J., Leahy, W. R., and Bearde, J. L. A digital simulation model of message handling in the Tactical Operations System: II. Extensions of the model for interactivity with subjects and experimenters. Research Memorandum 73-6, December 1973. (Also Technical Report TR-77-A24, October 1977.) (AD A046 407)

Extensions and improvements are described to a previously developed digital computer model for simulating the actions of operational field Army personnel performing their message processing tasks during a Tactical Operations Systems (TOS) mission. The computer model was made interactive via cathode ray tube to: (1) enable an experimenter to initiate and control computer simulation runs, and (2) allow TOS operators at a computer terminal to perform selected tasks during the simulation. A series of model improvements found desirable, as a result of prior simulation run experience, is described.

A revised version of the "user's manual" for the model is presented along with an Interactive Model User's Manual.

Leahy, W. R., Siegel, A. I., and Wolf, J. J. A digital simulation model of message handling in the Tactical Operations System: IV. Model integration with CASE and SAMTOS. Technical Report 413, October 1979. (AD A086 4[illegible])

The human performance oriented computer simulation, called MANMOD, of the U.S. Army's Tactical Operations System (TOS), was modified and extended to allow increased capability and generality. The modifications and extensions included but were not limited to: (1) incorporation of the capability to simulate error message receipt and processing, (2) interaction and integration with a modified CASE model and with the SAMTOS model which principally simulate TOS equipment functions, and (3) implementation of the MANMOD on the Univac 1108 computer system. The modified MANMOD was tested relative to sensitivity and reasonableness of output. The evidence supports the use of the model for a number of functions relative to system design, training requirements and objectives derivation, personnel requirements, and tradeoffs.

Leahy, W. R., Siegel, A. I., and Wolf, J. J. A digital simulation model of message handling in the Tactical Operations System: V. User's guide to the integrated MANMOD/CASE/SAMTOS computer simulation. Technical Report 414, October 1979. (AD A086 355)

This document is a complete guide for the use and interpretation of the computer simulation program--MANMOD. The program is stored in files on the Univac 1108 computer at the Edgewood Arsenal. The MANMOD program calls the Army Research Institute's MANMOD simulation of the Tactical Operations System and provides an interface with the CASE and the SAMTOS computer simulation models.

The MANMOD program is written in FORTRAN IV. Sufficient information is provided in this manual to allow simulations to be performed by individuals with minimum computer-related experience. In addition, detailed flow charts and variable lists are provided for the use of skilled

programmers who desire a more technical description of the mechanics of the simulation and to allow program changes to be made more easily.

Baker, J. D. Modeling the user. Working Paper HF-80-3, November 1979.

This report provides an overview of two simulation models concerned with different aspects of the impact of man on system effectiveness. The first, MANMODEL, was developed as a model of message flow through the Tactical Operations System (TOS) from receipt of free-text messages at the operations center to computer storage of the message. The second model, SIMTOS, is a man-in-the-loop simulation developed to support research on staff officer performance. This overview was originally prepared for presentation at the NATO Advanced Study Institute on Man Computer Interactions, MATI, Greece, 5-18 September 1976.

Data Organization

Patten, S. M. An inductive taxonomy of combat intelligence data. Research Memorandum 74-14, December 1974. (AD A076 802)

To effectively handle an increased volume of data, an intelligence analyst working on a specific problem must be able to selectively obtain information relevant to the problem without becoming bogged down in irrelevant information. To achieve an efficient information retrieval capability, whether using a manual or automated procedure, it is desirable for data to be stored in a form compatible with the requirements of the analyst.

This report presents an outline of one approach to data organization and provides the information taxonomy produced when this methodology was applied to one message set. While a number of information categories were unique to this message set, the taxonomy is expected to constitute a valuable starting point for future efforts of this type.

Siegel, A. I., Pfeiffer, M. G., and Warms, T. M. Development of evaluation of a content analytic approach in Army field system data organization. Technical Report TR-77-A11, August 1977. (AD A042 075)

This report describes the logic, methods, and results of a study into the derivation of a content analytic approach to Army field system data organization. First was a linguistic analysis of a set of battlefield messages and several multidimensional scaling analyses of a sample of messages representing all information classes yielded by the linguistic analysis. Four multidimensional scaling analyses were completed. Each was based on the linguistic similarity perceptions of one of four experienced battlefield analysts. High agreement was found among the factorial structures yielded by the data of each battlefield analyst.

Accordingly, an overall analysis was completed, and 15 factors were identified as representing the perceptual substrate of the Army field information linguistic system. On the basis of the derived factors, a battlefield language taxonomy was developed. The taxonomy was tested in two separate field oriented experiments.

The results of these experiments indicated that intelligence analysts can classify messages reliably within the taxonomy and that they can reliably use the taxonomy for inquiry purposes. Moreover, adequate subjective confidence was expressed by the analysts in the use of the system. Finally, a computer system for automatic classification of battlefield messages is presented.

Miron, M. S., Patten, S. M., and Halpin, S. M. Content analysis and the organization of combat intelligence data. Research Memorandum 78-7, February 1978. (AD A077 956)

This research examined and tested an application of a high-speed data processing technique designed to automatically provide organizational structure for incoming intelligence reports. A system of computer routines

known as the General Inquirer was developed to analyze message content. The computer identifies and catalogs a set of previously selected words and phrases in the text of intelligence reports from the field.

The data base consisted of 33 intelligence reports recorded by the 28th Infantry Division just before the Battle of the Bulge and 7 false reports designed to test the capabilities of the system.

The sample of 40 intelligence reports was keypunched on data entry cards, a dictionary of critical concepts was constructed, rules for identifying these concepts as they occurred in the text were developed, the occurrences of the identified concepts were tabulated for each message, and correlations and factor analyses were computed using these tabulations of identified concepts.

It was found that this logically coherent structure could aid intelligence analysts in organizing and analyzing the data in the message set. However, the content-analytic procedures need to be refined. Two inadequacies were the dictionary definition language and the fact that the entire General Inquirer System was programed only for the IBM S/360 or S/370 computer. Nonetheless, sufficient promise existed to warrant further investigation.

Data Retrieval

Operating Systems, Inc. MIQSTURE: An experimental on-line language for Army tactical intelligence information processing. Technical Report TR-78-A25, July 1978. (AD A064 323)

Analysis and specifications are presented for applying a mixed-initiative query system to intelligence data processing. The project had four principal steps: (a) development of a statement of requirements for interactive data processing in tactical intelligence analysis; (b) extension and application to the requirements identified in the first step of a concept of a mixed-initiative system, focused on task requirements and user needs; (c) development of detailed design specifications for six selected subsets of MIQSTURE (the Mixed Initiative Query System with Task and User Related Elements); and (d) preliminary evaluation of MIQSTURE. The six subsets developed in some detail were (a) normal querying of message records; (b) automatic alerting and input-driven querying; (c) normal tabular data base querying and calculation; (d) aids for representing the tasks which form the context of MIQSTURE; (e) procedures for cross-referencing graphic symbols and data-base elements; and (f) defining and maintaining data file structures. An analytic evaluation of MIQSTURE indicated high potential for application to tactical intelligence processing and other data processing situations involving a relatively restricted range of well-defined tasks.

Nawrocki, L. H. Word abbreviations in man-computer communication systems. Working Paper HF-79-04, June 1979.

This experiment is the first stage of an effort to empirically evaluate the feasibility and utility of incorporating natural linguistic processes into the word abbreviations rules for automated systems. The purpose of the present experiment was to compare decoding performance using human generated abbreviations lists to performance using lists stressing primarily economy, consistency, or both.

Each of 75 U.S. Army enlisted personnel were shown one of five sets of 120 single word abbreviations over a cathode ray tube (CRT). Each set of abbreviations was generated by one of five different sets of rules for the formation of abbreviations. Their task was to enter their best guess at the source word for each abbreviation onto the CRT. They were also asked to indicate, on a 0-100 scale, how confident they were that their responses on each abbreviation were correct.

Results indicate that economy appears to be the primary dimension of abbreviations affecting the research. The relationship between economy and percentage of abbreviations identified correctly was an inverse one, however. The lower the economy of the list, the higher the percentage the number of source words identified correctly. Results for all five sets of abbreviations are given and discussed.

Data Retrieval

Potash, L. M. Effects of retrieval term specificity on information retrieval from computer-based intelligence systems. Technical Paper 379, July 1979. (AD A072 312)

This experiment assessed the impact of using two levels of retrieval terms on formulating and inputting query statements. One level used specific terms to retrieve one element of information; the other level used global terms to retrieve blocks of information that would otherwise require five to six specific terms.

Participants in the study were enlisted personnel from Fort Belvoir, Va., with General Technical (GT) scores ≥110. Participants were assigned either to a specific group allowed to use only specific retrieval terms, or to a global-specific group allowed to use both global and specific retrieval terms. The retrieval terms and their definitions were listed in a data dictionary and were displayed on a data name chart.

After a 5-minute typing test, participants were given instructions on how to write query statements in the GIM II Query Language used in Army System for Standard Support Terminals (ASSIST).

Participants were then given a set of 48 problems. For each problem, the participants had to write and type a query statement that would satisfy the information requirements. An electric typewriter simulated the keyboard input of a computer terminal. Using a stopwatch, each participant recorded the time it took to write and type query statements. After finishing the problems, each participant was given an ancillary learning test to assess how well specific terms had been learned. Finally, participants rated the ease of use of the query language, indicated how they went about writing query statements, and rated the value of using global terms.

The opportunity to use global terms had no effect either on the time needed to write query statements or on the accuracy of typed query statements. Where the use of global terms was applicable, substantial savings in the time required to input query statements was shown. With the exception that the global-specific group reported that it made more use of the data name chart before using the data dictionary, the two groups indicated that they went about writing query statements in approximately the same way. Both groups gave high ratings to the value of using global terms.

Use of global terms is not recommended unless the specific items of information subsumed under the global term are normally retrieved together frequently.

Moses, F. L., and Potash, L. M. Assessment of abbreviation methods for automated tactical systems. Technical Report 398, August 1979. (AD A077 840)

Alternative methods of producing abbreviations of single words for use in automated military systems were empirically evaluated. Each of 50 enlisted men performed three tasks designed to assess five different abbreviation methods including two versions of truncation, two versions of contraction, and one procedure based on current Army practice. In the first four methods, abbreviation length was directly related to word length. In Task A,

participants used a 10-point scale to rate preference for abbreviations for each of 60 terms. Thirty of these terms were repeated in Task B; the other 30, in Task C. Task B required participants to decode 60 abbreviations into their original terms. Finally, Task C asked participants to encode (i.e., generate) a meaningful abbreviation for each of 60 terms. Results showed that abbreviations produced using simple truncation were consistently preferred, easily decoded, and frequently used for encoding terms. Scores for abbreviations from current Army practice were among the lowest except in Task C (encoding). Experience with abbreviations in Task A (preference) made decoding of identical abbreviations significantly easier in Task B, but did not affect the abbreviations encoded by participants in Task C. Simple truncation is the method suggested to produce good single word abbreviations quickly and to reduce the errors and the time requirements for user interactions with battlefield automated systems.

Katter, R. V., and Bell, G. Experimental evaluation of concepts for MIQSTURE: An online literature language for tactical intelligence processing. Research Note 80-19, December 1979.

This project evaluated selected aspects of an online language for Army tactical intelligence processing, called MIQSTURE. In the first of two experiments, U.S. Army tactical intelligence officers provided expert judgments on work-related and information utilization aspects of descriptions of selected tasks from Army tactical intelligence processing. The results provided indications of what query methods have potentials as aids for intelligence analysts. In the second experiment, an evaluation was made of the efficacy of a familiarization/refresher display arrangement for developing and maintaining a useful level of user/operator familiarity with little-used but essential elements of the interactive language. The results were promising for the display arrangement.

Ehrenreich, S. L. Design recommendations for query languages. Technical Report 484, November 1980.

For a discussion of this report, see the previous citation on p. II-21 of this paper.

Graphic Displays

McKendry, J. M., Mace, D. J., and Baker, J. D. Implications of BESRL research for displays in tactical information processing. Technical Research Report 1156, January 1969. (AD 688 581)

The present report summarizes BESRL (now ARI) display research findings that are amenable to immediate or near-future application to operational human factor problems in the display and assimilation of information in field facilities.

Problem areas identified through field exercise observations are reviewed in the context of greatest applicability of laboratory research done by BESRL as well as the feasibility of procedural modifications indicated by the research findings. Major principles pertaining to specific operational needs are defined. These are then translated into suggestions and their application illustrated by specific examples (especially with reference to the potential of TOTE-type displays and simple coding techniques for facilitating information presentation and assimilation). Research needs bearing on human factor problems involved in decision-making tasks in the operational setting are also discussed.

Nawrocki, L. H. Alpha-numeric versus graphic displays in a problem-solving task. Technical Research Note 227, September 1972. (AD 748 799)

The experiment reported here was designed to determine how alpha-numeric and graphic presentation of computer data displays affect performance, in terms of speed and accuracy, under two sets of system requirements: (1) the need to base a decision on memory of information previously displayed versus no memory requirement, and (2) the complexity of information to be held in memory (memory load).

Results of this study, in conjunction with previous comparative evaluation of the two alternative display modes, suggest that under a variety of tasks and conditions, there is no clear-cut advantage to the use of either alpha-numeric or graphic displays when memory of displayed material was required. Hence, the choice of display type may be primarily one of cost consideration if time and accuracy are the primary determinants of system performance. However, when memory was not required, alpha-numeric displays resulted in fewer errors of omission than did graphic displays. It was also found that increasing complexity caused a deterioration in speed when no memory was required and a decrement in accuracy when memory was required.

Nawrocki, L. H. Graphic versus tote display of information in a Simulated Tactical Operations System. Technical Research Note 243, June 1973. (AD 766 217)

As part of a continuing study, ARI compared the effects of graphic and tote display modes on the speed and quality of decisions based on the displayed information.

Graphic Displays

In the context of ARI's Simulated Tactical Operations System (SIMTOS), 28 officers, divided into two groups, were presented a command decision task. For one group, information requested by the officers from the data base was presented in graphic format emphasizing spatial and symbolic coding of the data. For the other group, the data were presented in tote form emphasizing tabular arrangement and alpha-numeric coding. Evaluation of the two display modes was in terms of speed and accuracy of the final decision and the number of nonredundant facts accessed by the subject.

The two groups did not differ significantly in accuracy of decision, speed of decision, or number of facts accessed. Therefore, the more economical tote form of displays should be used wherever feasible. Where graphic displays are used, the complexity and density of information presented can be considerably reduced by conversion to a form suitable for CRT or printout.

Colson, K. R., Freeman, F. S., Mathews, L. P., and Stettler, J. A. Development of an informational taxonomy of visual displays for Army tactical data systems. Research Memorandum 74-4, February 1974. (AD A082 951)

This is a detailed account of research conducted to develop a taxonomy of visual displays for the Army's tactical data systems. A major problem in effective display system design and development has been the lack of a comprehensive frame of reference and associated terminology that can be used to characterize displays and the functions they perform as part of a large information processing system. The taxonomy provides a structure for defining, evaluating, and comparing displays based on the user's information needs. An attempt was made to evaluate the taxonomy using operational display systems. The report includes background and references.

Granda, T. M. A comparison between a standard map and a reduced detail map within a Simulated Tactical Operations System (SIMTOS). Technical Paper 274, June 1976. (AD A028 752)

The use of reduced maps in place of standard Army maps has often been recommended for the upper command (e.g., Division) levels. Within the context of a simulated tactical operations system, several variables that were thought most likely to be affected by the use of reduced detail maps or echelon information needs were observed in an offensive planning phase and an offensive combat phase. Among the dependent variables included were number of data frames accessed, time to access data frames, and combat effectiveness scores.

The analyses of variance performed on the variables show significant main effects for the echelon factor for the amount and type of information accessed, and for one combat effectiveness score. No significant difference in performance during planning or combat was associated with the level of map detail factor. Therefore, the feasibility of using reduced detail maps in conjunction with a computerized graphic display capability should be investigated.

Graphic Displays

Granda, T. M. An evaluation of visual search behavior on a cathode ray tube utilizing the window technique. Technical Paper 283, February 1978. (AD A053 352)

Large or dense information displays cannot always be presented legibly on a cathode ray tube (CRT) all at once. This experiment evaluated the feasibility of using a window technique in CRT visual search. The first part of the experiment considered whether the super-display should be static and the window should move or whether the super-display should move and the window should be static. The second part of the experiment considered whether the length of a memorized target set affected information processing.

Ten participants searched a series of alphanumeric CRT displays for specific information targets. Display motion control, length of target list, target density, nontarget density, and window size were independent variables; time effects on performance were also measured. Five participants controlled window motion and five controlled super-display motion.

Results showed that a window technique is feasible for searching for targets on a CRT. Participants found most of the targets and made few movement errors. The most important variables were target density and the display-motion relationship. Participants using a moving window found more targets than those using the moving super-display; however, the moving super-display group made fewer control errors and took less time to view the entire display. Participants searched the displays as quickly for seven targets as they did for five or three targets. Window technique results can apply to any task in which the entire display cannot be presented at one time; information processing results can help structure similar tasks.

Moses, F. L., and Maisano, R. E. User performance under several automated approaches to changing displayed maps. Technical Paper 366, June 1979. (AD A073 726)

Performance in a route selection task was used to evaluate automated methods for changing from one displayed segment of a map to another. Participants were 24 Army officers who chose successive 6.75 x 9 km map segments (1:50,000 scale) for solving 12 problems. Each problem requested the fastest road route between pairs of cities within a 60 x 81 km region. Participants solved problems by electronically marking road routes across map segments. Methods for changing map segments were (a) continuous map scanning and (b) discrete map segments using three different amounts of border overlap (0%, 25%, and 50%). Results showed that different map change conditions did not significantly affect the quality of routes chosen. The least time for problem solutions occurred when map segments with 50% overlap were used, although 25% overlap produced similar data. Designers of map display systems for the military could optimize user performance time with discrete map segments that overlap by about 25%.

Graphic Displays

Gellman, L. H. Recent ARI research on alternative display formats. Research Report 1294, November 1980.

The need for alternative display formats results from the inadequacy of present symbologies for automated displays.

The paper is divided into three sections. Part I discusses the problems associated with clutter and how alternative formatting can lessen these problems. Part II examines two formatting techniques (sequencing and coding) and relevant ARI research. Finally Part III presents some suggestions for implementing these research findings.

Sidorsky, R. C. Color coding in tactical displays: Help or hindrance. Technical Report 496, November 1980.

The purpose of this research was to determine the effectiveness of color coding as a means for making tactical displays easier and faster to analyze.

Four groups of analysts observed visual displays of symbolically encoded information depicting the type, status, and disposition of friendly/enemy units on the battlefield. Each group used a different code format. The code formats differed with respect to the category of information conveyed by color coding. The performance of all groups was measured on three tasks. The tasks differed with regard to their level of complexity, i.e., required the extraction of one, two, or three categories of information from each symbol.

Analyses of variance were performed on measures of speed and accuracy of information processing. The results indicate that color can be of substantial benefit in terms of reduced processing time and errors. Information portrayed by traditional shape coding requires as much as 75% more processing time and produces 200% to 800% more errors. However, color is of value only if it is used to encode information that is extracted at the first level of analysis. The establishment of a standardized sequence of colors for tactical symbology to portray the status or condition of tactically relevant objects or events is suggested.

Symbology

Bersh, P., Moses, F. L., and Maisano, R. E. Investigation of the strength of association between graphic symbology and military information. Technical Paper 324, September 1978. (AD A064 260)

This investigation sought to determine the strength of associations of simple codes or geometrical shapes with military concepts. Symbols were chosen for easy generation on computer displays or for ease of manual reproduction.

Each of 114 enlisted men ranked battlefield information categories (e.g., Unit Level, Danger, and Firepower) in the order of their strength of association with different sets of symbols, with numbers of each set varying in a single characteristic. In a related task, these persons were asked to rank order military branch or duty designations and tactical function terms by how well they were suggested by both geometrical symbols and miscellaneous "stick" symbols. A second group of 137 enlisted persons had the reverse task of ranking symbols against one another for their strength of association with military concepts. Both groups of participants had only limited prior exposure to military symbology.

Results suggest that "natural" associations can be found between graphic codes or symbols and military concepts. Results were categorized as high, moderate, minimal, and insignificant associations, based on the statistical significance of differences among ranks and on the degree of reflexive associations between symbols and concepts. About half of the primary matches between tactical concepts and symbols fell into high- and moderate-association categories. These matches included the currently used link between numerosity and Unit Level (e.g., company and division) as well as the link of color with Danger and of square with Service Support. The remaining association results, including the currently used associations of an ellipse with Armor, X with Infantry, and of color for Friend/Enemy, fell into the minimal- or insignificant-association categories. The data gathered identify symbol characteristics for consideration in modifying current symbology. Natural codes or symbols based on such a consensus should be easily learned and interpreted.

Hemingway, P. W., Kubala, A. L., and Chastain, G. D. Study of symbology for automated graphic displays. Technical Report TR-79-A18, May 1979. (AD A076 916)

An extensive literature survey indicated a great variety of available alternative symbology formats. Before a specific format is selected, the necessary information requirements for a particular position must be determined. For Army tactical displays, this information should be gathered in experiments using realistic battle scenarios. As a related effort, alternative symbol formats were evaluated by civilians. Naive subjects generally preferred a pictorial symbol over traditional military alternatives. The report is written for a military audience.

Symbology

Sidorsky, R., Gellman, L. H., and Moses, F. L. Survey of current developments in tactical symbology: Status and critical issues. Working Paper HF-79-03, May 1979.

This report presents the results of a structured survey of nine of the Army's research and development efforts related to symbology. This survey dealt with such factors as mission, tasking, and coordination of the agency as well as methodology, equipment, perceived current problems, and future plans with regard to symbology. Three general problems in symbology briefly are discussed: the lack of an adequate definition of symbology, the lack of a symbology typology, and the need for improved coordination. The report concludes with a structured and annotated list of 34 current research issues representing the core questions or problems currently being discussed or researched in the R&D community.

Hemingway, P. W., and Kubala, A. L. A comparison of speed and accuracy of interpretation of two tactical symbologies. Technical Report 389, July 1979. (AD A075 428)

This report compares the speed and accuracy of interpretation of two tactical symbologies. One set of symbols was the standard set described in U.S. Army Field Manual 20-30. The other set was designed on the basis of previous research in symbology. A brief battle scenario was selected and for each symbol set 35mm slides were prepared representing updates in a tactical display. Results showed that (a) accuracy of interpretation did not vary between the sets, (b) the author-designed set was interpreted more rapidly, and (c) female participants were more rapid in interpreting the displays than male participants.

Ciccione, D. S., Samet, M. G., and Channon, J. B. A framework for the development of improved tactical symbology. Technical Report 403, August 1979. (AD A076 017)

The utility of symbology would be increased by making it more compatible with current and emergent tactical doctrine. A structured methodology based on a role-playing exercise was developed for eliciting graphically related tactical information requirements from experienced military tacticians.

The methodology, involving a two-stage elicitation process, employs doctrinally-sanctioned information-processing guidelines to prompt participants to generate task-related tactical questions (e.g., What is the principal deficiency of a specific enemy unit?) and candidate answers (e.g., mobility, personnel). A pilot test used two experienced staff officers and a European defensive scenario. The numerous question and answer sets obtained were organized into 22 clusters (i.e., data structures), with each one specifying questions in decreasing order of detail according to a common tactical theme (e.g., immediate threat, enemy vulnerability, priority targets). These data structures represent categories of task-based information requirements which can serve as potential building blocks in the development of a dynamic, flexible data base for tactical symbology.

Symbology

The framework also contains a preliminary analysis of symbol design effectiveness based on a taxonomy of basic information-processing behaviors, which include symbol discrimination, display search, and symbol learnability. Each of these processing components was used as a focus for examining relevant research literature and its implications; and as a result, preliminary guidelines were derived for improving symbol design effectiveness (e.g., minimize the amount of feature similarity among different members of a symbol set). Finally, to help monitor future symbology development efforts, a multifaceted evaluation strategy is outlined which calls for systematic attention to content-based, and tactical performance-based assessment criteria.

Farrell, J. P., and Halpin, S. M. The ability to extract terrain information from maps: Factors and measures. Technical Report 494, November 1980.

This paper describes two experiments used to test the validity of the Relief Format Assessment Test, a battery of eight tests tapping different aspects of map understanding for evaluating the effectiveness of various alternate map formats for the portrayal of terrain. The advantages of the Relief Format group of assessment test over traditional methods of evaluation, survey, and field testing are discussed.

Experiment I is a Field Validation of the Relief Format Assessment Test. Sixteen military personnel (sergeant to captain) were tested on portrayal of terrain for land navigation both in the classroom and in the field. Results from Experiment I support the predictive validity of the eight map tests as a measurement of the effectiveness of maps.

Experiment II involved Factor Analysis of the battery of tests to determine the psychological abilities involved in map reading performance. Fifty-nine Army personnel were administered the tests, yielding data for factor analyses. Two different factor analyses were conducted each yielding two factors. One factor appears to involve analytic and quantitative abilities, while the second involves visual factors.

Implications of the results are discussed.

Landee, B. M., Samet, M. G., and Gellman, L. H. User-oriented tactical information requirements with implications for graphic portrayal standards. Technical Report 497, November 1980.

The primary purpose of this research was to elicit and organize selected battlefield information requirements of tactical analysts, and to assess the adequacy of conventional symbology for satisfying these requirements. An elicitation procedure was developed and utilized with small groups of Army officers in a tactical role-playing exercise involving a specified Division-level scenario. Information requirements in the form of tactical questions were generated and reviewed by participants, both individually and together. In addition, for each question, the participants completed a form which provided descriptive information such as whether the answer to the question is available from a display with conventional

symbology (FM 21-30). In an effort to organize the information requirements, an hierarchical clustering technique was applied that analyzed the similarity between questions in terms of 58 semantic features (e.g., friendly, enemy, artillery, vulnerability, etc.).

The elicitation sessions resulted in the generation of a total of 272 distinct tactical questions. These questions formed seven major clusters which were assigned the following names to reflect the central theme of their respective information content: friendly, enemy, time/capability, status, activities/procedures, terrain/routes, and planning. The descriptive data about the questions, analyzed for each cluster of information individually and for the entire set of questions, indicated that conventional symbology fails in many respects to meet basic user needs. For example, 43% of the information requirements identified were said to be unavailable from a conventional display. Furthermore, there appears to be a proliferation of personalized techniques being employed by users to portray their information requirements. Some major informational deficiencies in conventional symbology are identified, and examples are given on how the findings can be employed in development efforts toward making standardized, tactical symbology more useful and effective.

Samet, M. G., Geiselman, R. E., and Landee, B. M. An experimental evaluation of tactical symbol-design features. Technical Report 498, November 1980.

Sixteen nonmilitary subjects learned each of two symbol sets (conventional, iconic) to criterion. Each set contained three basic symbols representing unit types of armor, mechanized infantry, and infantry, respectively. After learning a symbol set, each subject was shown a series of situation displays, where some displays contained symbols coded with either perimeter-density or vector projection to convey supplementary unit-attribute information (unit strength or firepower reach). For each display, the subject was asked questions corresponding to different behavioral processes (identification, search, comparison, pattern recognition). The results indicated that: (a) iconic symbols did not yield faster identification performance than conventional symbols, and conventional symbols yielded faster pattern-recognition performance than iconic symbols; (b) the portrayal of unit attributes slowed processing of unit-type information in all four tasks, but vector projection created less interference than perimeter density in three or four tasks; (c) unit-strength information was processed faster when it was portrayed as perimeter density, and fire-power-reach information was processed faster when portrayed as a vector projection. On a further task which required integration of several symbols into an analytical judgment (threat value assessment), performance accuracy was found to be insensitive to the conventional versus iconic symbology comparison. The results were discussed in terms of the complexity of the implications involved in the selection of symbol design features and their correspondence with tactical concepts.

Topographic Products and Procedures

Granda, T. M. A comparison between a standard map and a reduced detail map within a Simulated Tactical Operations System (SIMTOS). Technical Paper 274, June 1976. (AD A028 752)

The abstract for this reference appears on page III-22 of the section entitled Graphic Displays.

Potash, L. M. Design of maps and map-related research. Human Factors, 1977, 19, 139-150.

Hardcopy maps, i.e., maps printed on paper, are typically multipurpose displays that have to meet the needs of a variety of users. They must portray a large quantity of spatially overlapping geographic information which can result in clutter and interference among symbols if the map is not well designed. This paper will summarize and organize literature related to the design of hardcopy maps and map research.

The first portion of the paper defines and discusses some characteristics of hardcopy maps which, if ignored, can lead to faulty problem definition and to research having little applicability to hardcopy maps. Literature on cartography, visual displays, coding, and visual perception is reviewed in the second section of the paper. The last section summarizes research on extant maps.

Potash, L. M., and Jeffrey, T. E. Factors in the design of hardcopy topographic maps. Technical Paper 284, January 1978. (AD A049 621)

A literature survey on factors in map design, including visual coding techniques and assessment techniques, is summarized in this report, as the first step in improving legibility and usefulness of hardcopy (printed) topographic maps.

Map design determinants are scale, interrelatedness of symbols, and a body of standardized symbols and modes of coding. Map scale influences fidelity, as small scale requires selection, simplification, and magnification of features. Clutter can be reduced by coding to differentiate information: Color coding aids in identification and reduces location time; iconic and alphanumeric shape coding can be learned easily and are flexible; size coding requires considerable space and increases location time.

Among map assessment techniques, opinion sampling is relatively inexpensive but does not measure actual performance, and theoretical analysis is a limited first step only. Empirical analysis measures performance with the map product, either by assessing performance directly or by measuring the map-reading skills which underlie performance.

In comparisons of different types of hardcopy topographic maps, the best photo-based maps produce performance comparable to that with conventional line maps. Some Army users preferred to augment contour lines on conventional maps with layer tints for interpreting topographic relief.

Topographic Products and Procedures

Future airborne map displays should consider the information requirements of pilots, effects of vehicle movement, and map legibility in poor light.

Potash, L. M., Farrell, J. P., and Jeffrey, T. E. An approach to assessment of relief formats for hardcopy topographic maps. Technical Paper 356, April 1979. (AD A069 462)
(Also: A technique for assessing map relief legibility, Cartographic Journal, 1978, 15, 28-35)

The relief assessment test described in this report is designed to assess the effect of supplementing contour lines with other relief formats. It contains eight types of problems and a review of relevant aspects of map reading. It has been produced in three relief formats: contour lines, contour lines plus layer tints, and contour lines plus shading. Initial work indicates that addition of layer tints to contour lines can increase speed of reading some types of relief information; whereas, addition of shaded relief does not increase map reading speed more than use of layer tints and can cause a decrease in accuracy.

Map designers will be interested in this report.

Landee, B. M., Samet, M. G., and Foley, D. R. A task-based analysis of information requirements of tactical maps. Technical Report 397, August 1979. (AD A086 502)

A task-based approach for specifying and analyzing map information requirements was developed and demonstrated. A review of selected literature concerning the mapping process included methods for selecting environmental data to be shown on a map. Seven tactical tasks, representing common battlefield functions performed by different users and echelons (e.g., determination of enemy avenues of approach by a G2 officer at the division level), were sampled and analyzed in depth. A military role-playing and doctrinal verification procedure was used to divide tasks into subtasks so that corresponding information requirements could be specified. Each subtask (e.g., identification of obstacles to movement), in turn, was broken down into basic tactical questions about the environment (e.g., "Are there any vegetated areas through which the enemy cannot pass?," "Are there are slopes enemy vehicles cannot climb?"). The data required to answer each question defined the information categories (e.g., vegetated areas, slopes) and levels of details (e.g., tree spacing and trunk diameter, percent slope) necessary for successful task completion.

The resulting map-related information requirements were synthesized to generate representative map development guidelines. This synthesis--which emphasized information about vegetation, road networks, and built-up areas--was accomplished across tasks to identify those specific information needs which show either prominent commonality or uniqueness with respect to different tasks and user groups. Within the framework of these task-based comparisons, examples illustrate the types of implications that can be derived from the task-based analysis of information requirements.

Farrell, J. P., and Potash, L. M. A comparison of alternate formats for the portrayal of terrain relief on military maps. Technical Report 428, November 1979. (AD A081 739)

Two experiments evaluated the effectiveness of relief shading and layer tints as supplements to contour lines for solving eight types of military map-use problems. The addition of layer tints was found to increase the speed of solving most problems with no loss in accuracy. The addition of shaded relief increased the time required to solve problems requiring detailed information but may be valuable in providing a quick general impression. Personnel experienced in using military maps solved map problems more accurately but no faster, on the whole. Also, solving military map use problems in the classroom appears to correlate with performance in the field.

IV. SURVEILLANCE, RECONNAISSANCE, AND TARGET ACQUISITION

Surveillance and Reconnaissance Management
Remotely Monitored Sensors
Image Interpretation
Communications Intelligence

Surveillance and Reconnaissance Management

Bedarf, E. W. Responses to job assignment and preparation/training questions by G2 Air and image interpretation personnel. Research Memorandum 72-5, October 1972.

Summaries are presented of responses to sections of two questionnaires administered to G2 Air and image interpreter personnel. Data were taken from the Aerial Surveillance and Reconnaissance Questionnaire for G2 personnel and a questionnaire of the same name administered to image interpreters. The survey was conducted as part of an effort to determine the job requirements of the two categories of personnel, documented in Research Report 1181.

Youngling, E. W., Vecchiotti, R. A., Bedarf, E. W., and Root, R. T. Job requirements of G2 Air and image interpretation personnel. Research Report 1181, May 1974. (AD 780 815)

The purpose of this effort was to determine the tasks, duties, and associated procedures of G2 Air and image interpretation personnel. In practice, the effort served to identify (a) problems in the current Army air intelligence system, and (b) requirements of new systems that necessitate training modifications. Data were collected using three methods, namely (a) a comprehensive literature review, (b) in-depth interviews with knowledgeable Army personnel, and (c) mailed questionnaires sent to various Army aerial surveillance and reconnaissance units around the world. The data were integrated within the framework of the Army air intelligence system by using system flow diagrams and task analyses.

The main findings of the study focus on the G2 Air officer and the G2 Air officer position. The G2 Air officer is mainly a manager of resources, but the personnel who fill the positions receive inadequate training to prepare them for the job. There is a need to fill the G2 Air officer position only with appropriately trained personnel. A need also exists for tactical commanders to gain a better understanding of the capabilities and limitations of the aerial reconnaissance and surveillance system and the role of the G2 Air personnel.

Secondary findings suggest a need for more balance in training image interpretation personnel. There are tasks for which more than an adequate amount of training is given in comparison to the importance of the task. Other problems with the aerial reconnaissance and surveillance system involving equipment and procedures have also been identified.

Bedarf, E. W., and Potash, L. M. A field evaluation of the Aerial Surveillance and Reconnaissance MANAGER. Research Memorandum 75-14, December 1975. (AD A076 792)

A handbook, Aerial Surveillance and Reconnaissance MANAGER, had been developed from an earlier analysis of the responsibilities and duties of Army G2 Air officers, reported in Research Report 1181. The handbook was given field evaluation, using a survey technique. Questionnaires were sent

to practicing G2 Air officers, training instructors in pertinent courses, and individuals in closely related positions who had previously received copies of the handbook.

Almost all those responding perceived the primary function of the handbook as that of reference book and/or as a training aid. The major disadvantage cited, that not enough information was given, may have resulted partially from the fact that the manual was designed to serve both purposes.

Vecchiotti, R. A., Berrey, J. L., and Bedarf, E. W. Development of resource management materials for the G2 Air officer. Technical Paper 333, September 1978. (AD A061 695)

A major conclusion of a study of the job requirements for G2 Air and image interpretation personnel (ARI Research Report 1181) stressed the need to direct more attention to the training of the G2 Air officer. This present effort concentrated on developing resource management materials for the G2 Air officer that could be used for on-the-job training and guidance in the performance of duties and in intelligence school courses.

Resource management materials were compiled in the form of a handbook to achieve the training objectives. The first step involved gathering information on tasks as performed by operational aerial surveillance and reconnaissance units, preparing a comprehensive study data base, and conducting field observations and interviews to verify the data base. Next, a content outline of the handbook was prepared by integrating the field interview data with the existing data base. Knowledgeable personnel reviewed this outline. Third, preparation of the handbook itself took into account the various training techniques and aids appropriate for on-the-job and school application. Step four consisted of conducting a limited evaluation of the handbook to determine its usefulness, acceptance, and final structure. Next, a "preliminary edition" of the handbook used the information derived from the evaluation. Finally, an automated demonstration of a portion of the handbook illustrated how the materials could be used with possible future computerized information systems.

Vecchiotti, R. A., Berrey, J. L., and Narva, M. A. Training in utilization of surveillance and reconnaissance resources by combat arms officers. Technical Paper 325, September 1978. (AD 061 577)

The purpose of this effort was to increase the effective use of aerial surveillance and reconnaissance (AS&R) resources by combat commanders through analysis of current experience and training and subsequent development of materials that may be used for training and field use.

Contemporary training materials were analyzed for content.

Questionnaires pertaining to experience with, attitudes toward, and training received relative to AS&R were distributed to students at pertinent schools, and the responses were analyzed for implications for training.

Combat arms students receive limited training in the use of AS&R resources, and they felt they could use more information in this area. The more experience with AS&R, the more favorable has been the experience with this resource. More emphasis should be placed on practical exercises that permit appropriate interaction with the capabilities of AS&R.

The results of the analyses were used in the subsequent development of training materials and a field aid.

Shvern, U. Field evaluation of the combat commander's guide to aerial surveillance and reconnaissance resources. Technical Paper 380, July 1979. (AD A075 422)

This research evaluated the Combat Commander's Guide to Aerial Surveillance and Reconnaissance Resources on its usefulness, accuracy, clarity, and completeness.

An evaluation questionnaire was prepared and distributed, together with copies of the Commander's Guide, to 100 officers at U.S. Army units in Korea, Germany, Fort Hood, Tex., and Fort Bragg, N.C. Participants were required to have either command experience at the battalion level or above or G3/S3 experience. The questionnaire included a structured evaluation of the main sections of the Commander's Guide as well as a global assessment of the document. Participants could also elaborate further on their answers or comment on topics not specifically addressed in the questionnaire. Sixty questionnaires were returned--27 from battalion commanders and executive officers and 33 primarily from officers in G3/S3 assignments.

The individual sections of the Commander's Guide were judged to be more useful than the document as a whole. This seemingly paradoxical result was obtained with both the structured rating scales and the open-ended comments. Raters considered the Commander's Guide to be more suitable for the G2/S2 than for the battalion or brigade commander. Raters' comments concerning possibly excessive detail for a commander's needs are consistent with this finding. Reference to specific AS&R assets are outdated in many instances. Rapid changes in the AS&R area dictate frequent revision of any publication that refers to specific equipment.

The anticipated frequency of use of the Commander's Guide would increase greatly during wartime. If the Commander's Guide is revised, fundamental restructuring would be required to achieve high use rates by commanders during peacetime conditions. A consideration of the type of AS&R information that commanders are able and willing to use, as opposed to what they should ideally use, would be required. Otherwise a technically excellent publication might remain unused on the commander's shelf or be passed on to his G2 or S2. Unless the user has become familiar with the Commander's Guide, its effectiveness in an emergency is limited.

Surveillance and Reconnaissance Management

King, R. B., Rochford, D. S., Ray, T. E., and Bedarf, E. W. Development of a test bed for aerial surveillance and reconnaissance resource management. Working Paper HF-80-4, November 1979.

Recent job requirements analysis of the duties of Army G2 Air officers indicates that more attention should be given to training of management techniques. In response to this need, a handbook (Aerial Surveillance and Reconnaissance MANAGER) was developed to serve as an on-the-job reference and training aid.

This project developed a test bed for the evaluation of the MANAGER handbook and other resource management materials utilized by G2 Air officers. The test bed consists of a basic scenario interspersed with 91 multiple choice performance measurement items. Emphasis is given to management and decision-making processes and test items are divided among eight G2 Air task functions.

The test bed exists in both hardcopy and automated form. The automated version is designed for computer administration at the ARI Training and Information Systems Facility.

Shvern, U., and Coe, A. Collection resources allocation planning system: Draft user's manual for desk-top computer (IBM 5100) application. Working Paper HF-80-6, February 1980.

This paper describes procedures for utilization of a prototype collection planning system.

Special Reports

Aerial Surveillance and Reconnaissance MANAGER, 1973.

This document integrates information useful to the management duties of G2 Air officers. Emphasis has been placed on depicting the flexibility that often exists in the management of Aerial Surveillance and Reconnaissance (AS&R) resources. The duties and the AS&R resources discussed are those at the division and corps levels.

Combat commander's guide to Aerial Surveillance and Reconnaissance resources, 1974.

This document describes the capability of the Aerial Surveillance and Reconnaissance (AS&R) system. It was intended primarily for combat commanders at battalion and brigade levels who need an overall understanding of how to utilize the system. Closely related "field aids" were also prepared for each of three combat arms areas--Armor, Artillery, and Infantry.

Commander's field aid to Aerial Surveillance and Reconnaissance utilization, Armor, 1974.

Surveillance and Reconnaissance Management

Commander's field aid to Aerial Surveillance and Reconnaissance utilization, Artillery, 1974.

Commander's field aid to Aerial Surveillance and Reconnaissance utilization, Infantry, 1974.

Remotely Monitored Sensors

Edwards, L., Rochford, D. S., and Shvern, U. Comparison of four unattended ground sensor displays. Technical Paper 281, April 1977. (AD A039 056)

The research presented here compared the relative effectiveness of four different unattended ground sensor (UGS) displays--an X-T plotter, and three variations of the situation map display--in terms of their effect on monitor performance.

Four 2-hour UGS scenarios were compiled from previously recorded field tests of military targets. The recordings were played back to activate the displays during experimentation. Sixteen Naval personnel (eight relatively experienced with UGS and eight inexperienced) were given training on the displays. Each subject then monitored each display in turn for 2 hours, reporting target information as he would operationally. The reports were compared to known ground truth and were scored on total detections, false alarms, detection accuracy, and target direction (i.e., direction of target movement).

Operator performance was unaffected by the type of display used. Operators were able to detect a higher percentage of targets during periods of low target activity than during periods of high-target activity. However, the accuracy of the detections was higher during the high activity period. Levels of experience did not have a significant effect on performance.

Edwards, L., Pilette, S., and Martinek, H. Error analysis of unattended ground sensor operators' reports. Research Memorandum 77-1, November 1977. (AD A077 921)

This analysis was done to locate the chief causes of the relatively frequent errors made by operators monitoring grid arrays of unattended ground sensors (UGS). Error analyses were made of UGS operator performance data from three previous studies. A table categorized the errors and showed dependent and independent variables considered as error-causing factors. Difficulty indexes and target profiles of the three projects were calculated to pinpoint error-causing factors. Observations and calculated trends identified highly probable error-causing situations.

The results showed greater errors occurring (a) during increased target activity and target load, (b) because of false alarms during low target activity and low target load, (c) because of the effects of single and multiple vehicle target patterns on speed and direction estimation, (d) in determining direct and indirect target trails, (e) because of operator inattention associated with sequence of presentation of the target, (f) during variations in certain X-T plot pattern features, and (g) because of combined errors in measurement, calculation, and response requirement management.

Martinek, H., Pilette, S., and Biggs, B. The effects of work/rest, target activity, background noise and string size on operator interpretation of unattended ground sensor records. Technical Paper 300, June 1978. (AD A061 043)

This research (a) investigated the relationships between unattended ground sensor (UGS) operator performance and work/rest cycles, sensor string size, target activity levels, and noisy/quiet environments and (b) identified sources of operator error that can be eliminated through the use of new interpretation techniques, procedures, and training.

Operators monitored UGS records for 8 hours of worktime under four different work/rest conditions: 2 hours work, 1 hour rest; 2 hours work, 15 minutes rest; 4 hours work, 1 hour rest; and 4 hours work, 15 minutes rest. The UGS records included counterbalanced variations of three string sizes (2, 3, and 4 sensors), 12 targets per hour or 6 targets per hour, and high and low "battle" noise.

For a contemplated 8 hours of monitoring, 2-hour work shifts interspersed with 1-hour or 15-minute rest periods are to be preferred over 4-hour work shifts interspersed with 1-hour or 15-minute rest periods. For heavy short-term monitoring requirements, for example, enemy attack requiring periods of concentrated monitoring, an operator can perform satisfactorily for one 4-hour shift but performance will deteriorate during a second 4-hour shift.

Performance was equal using 2, 3, or 4 sensor strings in the low-target-activity condition. However, during the high-target-activity condition, use of 3 or 4 sensor strings resulted in more target detections as compared to use of 2 sensor strings.

Operator performance during the high "battlefield" noise was equal to that during low noise. During the high-target-activity conditions the operators detected more targets than during the low-target-activity condition. However, they detected a higher percentage of targets during the low condition.

Martinek, H., Hilligoss, R. E., and Lavicka, F. Comparison of three display devices for unattended ground sensors. Technical Paper 299, August 1978. (AD A060 558)

This report describes an experiment designed to determine the relative values of three devices for displaying activations of seismic unattended ground sensors (UGS): the operational RO 376 event recorder, a situation map display, and a time-compressed situation map display.

Three tape recordings, each 2 hours long, of the UGS activations were compiled from recordings taken during field tests. Twelve Naval personnel experienced in the use of the RO 376 were given 4 hours' training in the use of the situation map display and in the map display used with time compression. Each participant then interpreted each display using a different set of recorded activations each time, in counterbalanced order, and filled out a standard report form.

Use of the RO 376 resulted in higher accuracy and more complete reports than did use of the other displays. No differences were found between the two modes of situation map display.

Pilette, S., Biggs, B., and Martinek, H. The value of special training and job aids for improving unattended ground sensor operator performance. Technical Paper 304, August 1978. (AD A061 046)

This research was conducted to determine the value of unattended ground sensor operator training and job aids derived from an analysis of errors and to determine the effect on operator performance of target-activity level and number of sensors used in a string.

The training program and job aids were evaluated using the pretest and posttest design with 4 hours of scenarios containing typical target patterns at two levels of target activity generated by 2-, 3-, and 4-sensor strings. Operators detected and identified targets and estimated their speed and number.

The individualized training program resulted in significantly improved operator interpretation performance in target detection rights, identification rights, target speed, and target quantity estimation. Use of the job aid (nomograph) significantly improved performance in identification rights, target speed estimation, target quantity estimation, and reporting time. Student acceptance of the individualized training approach and both job aids was high. Operator performance on 3- and 4-sensor strings was 77% detection completeness with virtually no false alarms. Detection of targets was better during low-target activity than during high-target activity. The use of three sensors in a string resulted in the same operator performance as the use of four sensors.

Edwards, L., Pilette, S., Biggs, B., and Martinek, H. The effect of workload on performance of operators monitoring unattended ground sensors. Technical Paper 321, September 1978. (AD A061 694)

The purpose of the research was to determine the effect of workload (target activity level and number of sensors used) on unattended ground sensor (UGS) operators' target-detection ability, false-alarm rate, and direction and speed estimation accuracy.

Experienced operators monitored activations of UGS used in grids under six workload conditions--two levels of target activity x three levels of number of sensors monitored. Target activity level was defined as either 5 or 14 vehicle groups per 27 sensors per hour. The operators monitored in counterbalanced sequence 27 sensors (3 grids), 54 sensors (6 grids), and 108 sensors (12 grids).

Percentage of detections decreased linearly from 85% (4 to 6 vehicle groups per hour presented on 27 sensors) to 26% (about 40 vehicle groups per hour presented on 108 sensors). Without special training, operators should monitor no more than 60 sensors being activated by a maximum of 10 vehicular groups per hour (detection completeness for this condition was

76%). The number of false alarms and the accuracy of speed estimation did not significantly change over workload. Operator accuracy in direction estimation decreased significantly as a function of workload from the azimuth ±30° to true azimuth ±54°.

Martinek, H., Pilette, S., and Biggs, B. Vehicle identification using the acoustic sensor: Training, sensing concepts and bandwidth. Technical Paper 334, September 1978. (AD A062 601)

Experiments were designed to (a) develop and validate a training program for using the acoustic sensor to identify vehicles in convoy, (b) estimate operator performance in identifying vehicles using the acoustic sensor, and (c) investigate the effect of using different sensing concepts and bandwidths on the operator's ability to identify vehicles.

Following orientation and procedure training, 18 school-trained unattended ground sensor (UGS) operators were tested on their ability to identify vehicles in convoys. Their training used immediate feedback, self-scoring, paired comparisons, and practice. Following this training, operators were retested.

The training package increased operator vehicle identification performance by 46% to 16%, depending on the level of target detail required.

Pilette, S., Biggs, B., Edwards, L., and Martinek, H. Optimum patching technique for seismic sensors employed in a grid. Technical Paper 320, September 1978. (AD A061 573)

The requirement was to determine the effect of four patching techniques and associated job aids, training, sensor density, and target activity on operator performance in detecting targets when using unattended ground sensors employed in a grid configuration.

Trained operators interpreted tactical data recorder (RO 376) plots both before and after training using four patching techniques and associated job aids in the grid employment of seismic sensors. The plots represented both 9 sensors per square kilometer grid and 24 sensors per square kilometer grid. Completeness of target detection, number of false alarms, speed estimation error, and target direction deviation were measured.

Patching technique training (and job aids) increased detection completeness by 42%: The row patching technique was selected as the best. Use of the 9-sensor grid resulted in fewer false alarms and equal detection completeness as compared to use of the 24-sensor grid.

Pilette, S., Biggs, B., and Martinek, H. The value of special training for the interpretation of unattended ground sensors employed in a grid. Technical Paper 328, October 1978. (AD A063 594)

Based on an error analysis of unattended ground sensor operator target detection data, a self-paced training program was developed to reduce the

frequency and magnitude of operator errors and increase target detection rate. The first training unit dealt with solitary targets--only one vehicle or vehicle convoy traveling through the grid. The second dealt with target clusters--several vehicles or vehicle convoys traveling through the grid at one time.

To assess the value of training a pre-posttest design was used. Operators monitored for 2 hours activation data from seismic sensors employed in a grid, received the special training, and again monitored for 2 hours. The two monitoring periods were counterbalanced to control for differences in the target activation data. Four workload levels (numbers of targets activating the sensors) were used to ascertain training effects across a range of workloads typical of operational conditions.

The self-paced training program resulted in improved operator performance in target detection and target speed and direction estimation accuracy of both practical and statistical significance. Target detection improved from 58% to 79%, averaged over all conditions. Target detection after training averaged 61%, 66%, 94%, and 97% for the four workload conditions (27, 15, 8, and 5 targets/hour). Speed and direction estimation improved by 23% and 20% respectively as a result of training. The false alarm rate was negligible under all conditions. Conclusions and recommendations for the implementation of this training program and for utilization of grid deployment are provided.

Huntoon, R. B., Schohan, B., and Shvern, U. Visual search performance in simulated remotely piloted vehicle utilization as a function of auxiliary task loading on the observer. Technical Paper 357, April 1979. (AD A072 402)

Baseline data were obtained on how well observers could extract information from a TV monitor while performing auxiliary tasks under task loading conditions that might be encountered in use of a remotely piloted vehicle (RPV) as the sensor platform.

A simulation facility was used. It contained a terrain model, a TV camera transport, hybrid computing equipment, and a television display and control console.

Six pilots and six nonpilots participated in the three-phase effort. Phase A required participants to detect and recognize tank-sized targets in open and cluttered backgrounds from a simulated altitude of 2,000 feet and a simulated RPV velocity of 100 knots. Phase B required participants to monitor and correct deviations in the RPV course and altitude and to respond to two visual warning indicators. Phase B tasks were presented at two rates: one per 10 seconds and three per 10 seconds. Phase C combined the tasks of Phase A and Phase B with concurrent task demands upon the participants.

Increasing the auxiliary load level decreased the probabilities and ranges of target detection and recognition. Target acquisition task demands similarly increased auxiliary task response times. Cluttered background significantly degraded target acquisition task performance, particularly when the auxiliary task was performed concurrently.

Remotely Monitored Sensors

Pilette, S., Biggs, B., and Martinek, H. Requirements for target identification training for the acoustic sensor operator. Research Memorandum 79-4, April 1979. (AD A077 977)

The unattended ground sensor (UGS) operator in the field has few opportunities for formal training, or structured practice in identifying vehicles using the acoustic sensor. Actual operator performance levels are unknown. To assist in defining requirements for operator training, this research was designed to estimate the current performance level of operators under the ideal conditions of identifying vehicles traveling alone (not in convoys) using an acoustic sensor system with a high signal/noise ratio. In addition, the time required to identify a vehicle and the effects of additional training were investigated.

Twenty-four UGS operators identified 120 vehicle sounds which varied by type of vehicle (8) and length of time presented (1, 3, 6, 10, and 15 seconds), received 2 hours of training, and then were retested on the original 120 sounds.

The training produced large increases in operator performance (average of 31%), and decreased the time required to identify a vehicle (from 15 seconds to 6). Practice effects were found, indicating that practice is needed in the field and that training research in this area must be designed so that training effects are not confounded with practice. Operators required 6 to 10 seconds to identify vehicles after training, depending on the specific vehicle type. Selection, using readily obtained measures, of the top third of UGS operators resulted in a 25% increase in performance over that of the "average operator."

Martinek, H., Pilette, S., and Biggs, B. The effects of signal/noise ratio and bandwidth on the vehicle identification, using the acoustic sensor. Technical Paper 377, June 1979. (AD A073 715)

Three experiments were conducted to determine the effect of variations in signal-to-noise (S/N) ratio and increased bandwidth on the ability of remotely monitored sensor operators using the acoustic sensor to identify vehicles in convoy. In general, the operator was to discriminate between the following seven military vehicles traveling in typical convoys: jeeps, gamma goats, 2½-ton trucks, 5-ton trucks, 10-ton trucks, armored personnel carriers, and tanks. Targets were presented at each of four levels of S/N ratio: +6 decibels (dB), +12 dB, +18 dB, and +24 dB. The operational bandwidth of 50-2,000 hertz (Hz) was compared to that of 50-4,500 Hz. Special training under all of the above conditions was given.

The results indicate that operator identification completeness declines as the S/N ratio decreases approximately 1% per 1.5 dB of S/N ratio. No differences were found in use of the two bandwidths. Use of automatic gain control should be limited because the operator uses loudness variations to discriminate among targets.

Remotely Monitored Sensors

Martinek, H. Summary of ARI research on remotely monitored sensors. Research Report 1253, July 1980.

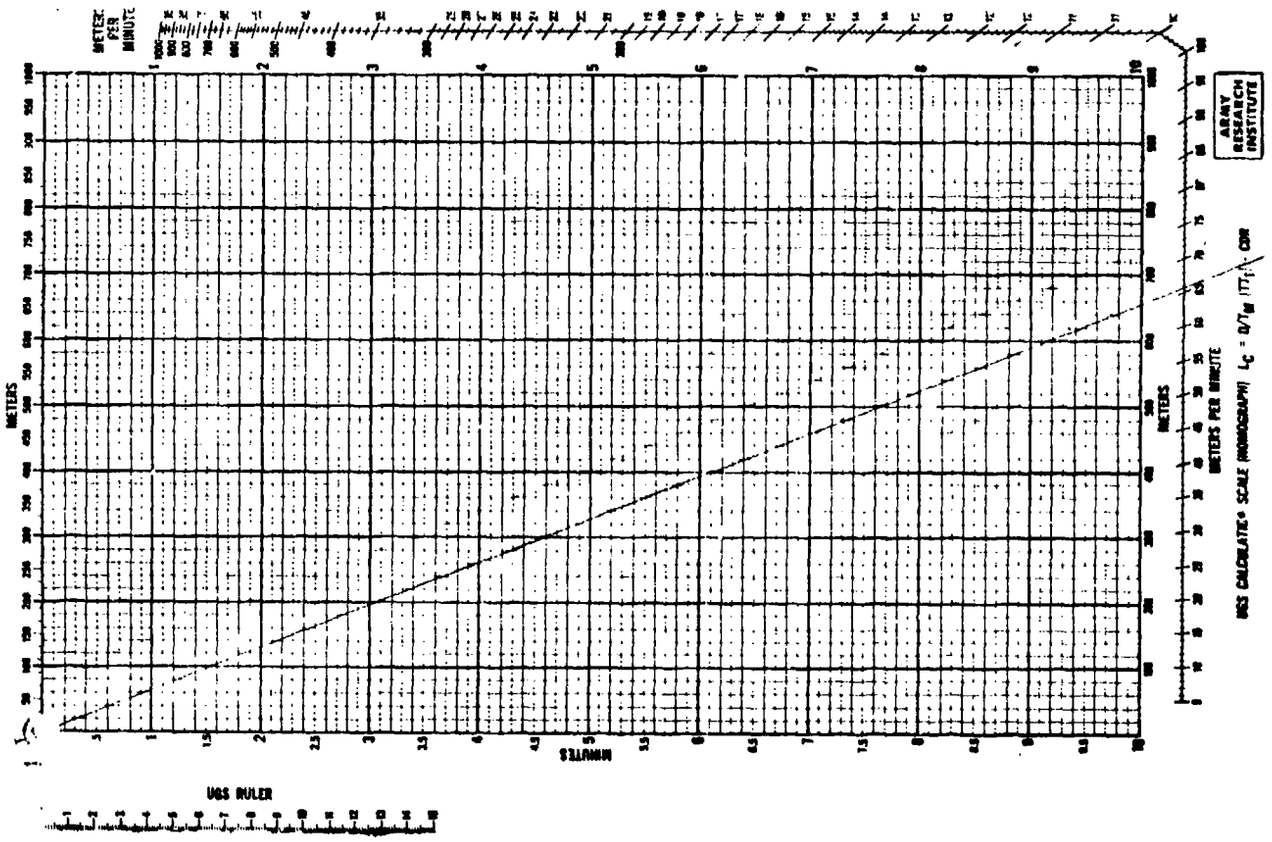
One relatively new source of intelligence information is remote monitoring of the battlefield, using seismic, acoustic, and magnetic remotely monitored sensors (REMS). When enemy personnel or vehicle movement activates these remote sensors, a monitor display located behind our lines indicates the activity. The operator can derive from this display not only the enemy's presence but also such information as direction and speed of convoys and personnel, number of vehicles in a convoy, and convoy composition--e.g., armored versus wheeled vehicles.

This publication summarizes ARI research on user problems of REMS, including direct operational applications of present and future utilization of REMS. Major findings are categorized into five areas--training, operator aids, operational procedures, REMS system design, and personnel requirements.

Special Reports

UGS nomograph and ruler, 1974.

This device was developed for the purpose of quick and accurate calculation of vehicular ground speed based on information obtained from unattended ground sensors.



Remotely Monitored Sensors

Operator's training workbook: Readout problem areas for UGS string employment (with instructor's guide), 1975.

Based on an analysis of operator errors, a training program was developed that stresses individualized instruction including self-pacing, immediate feedback, expert assistance when needed, and guaranteed student-mastery using criterion testing. The eight content areas are: the UGS ruler, 2-sensor strings and formula review, final-points, column-length quantity, irregular activations patterns, EMID, MAGID, and DIRID.

The individualized training program resulted in significantly improved operator interpretation performance in target detection rights, identification rights, target speed, and target quantity estimation. Student acceptance of the individualized training approach was high.

Operator's training workbook: Readout problem areas for UGS grid employment (with instructor's guide), 1976.

Based on an error analysis of unattended ground sensor operator target detection data, a self-paced training program was developed to reduce the frequency and magnitude of operator errors and increase target detection rate. The first training unit dealt with solitary targets--only one vehicle or vehicle convoy traveling through the grid. The second dealt with target clusters--several vehicles or vehicle convoys traveling through the grid at one time.

The self-paced training program resulted in improved operator performance in target detection and target speed and direction estimation accuracy of both practical and statistical significance. Target detection improved from 58% to 79%, averaged over all conditions. Target detection after training averaged 61%, 66%, 94%, and 97% for the four workload conditions (27, 15, 8, and 5 targets/hour). Speed and direction estimation improved by 23% and 20% respectively as a result of training. The false alarm rate was negligible under all conditions. Conclusions and recommendations for the implementation of this training program and for utilization of grid deployment are provided.

Target identification training using the acoustic remote sensor (with training tape recording), 1976.

The five-part training program is recorded on tape and can be used as a self- or a group-administrable package. Part I involves a short instructional briefing, followed by a two-convoy exercise in which the operators identified the vehicles. Feedback is provided to the operators by giving them the correct vehicle identification. The operators record the vehicle names on their target logs so that they can score their interpretations. The operators then are given the same convoys to analyze again as they observe their target logs with the correct identifications marked on them.

Part II involves a comparison of the sound of one vehicle with that of another immediately following. For each paired comparison, the vehicle identities are given before the sounds. Each of the target types (vehicles)

is compared with every other target type for a total of 21 paired comparisons. All target vehicles are traveling in the fast condition--about 40 kilometers per hour (kmph) or 24 miles per hour (mph). This exercise is designed to help the operators remember how the vehicles sound in relation to one another.

Part III involves the same procedures as in Part I, except that two convoys are used. This exercise gives the operators practice on the same vehicle types but with different individual vehicles and with different combinations and variations in signal/noise ratio and loudness.

Part IV involves the same matched-pairs procedure as Part II. However, the target vehicles are traveling slower than in Part II, about 20 kmph or 12 mph. This exercise is designed to give operators a chance to compare the sound of one slow-moving vehicle with another, a distinction required because the sound signatures of vehicles can differ, depending upon speed.

Part V involves a replay of the four convoys that the operators had previously worked with. The convoys are administered in random sequence, and the operators again report vehicle types on the target logs. Feedback is then given, and the operators score themselves. The training was shown to significantly improve operator performance.

Image Interpretation

Birnbaum, A. H., Sadacca, R., Andrews, R. S., and Narva, M. A. Summary of BESRL surveillance research. Technical Research Report 1160, September 1969. (AD 701 907)

The Surveillance Systems research program of the U.S. Army Behavioral Science Research Laboratory (BESRL--now ARI) had as its objective the production of scientific data bearing on the extraction of information from surveillance displays and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. The present technical research report summarizes in integrated fashion the major problem areas, the rationale of BESRL's approach to their solution, and the general course of research studies completed or in progress in the surveillance areas of manned systems experimentation. The research effort is conducted within the following fields: (a) Interpreter Techniques--the determination of interpreter techniques in a surveillance facility; (b) Image Interpretation Displays--influence of displays on image interpreter performance; (c) Intelligence Systems--intelligence information processing systems; (d) Image Systems--information processing in advanced image interpretation systems. Surveillance Systems research programs have resulted in findings which are applicable in optimizing human component performance in existing systems and in providing systems developers with information useful in design specifications for future systems.

Samet, M. G. Checker confidence statements as affected by performance of initial image interpreter. Technical Research Note 214, September 1969. (AD 700 127)

Experiments on interpreter/checker performance have generally concentrated on completeness, accuracy, and timeliness as measures of individual and team proficiency. With the advent of computer-aided intelligence systems, emphasis on techniques for processing probabilistic information has grown. The present publication reports on one aspect of assigning interpreters to work as two-man teams in which one interpreter checks interpretations made independently by his teammate. The study was specifically concerned with determining how different levels of identification accuracy and of confidence validity associated with an initial interpreter affect the confidence validity of the checker. Four equivalent imagery sets of 60 annotated targets were used in the experimental procedure. The first set of 60 targets was assigned to 18 newly trained interpreters in an initial performance test which required the subjects to supply identifications and confidence statements for each annotation. Target identifications and confidence statements attributed to an initial checker were developed for each of the three remaining sets of imagery. In the preliminary test phase, confidence estimates were stated under a point payoff scheme in which it was to the disadvantage of the interpreter to overstate or understate his confidence. Half of the interpreters were given feedback on individual performance. In the experiment proper, each interpreter was given three sets of preannotated imagery with associated hypothetical confidence statements which he was required to examine, note previous identification/confidence information, and then state his own confidence in the given identification. Task performance was accomplished under the point payoff condition.

Analysis of data obtained on seven derived measures yielded the following findings: (a) Checkers typically improved on the confidence validity of interpreters who were poor or only moderately good in stating confidence. (b) Checker confidence statements in identifications made by interpreters with "excellent" record of confidence validity were less valid than those of initial interpreters. (c) Interpreter's confidence statements were more valid when they were checking than when they were stating confidence in their own identifications. (d) Checker's confidence statements were more affected by observed variations in identification accuracy of the initial interpreter than by his confidence validity. (e) Receipt of feedback on initial identification and confidence proficiency had no effect on subsequent checker performance.

Levine, J. M., Feallock, J. B., Sadacca, R., and Andrews, R. S. Method for quantifying subjective costs of large numbers of image interpretation errors. Technical Research Note 218, November 1969. (AD 704 706)

Reliable quantitative estimates of the cost of erroneous items of surveillance information are needed so that intelligence requirements of field commanders can be stated with greater precision. This research developed a practical and rapid method for measuring, in the field, the subjective costs that unit commanders attach to the consequences of decisions based upon different errors or deficiencies in image interpretation. Nearly 3,500 interpretation errors were defined by means of a hierarchical target classification and reporting scheme constructed for the study. Magnitude Estimation (ME) was chosen as the feasible method for determining the interval scale for costs for such a large number of errors. Costs were measured for a sample of several hundred errors directly, based on combat officer judgments, and costs of the remaining errors were predicted by multiple regression analysis. Cost estimates obtained by applying two scaling procedures and the ME procedure were compared statistically to evaluate scale validity, reliability, and sensitivity. Direct cost estimations yielded mean validity coefficients of .67 and .73 based on the two criterion scales; mean reliability was .80. The ME scale was sensitive to differences in the tactical situation--offensive versus defensive--for which the aerial surveillance information was required. The utility of error cost matrices in military situations is discussed.

Cockrell, J. T. Maintaining target detection proficiency through team consensus feedback. Technical Research Note 219, December 1969. (AD 707 376)

An exploratory study, reported on in Technical Research Note 195, "Maintaining Image Interpreter Proficiency Through Team Consensus Feedback," was designed to assess the usefulness of the team consensus feedback process as a possible aid to proficiency maintenance for interpreters in an image interpretation facility. The objective of the present experiment was to determine if the target detection skill of individual interpreters can be improved by feedback which team members generate for themselves as they compare and discuss their work. This experiment differed from the exploratory study in that only target detection was required, rather than detection plus identification. In addition, the experimenter investigated the impact

on individual interpreter performance of (a) size of team (three-man versus two-man); (b) discussion versus no discussion; (c) initial proficiency level of team members; and (d) team composition (heterogeneous versus homogeneous) with respect to initial proficiency level. Sixty USAIS graduates participated in the experiment. Treatment was a 3-day practice session. A pre- and posttreatment test was administered to each interpreter to assess detection proficiency. Interpreters assigned to feedback conditions practiced in teams and were permitted to either discuss or compare their work; the no-feedback interpreters practiced alone and were not permitted to discuss or compare their work with anyone. Neither group received ground truth feedback under the experimental procedure.

It was found, as in previous experiments, that interpreters working in teams with consensus feedback showed greater improvement than interpreters working alone in reducing inventive errors; there was no difference, however, in errors of omission. No difference obtained between discussion versus no-discussion and three-man teams versus two-man teams, but interpreters working in heterogeneous teams showed significantly greater gain in performance on all measures than interpreters on homogeneous teams. Findings also indicated a relatively greater improvement in performance of team members who are initially low in proficiency than those who are initially high in proficiency. From both experiments conducted to date, evidence points to the effectiveness of team consensus feedback in maintaining and enhancing performance of interpreters in field units, particularly in target identification and reduction of inventive errors. The technique appears to be especially useful where ground truth is not available.

Jeffrey, T. E. Unaided reading of coded reconnaissance data. Technical Research Note 220, December 1969. (AD 707 377)

The general objective of the research was to determine the feasibility of having image interpreters decode sensor and terrain information encoded on imagery by direct viewing instead of resorting to use of elaborate code reading machines. The investigation sought specifically to determine: (a) speed with which image interpreters can decode designated positions of the code matrix block (CMB) data; (b) accuracy of decoding performance; (c) usefulness of CMB magnification as a means of enhancing the interpreter's speed and accuracy in decoding matrix content. Subjects in the experiment (16 graduate image interpreters plus one experienced interpreter) read portions of 15 different code matrix blocks arranged in 3 sets of 5 blocks each on which reconnaissance information was encoded. The interpreters had been trained to recognize spatial patterns of dots representing the information to the point of 2 error-free performances. Three 5-man groups decoded each matrix block, each set under 1 of 3 different levels of magnification--single power (unaided eye), 2-power (stereoscope), and 7-power (tube magnifier).

In the experiment proper, achievement was measured in terms of time required for interpreters to locate the required block, decode and record the data, and number of correct decodings. Analysis of the data obtained indicated: (a) Average interpreter was 98% accurate in translation from code to clear language; (b) direct inspection (unaided eye) was not significantly aided by magnification; (c) use of seven-power magnification reduced decoding

time over two-power magnification; (d) practice significantly reduced decoding time; accuracy was not affected. Findings suggest utility of establishing training procedures and providing flash cards for interpreter practice and improvement in recognizing the spatial patterns used in encoding reconnaissance data. In addition, equipping the seven-power magnification now issued in the PI Kit with a reticle designed to aid in defining the data fields would be useful.

Epstein, S. Effects of image incongruence on location of common terrain in comparative cover. Technical Research Note 222, February 1970. (AD 707 441)

The study was designed to determine the effects of differences in photo scale and orientation of early and late cover and of variation in percent of overlap on inventive error, completeness, and speed with which image interpreters identify the comparative cover photographs and confidence in reports. In the experiment 96 trained image interpreters were given the task of locating, on rolls of new photographic cover (late cover), frames depicting the same terrain as that presented in the early cover. There were 12 experimental conditions involving 2 levels of difference in photo scale (1:1 and 1:2), 3 levels of variation in orientation (identical or 0°, 30°, and 180°) and 2 levels of percent of overlap (100% and 50%). A Greco-Latin square counterbalanced arrangement was employed in presenting the subjects (24 groups of 4 interpreters each) with the search rolls and the early cover frame. Interpreter performance was measured in terms of the following criteria: (a) time--number of seconds to locate the relevant late cover frames, (b) frame location completeness--percent of relevant search roll frames correctly selected, (c) inventive errors--number of frames incorrectly selected, and (d) confidence--expression of self-confidence in responses rated on a 3-step scale.

The inventive error, completeness, speed, and confidence of interpreter performance seem to be seriously affected when comparative cover varies in scale and orientation and is not completely overlapping. Specific effects were: Frame location completeness decreased with variation in amount of overlap and with increased scale and orientation discrepancy, overlap differences having the greatest effect. Search time increased significantly with reduced overlap but was less affected by discrepancy in orientation and photo scale. Inventive errors increased with reduced overlap and with greater scale and orientation variation, overlap difference again having the greatest effect. Although reduced overlap and orientation discrepancy decreased interpreter confidence significantly, scale discrepancy had no appreciable effect. Findings suggest that, in operational practice, degrading effects of image incongruence upon interpreter performance in identifying comparative cover can be minimized by the availability of variable magnification and image rotation capabilities in the display system.

Martinek, H., and Bigelow, G. F. Compendium of BESRL performance measures for image interpretation research. Research Study 70-1, April 1970.

The BESRL (now ARI) Technical Support Branch film library maintained a large number of image interpreter performance measures based on imagery

in various media acquired and analyzed by branch personnel. The present publication provides a listing of image interpretation performance measures for which roll film was available in the library as of 1 January 1970.

For each performance measure, identification and description were provided under the following rubrics:

Identification. Roll numbers; number of rolls and number of frames in each roll; consecutive exposures (bursts) or individual scenes.

Use. Appropriate use and reference to relevant BESRL research publications.

Content. Exercise on which flown; terrain; target areas; target types included.

Technical Data. Format, scale, quality, ground resolution, annotations, stereo/nonstereo, transparencies, positive/negative, how reproduced; flight information.

Availability. Form in which available for reproduction and use.

The imagery and the film rolls developed for performance measures have potential utility for future studies in image interpretation by BESRL researchers and research scientists in other organizations. This compendium is designed to provide prospective users with sufficient information for them to identify measures which are suitable for specific research objectives.

Cockrell, J. T., and Sadacca, R. Training individual image interpreters using team consensus feedback. Technical Research Report 1171, June 1971. (AD 747 827)

Four experiments explored various team consensus feedback methods with varying conditions of image interpreter team size and composition. The experiments were directed to developing team practice methods which would lead to the greatest performance gains by individual interpreters in an advanced interpretation system.

The first experiment was designed to obtain a general assessment of the usefulness of the consensus feedback process in both target detection and target identification. The second experiment sought to determine if team consensus feedback would be effective in enhancing target detection performance only. Experiment III evaluated modified team consensus feedback techniques designed to minimize feedback delays. Experiment IV was concerned mainly with the nature of learning curves using team consensus feedback techniques and with evaluation of the most effective procedures identified in the first three experiments.

Team consensus feedback was demonstrated to be an effective method of maintaining and improving image interpreter proficiency in an operational image interpretation facility. Greatest performance gains were made in target identification. Results showed that interpreters who were

initially low in proficiency achieved the most significant gains in performance. Low proficiency interpreters learned from, or benefited through their collaboration with, higher proficiency interpreters. Neither team discussion nor team size significantly affected interpreter performance; however, these variables did combine to produce an overall effect. The ideal procedure seems to be one using three-man teams, heterogeneous in terms of initial proficiency, in which individuals first perform initial interpretation on an individual basis and then discuss their identifications freely in deciding on the team report.

Jeffrey, T. E. Vertical photographic coverage obtainable with varying film format, film footage, lens focal length, altitude, overlap, and sidelap. Research Memorandum 77-2, June 1972. (AD A079 384)

Two tables are presented that make it possible to obtain an estimate of the linear and area coverage obtainable on 25 feet of 70 mm film using a vertical camera equipped with one of three specified focal length lenses, at altitudes ranging from 500 feet to 21,000 feet, with or without overlap on successive exposures and with or without sidelap between successive runs of the mission. Table 1 is used to determine the denominator of the photo scale of the imagery. This value is called the Photo Scale Reciprocal (PSR). PSR is used to enter Table 2 to obtain the desired area coverage. Area coverage is given in square meters and for four different conditions--no overlap and no sidelap, no overlap and 10% sidelap, 60% overlap and no sidelap, and 60% overlap and 10% sidelap. The effect of film format on the amount of ground coverage is not directly given, but can be estimated from Table 2 data. Table 1 can be used to determine the mission altitude and/or lens/focal length that must be used to obtain imagery of the desired scale.

Narva, M. A. Consideration of the AR-85A viewer-computer for use in computer-aided instruction in image interpretation. Research Memorandum 72-3, June 1972. (AD A079 385)

The feasibility of using the AR-85A Viewer-Computer as a vehicle for administering computer-assisted training in image interpretation is assessed. The Viewer-Computer, designed to be used for mensuration and reporting functions, includes a limited computer capacity with associated limited input-output capabilities. When this capability is not being used for its principal functions, it would possibly be used as a tool for instruction. The most promising use would appear to be in identification training and in the presentation of feedback to the trainee. Small units of instruction might be feasibly incorporated at various points in the program of the individual trainee.

Lepkowski, J. R., and Jeffrey, T. E. Some factors affecting mensuration variability among image interpreters. Research Memorandum 72-7, September 1972. (AD A079 387)

From results of this exploratory study, the following tentative conclusions were drawn: (a) The use of interpreter scales or reticles graduated to thousandths of a foot or in millimeters had no significant effect

on mensuration variability. (b) Measurement variability for targets of the size used in these experiments did not vary significantly with target ground size. (c) Imagery scale had no significant influence on the variability of target measurement. The significant interaction obtained in the four-factor analysis between target size and imagery scale was probably an artifact. (d) Magnification level had no significant effect on mensuration variability. (e) Measurements made using reticles appeared to be less variable than those made with an interpreter scale. (f) Interpreters tended to maintain their relative position from measurement task to measurement task with respect to the mean measurement of the group.

Martinek, H., Hilligoss, R. E., and Herrington, B. Effectiveness of an error key for image interpretation in Vietnam. Technical Research Note 230, September 1972. (AD 752 437)

Experimentation to develop a specialized reference key to enable interpreters to avoid certain common errors in reporting information derived from imagery taken over Vietnam is reported here. The research was undertaken to construct and validate a new type of reference--an error key--for use in Vietnam. The key was constructed from operational imagery of Vietnam territory with annotations pointing out types of error to be avoided. Evaluation was conducted using trained interpreters to determine if use of the error key would achieve the following effects on image interpreter reports: (a) increase number of right responses; (b) decrease number of wrong responses; and (c) increase accuracy of identification.

Performance results achieved by 122 enlisted image interpreters (recent II Course graduates) were used in evaluating effectiveness of the error key. Each of two matched groups interpreted two sets of imagery, one set using the error key, the other without using the key. Analysis of results showed that (a) the BESRL error key significantly improved the accuracy of inexperienced interpreters in dealing with operational imagery on Vietnam--39% increase in rights, 26% decrease in errors made, and 43% increase in accuracy rate; (b) the error key significantly improved the completeness of reporting on the subject imagery; and (c) differences in performance as a function of mission and group were evident.

For optimal operational use, the present key should be extended to include different areas of Vietnam, different scales and types of photography, and different sensors such as infrared. There is apparent advantage to be obtained in use of the key in the field (Vietnam) and for training in the Image Interpretation (II) Course.

Martinek, H., and Hilligoss, R. E. Accuracy and completeness of interpretation as a function of time for selected conditions. Research Memorandum 72-6, October 1972.

Assignment of image interpreter personnel and procedures applied must ultimately take into account the time required for varying degrees of accuracy and completeness of interpretation. A beginning was made in an effort to determine the relationship of accuracy, completeness, and time spent in

interpretation under a variety of conditions and to obtain some parametric data concerning these variables. Curves are presented showing these relationships.

Jeffrey, T. E., and Beck, F. J. Intelligence information from total optical color imagery. Research Memorandum 72-4, November 1972.

This report describes an evaluation of total optical color (TOC) imagery as a source of intelligence information. The imagery consisted of aerial surveillance photographs acquired over the UNDERBRUSH test range at Eglin Air Force Base. The Total Optical Color (TOC) 35 mm system was compared to a system providing conventional color imagery and to a system providing monochromatic imagery. The only performance index showing significant difference between chromatic and achromatic color presentation was time taken to extract information from a slide. Black-and-white imagery required about 20% longer than the color.

Information extraction can be accomplished more rapidly from chromatic than from achromatic color imagery. The time savings is accomplished with no decrease in the accuracy or completeness of target detection and identification. Subjects expressed a preference for color imagery over black-and-white, and for imagery on conventional color film over the achromatic color imagery from the TOC system.

Narva, M. A. Evaluation of selected pictorial characteristics of reference materials for use in image interpretation. Technical Research Note 233, November 1972. (AD 754 567)

Three related experiments investigated the characteristics of pictorial content of reference materials (keys) used by image interpreters with a view to determining the most effective way of representing objects in the key. The set of experiments was concerned with obtaining information pertaining to the optimal manner of presenting recognition features in a key so as to aid an interpreter in final identification of an object seen in imagery. Each experiment involved different combinations of the characteristics under study--(a) type of presentation (use of photographs or outline drawings, or both), (b) viewing angle (vertical, oblique, or both), and (c) scale of the image in the key (large or small). In the first experiment, computer-aided procedures for selecting the category of the object imaged were included. In experiments two and three, no computer aids were employed. The interpreter used only the key which contained no textual material. In each experiment, recently graduated image interpreters identified a series of 16 vehicles organized into four sets and presented in a balanced research design. Two levels of quality were used in the test imagery.

Performance was more rapid with photographs than with line drawings when the key was used with a computer-assisted category selection procedure. When the key was used alone, no difference between photographs and drawings was found in speed or in number of correct identifications. No advantage was obtained in presenting more than one viewing angle nor by presenting photographs and schematic representations together. Reduced scale in the key images required greater identification time, but did not result in

greater accuracy. A net result of the experimentation is to permit greater leeway in the materials included in keys and in the manner of presentation.

Epstein, S., and Jeffrey, T. E. Common area demarcation, target annotation, and target lists as aids in change detection. Technical Research Note 238, March 1973. (AD 761 128)

Experimentation to improve performance in detecting changes that may have occurred in a given area between photographic reconnaissance missions sought to determine whether change detection in image interpretation is improved by (a) demarcation of common areas in early and late imagery, (b) annotation of targets on early imagery, and (c) use of a list of targets appearing on the early imagery.

Image interpreters (N = 88) were given a change detection task on nine pairs of early and late photographic cover. The interpreter subjects were assigned in groups of 11 to each of 8 treatment combinations of the 3 variables. Performance was evaluated in terms of number of correct change detections with respect to "unchanged," "gone," and "new" targets, number of erroneous detections, and total working time. Principal findings of the study show that (a) the presence or absence of common area demarcation had no significant effect upon the mean number of correct change detections in any of the three change categories; (b) providing the interpreter with target information in the early cover significantly increased mean number of correct change detections for "unchanged" and "gone" targets; (c) common area demarcation did not decrease the mean number of erroneous change detections; (d) use of target lists also increased the mean number of correct detections, but at the same time increased the number of "false alarms," and increased working time by about 20 percent; (e) combined use of target annotations and target lists to provide information about early cover imagery appears to maximize the number of correct change detections.

Kause, R., Thomas, J. A., and Jeffrey, T. E. Coordinate determination of SLAR imaged features. Technical Research Note 234, April 1973.

This research project was conducted to improve the performance of operators in interpreting SLAR (side-looking airborne radar) imagery in real-time or near real-time inflight display systems. The principal objective of this experiment was to determine the precision with which image interpreters can determine the coordinate location of targets detected on a near real-time SLAR display or in a simulated situation.

In the experiment, 22 graduate enlisted interpreters performed in small groups (no more than 6) as airborne sensor operators. After about 4 hours spent in a review on radar interpretation and the use of GEO (geographic) and UTM (Universal Transverse Mercator) grid systems, the men were given 2 tasks under 4 treatment conditions. The tasks were (a) to identify and provide location coordinates for targets annotated on the imagery (directed search) and (b) to detect, identify, and locate tactical targets on an unannotated imagery (free search). Each task was performed using imagery acquired by a noncoherent radar system AN/APS-94 and again using imagery acquired by a coherent system AN/APQ-102A. Other factors varied were

topographic maps versus radar mosaics for determining ground location, and UTM versus GEO coordinates for reporting location. Performance was evaluated in terms of accuracy and completeness in target location, in target detection, and in target identification.

Neither directed nor free search resulted in location data that met general operational requirements for accuracy. In both directed and free search, accuracy and completeness of target identification was significantly better with noncoherent imagery. In free search no differences obtained across sensors for accuracy and completeness in target detection. Over the entire range of location errors, the median error for those reporting GEO coordinates was 4,600 compared to 5,900 for those reporting UTM coordinates. Findings point to need for development of improved operator techniques so that targets detected in SLAR imagery can be more accurately located.

Kause, R., Thomas, J. A., and Jeffrey, T. E. Effect of training on coordinate determination of SLAR imaged features. Technical Research Note 235, April 1973. (AD 762 342)

This research developed and evaluated a training program to improve the performance of operators in locating targets in side-looking airborne radar (SLAR) imagery. This study developed a trainee-participation instructional program with immediate feedback and assessed its effectiveness in enhancing image interpreter performance with respect to accuracy in locating and identifying map coordinates of detected targets.

A four-phase instructional unit was developed varying in imagery and map scale, orientation cues, and presentation order. The experimental subject group (12 school-trained interpreters) performed two tasks involving detection, identification, and determination of location data for SLAR imagery targets under conditions of directed search and free search. Performance of the experimental group was compared to that of a control group who performed the same tasks under the same conditions but who had received no individualized pretest training.

The use of a systematic training procedure coupled with immediate feedback (knowledge of results) yielded improved performance in the determination of coordinate location of tactical targets annotated upon SLAR imagery. The experimental group determined location data for targets with greater precision than did the control group. Accuracy scores were lower for the interpreters who had been given specialized training than for the control group. Absolute magnitude of location errors in both groups exceed that specified as operationally acceptable. This aspect may be particularly critical when considering the use of small-scale SLAR imagery and a relatively small-scale topographic map (1:250,000). An improved version of the experimental instructional unit developed should prove useful in increasing interpreter effectiveness in correlating SLAR imaged positions with map locations.

Image Interpretation

Jeffrey, T. E. Effect of photo degradation on interpreter performance. Technical Research Note 245, June 1973. (AD 763 908)

Scale, haze, and image motion were judged to be the key factors in determining the interpretability of photographs encountered operationally, and images varying in these factors were produced by manipulating operational imagery in the laboratory. Image interpreters were given tasks of detecting and identifying military targets on these images. Their scores were used to assess interpretability as a function of scale, haze, and image motion.

Results of the experiment showed: (a) When considered singly, scale, haze, and image motion had little effect on interpreter target detection performance. When two or more of these sources of degradation were present simultaneously, target detection performance deteriorated markedly. (b) In general, the decrease in target detection accuracy obtained with increased photo degradation appears to be due more to erroneous classification of nontargets as targets than to the misclassification of targets as nontargets. (c) Target identification accuracy and completeness were significantly reduced by either unidimensional or multidimensional degrading conditions of the type used in this experiment. (d) When photographic scale was small, the effect of other sources of degradation on interpreter performance was significantly greater than when photographic scale was large.

The findings provide direction for a continuing search for improved techniques for predicting the utility of aerial reconnaissance photographic missions and for guiding the establishment of mission requirements.

Powers, J. R., III, Brainard, R. W., Abram, R. E., and Sadacca, R. Training techniques for rapid target detection. Technical Paper 242, September 1973. (AD 768 194)

Basic to the acquisition of intelligence information from aerial surveillance/reconnaissance sensor products is the ability of the image interpreter to detect (distinguish objects from their background) and correctly identify targets on the product imagery. This publication reports on the evaluation of two systematic search strategies and a "speed-reading" technique for use in training interpreters to search imagery more rapidly and to improve detection accuracy and completeness.

Systematic search strategies for increasing detection completeness and for reducing inefficient search behavior were (a) geometric (structured practice in executing a geometric search pattern) and (b) tactical (structured practice in executing a content-oriented search pattern). To complement the search strategies, a "speed-reading" technique was developed to reduce visual fixation time and expand the size of the perceptual field, through "speeded search"--practice under free search conditions with emphasis on speeded performance. A fourth and control condition allowed practice under free search conditions without emphasis on speeded performance. Eight subjects were assigned to each of the four experimental conditions, and their pre- and posttraining target detection performances were compared. An error-avoidance training technique was also tried out.

Training in the two strategies increased the number of target detections over pretraining levels and also increased the number of inventive errors. The speeded search group made the greatest gain in image search speed, close to 200%, which was achieved without loss of accuracy of completeness. The separately studied error avoidance training technique, using an error key approach, substantially reduced inventive errors. Error avoidance training used with training in rapid systematic or free search appears helpful in improving detection performance.

Clarke, F. R., Welch, R. I., and Jeffrey, T. E. Development of a psychophysical photo quality measure. Research Report 1178, January 1974. (AD 776 369)

In extracting information from aerial reconnaissance/sensor products, the image interpreter must often work with imagery of less than ideal quality. The Surveillance Systems research program of the Army Research Institute is designed to identify factors of photo quality that can help measure the interpretability of operational imagery. In the present experiment, image scale, atmospheric haze, and image motion were judged to be key factors in operational interpretability of imagery. Laboratory manipulation of representative operational images produced experimental images with controlled degradation of these three factors, separately and in combination. Image interpreters were asked to detect and identify military targets on this degraded imagery. Their scores were used to assess interpretability as a function of scale, haze, and image motion. In a parallel experiment, geometric shapes were positioned on background panels of black, white, and grey. Photographs of this array were degraded with respect to scale, haze, and image motion to the same levels as the first experimental imagery, and similar tests were conducted.

Degradation of image quality by changes in scale, haze, or image motion, taken singly, had little effect on interpreter performance in target detection or identification. When more than one factor was degraded in the same image, however, significant degradation in performance was noted.

A simple model based on ground-resolved distance, a variable combining the effects of scale, haze, and image motion, effectively predicted interpreter performance for actual aerial imagery and for the parallel tests using fabricated geometric target shapes on constructed model imagery. A prototype catalog of image quality previously developed by ARI with variants in scale, sharpness, and scene complexity also predicted the interpretability of the aerial imagery used.

Analytical models such as these can measure the interpretability of aerial reconnaissance imagery, and thus aid in selecting the more interpretable frames and enabling skilled interpreters to extract intelligence information most efficiently. The fabricated imagery arrays are useful as low-cost research tools for identifying image quality factors independently of scene content.

Image Interpretation

Levine, J. M., and Eldredge, D. Effects of ancillary information upon photointerpreter performance. Technical Paper 255, September 1974. (AD 785 706)

This report evaluates the improvement of photointerpretation performance achieved by providing ancillary intelligence information to the photointerpreter. The research is presented in two sections: a reprint from Human Factors, 1972, 14(6), 549-560; and an appendix that supplements the journal article with additional detail on the photointerpretation task studied and the methodology employed.

Thirty-two trained surveillance officers identified single annotated targets within controlled and matched sets of imagery. For each annotation, the subjects' task was to provide a vector of subjective probabilities, with each probability representing the estimated likelihood that a particular target name was the correct identifier for the annotated item.

Half the subjects were provided with ancillary intelligence information at the time they evaluated the image displays; the other half made their evaluations without information, then made a second and revised evaluation using the ancillary information. Four modes of performance were examined: no information, simultaneous information/image interpretation, postinformation (the revised evaluation), and computer integration (in which a computer integrated interpreter no-information evaluations with the ancillary information). Half the information supplied was qualitative in nature, half quantitative; information variables, which included target difficulty, credibility, and consistency, were arranged so that their influence on interpreter performance could be assessed. A two between-subject, seven within-subject factorial research design was employed.

The results indicated that the provision of ancillary information enhanced accuracy of identification regardless of whether the information was qualitative or quantitative, and regardless of whether that information was presented simultaneously with or subsequent to the imagery. Furthermore, under the conditions of this study, the integration function proved to be best carried out by the interpreter, not by computer.

Root, R. T., Myers, L. B., and Narva, M. A. Effects of acquisition parameters on interpretability of infrared imagery (U). Technical Research Note 240, December 1974. (CONFIDENTIAL) (AD C000 358)

Infrared sensing systems permit the acquisition of intelligence information under an extended range of weather conditions, provide round-the-clock collection capability, and permit the collection of information not obtainable with other systems. This research investigated the influence of various factors involved in the acquisition of infrared imagery upon the interpretability of the imagery and to determine what information may be obtained under various conditions. Inexperienced interpreters, after a brief training course, were asked to interpret sets of imagery that presented selected combinations of acquisition parameters in order to discover the influence of each parameter on interpretability. The results can be useful in planning imagery acquisition missions.

Image Interpretation

Root, R. T., Young, R. B., and Narva, M. A. Characteristics of reference keys for use in the interpretation of infrared imagery (U). Technical Paper 248, December 1974. (CONFIDENTIAL) (AD C000 538)

ARI's surveillance systems research program produces scientific data bearing on the extraction of information from surveillance displays, and on the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. The present report deals with determining the most effective content of reference keys for use in interpreting infrared imagery.

Cockrell, J. T. Evaluation of four target-identification training techniques. Technical Paper 301, August 1978. (AD A061 175)

As part of a research program seeking more efficient methods of training image interpreters in target identification, four alternative experimental instructional techniques were evaluated. Eight recently trained image interpreters used each method (N = 32). Two of the four methods used pictures instead of text, one in a random presentation and the other in a structured sequence of increasing difficulty. The third method used programed text to teach verbal identification cues, and the fourth combined programed text in the first half and the structured pictorial method in the last half of training. In each method, half the students received feedback of both the correct answer and the reason a wrong answer was wrong, and half received only the correct answer.

Students were evenly divided across all conditions by their general technical (GT) aptitude score: high (at or above 124) and low (below 124).

Posttests on visual target identification and verbal target cues evaluated the effectiveness of the methods and feedback conditions for each GT level.

Target identification performance was significantly poorer with the structured text method but about the same among the three methods using pictures. Recognition of target cues was significantly better when verbal instructions on target cues were given than when training was entirely pictorial. Type of feedback had no significant effect. Learning performance did not differ as a function of GT aptitude, but interpreters with lower aptitude forgot their training more rapidly.

Lepkowski, J. R. Image interpreter screening performance as affected by resolution, presentation rate, and scale. Technical Paper 335, September 1978. (AD A064 262)

This study measured performance levels of image interpreters, using both direct viewing and viewing with magnification, to screen 70mm photographic imagery moving at six different rates and varying in scale and resolution. The resolution of the imagery was varied to simulate imagery obtained with different transmission bandwidths. The results were as follows:

1. There was little loss in screening accuracy at any level of resolution and/or magnification for frame presentation rates of 6.0 to 1.5 sec/frame with the 1:2,000 scale imagery and 6.0 to 2.0 sec/frame for the 1:4,000 scale imagery.

2. In general, the poorer the image resolution, the lower the screening accuracy.

3. For constant display format and image resolution, screening accuracy was significantly greater for the larger scale display.

4. Two-power optical magnification of the photographic imagery resulted in a decrease in screening accuracy. Increasing viewing time for magnified imagery by a factor of four so that the incremental area viewed per second was equated for direct and magnified viewing resulted in no significant difference between the two viewing conditions.

Tradeoffs are possible between and among the factors of scale, presentation rate, and resolution.

Sewell, E., Bradie, R., Harabedian, A., and Jeffrey, T. The effects of photo characteristics upon location determination in a photogrammetric facility. Technical Paper 346, October 1978. (AD A062 255)

The operator of the Army Analytical Photogrammetric Positioning System (APPS) must perform a critical step in the coordinate determination procedure by the subjective comparison of dissimilar images. He must correlate reconnaissance mission imagery with aerotriangulated photographic stereoscopic pairs, known as data base imagery, and visually identify the image position on the data base of a target detected on the mission image. Results obtained from 40 image interpreters performing this task using vertical, oblique, and panoramic mission imagery are given. Two levels of target position difficulty were established: (a) A-points located at terrain or man-made features mutually identifiable on both mission and data base imagery; (b) B-points remote from terrain or man-made features mutually identifiable on mission and data base imagery.

Transfer of A-points for vertical, oblique, and panoramic photographs was accomplished with good accuracy--median location error was 19 meters or less. Performance was significantly better when A-points in panoramic missions were located in the near-vertical half of the image in contrast to the near-horizon half. Similarly, panoramic mission imagery in film transparency form resulted in more accurate transfer than when presented as an opaque paper print.

Transfer of B-points was more difficult. For vertical missions, median location error was about 20 meters. For oblique or panoramic imagery, location errors were markedly greater when the B-points were located in the horizon half of the image as compared to performance when the points were in the near-vertical half of the image. B-points in the horizon half of low panoramic missions were more accurately transferred when in film transparent format than when displayed on opaque paper prints.

Sewell, E., Harabedian, A., and Jeffrey, T. Mission/data-base imagery correlation techniques (M/DICT). Technical Paper 347, October 1978. (AD A064 264)

The Analytical Photogrammetric Positioning System (APPS) was developed to determine accurate target location data. APPS operators transfer target locations from mission images to a vertical data-base photograph in determining target coordinates.

The speed and accuracy with which experienced interpreters of side-looking radar, infrared, and television images transferred annotated locations from such sensor images to a vertical data-base photograph were determined. Annotated locations used were A-type (those on or near a terrain feature identifiable on mission and data-base images) and B-type (those 200 or more meters distant, on the ground, from such mutually identifiable features). Transfer techniques were of two kinds: (a) direct transfer in which visual correlation of mission and data-base images was used; (b) indirect transfer where the required point was transferred using a photogrammetric transformation method employing auxillary points that were mutually identifiable on mission and data-base images.

Results from nine interpreters are summarized below:

Proportion of Transfers by Error Range (Meters)

Transfer technique	A-type locations			B-type locations		
	25%	50%	75%	25%	50%	75%
Direct	0-21	0-34	0-52	0-39	0-75	0-130
Indirect	Same as above			0-35	0-54	0-64

The improved accuracy of the indirect method for B-type locations requires more time. Direct transfer required about 1.3 minutes per target on the average while indirect transfer per target on the average was five times that amount of 6.5 minutes per target.

Sewell, E., Harabedian, A., and Jeffrey, T. Total system accuracy for APPS (The Analytical Photogrammetric Positioning System). Technical Paper 348, October 1978. (AD A063 595)

The accuracy and speed with which experienced APPS operators can obtain UTM coordinates and the elevation above the datum plane for points of interest designated on various reconnaissance imagery types were determined. These points of interest were transferred by an analytical method from representative operational imagery--panoramic photography, infrared, and radar--to 1:100,000 scale data base photography and their UTM coordinates and elevation above the datum plane determined. Results were compared with known values and error magnitudes and performance time requirements obtained. Results indicate that experienced APPS operators are very consistent in their

placement of points of interest under the reference dot (monocular pointing). (NOTE: All distances are reported at ground scale and not at the distance measured on the data base image.) The median variability error was 1.6 meters in the XY-plane. Time required per point for monocular pointing was about .18 minutes. On the average, stereoscopic pointing--the placement of the point of interest in the three-dimensional data base model in apparent contact with the floating reference dot--was accomplished with a median elevation error of 3 meters, a median XY-plane error of 6 meters, and a median total error of 7.5 meters. Median time required per point for stereoscopic pointing was .8 minutes. Finally, the transfer of a point of interest from a reconnaissance to data base image combined with stereoscopic pointing gave results that varied with the type of reconnaissance imagery used. For infrared imagery, median elevation error was 5.7 meters, median XY-plane error was 9.5 meters, and median total error was 12.3 meters. The median time per point to transfer and obtain coordinate data was about 7 minutes. Similar but somewhat larger median errors were obtained for panoramic and radar reconnaissance missions. The speed and accuracy with which these experienced APPS operators determined coordinate and elevation data are well within the initially stipulated requirements.

Huntoon, R. B., Schohan, B., and Shvern, U. Visual search performance in simulated remotely piloted vehicle utilization as a function of auxiliary task loading on the observer. Technical Paper 357, April 1979. (AD A072 402)

Baseline data were obtained on how well observers could extract information from a TV monitor while performing auxiliary tasks under task loading conditions that might be encountered in use of a remotely piloted vehicle (RPV) as the sensor platform.

A simulation facility was used. It contained a terrain model, a TV camera transport, hybrid computing equipment, and a television display and control console.

Six pilots and six nonpilots participated in the three-phase effort. Phase A required participants to detect and recognize tank-sized targets in open and cluttered backgrounds from a simulated altitude of 2,000 feet and a simulated RPV velocity of 100 knots. Phase B required participants to monitor and correct deviations in the RPV course and altitude and to respond to two visual warning indicators. Phase B tasks were presented at two rates: one per 10 seconds and three per 10 seconds. Phase C combined the tasks of Phase A and Phase B with concurrent task demands upon the participants.

Increasing the auxiliary load level decreased the probabilities and ranges of target detection and recognition. Target acquisition task demands similarly increased auxiliary task response times. Cluttered background significantly degraded target acquisition task performance, particularly when the auxiliary task was performed concurrently.

While the results of the research are important to military management, research scientists will be the principal readers of the report.

Image Interpretation

Evans, L. A., and Swenson, R. C. Vectors of probable accuracy of image interpreter performance. Working Paper HF-79-05, June 1979.

The purpose of this report was to investigate techniques for obtaining complete probability vectors for each target reported by an image interpreter. Three general techniques were compared. Three groups of trained Army image interpreters were used, each group employing one of the three probability vector generating techniques. A hierarchically organized target list was developed for the interpreters' reports. Knowledge-of-results training was given to improve the interpreters' ability to estimate the probable accuracy of their reports. Test sessions examined transfer of feedback training and differences in judgment techniques to a free search interpretation task. The feasibility of using multiple regression prediction equations to improve the interpreters' direct estimates of their probable accuracy was also investigated. Of the techniques investigated, the direct name vector approach appeared to maximize the amount of information which could be obtained. Since the basis on which interpreters made estimates appeared to change from training to test sessions, the multiple regression adjustment procedure was inconclusive.

Laymon, R. S. Studies of image interpreter estimates of unit identification. Working Paper 79-06, June 1979.

Four pilot studies were conducted to obtain information as to how well relatively inexperienced image interpreters could estimate probabilities, probability vectors, and make confidence estimates with respect to large military units given the compositions of the units and a sample of targets from one of the units. The units were defined as company or battalion level units consisting of a variety of vehicles. The sample was a subset of vehicles from one of the units. Several procedural techniques for enhancing subject performance were studied as well as various characteristics of the samples and units. By and large, the sample/unit problems used in these studies were too difficult for the subjects to provide useful information. This result indicates that for the types of units used in these studies, that is, company and battalion level units with sample sizes ranging up to 75% of the unit, relatively naive image interpreters should not be permitted to make such judgments.

The results of Study Four do provide some specific data on certain sample/unit characteristics that appear to enhance or degrade performance. Further, experience in operating the computer program developed for Study Four indicates that the tasks imposed by these studies may be reasonable for interpreters who receive intensive training to make similar judgments by means of this computer program.

Recommendations for further research are discussed.

Martinek, H., and Zarin, A. The effects of bandwidth compression on image interpreter performance. Technical Report 396, August 1979. (AD A077 840)

Conventional imagery differing in resolution (8-inch ground resolved distance (GRD), 16-inch GRD, and 24-inch GRD), digitized and treated to

represent four levels of bandwidth compression (1:1 = no compression, 4:1, 8:1, and 10:1) was interpreted by 12 experienced image interpreters. A Greco-Latin square design was used to control for differences between interpreters, imagery subsets, and period effects at each GRD and to test the effects of bandwidth compression. The dichotomized image variables of sun angle, image contrast, and target obscurity were distributed equally across all conditions, but could be analyzed only for the 24-inch GRD imagery. Significant decreases were found in the number of correct identifications due to bandwidth compression; the largest decrease occurred between 4:1 and 8:1 bandwidth compression ratios. System developers should make careful trade-off evaluations in using bandwidth compression. More research in this area is required on the search function of interpretation and interactions of image variables.

Montgomery, C. A., Thompson, J. R., Katter, R. V. Imagery intelligence (IMINT) production model. Research Report 1210, January 1980. (AD A086 455)

The Imagery Intelligence (IMINT) Production Model presented in this report was developed as a part of a study entitled "Investigation of Methodologies and Techniques for Intelligence Analysis," which is aimed at constructing a model of the cognitive processes underlying intelligence analysis. The approach to constructing such a model is based on the investigation of analytical processing in two types of single source analysis (SIGINT and IMINT), subsequently generalizing to multisource analysis. For the purposes of this investigation, intelligence analysis was defined as a spectrum of analytical judgmental activities involved in the processing and production of intelligence, where particular individuals may devote more or less time to different aspects of such activities according to their individual roles in the intelligence cycle.

The IMINT production model described in this report was developed to serve as a basis for selecting IMINT processes involving high analytical and judgmental content for further study, directed at understanding the cognitive functions that underlie these IMINT processes. Thus, the model was constructed with a specialized focus, for the purposes of the study described above. Rather than concentrating exclusively on either strategic or tactical IMINT, the model was designed to encompass both dimensions of IMINT. The rationale for this decision was the fact that imagery interpretation analysts (IIAs) with more than minimum length of service are likely to operate in each type of mission at some time in their career, demonstrating the practical assumption that the required knowledge base and cognitive skills are similar for the two dimensions of IMINT. The imagery interpretation analyst is the true generic focus of the IMINT production model presented in this report; in order to gather data for developing the model 56 interviews with IIAs were carried out at 8 sites, including both strategic and tactical missions.

The report contains three sections: an introduction, an overview of the IMINT production model, and the model description. Section 1 describes the IMINT model in the context of the study discussed above, and also treats the scope of the model and the collection of the information on which the model is based. Section 2 presents an overview of the model, describing

findings about the role of the imagery interpretation analyst, the impact of management on analysis, the IMINT time dimension, and the special role of informal information channels in IMINT analysis. This section also describes the format of the model description, which is represented in terms of hierarchical input-process-output (HIPO) charts. Section 3 presents the model, which is segmented into two major parts: IMINT production management activities and IMINT processing, analysis, and reporting activities.

Jeffrey, T. E., Martinek, H., Shvern, U., and Johnson, E. M. Summary of ARI image interpretation research. Research Report 1252, July 1980.

Image interpretation research conducted at ARI has produced scientific data on improving the extraction of information from surveillance displays and on the efficient storage, retrieval, and transmission of this information. This report summarizes research on image interpretation completed by ARI between 1970 and 1979, organized according to nine major problem areas. The rationale of ARI's approach to the problem, findings, operational applications, and further research requirements are presented for each area. The research areas cover image interpretability, real-time and near real-time imagery interpretation, man/computer decision processes, change detection, mensuration and coordinate determination, training and proficiency maintenance, key development, and reconnaissance resource management and utilization. Continued utilization of these research findings can enhance the performance of the human component in current systems as well as provide information for system developers to help them provide design specifications for future systems and to determine areas needing further research.

Ray, T. E., King, R. B., and Narva, M. A. Experimental investigation of near real-time interpretation techniques for transmitted imagery (U). Research Note 80-24, August 1980.

Eight interpretation concepts such as might be utilized at a ground terminal in conjunction with the handling of transmitted imagery were simulated. Four were one-man concepts while the other four utilized two-man teams viewing the imagery in sequence. The one-man concepts were formulated around different combinations of the elements of availability of film speed control, viewing area, and methods of target designation and location reporting. The two-man concepts differed on the availability of speed control and the decision criteria for the initial man of the team and the associated rescreening strategy of the second man of the team. Military image interpreters detected, identified, and reported targets on the imagery, presented on motorized light table under two film input rates, utilizing the conditions of the various experimental interpretation concepts. Interpretation performance was found to be influenced by the size of the viewing area and the use of a magnifying reticle to localize targets, in the one-man concepts. The incorporation of the speed control option did not significantly affect performance. Provision for control of film movement or differential emphasis on accuracy or completeness had no significant effects in the two-man concepts.

Image Interpretation

Root, R. T., Ray, T. E., Brahosky, A. E., and Narva, M. A. A study of the design and utilization of an infrared data base for an advanced image interpretation facility. Research Note 80-25, August 1980.

A reference information data base for use in an advanced image interpretation facility was designed. The data base utilized three types of organization. Two types of organization utilized primarily representative infrared imagery examples. One type presented views of several targets under one set of acquisition parameters while the second type presented views of one target type under all of the acquisition conditions. The third type of organization utilized primarily textual information. An indexing scheme and retrieval methodology were devised. The experimental data base, with associated software, was utilized to subject-developed concepts to empirical test. One test was designed to ascertain if structured exposure to the data base would increase interpreter proficiency while another test was designed to study the efficiency of such a data base as an aid during interpretation.

It was found that the request formats used on the CRT computer interface could be efficiently utilized with little training. The information presented on the slides in the data base could be easily utilized for training and as reference keys. Structured exposure to the data base in training sessions served to increase the participants' proficiency in identification, at the category level. However, no differences were found in performance between the two organizations of the imagery in the data base.

King, R. B., Cooper, L., and Jeffrey, T. E. Real time infrared interpretation in the Mohawk (U). Research Note 80-26, September 1980. (CONFIDENTIAL)

This research had two objectives: (a) to obtain estimates for the levels of infrared interpretation performance that an operational airborne sensor operator might attain in extracting intelligence information from the Mohawk, OV-1D, inflight display; and (b) to examine the relative effects of selected display and mission variables on operator performance. To accomplish these objectives, three levels of aircraft velocity and three levels of field-of-view (FOV) were experimentally manipulated under conditions simulating line, area, and point surveillance missions. The effect of utilizing the frame-hold capability inherent in the display was investigated in conjunction with the simulated point surveillance condition.

Special Reports

Key to U.S. Army tents, 1969.

ARI designed and developed an image interpretation key to Army tents (Martinek, Bigelow, & Jorgenson, 1968). It was prepared specifically for the use of ARI image interpreters in preparing scoring keys for research purposes and for Army and other military personnel participating in image interpretation research. It was intended to help interpreters identify various types of tents rapidly and accurately.

The key included most of the standard Army tents then in common use (September 1966). A few types were obsolete and were so designated. They were included because they still occurred in isolated instances on recent photographs of Army camps and, more frequently, on earlier photo coverage.

Operational Applications. The Army tent key can be used as a research tool to help identify tents in the determination of "image truth" for scoring purposes by experimental subjects in responding to test materials involving U.S. Army equipment, and in training exercises in the field.

Target reporting terminology and target recognition key (JTF-2 test 4.4), 1969.

Joint Task Force Two (JTF-2) was organized by the Joint Chiefs of Staff to conduct a series of coordinated and integrated tests to determine the capabilities and vulnerabilities of offensive and defensive reconnaissance systems in the low-altitude flight regime. Among other objectives, Test 4.4 of the test program was designed to measure the target acquisition capabilities of both the aerial observer and image interpretation systems in representative aircraft systems under visual flight conditions over rolling terrain.

ARI was requested to develop material to standardize reporting terminology and to acquaint aircrews and image interpreters with the characteristics of the different target complexes. ARI prepared a booklet that contained a Target Reporting Terminology List (section A) and a Target Recognition Key (section B) (Army Research Institute, 1969). The Target Reporting Terminology List specified the names of the various target complexes and identified the vehicular and/or equipment content of each target complex. The Target Recognition Key presented these same target complexes in oblique and vertical views accompanied by annotation of target items in each complex, descriptions of the vehicles and items of equipment shown, description of the target environment, and factors useful for making identifications. These booklets must have been useful to the aircrews participating in Test 4.4 because few were returned after the test.

Operational Applications. The material developed was tailored for the JTF-2 field evaluation and is not directly applicable to other situations. The technique employed is general and would be useful as a way to standardize aerial observer (and other) reports and to train aerial observers to recognize targets and items of equipment in other situations.

U.S. Equipment Mini-Key, 1969.

An unpublished key (ARI) termed the U.S. Equipment Mini-Key is a two-page photographic key produced by ARI. Scale model vehicles (HO gauge 1:80) and items of U.S. equipment were arrayed on a terrain board and photographed in vertical and oblique views. The objects in the arrays were tic marked and numbered. Target names and dimensions are given on the lower half of the vertical imagery.

This key was developed for use in research by interpreters participating in experiments. It provides a convenient method of assisting interpreters to identify various objects of U.S. equipment. Several operational units (in the Air Force and Army) have found this key to be useful for training and maneuvers. The two pages of the Mini-Key appear as Figure 5 and Figure 6.

Operational Applications. The Mini-Key provides a useful and convenient guide for identifying Army equipment for research and operational use. Several operational units use the key for training exercises.

Mini-Keys of potential enemy equipment should be developed for training and operational use.

Research Recommendations. None.

Exercises for error avoidance training in image interpretation, 1971.

An unpublished instructional manuscript (Army Research Institute, 1971) was developed as a training package to familiarize students with the use of image interpretation keys to detect common errors made in identifying objects on aerial photographs. Two distinct image interpretation keys were presented. The first document, Error Keys as Reference Aids, provided the explanatory material for photographic imagery acquired in France and Belgium during World War II and had been used in an earlier error key research (Birnbaum, Sadacca, Andrews, & Narva, 1969). This text material provides a step-by-step set of instructions to the student, explaining the various error types, such as tree shadow error, size error, tree top error, and so forth. Annotated locations on the imagery used with the instructions are specified.

The second document, Interpretation Errors on Vietnam Imagery, parallels the first for a different geographic area and for another culture. In addition to tree errors and size errors, probably the largest number of errors made on Vietnam imagery were caused by misinterpreting local religious and agricultural features as military targets. Shrines, temples, walled graves, and grave mounds appear frequently and are often misinterpreted. In the first document, the student was given a systematic tour through the various types of errors frequently made by peers. In addition, the second document emphasized common omissions made by interpreters of targets of military significance in Vietnamese imagery.

Operational Applications. These manuscripts provide a point of departure for the development of a training unit on error avoidance for formal training of image interpreters and/or for on-the-job training.

Research Recommendations. Work should be extended on the development of expanded training units for error avoidance.

Communications Intelligence

Castelnovo, A. E., Tiedemann, J. G., and Dobbins, D. A. Performance of single vs. multiple voice radio transcribers working under three speech to noise ratios. Technical Research Note 135, September 1963.

The accurate reception of a radio message when the voice is masked by atmospheric noise remains a serious problem in radio communication. In research to improve the output of the Army's voice-radio communication systems, a study was conducted to explore the possibility that a transcription method based on the efforts of two or more operators would result in fewer errors and a more complete transcription than would efforts of a single transcriber.

Three work methods differing in the number of transcribers contributing to the final product were compared with respect to accuracy and completeness of the resulting transcription. These methods (involving one, two, and three transcribers) were tested under three levels of noise which yielded high, medium, and low intelligibility under standard conditions. Data obtained were interpreted by analysis of variance techniques.

A small but consistent difference in favor of multiple transcriber work methods was found. While differences were small (significant only at the medium noise level), the additional amount of material correctly transcribed might be of sufficient importance in critical situations to warrant use of more than one transcriber. Repeated exposure to a given message resulted in some increase in accuracy at low and medium noise levels. At high noise level, repeated exposures were conducive to error.

Castelnovo, A. E., Tiedemann, J. G., and Skordahl, D. M. Individual differences in transcribing voice radio messages embedded in atmospheric noise. Technical Research Note 137, October 1963.

Getting accurate and complete versions of a radio message when the voice is masked by atmospheric noise remains a serious problem in radio-telephone communication. Do individuals show consistent differences in accuracy and completeness of transcription of voice radio messages? Are any such differences predictable by conventional measures?

Voice-radio transcriber performance under low, medium, and high levels of atmospheric noise and for six daily 3-hour sessions was analyzed for stability of performance over time and across noise levels. Results of the small sample of 50 trainees indicated pronounced and reliable individual differences in completeness and accuracy of the transcripts produced. Ability to minimize the introduction of wrong words also appears stable. However, the process of introducing error into a transcript appears complex, as indicated by the pattern of correlation between wrong and right responses--negative at low noise level and positive at higher levels--and by the fact that wrong scores proved less predictable than did right scores by means of tests of the Army Classification Battery.

Individual differences were significantly predicted by several ACB tests (Verbal, Army Clerical Speed, Arithmetic Reasoning), but development of

instruments usefully predictive of performance in the operational situation evidently cannot rely wholly on conventional paper-and-pencil tests.

Stichman, E. P., and Renaud, G. E. Information extraction from voice communications: Work methods for single transcribers. Technical Research Note 154, June 1965. (AD 618 322)

Studies are conducted by the Combat Communications Task in voice-radio communications techniques and overall performance of personnel involved in communications operations. An experiment was designed to determine the effects of 20 different transcription methods on the performance of 12 Army enlisted men in transcribing word lists received at 4 signal-to-noise levels. Three aspects of communications procedure were examined: listening to the message, writing the message as it was heard, and using a previous transcript of the message as an aid in relistening and retranscribing.

Significant improvement in performance was obtained when subjects both listened to and wrote the word lists more than once. Performance did not improve at any signal-to-noise ratio when listening to a given word list more than once before writing the transcript nor when the subjects used a first or second transcript as a reference aid in retranscribing a word list. The conclusion was that although the actual absolute gain in accuracy was low, there was sufficient improvement to warrant repeated listening and repeated writing of messages when reception conditions are below the marginal level of channel communications.

Stichman, E. P. Transcriber confidence in relation to accuracy of transcription. Technical Research Note 175, July 1966. (AD 642 544)

In continuing research conducted under controlled laboratory conditions, the Combat Communications Task is investigating voice radio-telephone communications techniques and improvement of performance of personnel in communications operations. The present study was designed to determine the relationship of transcriber confidence to transcription accuracy. Measures of two aspects of performance--message intelligibility and expressed confidence in the correctness of transcription--were obtained from eight Army enlisted men (untrained in communications) transcribing word lists received at three signal-to-noise ratios. Confidence was expressed through the use of a five-point rating scale ranging from "fully confident" to "not at all confident," and a separate rating was assigned to each word in a list as it was transcribed.

A significant relationship was obtained between transcriber confidence and accuracy of transcription. As expected, both mean intelligibility and mean confidence ratings increased as a direct function of signal-to-noise ratio. Signal-to-noise ratio did not similarly affect the relationship between confidence and accuracy. Because of generally unpredictable and unstable listening conditions in the field, the relationship between confidence and accuracy--averaged across signal-to-noise ratios--apears to provide a stable measure which is the best practical basis for estimating transcript accuracy. The conclusion was that a positive relationship exists between transcriber confidence of correct reception and message intelligibility, even when personnel untrained in communications serve as transcribers. While

far from perfect, the relationship is sufficient to warrant further research using trained communications transcribers.

Stichman, E. P. Relationship of expressed confidence to accuracy of transcription by operational communications personnel. Technical Research Note 192, October 1967. (AD 662 069)

The study sought to determine whether operational communications personnel can rate their performance in transcribing voice radio messages partially embedded in noise with sufficient precision for the ratings to have potential operational utility. Eight experienced communications operators rated their confidence in the accuracy of their reception and transcription of messages received at three signal-to-noise ratios (-6 dB, 0 dB, +6 dB), using a five-point rating scale. As a control, subjects also received and transcribed the messages without making ratings. Measures of transcript accuracy and expressed confidence in transcription were compared with results from a prior study in which subjects had no formal training or experience in communications or transcription (Technical Research Note 175). Experienced operators were highly successful in judging their own accuracy, the relationship between confidence and accuracy being $r_{tet} = .78$. Some overconfidence at the upper end of the rating scale and underconfidence at the lower end were evident. Intelligibility improved from 20% to 88% as signal-to-noise ratio increased. The communications operators performed better than the noncommunications trained subjects in the former study both in accuracy of transcription and in precision of confidence ratings. Judging the transcription did not affect the average accuracy of the transcripts in either study. In both studies, subjects tended to make effective use of less than all five points of the confidence rating scale.

Stichman, E. P. Intelligibility differences among monosyllabic words. Research Memorandum 68-1, January 1968.

The objective of this experiment was to explore the possibility that monosyllabic words selected from a base of 1,000 words and used to construct phonetically-balanced (PB) word lists were sufficiently different in intelligibility to be potentially useful in developing a noise-resistant language. High and low intelligibility words were selected from an intelligibility-confidence rating scatterplot of PB word scores from previous research and assembled into high and low intelligibility lists of 50 words each. Trained subjects transcribed these at three signal-to-noise ratios. Scores on the high intelligibility lists were significantly higher and scores on the low intelligibility lists were significantly lower in intelligibility than the scores on the standard PB lists.

Castelnovo, A. E. Effects of spectrum sampling on speech intelligibility. Technical Research Note 207, March 1969.

In the Monitor Performance Work Unit, ARI studies the effects of factors associated with the signal, the monitoring task, the environment, and the individual in a variety of combinations. One segment of work unit effort is concerned with variables affecting the intelligibility of audio signals and

speech, with present emphasis on the area of spectrum selection and binaural listening. The current publication reports on a study of the effect on the intelligibility of phonetically balanced (PB) words of excising several narrow bands from a curtailed speech spectrum (1,300 cycles). A spectrum composed of several discrete pass bands was compared to (a) the total curtailed spectrum, (b) the curtailed spectrum with one large segment removed from the end, and (c) the articulation predicted by the Articulation Index. Eighteen PB word lists uttered at three speech-to-noise ratios constituted the stimulus material presented to 36 subjects through a filter system with selected pass bands. Results indicated that at the higher speech-to-noise ratios, eliminating several narrow bands from the spectrum does not result in a corresponding reduction in intelligibility. When the speech is 35 dB above the noise, a reduction of 20% or more can be made in bandwidth without noticeable reduction in intelligibility. As the speech-to-noise ratio is decreased, the decrement in intelligibility becomes more nearly proportional to the decrease in bandwidth. A given bandwidth distributed over a spectrum area is more effective than an equivalent bandwidth massed in one part of the spectrum. Distributed sampling of the spectrum was found to be more effective than would be expected from Articulation Index computations.

House, J. L., and Cohen, S. L. Current procedures in selection training and utilization of voice processors (U). Research Study 70-4, April 1970. (CONFIDENTIAL)

Opinions of a cross section of linguistic personnel concerning present procedures and suggestions for changes in the selection, training, assignment, and career development of the Army transcriber are discussed.

Dean, R. F. Operator performance variables in LeFox Grey (U). Research Study 70-5, May 1970. (CONFIDENTIAL)

The complex weapons and surveillance systems of the modern Army have created a relatively new series of jobs requiring operators to monitor instrument panels, radar scopes, communications nets, and other types of signal detection apparatus.

The present research study reports on observations made by ARI scientists of a computer-assisted communications processing system with a view to identifying variables which adversely affect human operator performance.

House, J. L., and Cohen, S. L. Quantitative evaluation of current procedures in voice processing (U). Technical Research Report 1174, July 1971. (CONFIDENTIAL) (AD 516 989)

In the conduct of human performance experimentation research, ARI has a primary objective to improve performance in Army monitor jobs, with special emphasis on developing and testing new work methods. An important segment of the research is concerned with human factors studies in communication analysis and processing. The present report describes a study primarily directed to evaluating methods of gisting, that is, abstracting essential elements of a voice communication as a means of identifying problems in extracting intelligence information from voice communications.

House, J. L. A comparison of two methods of gisting. Technical Research Note 236, March 1972. (AD 743 185)

An important segment of ARI research on monitor performance is devoted to human factors studies in communication analysis and processing. The present publication reports on research to evaluate two experimental methods of gisting--that is, abstracting the essential elements of a voice message--in comparison with baseline performance in simulated on-line gisting.

Twenty-four communications processors were each tested using two methods of gisting. In one method (free repeat), the processor listened once to the complete message with no option to stop or replay, preparing as complete a gist as he could, and was then free to replay the tape as he judged necessary to complete the gist. In the second method (forced repeat), the processor listened to the complete message once and prepared as complete a gist as he could. He then listened to the complete message five additional times with no option to stop or replay.

The free repeat method produced a higher quality gist and a higher percentage of key items correctly reported than did the forced repeat method. The free repeat method also took less time to produce a complete gist. However, the time spent on each repetition was controlled in the forced repeat method. In both methods, repetition produced gains in number of key items reported correctly and in the overall quality of the gist.

Cohen, S. L., and Turney, J. R. Comparison of operator gisting skills in LeFox Grey and standard systems (U). Technical Research Report 1184, November 1974. (CONFIDENTIAL) (AD C000 382)

An experimental semiautomated communication processing system, LeFox Grey, was tested in parallel field operation with the current standard system. Comparisons were made to determine whether differences in the output of the two systems were attributable to system differences or to differences in operator proficiency.

The research showed that operators in the LeFox Grey system and in the standard system did not differ in gisting ability. Operators in both groups produced better gists from the message containing more items of critical information--better in both percentage of correct identifications and in rated quality of gists. Therefore, results of comparisons between the LeFox Grey system and the standard system were functions of aspects of the man-machine interface of the systems and not of differences in operator proficiency.

Cohen, S. L. Comparative work environment perceptions of operating personnel within experimental and standard communication systems. Research Report 1180, February 1975. (AD A005 215)

An experimental semiautomated field communication system was evaluated in comparison with the current standard communication system. Scanners in the experimental system and operators and transcribers on the standard system completed two questionnaires dealing with past training and experience

and perceptions of jobs in the system. Responses were analyzed with special reference to acceptability of the equipment and working aids, adequacy of job assistance and performance feedback, superior/subordinate and peer/peer interaction, and the individual's perception of his role in the system. Results showed that the system being evaluated was superior to the standard system. Neither system provided adequate procedures for man-man interaction. Insufficient feedback on performance, and little positive recognition, guidance, or job assistance were provided for operating personnel. Work aids were generally unsatisfactory.

Personnel were able to perform for longer periods of time with less noticeable fatigue in the experimental system than in the standard system.

The research has provided leads for improving motivation through improved utilization of feedback information and the evaluation of such feedback in terms of system productivity.

Shields, J. L. Speed listening for message classification. Technical Research Memorandum 75-2, March 1975. (FOR OFFICIAL USE ONLY)

Listeners attempted to identify the subject matter of tapes with four types of communication. Rate of presentation had a significant effect. Best performance occurred at regular speed followed by 1.5 times, then 2 times. This general pattern held for most but not all communication types. In general, participants were unable to accurately state the subject matter of the communication at 2 times; they were able to state a part of the communication at 1.5 times. There was a close agreement between the participant's subjective estimates of their performance and their ability to identify the subject matter of communications presented. The report suggested directions for further study.

Cohen, S. L., and Turney, J. R. Results of an organizational diagnostic survey of an Army field facility work environment. Technical Paper 272, January 1976. (AD A020 934)

The aim of organizational effectiveness research is to increase human performance effectiveness in an organization and to improve teamwork and job satisfaction, by developing diagnostic instruments to identify problem areas, intervening with organizational development techniques to correct the problems, and finally evaluating the intervention results in terms of productivity and job satisfaction.

A diagnostic Work Environment Questionnaire (WEQ) was developed and validated over a 3-year period at an Army field installation. It elicited from both supervisors and subordinates their attitudes and perceptions on their job duties, training, performance standards, and consequences, and on their organizational supervision, work group, job importance, and feedback. Three versions were tailored with job-specific items for a supervisory NCO position and two different subordinate positions; the items are readily adapted to a variety of actual duties. Data from the 1972 pretest and 1973 survey supplemented the 1974 WEQ survey reported in detail in this report.

Communications Intelligence

Seven major organizational problem areas were identified in both 1973 and 1974: peer group norms which failed to encourage good performance, insufficient performance feedback need for training in supervisory techniques, role ambiguity and conflict, inadequate intergroup communication patterns, lack of clear performance-reward relationships, and ambiguous performance evaluation standards.

A program of active intervention has since been designed and implemented to reduce these problems; a resurvey has indicated that the intervention did successfully decrease certain problems and increase job satisfaction and performance.

Turney, J. R., and Cohen, S. L. The development of a work environment questionnaire for the identification of organizational problem areas in specific Army work settings. Technical Paper 275, June 1976. (AD A028 241)

The aim of organizational effectiveness research is to increase human performance effectiveness in an organization and to improve teamwork and job satisfaction, by developing diagnostic instruments to identify problem areas, intervening with organizational development techniques to correct the problems, and finally evaluating the intervention results in terms of productivity and job satisfaction. This report discusses the development and validation of the Work Environment Questionnaire (WEQ) which is used to identify organizational problem areas and evaluate interventions.

The WEQ was developed and validated over a 3-year period as part of an organizational effectiveness program at an Army field installation. Focusing on individual work motivation and the situational factors affecting this motivation, it is designed to elicit from both supervisors and subordinates their attitudes and perceptions on their job duties, training, performance standards, and consequences, and on their organizational supervision, work group, job importance, and feedback. Section formats are designed to apply to a wide range of Army settings, but item content is specific to the Army work setting and job. Three questionnaires were tailored with job-specific items for a supervisory NCO position and two different subordinate positions; the three as a whole comprise the WEQ. Validation procedures significantly correlated the attitude measures with independent measures of performance and effort.

The WEQ provides indexes of soldier perceptions, motivations, and satisfactions in specific terms which can identify problem areas suitable for corrective intervention. A further survey in the field installation has since identified seven major problem areas, and a program of active intervention has been designed to reduce these problems.

deHaan, H. J. A speech-rate intelligibility/comprehensibility threshold for speeded and time-compressed connected speech. Technical Paper 297, June 1978. (AD A061 172)
(Also in Perception and Psychophysics, 1977, 22, 366-372.)

The speech rapidity threshold is a new method for determining the maximum rate of speech understood by individual listeners. It involves repeated judgments of the comprehensibility of speech as the rate of speech varies. The purpose of the present experiment was to determine the relationship of the speech rapidity threshold to the intelligibility and comprehension of speech.

To accomplish this, two experiments were conducted. The first experiment compared two types of speech reportedly different in intelligibility, simple speeded speech and compressed speech. Thresholds for compressed speech were significantly higher than those for speeded speech, an indication that the threshold at the very least reflects intelligibility.

The second experiment correlated threshold values with traditional comprehension test scores. In general, correlations were low, an indication that the method is not a measure of comprehension. Results were interpreted to mean that the threshold reflects an intermediate level of information processing involving the perception of the potential for interpretation or comprehension rather than the complete act of comprehension per se.

deHaan, H. J., and Schjelderup, J. R. Threshold of intelligibility/comprehensibility of rapid connected speech: Method and instrumentation. Technical Paper 296, June 1978. (AD A060 556)
(Also in Behavior Research Methods & Instrumentation, 1978, 10, 841-844.)

The technology of speech compression demands new methods for measuring the intelligibility and comprehensibility of compressed speech. The present report describes a method in which repeated judgments of the comprehensibility of speech are obtained as the rate of speech is made to vary. The method is similar to the Békésy method for the determination of pure-tone thresholds but differs from it in that rate of speech is varied rather than the intensity of an auditory signal. The result is a threshold value representing the maximum rate of speech judged comprehensible by an individual listener. Instrumentation that varies speech rate, accelerating or decelerating the rate either with or without pitch changes, was developed for this determination and is described in some detail. Both the method and associated instrumentation have potential for a variety of applications.

Lambert, J. V., Shields, J. L., Gade, P. A., and Dressel, J. D. Comprehension of time-compressed speech as a function of training. Technical Paper 295, June 1978. (AD A058 204)

This experiment studied five training methods for effective listening of time-compressed speech. Army subjects trained by two methods using incentives understood speech played 2.2 times faster than normal without degradation of performance. Subjects trained by three methods not using

incentives had significantly degraded performance when compressed speech was presented at rates faster than 1.85 times the normal rate.

Gade, P. A., and Gertman, D. Listening to compressed speech: The effects of instructions, experience, and preference. Technical Paper 369, August 1979. (AD A075 408)

This experiment attempted to assess the effects of different information-seeking strategies on the rate at which individuals chose to listen to passages of time-compressed speech, and on their comprehension of those passages. The research also assessed the effects of prior experience with compressed speech on listening rates and on comprehension of 48 Army enlisted men and women. The various information-seeking strategies employed produced no significant differences in speed or accuracy of performance. Personnel preferred to listen to speech rates well above normal speaking rates ($p < .001$). Although prior experience with compressed speech did not influence preferred listening rates, it did influence the participants' listening rates when they were induced to listen to speech as rapidly as possible ($p < 0.001$). Results are discussed in terms of Berlyne's epistemic curiosity hypothesis and in relation to the results of preference research by Lass, Foulke, Nester, and Comerci (1974).

Martinek, H., Johnson, E. M., and Jeffrey, T. Communications intelligence: Transcriber output enhancement. Research Report 1268, September 1980.

A workflow model of major transcriber functions was developed and time data for these functions were collected on 52 operational personnel. A time analysis was performed with respect to individual functions and logical sets of functions for a representative sample for the operationally meaningful groups of transcribers. The time analysis of transcriber functions indicated that about one-third of productive time was spent in the Listen, Rock, and Search functions and another one-third in doing these functions in conjunction with others. About 11% of the transcribers' time was spent in obtaining help from reference material, 5% in the tape changing functions, and 8% in team work functions. Differences clearly existed between organizational groups in the time spent on specific transcriber functions. Development of procedures to enable transcribers to exploit digitization and computer storage of taped communications should improve productivity at least 10% to 20% by eliminating search and tape changing functions, by reducing time spent in getting help from reference material and other transcribers, and in giving help, and improving exploitation of source material.

V. COMMAND STAFF SIMULATION AND GAMING

Simulation and Gaming: General
SIMTOS
Command Group Training

Simulation and Gaming: General

Tiede, R. V., Burt, R. A., and Bern, T. T. Design of an integrated division-level battle simulation for research, development, and training. Volume I. Technical Report 420, August 1979. (AD A082 761)

The requirements of this study were: (a) to develop a top-down design for an integrated family of modular division-level battle simulations which separately or jointly will exercise players performing critical functions in command and control (Vol. I); and (b) to develop detailed design specifications for the Intelligence Staff module of the integrated battle simulation (Vol. II).

The design approach involved the following principles: selection of the decision variables to be manipulated by the division staff modules and the event threads both within and external to the staff modules thereby fixing the event sequence and time of occurrence; and incorporating into the simulation every event thread needed to support the input/output relationship. The dynamic realism needed to place decisionmakers in a realistic environment is achieved by means of an event store technique. The five classes of events of which the event threads are composed are defined and the logical flow of the event store simulation is illustrated. A sixth class of event needed for operation in an ADP-assisted mode is also defined. The approach begins at the heart of the information system, the decisions, and then develops the simulation needed to implement them--the inverse of the usual approach.

The design concept provides for a man in the loop in that any one or any combination of five basic staff modules (Cmd Grp, G2, G3, G1/G4, FSCE) plus one enemy module (Cmd Grp) may be either occupied by human players or simulated. The module simulations are designed as "plug-in" modules, any one or more of which can be replaced by players. The simulation also contains a battle outcome generator which simulates all other events within the division and the enemy force opposing it, and which feeds back to the players in slow, real, or fast time (at the option of the user) the results of their decisions. The design also provides for interfaces with higher and adjacent units. It includes the following features:

1. The modules are based on the traditional G-staff structure.

2. Nuclear battle events are included.

3. Live modules may be required to perform simultaneous planning and execution; the results of such planning may be evaluated by subsequent execution of plans.

4. Other staff elements not included in the basic five modules (e.g., engineer, signal) are "hardwired" components of the simulation.

5. The basic design provides for manual operation by live players but it is readily expandable to permit player operation in an ADP-assisted mode.

Tiede, R. V., Burt, R. A., and Bern, T. T. On the design of simulations of command and control processes. Research Note 80-39, in press (November 1980).

This report covers two additional design requirements to an existing design for a battle simulation intended for research, development, or training. The first requirement is to simulate the command control processes so that they reflect human performance in the information processing and decision-making sequences. The second is to provide alternative configurations for the "player" staff modules so that the investigator may select the configuration best suited to his behavioral research objectives. Both problems are approached by combining the known human factors in command and control with a detailed structuring of the action processes employed by the command group/staff. All relevant aspects of human performance except the higher-level decision-making operations can be realistically simulated. A trade-off is found to exist in the alternative configurations between the realism of staff play, the ability to make behavioral measurements, and the cost of personnel and computer hardware/software.

Tiede, R. V., Burt, R. A., and Bern, T. T. Some guidelines for effective task design in command and control simulations. Research Note 80-40, in press (November 1980).

This report develops principles of task design for interactive simulations in which staff players execute the command and control of a simulated battle. A companion report on the design of simulations of command and control processes presents the basic design framework of a battle simulation capable of application alternatively to research, development, or training. This framework includes consideration of alternative configurations of the "player" staff modules so that an investigator may select a configuration best suited to his behavioral research objectives. The guidelines for effective task design are developed from the alternative configurations.

SIMTOS

Ryan, T. G. Studies of tactical military decision making II. An information network aid to scenario development. Research Study 69-11, September 1969.

Current military field manuals and military information system reports were used to develop a Tactical Decision Information Network to aid in the preparation of test scenarios to support research concerned with the flow of tactical information and its relationship to decision-making behavior in the Army's tactical operations systems. From these official sources, command unit organization, command decision-making responsibilities, and information requirements of staff elements were defined. Within the sequence of actions in developing and executing a course of action, decision points were defined, decisionmakers were specified, and information categories were delineated. These data were then organized in the form of function flow block diagrams and associated data input sheets which, collectively, constitute the Network.

The Network provides a framework of checklists for information inputs and flow diagrams encompassing the total information analysis and decision-making sequence. Sections of the Network can be delimited according to requirements of the problem to be studied experimentally.

Krumm, R. L., Rowe, C. H., and Torpey, F. E. Research on tactical military decision making: I. Design of a Simulated Tactical Operations System (SIMTOS). Research Problem Review 70-1, October 1970.

Conditions necessary for a realistic test facility environment, scenario form and content, and testing practicalities were delineated. On the basis of these, plans were outlined in brief for a sequence of research designed to provide a capability to study decision-making behavior during free-play two-sided war games using a simulated tactical operations system (SIMTOS) for laboratory research.

SIMTOS capabilities available in ARI to support the research were examined and additional support capabilities needed were identified. Details of the required physical facility are given. The report provides the broad outlines of a six-phase research plan designed to produce a simulated tactical operations system (SIMTOS) for exercise within a simulated tactical operations center (SIMTOC).

Krumm, R. L., Robins, J. E., and Ryan, T. G. Research on tactical military decision making: III. Predictor variables and criterion measures. Technical Research Note 229, May 1973. (AD 765 457)

The Command Systems program is concerned with human factors problems of information presentation, processing, and utilization in command and control systems. One major objective is to provide research findings by which information assimilation and decisionmaking may be facilitated. The present publication describes research to develop and evaluate a scenario for a test of tactical military decisionmaking and to derive methods for scoring the

decision-making behavior for use in a broad program of manned systems research to improve tactical decisionmaking.

The experimentation was conducted by personnel of the BUNKER-RAMO Corporation in the Simulated Tactical Operations System (SIMTOS) facility. A test scenario was developed and administered individually to 20 senior field grade officers. The assigned task required each officer to write a defense plan for his division sector against an expected attack by two mechanized infantry divisions. The scenario was presented by using cathode ray tube (CRT) displays, computer-driven typewriters, and random access slide projection equipment. Defense plans were scored using USA CGSC school solutions as criteria. Two scoring procedures were utilized: (a) Leavenworth Standard (based on rationales and solutions in the CGSC lesson plans) and (b) Consensus Standard (to provide for computing average subject responses in the event CGSC Standards were inappropriate as a result of scenario changes).

The experiment demonstrated the practicality of developing a priori scoring standards for complex decision-making tasks. The test proved reliable. Measures of the decision-making behavior of the officers were highly correlated with the criterion score. A combination of four measures, Experience, Ability, Decision Process Pattern, and Significant Facts, were highly effective as criterion score predictors.

Robins, J. E., Buffardi, L., and Ryan, T. G. Research on tactical military decision making: Applications of a decision prediction concept in a SIMTOS environment. Technical Paper 246, March 1974. (AD 780 812)

The present experiment was conducted to determine whether predictors of decision quality established in a prior experiment--based on academic achievement and information processing strategy--maintained their effectiveness in a defensive planning scenario incorporating a fully computerized information retrieval capability. A test scenario for defensive planning was developed and administered individually to 20 senior field grade officers, 4 at a time. Access to data base and presentation of stimulus material were fully automated. Each officer, assuming the role of a G3 operations officer, planned a division defense, in sector, against an expected attack by two mechanized infantry aggressor divisions. Decision quality was scored according to standards developed by the USCGSC at Fort Leavenworth. Nine predictors selected in a prior experiment were included in the present analysis. These were based on an individual's career experience, his academic records in staff college, the information processing and assimilation strategy he uses, and number of relevant facts obtained in processing tactical information.

Four predictors maintained substantial predictive stability in the present SIMTOS environment (yielding a multiple correlation coefficient of .79 which reduced to .59 where corrected for shrinkage): (a) recency at CGSC; (b) CGSC class standing; (c) information request slope, the number of information requests made by the officer early in the decision-making process in relation to decision quality; and (d) terminal pause, the time between final information request and decision. Predictors demonstrated their effectiveness in a static tactical planning situation. Final

determination of the utility of the predictor concept awaits its application in a simulated combat environment.

Baker, J. D. SIMTOS: A man-in-the-loop interactive simulation of a tactical operations system. In Huber, R. K., Jones, L. F., and Reine, E. Military Strategy and Tactics. New York: Plenum, 1975.

Shubik and Brewer [1] recently reported findings from a detailed survey of 132 Models, Simulations, and Games (MSG) used in the U.S. Department of Defense (DOD). Among the findings, they discovered that only 10% of the MSG's dealt with man-machine or manual system problems. Additionally, they found that approximately 75% of the MSG's employed in the DOD are large and deal primarily with machine simulations or force structure, i.e., they are mainly machine (or weapons system) evaluation tools. They also found that most of the MSG's being used were not very scientific and, consequently, rarely were the MSG's used as research tools.

In contrast to the trends cited by Shubik and Brewer, the present paper will deal with a "minority" MSG, namely, a man-machine simulation facility. The facility under discussion will be the SIMTOS (Simulated Tactical Operations System). It is a further oddity among MSG's in that it is a research tool which has been successfully employed to integrate system users into system design procedures. What follows is a delineation of the scope and limitations of SIMTOS, a brief description of the physical facility employed, a summary of the research and findings to date obtained while using this facility, and a discussion of some of the ongoing SIMTOS efforts.

Cook, J. R., and Herzer, I. Development of scenario material to support two-person play within SIMTOS (I: SIMTOS 23; II: SIMTOS-OD). Technical Report TR-79-A1, January 1979. (AD A066 781)

The proposed modifications of the current SIMTOS were to accommodate: (a) joint play wherein an Intelligence Officer (G2) and an Operating Officer (G3) would interact in decisionmaking and problem solving in a simulated tactical operations center environment (SIMTOS-23); and (b) to put a live G3 in a defensive (D) role against a live G3 in an offensive (O) role (SIMTOS-OD). Past experiments had employed a computer as the player's opponent.

In SIMTOS-23, individual and joint scoring posed unique problems. Within a real world environment where constant, rapid, and demanding interaction is the norm, it is difficult to measure with precision the individual decision processes and use of decision aids. To achieve the basic purposes of a G2/G3 SIMTOS experiment, certain artificialities were introduced but these were minimized.

In OD SIMTOS certain significant problems were readily apparent. One was to overcome the difficulties an Aggressor G3 would encounter when faced with structuring and maneuvering a large foreign military force against a Defender G3 who was trained for and had extensive experience in U.S. force structure and maneuvering. Secondly, the Aggressor G3 had to function as a

live, independently thinking, and active individual, not as a computer. And lastly, the quantity and quality of intelligence to be provided opposing G3's had to be addressed.

This report is primarily addressed to military researchers engaged in man-in-the-loop simulations which investigate player behavior in cooperative and antagonistic circumstances.

Granda, T. M., Johnson, E. M., Halpin, S. M., and Burgess, G. SIMTOS (1967-1977): Review of an approach to the experimental analysis of tactical information processing. Research Report 1293, in press (November 1980).

This report summarizes and evaluates the SIMTOS research program (1967-1977) and makes recommendations for future SIMTOS research and/or future battle simulations.

The origin and development of SIMTOS as a research vehicle is traced, as well as as a physical simulation. Experiments utilizing the SIMTOS are reviewed and critiqued. Problems encountered, lessons learned from the SIMTOS are enumerated and discussed. Specific recommendations for future tactical/battle simulations, in SIMTOS and non-SIMTOS environments, are discussed.

The findings reveal that SIMTOS achieved a high degree of face validity and it was considered to be a reasonable first approach to a computerized TOC research vehicle.

It demonstrated that computer technology can be brought to bear on the immense information processing to tasks inherent in a division TOC.

However, major problems hindered the SIMTOS effort. Among the problems were many hours of computer down-time, an out-of-date computer system, player acquisition, lack of appropriate tasking, and lack of consistent scoring criteria. These problems and others contributed heavily to the fact that the research results did not produce major behavioral findings.

It was concluded that a significant behavioral impact in the area of tactical, division level man-computer information processing could be forthcoming with the following improvements to SIMTOS or SIMTOS-like systems: (a) acquisition of modern reliable and sophisticated computer and peripherals (e.g., input/output devices); (b) closer cooperation between military research team and participant sources; (c) careful design of scenario and tasking components; and (d) validated and standardized scoring procedures.

Tactical games and simulations are being widely studied by the U.S. Army agencies. These games range in sophistication and automation. They all, however, are linked by the fact that none have been validated and none can be used as research vehicles. This report on SIMTOS can be used by development agencies as a guideline or standard in their current efforts to study tactical decisionmaking and information processing via simulation.

Command Group Training

Tremble, T. R., and Costner, R. S. Information flow in training exercises with the Combined Arms Tactical Training Simulator (CATTS). Research Memorandum 77-20, November 1977.

This document reports a study conducted by the Fort Benning Field Unit of ARI on the demonstration model of the Combined Arms Tactical Training Simulator (CATTS). The study was undertaken as part of ARI's research support of the CATTS Directorate during system definition research on CATTS. The overall purpose of system definition research was to develop a training device requirement and user input to technical specifications for a follow-on version of CATTS. The present study was to describe the flow of information in training exercises conducted during the research period. This document presents the results, conclusions, and implications of that research.

Olmstead, J. A., Baranick, M. J., and Elder, B. L. Research on training for brigade command groups: Factors contributing to unit combat readiness. Technical Report TR-78-A18, June 1978. (AD A056 054)

This research examined the relationships between (a) brigade command group effectiveness in performance of Army Training and Evaluation Program (ARTEP) during Computer Assisted Map Maneuver System (CAMMS) exercises and (b) the quality of performance within the brigade of certain organizational processes found in previous research to be related to combat effectiveness. Data were collected on 11 brigades. Seven of 9 process dimensions were found to be highly correlated with Brigade Command Group Effectiveness as evaluated by exercise controllers. Furthermore, large significant correlations were found between the organizational process dimensions and a number of dimensions subsumed under the rubric Supervision and Control, which were also highly correlated with Brigade Command Group Effectiveness. Implications of the findings are discussed.

Olmstead, J. A., Baranick, M. J., and Elder, B. L. A training feedback system for brigade command groups. Technical Report TR-78-A19, June 1978. (AD A056 342)

This document describes a system for analyzing the performance of an Army brigade command group during participation in Computer Assisted Map Maneuver System (CAMMS) exercises and for providing to participants systematic feedback which will stimulate improvement by the command group of its ability to meet Army Training and Evaluation Program (ARTEP) standards.

Kaplan, I. T., and Barber, H. F. Battalion command group performance in simulated combat. Technical Paper 353, March 1979. (AD A070 089)

The behavior of 27 battalion command groups was studied in a simulated combat environment provided by a computer-driven battle simulator, the Combined Arms Tactical Training System (CATTS). Of the 61 subtasks described in the Command Group Module of the Army Training and Evaluation Program (ARTEP), 50 were evaluated in the CATTS exercises. Nineteen subtasks were

identified as relatively weak on the basis of their comparatively low performance ratings, and 23 subtasks were found to be highly correlated with the overall effectiveness ratings. Fourteen subtasks were identified as critical because they were both low rated and highly correlated with overall effectiveness ratings. The critical subtasks included identifying, gathering, analyzing, and disseminating intelligence, planning fires, determining the critical place and time, communicating plans and orders, defeating electromagnetic intelligence, reacting to jamming, and concentrating combat power. These subtasks were related to more basic processes, identified in previous research as important determinants of organizational effectiveness, viz., sensing, decisionmaking, communicating, and coping with changes in the environment.

The critical performance identified in this report can be given particular emphasis in the development of command group training systems, training programs, and information-processing and decision-aiding technologies.

The report is written primarily for the research scientist working in command/control simulation, although military personnel will be interested in the conclusions.

Kaplan, I. T., and Barber, H. F. Evaluation of a computer-assisted battle simulation: CAMMS vs a CPX. Technical Paper 355, April 1979. (AD A068 014)

The Computer-Assisted Map Maneuver System (CAMMS) creates a simulated battle to train battalion and brigade command groups in the exercise of command and control. In contrast to a conventional manual command post exercise (CPX) which is driven by prefabricated messages, CAMMS calculates weapons effects, movement rates, and logistical support in real time to provide the command group with realistic feedback about the consequences of its actions. The purpose of this investigation was to evaluate the cost and training effectiveness of CAMMS in comparison to a CPX.

The players' attitudes toward the alternative training systems were assessed by means of questionnaires administered to 50 battalion command groups and 12 brigade command groups after they participated in CAMMS exercises. Estimates of the preparation time and the number of controllers required for each type of exercise were obtained from 14 CAMMS exercise directors and, for a CPX only, from 5 division and brigade commanders.

Analysis of the data showed that the players judged CAMMS to be significantly and consistently more realistic and more interesting than a CPX. The functional areas in which CAMMS enjoyed the greatest advantage were related to preparing and organizing the battlefield, controlling and coordinating combat operations, and concentrating combat power as rated by the S3; and in the exercise of command and control rated by the commander, especially exposure to the capabilities of enemy weapons systems, facing a thinking enemy, and making decisions under real-time constraints.

The principal weaknesses of CAMMS were that it did not produce much stress, and it did not exercise the players in security procedures, such as

electromagnetic and communications security, nor did it require them to react to special situations like enemy jamming, chemical, biological, or nuclear warfare. The CPX also received low ratings in these areas.

A CAMMS exercise cost 25% to 30% less than a CPX, primarily because CAMMS required much less preparation time.

Overall, CAMMS produced a distinctly superior exercise at a moderate saving in cost over a conventional CPX.

This report is written for the researcher in command/control investigations, although military personnel will be interested in implications of the results.

Barber, H. F., McGrew, J. F., Stewart, S. R., and Andrews, R. S. The computer-assisted map maneuver system: A preliminary examination of its training effectiveness and suitability for use as a research vehicle. Research Memorandum 79-9, June 1979.

The Computer-Assisted Map Maneuver System (CAMMS) is a battle simulation designed to train commanders and staffs of armor, mechanized infantry, light infantry, and cavalry units at both the brigade and battalion command levels. The command groups play within a nonnuclear environment and against a given enemy force.

This preliminary examination (a) estimated the training effectiveness of CAMMS, (b) refined performance measurement procedures, (c) estimated the feasibility of continuing to utilize CAMMS as a vehicle for investigating command group training. Five battalion command groups--two mechanized infantry and three armor--participated. A pretest and posttest design was used.

Based on the findings, the researchers concluded that (a) CAMMS showed evidence of being an effective training vehicle for improving battalion command group proficiency, as subjectively judged in terms of differential performance on ARTEP tasks and subtasks and an overall assessment of the total command group and each major staff element; (b) development of a greater number of objective measures of command group performance in CAMMS is feasible, both to supplement and to alternately supplant some of the existing subjective ratios; (c) the relationship of command group performance to battlefield outcomes is complex; (d) performance on some ARTEP subtasks appeared to influence battlefield outcomes; (e) organizational process measures as used in this effort did not discriminate performance differences among the various measures themselves or change in performance as a function of the training exercise; and (f) CAMMS has the potential for fulfilling the requirements for a vehicle training and training research for long-term training effectiveness analysis.

CAMMS may be the only reasonable vehicle for examining the integration of troops on the ground with the play of a battalion-level command group situation.

Command Group Training

Kaplan, I. T., and Barber, H. F. Training battalion command groups in simulated combat: Identification and measurement of critical performances. Technical Paper 376, June 1979. (AD A075 414)

The behavior of 23 battalion command groups was investigated in a simulated combat environment provided by the Combined Arms Tactical Training Simulator (CATTS). Thirteen mechanized groups performed a covering-force operation followed by an attack, and 10 nonmechanized groups performed a defense and an attack. Their performance was rated on items derived from the subtasks of the battalion command group ARTEP (Army Training and Evaluation Program). Fifteen subtasks were identified as critical, because they or their elements were both low rated and highly correlated with ratings of overall effectiveness.

The four missions observed in this investigation were markedly different with respect to subtask criticality. All but 1 of the 15 critical subtasks were identified in the covering-force mission, 5 subtasks were critical in the mechanized attack, 1 in the defense, and 1 in the nonmechanized attack.

There were significant differences among ratings of the same command group by several observers, each of whom observed the exercise from a different point of view. These results indicate a need for further research (a) to develop more objective measures of performance and (b) to identify those subtasks for which the different perspectives of the raters should produce valid differences in performance ratings.

This report is written primarily for specialists in command/control simulation, although the military will be interested in the results.

Kaplan, I. T. Information flow in battalion command groups. Technical Report 499, in press (November 1980).

Information flow in battalion command groups was measured via a questionnaire based on information presented during the brigade briefing. Data from 13 groups showed that a substantial amount of information was lost in the processes of communication and remembering. Averaged over all command groups, there were consistent differences in the percentage of available required information communicated through particular channels, varying from 17 to 80%. Among battalion commanders, those who transmitted more information received less from their staffs. The fact that information loss was concentrated in specific, identifiable areas, indicates that efforts to improve communication can be focused where they are needed.

VI. EXPLORATORY RESEARCH AND SUPPORTING TECHNOLOGY

Technology Base
Software Development

Technology Base

Strub, M. H. Perception of military event patterns in a two-alternative prediction task. Technical Research Note 221, February 1970. (AD 707 379)

As part of the continuing effort to provide research information which will facilitate maximum operations effectiveness within command information processing systems, the Tactical Operations System (TOS) Work Unit undertook a study of perception of military event patterns. The focus of the study was the recognition of complex cues to enemy action. Objectives of the investigation, reported in the present publication, were to determine the role of (a) different forms of second-order patterns, (b) second-order pattern strength, (c) continuity, and (d) experience as factors in the recognition of second-order patterns. In the experiment, 48 enlisted men viewed sequences of military events representing 8 patterns (form), high and low pattern strength, continuous versus discrete occurrence, and experience (from 1 to 10 100-trial periods) presented in systematic design on CRT screens. The subjects participated in two experimental sessions, each consisting of five 100-trial periods with 10-minute interval breaks. Each man worked individually and was self-paced. The men indicated which of two enemy activities, A(ttack) or R(est), was likely to follow each two previous events. They also responded to indicate confidence in their decisions. Findings showed that given event patterns occurring with high frequency (80% of the time), the decisionmaker learned to predict the third sequential event as often as it occurred. However, under conditions of less frequent pattern occurrence (68% or less of the time), pattern recognition did not occur: Only one second-order pattern was predicted as often as it appeared. Confidence in predicted decisions was affected by increase in experience and pattern form but not by pattern strength nor continuity. It appears from the present findings that tentative limits are set on second-order military pattern recognition. Men can perceive strong second-order patterns. Computer aids would be quite helpful, however, in situations where military event patterns of the class investigated are weak but substantial enough to improve decision accuracy.

Johnson, E. M., and Halpin, S. M. Preliminary evaluation of a multistage Bayesian inference system. Proceedings of the 1972 International Conference on Cybernetics and Society. New York: IEEE, 1972, 431-435.

The inferential leap made by decisionmakers in going from data set to hypothesis set is a major problem in the development of computer-aided inference systems. A potential solution to this problem is the use of multistage/hierarchical inference techniques. A multistage Bayesian inference system has been developed and an on-line test-bed being used to develop and evaluate related concepts is presented. Tentative findings from an ongoing exploratory study are discussed.

Technology Base

Halpin, S. M., Johnson, E. M., and Thornberry, J. A. Cognitive reliability in manned systems. IEEE Transactions on Reliability, 1973, R-22, 165-170.

Human components in manned systems often compensate for hardware error by utilizing other information and past experience in addition to the normal hardware output. However, errors in human information processing and utilization, cognitive reliability, often lowers the overall system reliability. Cognitive reliability in manned systems is discussed in terms of the types of human errors which may occur and in terms of factors which affect the occurrence of these errors. It is a complex function of attitudinal and structural factors and their interaction. Cognitive reliability is useful for examining man's role in complex systems where cognitive as well as perceptual-motor skills are required.

Johnson, E. M., Cavanagh, R. C., Spooner, R. L., and Samet, M. G. Utilization of reliability measurements in Bayesian inference: Models and human performance. IEEE Transactions on Reliability, 1973, R-22, 176-183.

A normative two-stage model for incorporating reliability measurements of data-reporting sources in a Bayesian inference system is presented. An experiment required human subjects to make intuitive inferences about two hypotheses on the basis of sample data which were reported with a given reliability. When compared with the optimal model, subjects exhibited systematic errors in estimating the diagnostic impact of less than perfectly reliable data. Their responses reflected the use of specific nonoptimal heuristic strategies to process the information. A utility function was added to the normative model to illustrate how a best choice might be made from among potential data-gathering experiments whose costs increase with their reliabilities. Recommendations for using computer aids to enhance efficiency in inference systems are made.

Levine, J. M., and Samet, M. G. Information seeking with multiple sources of conflicting and unreliable information. Human Factors, 1973, 15, 407-419.

The effects of information conflict, the frequency with which the information is updated, and the reliability of the information sources upon information seeking and decision behavior were studied. Sixteen U.S. Army enlisted men performed a computer-controlled task in which they had to request updated enemy-position reports from three information sources to determine which of eight locations was the target of a gradual enemy advance. Forty problems, presented twice each, were arranged in two within-subject factorial designs--with source reliability varied between and within problems, respectively. Subjects were permitted to make up to three decisions on each problem, with correct decisions rewarded and incorrect decisions penalized according to a nonlinear payoff function. Results from analyses of variance indicated that less information was sought prior to an initial decision (a) for higher than for lower reliability conditions, (b) as update frequency decreased, and (c) as degree of conflict increased. When all sources were of higher reliability, accuracy of decisions was higher; but, in general, accuracy was complexly affected by conflict and update frequency. These results

were discussed in terms of the cost of requesting information and the probability that an update would contain accurate information. Information sampling and decision latencies as well as other indices of performance were also evaluated and discussed.

Baker, J. D., and Johnson, E. M. (Eds.) Field testing: The delicate compromise. Special Issue of Human Factors, June 1974, 16, 203-214.

This paper selectively compares human factors field testing with laboratory experimentation. Although each is derived from the scientific method, there are critical differences between the two research settings. Field testing is not a simple extension of the laboratory into an operational setting. Techniques, procedures, and research strategies differ; a technology is evolving to bridge the gap between the two research domains.

Levine, J. M., and Samet, M. G. Information seeking with input pacing and multiple decision opportunities. Human Factors, 1974, 16, 384-394.

Forty-eight college students performed a task in which they had to request updated enemy position reports from three information sources to determine which of eight locations was the target of a gradual enemy advance. Eight different problems, presented twice each, were arranged into two factorial designs. In Design FP, the effects of pacing rate, pacing variability, and the number of decision modification opportunities were evaluated. In Design SP, information requests were self-paced rather than forced-paced; the effects of the number of decision modification opportunities and basis of payoff were studied. Results indicated that (a) self pacing and fast forced pacing resulted in more information seeking and greater accuracy than did slow forced pacing, and (b) increased opportunities for decision modification generally decreased the accuracy of, and confidence in, first decisions. The rate at which information was presented was more important than whether it was provided automatically or upon request.

Johnson, E. M., and Halpin, S. M. Multistage inference models for intelligence analysis. Proceeding of the 1974 Army Science Conference. U.S. Military Academy, West Point, N.Y., 18-21 June 1974.

The objective of intelligence analysis is to impose a consistent and coherent interpretation upon seemingly unrelated or even conflicting bits and pieces of information, i.e., to transform information into intelligence. A lack of structure and the frequent absence of a logical relation between the available information and potential enemy capabilities make that task intellectually complex and demanding. Multistage inference models provide a potentially meaningful and useful aid for intelligence analysis. Multistage Bayesian inference models are described and their derivation outlined. These models are based on a decomposition of the conditional relationship between a data set and an hypothesis set into a logical sequence of intermediate sets linking the data set to the terminal hypothesis set. These models describe optimal, normative inference strategies which are analogous to the intuitive procedures currently used by intelligence analysts, but which facilitate the integration of historical data and expert opinion into

a formal inference model while reducing the cognitive demands on the analyst. Several experiments on human performance in multistage inference tasks are presented. These experiments compared intuitive (unaided) inferences and inference strategies with the normative multistage model, and examined intelligence officer's performance with and reaction to an on-line aid based on a multistage model.

Johnson, E. M. The effect of data source reliability on intuitive inference. Technical Paper 251, July 1974. (AD 784 097)

As part of a continuing effort to provide research information which will facilitate improved intelligence information processing, the Intelligence Information Processing Program undertook a study of man's processing and utilization of unreliable data. Reports from data sources of given reliability and diagnosticity were presented to 22 subjects in a series of two hypothesis decision problems. On each problem, each subject indicated the most likely of the two hypotheses and the subjective odds favoring that hypothesis. Subjective odds varied as a function of the data diagnosticity and source reliability. However, the subjects generally failed to extract as much certainty as possible from the data--subjective odds were generally conservative with respect to odds computed by a normative Bayesian model. However, in most cases, as reliability decreased, subjective odds increased relative to Bayesian odds until they were generally greater than Bayesian odds at the lowest level of reliability. Subjects' protocols and data analyses indicated that subjects were using nonoptimal inference strategies in which reliability was incorporated as a multiplicative weighting factor. If the diagnostic impact of the data "if it were true" is correctly evaluated, this strategy leads to increasingly inaccurate subjective odds as reliability decreases and the data diagnosticity increases.

Kneppreth, N. P., Gustafson, D. H., Leifer, R. P., and Johnson, E. M. Techniques for the assessment of worth. Technical Paper 254, August 1974. (AD 784 629)

Subjective worth forms the basis for the selection of future alternatives and the evaluation of past actions. During the past few years several formal methods of worth assessment have been developed. These methods provide an explicit basis for incorporating military judgment into the assessment process in a manner designed to produce consistent and valid assessment. Seven general methods for worth assessment are reviewed. Step-by-step procedures, a specific example, and variations of each method are provided. The description of each method includes training and equipment requirements, possible problems, type of results, the advantages and disadvantages, methods for checking accuracy, and sources of information. The methods cover four areas of assessment: those which yield worth on an ordinal scale, those which yield numerical values directly, the gamble methods involving probabilities, and the multivariate methods for dealing with multiple or dependent factors.

Rapoport, A., Burkheimer, G. J., and Stein, W. E. Studies of detection of change processes. Research Memorandum, Draft, November 1974.

This report considers a two-state discrete-time Markov decision process with partially observable states. The process occurs in equipment checking, intelligence gathering, target search, signal detection, medical diagnosis, and reaction time studies. Informally, it is characterized by: (a) a partially observable state S_0 that at some stage, which is determined probabilistically and independently of the decisionmaker's (DM) actions, turns into another partially observable state S_1 and stays there permanently; (b) observations that are taken sequentially, one on each stage, and that provide DM imperfect information about the true state; (c) a binary decision on each stage: C--the change has occurred (i.e., S_1 is the true state), or W--continue (i.e., take one more observation); (d) an appropriate cost structure, which reflects both the decision made and whether or not it is correct; and (e) a well-informed DM who attempts to minimize the expected loss of the process.

Two variants of the process are presented and discussed in chapter 1. The optimal decision policy, which minimizes expected loss, is presented and examined for both variants in chapter 2. Three deterministic response models are formulated and investigated in chapters 3, 4, and 5. The first, model I, prescribes a C decision as soon as DM's probability that the change has occurred exceeds a predetermined probability boundary. According to model II, a C decision is made as soon as a predetermined number of observations, k, greater than or equal to a fixed critical observation value have been taken. Model III is like II with the only exception that the k observations must be successive. Testable predictions are derived for all three models, including the probability of an incorrect C decision (false alarm), the probability distributions of number of observations taken conditional on the starting or terminal state, and the probability distribution of number of observations after the change.

The sensitivity of the optimal model to perturbations in the parameter values is examined in chapter 6. A systems operating characteristic (SOC) curve is proposed to assess the sensitivity of the optimal policy and to compare the three models to one another. The optimal model as well as the three models are tested in a computer-controlled detection of change experiment in which seven paid subjects participated individually in sixteen 3-hour sessions. A modification of model I, which allows for problem-to-problem learning, is proposed to best account for the data.

The two-state process is extended to the multistate case in chapter 8. The optimal policy for the general case is presented, several cases with three states are examined in detail, and several numerical examples are presented and discussed. Concluding remarks are presented in the final chapter.

Pask, G. Current approaches to decision making in complex systems. Technical Report TR-76-B1, April 1976.

In July 1975, a conference was held at Richmond, Surrey, England to elicit a fair picture of the state-of-the-art in decisionmaking in Europe;

the status of decision oriented disciplines and ongoing or contemplated lines of research. Twelve papers on the subject of human decisionmaking were presented and discussed.

1. The otherwise confusing picture of human decisionmaking is somewhat simplified by the existence of individually and culturally consistent cognitive styles and methods of recall.

2. It is possible that people may be trained to respond in a particular way that yields performance data: for example, to use confidence estimation and rating facilities. However, this does not mean that they can be trained to decide.

3. Attempts to fit simple models to human performance are generally unsuccessful, especially for sequential and temporally dependent choice. More predictive models are available at the price of increased sophistication.

4. Decision analysis is not a prescriptive exercise, introducing the decisionmaker to what he should do. Nor, as sometimes supposed, is it descriptive. The chief merit of the method is to establish a compromise between the decisionmaker and the expert. It was suggested that man/machine systems could be analyzed and designed from a similar point of view.

Johnson, E. M., and Huber, G. P. The technology of utility assessment. IEEE Transactions on systems, man and cybernetics, 1977, SMC-7, 311-325. (Also in Sage, A. P. (Ed.) Readings in Systems Engineering Methodology and Applications. New York: IEEE Press, 1977.)

Utility assessment includes the entire process of identifying, measuring, and combining attributes to create an explicit value structure that can form a basis for evaluations and decisions. The utility assessment process is reviewed, and selected issues and problems are discussed. The focus is on applications in field and field-like settings where it is necessary, in order to solve a problem, to assess the utility of items or alternatives having more than one valued property. Although some aspects of the paper are new, much of the paper is tutorial in nature. Assessment techniques are discussed with particular emphasis on the factors which determine the relative effectiveness of the various techniques in specific situations. Assessment models are discussed, along with a description of the areas where they have been applied. Guidelines are developed for improving the probability of success in applying utility assessment, and suggestions made for the research necessary to further improve the technology of utility assessed.

Kneppreth, N. P., Hoessel, W. H., Gustafson, D. H., and Johnson, E. M. A strategy for selecting a worth assessment technique. Technical Paper 280, February 1978. (AD A055 345)

A variety of techniques exist for evaluating and assessing subjective worth. This paper develops and presents a strategy for selecting the most appropriate worth assessment technique for a given situation.

Technology Base

A three-round Delphi procedure was used to systematically solicit and collate informed judgments from practitioners and experts in the field of worth assessment. The first Delphi questionnaire identified 41 factors influencing the selection and successful use of worth assessment techniques. The second Delphi questionnaire was used to determine the relative importance of the 41 factors identified in the first round of the Delphi. Ten composite factors, four dichotomous and six continuous, were developed which appeared to account for the 41 factors and their relative weights. The third Delphi questionnaire was used to develop a profile for nine different worth assessment techniques on the six continuous factors. A three-step strategy, based on the 10 composite factors, was developed for selecting a specific worth assessment technique for a given situation. The strategy developed for selecting a worth assessment technique should serve to increase the successful application of worth assessment techniques to specific situations, such as occur in the appraisal of intelligence information.

Goodman, B., Fischhoff, B., Lichtenstein, S., and Slovic, P. The training of decision makers. Report of a Conference held at the Oregon Research Institute. Technical Report TR-78-B3, March 1978.

The past 15 years have seen important advances in the understanding of behavioral decision processes. Despite these advances there has been surprisingly little attention paid to the training of decisionmakers. This report provides a summary of a conference held in July 1976 in Eugene, Oregon, to evaluate the state of knowledge regarding the training of decisionmakers, identify important research questions and recommend directions for future research. The report provides both a brief review of current training programs, including a discussion of key attitudes and skills required for decisionmaking, and a list of the most important research questions that emerged during the conference; three aspects of the training problem recommended for immediate attention were (1) training specific skills, (2) evaluating the quality of decisions, and (c) implementing the knowledge obtained through decision research.

Pask, G. (Ed.) Current approaches to decision making in complex systems II. Technical Report TR-78-B4, March 1978.

The proceedings of the Second (1976) Richmond Conference upon "Current approaches to Decision Making in Complex Systems" held at Richmond are reported. The report follows an earlier report "Current Scientific Approaches to Decision Making in Complex Systems", the proceedings of the First (1975) Conference on the theme, issued as ARI Technical Report TR-76-B1.

The following main conclusions were reached: (a) Some individuals at least can be treated as decisionmakers. (b) There is no uniquely "best" decision training method but quite a lot can be said about techniques that do not work on their own (though they may contribute to a training process). (c) Decisionmaking is probably a collection of skills integrated in the framework of tasks between which there is adequate generalization. (d) In specific situations decision skill can be improved. (e) Decisionmakers must learn, in concepts, facts, principles, attitudes, procedures and heuristics. (f) "Learning to Learn" applies to a decision situation (or class of

situations). (g) The "optimum balance" of aiding against training appears to be task dependent and dependent upon idiosyncracies of decision style. (h) Several coherent structuring schemes were discussed.

The following issues were regarded by most participants as inadequately explored by current empirical studies and theoretical developments: (i) Prescriptions for training that involve problem formulation and recognition in large but specific task settings. (j) Logics of action. (k) Structuring, both internal and external.

Smith, D. E., and Gardner, R. L. An approach for providing more accurate probability assessments. Technical Report TR-78-B7, May 1978.

This report describes a possible approach for providing more accurate probability assessments in those real-world decision-making situations for which relative frequency information generally does not exist. In this approach an estimated functional relationship is obtained from a comparison, in relative frequency base (RFB) problems, of a person's posterior probability assessments with the true posterior probabilities. Then, the functional relationship is used as a model to provide probability predictions for new problems by adjusting the person's corresponding probability assessments. Experimental evidence indicated that the resulting models can provide satisfactory probability predictions for problems having identical structure to those used in model construction. At this time, some obstacles prevent immediate use of these models for probability prediction in non-relative frequency base (NRFB) problems. However, it would be unwise to discount the feasibility of developing a practical RFB-based model for adjusting real-world probability estimates until the approach were tested with participants and problems in a field of common expertise (such as intelligence analysis or weather forecasting, for example) where more uniformity of background and experience exists.

Negroponte, N., Herot, C., and Weinzapfel, G. One-point touch input of vector information for computer displays. Technical Report TR-78-TH3, October 1978. (AD A064 278)

The finger as a graphical stylus enjoys a coefficient of friction with glass sufficient to provide input of direction and torque as well as position from a single point. This report describes a pressure sensitive digitizer (PSD) capable of accepting these force inputs, and discusses a set of five simple input applications used to assess the capabilities of this device. These applications include techniques for specifying vectors, and pushing, pulling, dispersing, and reorienting objects with a single touch. Experience gained from these applications demonstrates that touch and pressure sensing open a rich channel for immediate and multidimensional interaction.

The project is an example of basic research with potential for future application. The report will be of interest primarily to research scientists in the field of graphic CRT displays.

Technology Base

Lichtenstein, S., and Fischhoff, B. Training for calibration. Technical Report TR-A78-A32, November 1978. (AD A069 703)

Two experiments attempted to improve the quality of people's probability assessments through intensive training. The first involved 11 sessions of 200 assessments each followed by comprehensive feedback. It showed considerable learning, almost all of which was accomplished after receipt of the first feedback. There was modest generalization to several related probability assessment tasks, no generalization at all to two others. The second experiment reduced the training to three sessions. It revealed the same pattern of learning and limited generalization. The implications of these results are discussed.

Bloomfield, J. R., Beckwith, W. E., Emerick, J., Marmurek, H. H., Ebo Tei, B., and Traub, B. H. Visual search with embedded targets. Technical Report TR-78-TH8, December 1978. (AD A069 666)

Visual search may be necessary where nontarget objects in the search area compete for attention with the target object (competition situation) or where a target blends with its background (embedded situation). This research is the first direct investigation of parameters of embedded target search situations. The research sought (a) to determine the relationships between measures of visual search performance, peripheral visual acuity, and ratings of discriminability obtained with embedded targets, and (b) to compare competition and embedded search tasks.

Competition tasks used constructed color displays; embedded tasks used five different color and four different textural black-and-white displays. Embedded target discriminability was rated by 28 observers for all 5 colors and 4 textures, in 3 different target locations. Several sets of visual search experiments were carried out. In 2 experiments using embedded target displays, search times were recorded for the 5 color targets and the 4 black-and-white textural targets. In 4 experiments, with the elements of the color display separated to varying degrees to create competition search tasks, search times were recorded, for a target that differed in size (1 experiment) and for 2 of the color targets (3 experiments). Peripheral visual acuity was measured for the color embedded display, the color separated displays, and the black-and-white embedded display.

Search time was inversely proportional to peripheral acuity and to discriminability. Embedded search was easier than competition search. In comparing competition and embedded target search tasks, two opposing effects were noted. As the separation of the background elements increased, the target became harder to discriminate, tending to increase search time, but the number of background elements present within the fixed display area decreased, tending to decrease search time. The order of difficulty of the two color targets used changed in going from the embedded to the competition task.

This report shows that, using complex texture backgrounds, simple relationships exist between visual search time, peripheral visual acuity, and rated discriminability. The technological base research, of interest primarily to research specialists, suggests that further study may lead to the development of predictive procedures for search performance in complex real

world tasks (such as air-to-ground target acquisition), and could give us the ability to select and train effective observers for these search tasks.

Bonnet, D. G., and Synder, H. L. Prediction of the recognition of real objects as a function of photometric and geometric characteristics. Technical Report TR-78-TH7, December 1978. (AD A071 118)

The purpose of this research was to predict target-by-target acquisition performance of air-to-ground imagery from microdensitometrically determined photometric and geometric characteristics of the scene. Results showed that it is feasible to predict the ground range at which a given target will be detected by an airborne observer. This prediction could be made totally automatically, given reconnaissance imagery, a microdensitometer, and a small computer.

Seventeen characteristics of targets, backgrounds, and target/background relationships which reliably correlate to target acquisition performance were identified. Sixty regression equations combining these variables into linear predictive models of target acquisition performance were developed from one set of targets and mission conditions and cross-validated against targets contained in three different reconnaissance missions.

The best prediction is obtained when at least two orthogonal scans are passed through the target of at least two frames of the reconnaissance film. With three properly weighted predictor variables derived from these scans, up to 92% of the variance in target detectability is predicted. The prediction equation contains one measure of target size, one of background heterogeneity, and one of target/background contrast. Performance is most predictable when the minimum available range is taken as the criterion in the event of an incorrect response.

The report is of primary interest to research personnel.

Shaket, E., Ben-Bassat, M., Madni, A., and Leal, A. Applications of adaptive programming technology to command group training and performance improvement. Technical Report TR-79-A22, May 1979. (AD A076 234)

This report provides a feasibility analysis and evaluation of the application of Adaptive Programming Technology (APT) to the improvement of command group performance. The final high payoff application area recommended is a situation assessment aid for a division-level G2. APT technology is expected to provide a concept-oriented, interactive aid to integrate the large information volume available into a coherent global situation assessment. A 5-year development program is provided.

Badre, A. N. Selecting and representing information structures for battlefield information systems. Technical Report TR-79-A20, June 1979. (AD A071 117)

The objective of this research was to identify and apply experimental techniques for locating and evaluating data patterns and informational chunks

which are meaningful to the battlefield commander in his decision-making tasks. The identification of meaningful chunks of information is useful in specifying criteria for the development of decision-aiding algorithms that search for, classify, and display information. Two main tasks were used for collecting data about informational chunks; reconstruction and copying. In the reconstruction task an experimental run consisted of a successive number of trials. In each trial the participant first viewed a battlefield map scenario for either 10 seconds or 1 minute after which it was removed and he was asked to reconstruct it. In the copying task, the participant was asked to copy the scenario as rapidly and as accurately as he could. As the participant reconstructed or copied the unit symbols of each scenario, the experimenter recorded both the order and time of symbol placements. Two entirely different criteria were used to partition the reconstructed scenarios into chunks of symbols. These were the interplacement times criterion (IPT), which is based on computing the average placement times for the copying task; and the sequence of tactically related symbols (sequential) derived from a predetermined set of tactically meaningful relations. Both criteria proved useful in evaluating participant use of information chunks.

Lippman, A., and Negroponte, N. Graphical input techniques. Technical Report 409, September 1979. (AD A075 427)

A graphic work station has been created where three aspects of man-machine interaction may be tested: (a) interaction with a flat display; (b) coplanar input and output; and (c) the ability to "see through your hand" to a display below. All three are created by a suitable arrangement of mirrors to direct a projected television image to a back-projection screen which is in turn optically superimposed onto a data tablet surface via a semitransparent mirror. Uses and benefits of the device are demonstrated by means of a set of games which simulate a situation where a user must interact with dynamically changing data and imagery, and annotation programs where rapid data entry from hard copy is required.

Halpin, S. M. Utilization of partially accurate output from a computer aid. Working Paper HF-80-5, November 1979.

This paper provides a compilation of research conducted at ARI during 1972-74 on the issue of the credibility of computer output as a decision aid. This research addresses itself to a concern among those engaged in the development of computer support of decisionmaking, this being the extent to which the intended user will actually benefit from the aid. Results from research done in the area have shown that even those who have more or less grown up with computers fail to take full advantage of the tools provided by system developers.

The first part of this paper (chapter 1) presents an overview of research presented to Division 21 at the American Psychological Association meeting, 1974. The second part of the paper (chapters 2 and 3) presents detailed descriptions of the individual experiments.

Pask, G., and Robinson, M. Current approaches to scientific decision making in complex systems III. Vol. 1: Final technical report. Research Note 80-10, January 1980.

The main theme of the Third Richmond Conference was the area of foundational problems in decisionmaking. The conference is reported in two volumes. Volume II contains the major papers presented at the conference: Observable Components of the Decision Process and a Revised Theoretical Position, Gordon Pask; Decisionmaking as an Event-search: Traffic on a Multidimensional Structure, R. H. Atkin; Decision: Foundation and Practice, Brian R. Gaines; Competing Modes of Cognition and Communication in Simulated and Self-Reflective Systems, Stein Broten; On the Spontaneous Emergence of Decision Making Constraints in Communicating Hierarchical Systems, John S. Nicolis. Volume 1 contains an overview of each paper, the author's commentary, and the resulting discussion by the conference participants. Each volume may be read independently.

Pask, G., and Robinson, M. (Ed.) Current approaches to scientific decision making in complex systems III. Vol. 2: Position papers. Research Note 80-11, in press (January 1980).

For a discussion of this report, see the preceding entry on this page.

Pask, G. Cognitive mechanisms and behaviors involved in other than institutional learning and using principles of decision. Research Note 80-4, February 1980. (AD A084 066)

The report describes studies of individual and team decisionmaking in complex command, control, and communication systems involving man-machine and computer regulated interaction. The most recent advance is a comprehensive team decision system able to exteriorize normally hidden conceptual operations as behavioral records. The system has training, testing, and operational applications. It incorporates an on-line, novel concept, interrogation system, records for which (together with logging the condition of a space environment) provide indices of decision-making style and performance which are compared with data from (also novel) tests for learning style. The system also incorporates a computer implemented planning and representation method as well as an environment in which the decision process is instituted by essential bifurcations. The method is a microbehavioral conversation, based on conversation theory, from the conversation laboratory studies.

Summary analyzed results of earlier parts of the research project are presented, but the recent research is exemplified by detailed records since work is continuing under Grant DAERO-79-G-0009. It should be possible to establish indices of decision style, performance, and an index of individual and team behavior under more or less stringent conditions, but the data are bulky and not easily analyzed. Among the anticipated results are relations between learning and conceptual styles, team stability, the alternation of roles, predictions regarding performance quality and responsibility, and, finally, the realistic prospect of a powerful decision aid to be used either regularly or as an optimal response device under circumstances when the participants have no opportunity to make thoughtful and wise decisions.

Price, H. E., Fiorello, M., Lowry, J. C., Smith, M. G., and Kidd, J. S. Department of Defense and service requirements for human factors R&D in the military system acquisition process. Research Note 80-23, in press (July 1980).

This research note presents a thorough analysis of Department of Defense and service-level policy requirements for human factors in the military system acquisition process. It is intended as a companion document to ARI Technical Report 476, and as such provides detailed indoctrination into both the system development process and human factors R&D. It will be particularly useful to those who require a greater understanding of this process.

After an explanation of each system development phase, human factors R&D requirements are integrated into the system development framework. This is accomplished through direct referral to Department of Defense Directives, Specifications, and Standards. Because differences occur in Army, Navy, and Air Force implementation of human factors R&D, formal service documentation is presented for human factors in each phase of system development. These documents include service regulations and instructions. Formal service documentation provides only that human factors requirements be implemented, without setting forth a particular implementation plan. Informal service documentation is presented to illustrate the processes by which human factors R&D is implemented in system development programs initiated by each service.

Price, H. E., Fiorello, M., Lowry, J. C., Smith, M. G., and Kidd, J. S. The contribution of human factors in military system development. Technical Report 476, in press (July 1980).

This document reports on an effort to determine (a) the conceptual basis for human factors contributions to military system development and (b) the feasibility of an impact assessment methodology to measure the value of human factors R&D in system development. For these purposes, two parallel analytic processes were implemented.

One analytic process provided the conceptual basis for human factors in military system development. First, a rationale for human factors contributions and products was prepared. This rationale was further supported by policy documentation containing requirements for human factors R&D. The second analytic process provided the basis for evaluating human factors contributions. A review of cost-benefit analysis techniques applicable to human factors was performed together with a derivation of measurement metrics. These efforts resulted in a framework for performance of impact assessment and a determination that it is a feasible methodology for application to evaluations of human factors contributions to military system development.

This technical report provides recommendations for further refinement and validation of impact assessment in the measurement of the value of human factors efforts and products. Recommendations for developing human factors impact assessment handbooks are also provided.

Badre, A. N. Representing and displaying information for tactical decision processing. Technical Report 495, in press (November 1980).

One of the main tasks required in developing user-compatible systems is the specification of criteria for the development of algorithms that search for, classify, and order the display of chunks of tactical information such that they are meaningful to the decisionmaker. The aim of this study was two-fold: (a) to investigate the effects of the sequential displaying of chunks on the assimilation of tactical information; and (b) to determine the effects of presenting a tactical scenario as a member of a sequence of scenarios on chunking.

Two experiments were designed and conducted. The general procedure was to utilize battlefield scenarios to be reconstructed and copied under varying conditions of presentation and viewing by a select group of battlefield commanders (participants). The results indicated that presenting information sequentially and incrementally by meaningful chunks leads to higher recall accuracy than if the same information is presented either in nonmeaningful chunks or in meaningful chunks that are viewed in an order different from that of the original reconstruction.

The findings show no difference in accuracy of recall under varying contextual conditions, suggesting that the viewer's recall strategy is to foreground the entire sequence of scenarios, not only the one to be constructed. Sequential context had no effect on chunk size. The availability of an invariance in the sequence of scenarios had a significant effect on the order in which symbols were reconstructed and on chunk content.

Software Development

Atwood, M. E., Turner, A. A., Ramsey, H. R., and Hooper, J. N. An exploratory study of the cognitive structures underlying the comprehension of software design problems. Technical Report 392, July 1978. (AD A073 727)

An experiment was conducted to evaluate a framework for the study of software complexity and comprehension. Basic to this framework is the concept that a person's knowledge of, and experience with, software design affects that person's ability to comprehend a software problem and its potential solutions. Past research on software complexity and comprehensibility has largely been based on the assumption that complexity is a function of surface properties, such as variable names and flow of control. Such measures, however, ignore the effects of experience.

Research on expert-novice differences in problem solving suggests that experts possess a large number of previously developed knowledge structures, or schemata, that can be used to understand or solve the current problem. Research on text comprehension provides theoretical concepts and experimental paradigms that are useful in determining the structure and content of these experience-related schemata.

An experiment examined the knowledge structures used by participants, at differing levels of experience, in comprehending software system specifications. Six participants, at each of five levels, studied a software system specification and then summarized both the presented specification and the probable form of the corresponding software design. The results indicate that software designers use previously learned schemata in understanding a software design problem and in actually constructing a design and that these schemata differ as a function of experience. In addition, the structure and content of these schemata were investigated. It is suggested that by determining the structure and content of such schemata, software complexity and comprehensibility can be considered in a more meaningful manner.

Atwood, M. E., and Ramsey, H. R. Cognitive structures in the comprehension and memory of computer programs: An investigation of computer program debugging. Technical Report TR-78-A21, August 1978. (AD A060 522)

A theoretical framework, based upon recent studies in cognitive psychology on memory for text, was developed to explain certain aspects of human behavior during computer program comprehension and debugging. A central concept of this framework is that the information contained in a program is represented in a programmer's memory as a connected, partially ordered list (hierarchy) of "propositions" (units of information with properties similar to those observed in research on text memory). An experiment was performed to test the hypothesis that the difficulty in finding a program bug is a function of the bug's location in this hierarchy. This experiment compared the effects of bug location, bug type (array, iteration, assignment) and specific program. Each of 48 subjects debugged two separate programs, with one type of bug at two different hierarchical levels in each program.

A preliminary analysis suggested that all three factors--program, bug type, and bug location--significantly affected the time required to locate program bugs. Detailed analyses, however, suggested the program and bug type variables could be explained in terms of the bug location variable and that a bug's location in a program's underlying propositional hierarchy is a principal factor affecting performance in a comprehension and debugging task.

Ramsey, H. R., Atwood, M. E., and Van Doren, J. R. A comparative study of flowcharts and program design languages for the detailed procedural specification of computer programs. Technical Report TR-78-A22, September 1978. (AD A069 604)

An experiment was performed to assess the relative merits of Program Design Languages (PDL's) and flowcharts as techniques for the development and documentation of detailed designs for computer programs.

Twenty students in a computer science graduate course participated in this experiment. Working individually, the students designed a two-pass assembler for a simple minicomputer. Half the students expressed their design for the first pass of the assembler in the form of a flowchart, and expressed their design for the second pass in a Program Design Language. The other half of the students used a PDL for pass one, and a flowchart for pass two. Flowcharts and PDL's were compared on the basis of various measures of overall design quality, design errors, level of detail of designs, time expended in developing designs, and subjective preferences.

Having completed this design task, the subjects then performed an implementation task. They were given fairly detailed procedural designs for a program which simulates the function of a fairly sophisticated minicomputer. They were then required to develop a working version of the program in PL/1. Although the designs were logically equivalent, half the students received their simulator design in flowchart form, and half in PDL form. Flowcharts and PDL's were compared on the basis of design comprehension test performance, various measures of overall implementation quality, implementation errors, and subjective preferences.

In the context in which this study was performed, the use of a Program Design Language (PDL) by a software designer, for the development and description of a detailed program design, produced better results than did the use of flowcharts. Specifically, the designs appeared to be of significantly better quality, involving more algorithmic or procedural detail, than those produced using flowcharts. In addition, flowchart designs exhibited considerably more abbreviation and other space-saving practices than did PDL designs, with a possible adverse effect on their readability.

When equivalent, highly readable designs were presented to subjects in both PDL and flowchart form, no pattern of short-term or long-term differences in comprehension of the design was observed. No significant differences were detected in the quality or other properties of programs written as implementations of the designs. Subjective ratings indicated a mild preference for PDL's.

Overall, the results suggest that software design performance and designer-programmer communication might be significantly improved by the adoption of informal Program Design Languages, rather than flowcharts, as a standard documentation method for detailed computer program designs.

Atwood, M. E., Ramsey, H. R., Hooper, J. N., and Kullas, D. A. Annotated bibliography on human factors in software development. Technical Report P-79-1, June 1979. (AD A071 113)

As part of a larger ARI effort to survey, synthesize, and evaluate the state of the art in the area of human factors as applied to software development, a fairly extensive literature survey was conducted. This resulting bibliography contains citations of 478 articles or reports pertaining to the behavioral aspects of software design, programming, coding, debugging, testing, evaluation, and maintenance. Most citations are accompanied by descriptive abstracts, and all are indexed by author, publication source, institutional affiliation, and subject. To help the user unfamiliar with the area, the bibliography contains brief, basic reference lists in the areas of software engineering, the psychology of software development, the Structured Programming Series, and the DoD software program. Coverage is exhaustive through 1977 with a few references in 1978.

Ramsey, H. R., Atwood, M. E., and Campbell, G. D. An analysis of software design methodologies. Technical Report 401, August 1979. (AD A081 320)

Four formal software design methodologies were described and briefly analyzed: (a) Structured Design, (b) Jackson's Methodology, (c) Integrated Software Development System (Higher Order Software), and (d) Warnier's "Logical Construction of Programs." Relative strengths, weaknesses, and commonalities among the methods were identified and human factors problem areas were analyzed.

Several major human factors deficiencies and problems were identified. Formal software design methods differ in terms of (a) applicability to problems of different types, size, or complexity; (b) susceptibility to design errors; and (c) constraints and limitations imposed on the software designer. Various methods limit the designer's ability to select an appropriate problem representation, prevent the designer from utilizing relevant knowledge and experience, or impose potentially significant information loads on the designer. Improvements in design methodologies require a better understanding of the problem-solving behavior of software designers; potential research topics in this area were identified.

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