LEVEL II

ARI IMAGE INTERPRETATION RESEARCH: 1970-1 80

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July 1980

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Image interpretation research conducted by the Army Research Institute 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 1980, organized according to nine major problem areas. The text presents, for each area, the rationale of ARI's approach to the problem, findings, operational applications, and

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Item 19 (Continued)

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Summary--image interpretation research

Item 20 (Continued)

further research requirements. The research areas are 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 to system developers to help them provide design specifications for future systems and to determine areas needing further research.

ARI IMAGE INTERPRETATION

RESEARCH: 1970-1980

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Image Interpretation

The Human Factors Technical area of the Army Research Institute is concerned with the future battlefield demands for increased man-machine capability to acquire, transmit, process, disseminate, and utilize information. Image interpretation research deals with extraction of information from surveillance displays and with the efficient storage, retrieval, and transmission of this information. Research results are used to design future systems and to develop improved interpretation techniques in current systems.

This report summarizes the research completed by ARI between 1970 and 1980, organized into nine main problem areas. In each case, the rationale of ARI's approach to the problem, findings, operational applications, and further research requirements are presented. The problem areas included are image interpretability, near real-time imagery interpretation, real-time imagery interpretation, man/computer decision processes, change detection, mensuration and coordinate determination, training and proficiency maintenance, imagery interpretation key development, and reconnaissance resource management and utilization.

ARI image interpretation research has been conducted as an in-house effort augmented by contracts with several different organizations having unique capabilities and facilities for research in specific areas. This summary is responsive to requirements of Army FY80 Project 2Q162722A765. The report was prepared in collaboration with personnel from Battelle Columbus Laboratories.

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ARI IMAGE INTERPRETATION RESEARCH: 1970-1980

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EXECUTIVE SUMMARY

GENERAL

This report summarizes image interpretation research conducted by the U.S. Army Research Institute for the Behavioral and Social Sciences during the past decade. Most of these research efforts were conducted in response to specific military requirements to optimize the completeness, accuracy, and speed with which intelligence information was extracted from reconnaissance/ surveillance records. The results of this research have been used to improve current and future advanced interpretation systems. Findings of the research efforts are of continuing interest to systems users (interpreters, G2 and G2 Air officers, commanders, and others), system designers and engineers, the U.S. Army Intelligence Center and School (USAICS), and the intelligence community as a whole.

The research efforts have been grouped into eleven areas: research and operational support, image interpretability, near real-time interpretation, real-time interpretation, man/computer decision processes, change detection, mensuration and coordinate determination, training and proficiency mainte- nance, key development, reconnaissance resource management and utilization, and basic research. Each area is briefly reviewed in the beginning of each section; then, each research project is summarized; and the results, opera- tional applications, and further research needs in that area are listed. A summary of operational applications and further research needs for all image interpretation research areas is provided at the end of this report. Table 1 shows the primary operational application of the research results for nine research areas (two areas were not directly responsive to operational needs). Table 2 shows the primary users of the research for the nine research areas.

The following is a summary of selected operational applications of this research in the various image interpretation areas. Although some opera- tional applications are valid across many situations, others pertain only to specific circumstances or contexts. As a general principle, if the condi- tions are substantially different from those under which the research was performed, application in the operational situation should be done with caution. In no case should operational applications of the results be insti- tuted without prior review of the research report cited. Interaction with ARI scientists is recommended to help insure effective, optimal application of results.

Both hard- and soft-copy imagery will be useful to the Army in the 1985 time frame (TRADOC report, "Tactical Imagery Exploitation," 25 Jan. 1979). Different imagery types will be used, with emphasis at corps level and below on digital and analog, near real-time transmissions to satisfy the commanders' requirements for timeliness. This report directly and indirectly relates to many aspects of these concerns.

Table 1

Operational Application for Each Research Area

Research area	Primary Focus of Application of Research					
	Platform	Imagery	Techniques/ procedures	Aids	Doctrine	Facility/ equipment
Image interpretability	x	x				
Real-time and near-time interpretation (combined)	x	x	x	x	x	x
Man/computer interaction	x		x	x	x	x
Change detection	x	x	x		x	x
Mensuration/location			x	x	x	x
Training			x		x	x
Keys/references			x	x	x	x
Resource management	x				x	x

Table 2

Users of Research for Each Research Area

Research area	Primary users of research		
	Trainers & trainees	Doctrine developers	Systems developers & designers
Image interpretability		x	x
Real-time and near-time interpretation (combined)	x	x	x
Man/computer interaction	x	x	
Change detection		x	x
Mensuration/location	x	x	x
Training	x	x	
Keys/references	x	x	x
Resource management		x	

IMAGE INTERPRETABILITY

Image quality limits the amount of intelligence information that can be extracted from a reconnaissance/surveillance mission; it depends on the resolving capability of the sensor system, the stability of the aerial platform, the altitude at which the mission is flown, weather conditions, time of day, and the granularity and chromaticity of the film. Successful mission planning requires knowledge of the effect of the interrelationships of these factors on interpreter performance. If the quality of the imagery can be assessed in the field as soon as it is processed, the facility manager can quickly determine whether the interpreter will be able to extract the required intelligence information or whether the mission must be rescheduled. Techniques exist for assessing image quality empirically using special equipment and computational techniques. Research has focused upon developing quicker, subjective techniques for evaluating image quality and on the effects of mission factors on image quality.

Operational Applications

Using the Image Quality Catalog, the facility manager can make subjective estimates of interpretability to predict expected performance. These predictions can be used to determine if new imagery is required to meet the commander's needs, to select which frames in a mission should be interpreted and in what order, and to help the manager of an image interpretation (II) facility determine workload requirements.

Mission planners and sensor designers should consider the interactive effects of scale, haze, and image motion on interpretability in the initial stage of their planning.

Optimal planning of infrared missions is critical to insure that the imagery can be effectively interpreted.

NEAR REAL-TIME IMAGERY INTERPRETATION

Film processing introduces a serious delay in the imagery interpretation process. Bandwidth limitations may preclude the transmission of high-quality, inflight processed photographic imagery to ground stations; however, degraded imagery may be useful for screening purposes. Near real-time imagery interpretation involves many factors for which there is little data or operational experience available to guide system developers, trainers, or managers. Research has been concerned with determining which factors affect interpreter performance and with developing techniques to improve near real-time interpretation.

Operational Applications

The factors of image resolution, presentation rate, and scale affect interpreter performance and thus are important in the design of imagery displays and related doctrine. For example, more time beyond 2 seconds per

frame does not improve interpreters' screening accuracy for poor resolution imagery.

For target location on infrared (IR) imagery, use of a reticle and the automatic readout of location inherently provide more accurate estimates than manual methods. With use of the reticle, fewer target misidentifications are made, but at a cost of a greater time lag. System designers should consider the trade-offs of location accuracy, performance accuracy, and time lag in recommending use of a reticle.

Interpreters require more training and/or experience in the interpretation of SLAR imagery than that possessed by the sample of interpreters participating in the research. In directed search, fewer than half of the targets were identified correctly; in free search, 22% of the targets were detected, and of these only 20% were correctly identified.

Intelligence analysts should be aware of the accuracy and completeness of reports based on the present-day interpretation of side-looking airborne radar (SLAR) and adjust their intelligence estimates accordingly.

REAL-TIME INTERPRETATION

Real-time information on events beyond the forward edge of battle area (FEBA) may be provided by inflight displays in the aircraft, or the imagery may be telemetered to a ground sensor terminal for interpretation in real time. The remotely piloted vehicles (RPVs) being developed will be able to transmit in real-time the information from a variety of sensor systems, including television cameras. Ground personnel will control the flight of the platform, control the sensor parameters, and interpret the real-time displays. Telemetering of data to ground sensor terminals involves using man-machine considerations, including bandwidth availability, since bandwidth reduction degrades quality. Research has dealt with the interpretation of infrared and TV displays and with the effect of bandwidth compression of digitized imagery on interpreter performance.

Operational Applications

IR interpreters require additional training and experience to improve their completeness and accuracy scores. Modification of operator techniques, training, and procedures is suggested.

The RPV observer usually needs to devote full attention to target acquisition. Concurrent tasks can significantly degrade visual search performance, and the search task can degrade the performance on concurrent tasks.

Bandwidth compression of digital imagery degrades interpreter performance but can be used under several conditions. Mission planners should consider the interactive effects of sun angle on performance.

MAN/COMPUTER DECISION PROCESSES

The proliferation of intelligence gathering systems can overload a commander with information--some is critical and some is of little concern, some is accurate and some is relatively inaccurate; all information contains a combination of these factors. Working as parts of a system, image interpreters and the interpretation facility computer can enhance the usefulness of intelligence information for the commander. The decision model of this system is probabilistic because the true state of the conditions confronting the decisionmaker is usually not known with certainty. However, the cost of each interpreter error to the commander's mission can be estimated. This cost, combined with the interpreter's estimates of the correctness of the report, can help the commander choose a course of action. Research on usefulness of this approach has focused on the interpreter's ability to estimate the required probabilities and on the decisionmaker's ability to estimate the costs associated with errors.

Operational Applications

The usefulness of reports received from the interpretation system can be controlled by the G2 through adjusting the acceptable cost level based on mission requirements. A low acceptable cost level results in fewer reports of greater accuracy; a high acceptable cost level results in more reports of lower accuracy.

If the interpreter is no better than moderately good in stating confidence (probability of error), use of a second interpreter to check the work of the first interpreter will improve confidence validity.

If information is available from other intelligence sources, image interpreters can make more accurate confidence estimates.

Inexperienced interpreters cannot estimate successfully the probability that a sample of targets identified on a surveillance mission came from a specific type of unit. A computer program has been developed that can accurately calculate the probabilities that certain targets came from specific units.

CHANGE DETECTION IN IMAGE INTERPRETATION

Change detection provides the commander with valuable insight into the enemy's intent and capabilities. How well image interpreters perform change detection varies depending on several aspects of the imagery. For example, departures from congruence (same scale, same flight path, etc.) of early and late coverage degrade change detection performance. Research has been completed on several techniques to enhance change detection performance.

Operational Applications

Mission planning should consider controlling for the equivalence of early and late area coverage.

Provision of variable orientation and magnification equipment to compensate for scale and orientation differences between early and late coverage improves change detection performance.

Annotating targets on the early imagery increases the number of correct change detections.

Combined use of annotation and target lists for the early imagery maximizes the number of correct change statements, but with some increase in working time (time may not be a factor in an automated facility).

MENSURATION AND COORDINATE DETERMINATION

One critical task in image interpretation is measurement, e.g., plotting area coverage, determining the size of objects, and providing ground location data. Some tasks can be automated, but a manual backup is usually necessary; other tasks still require an interpreter. Measurement accuracy is usually necessary to determine if a target is properly identified, if it can be hit by artillery, and if the derived intelligence allows the commander to properly assess the enemy situation. A number of experiments using different types of imagery and utilizing interpreters with different experience levels have been performed to determine the magnitude of errors that occur under various conditions. Some of this work included using the Analytical Photogrammetric Positioning System (APPS).

Operational Applications

Within a particular operational unit, the most accurate (in terms of measurement) interpreters should be used for critical measurement tasks.

Interpreters can oe trained easily to accurately read out the pertinent coded reconnaissance data to insure a manual backup capability.

Additional training significantly improves the accuracy of coordinate location on SLAR imagery; however, the errors obtained by manual means are still excessive. Only interpreters with the proven ability to locate targets accurately should be used operationally with SLAR imagery.

Locations remote from terrain features identifiable on both mission and data base imagery cannot be transferred visually with consistent accuracy.

The most accurate location data can be determined from vertical or near vertical photographic mission imagery.

The reduced resolution of paper prints results in lower location accuracy than that obtained from transparencies in some cases.

Points on terrain features in vertical, oblique, high-panoramic, and low-panoramic photographic missions can be transferred to the data base with a ground error of less than 20 meters CPE (Circular Probable Error). Points 200 meters distant from mutually identifiable terrain features can be located within 20 meters CPE on vertical photographic missions only.

Old data base imagery makes transfer difficult because manmade changes have occurred in the interim. Similarly, changes due to seasonal variations also make correlation difficult.

Point transfers can be made with useful accuracy to a photo data base from radar and infrared reconnaissance imagery that has a wide range of scales and ground resolutions.

For some imagery types, points remote from identifiable terrain features on both sets of imagery cannot be transferred visually with consistent accuracy. However, they can be transferred using the indirect transfer technique. Compared to direct transfer, this technique takes about 5 minutes longer.

TRAINING AND PROFICIENCY MAINTENANCE

Training is a continuing process in developing proficiency in image interpretation. The image interpretation course at the U.S. Army Intelligence Center and School (USAICS) provides training in basic interpretive skills; these basic skills need to be expanded with training in unit skills, interaction with more experienced interpreters, familiarization with relevant publications, and other means. Several ARI research efforts have been concerned with upgrading and maintaining interpreter proficiency. The techniques are particularly applicable for on-the-job training, although they can be applied to more formal training situations.

Operational Applications

Search speed can be improved by training, but only at the expense of fewer detections or more errors.

The search time and the number of false target detections can be reduced by training with an error key. Systematic development and use of error keys at the school, on-the-job, or both should be initiated.

Precise feedback produced greater learning than did other methods; however, it may be impractical in operational units (but not in the school).

Team consensus feedback can increase target identification proficiency and reduce the number of false target detections. Teams of heterogeneous proficiency show greatest gains in learning.

Effective school and on-the-job training in target identification can be provided with a minimum of instructor participation using operational imagery as the basic instructional material. Immediate feedback on right and wrong answers is vital.

IMAGE INTERPRETATION KEY DEVELOPMENT

The availability of references (keys) for relevant military targets may be critical for accurately identifying potential targets and for reducing inventive errors and errors of omission. These references are also used for training in the school and on-the-job proficiency maintenance. Both the type of key and the format affect the usefulness of references. ARI has investigated the types of errors made by image interpreters and has developed and tested both formats and types of keys. In each case, actual improved interpreter performance (increased speed or accuracy or reduced error rates) was the basis for the recommendation on keys.

Operational Applications

Error keys reduce inventive errors and omissions in image interpretation. Error keys are most useful if they are developed for a specific geographical area so that they include objects common to that locale.

Error avoidance training using error keys should be incorporated into formal training and on-the-job training of image interpreters.

Line drawings are as effective as photographs in interpretation keys.

Viewing angle is not a significant factor in interpretation keys.

Reduced scale of key pictorials does not affect accuracy but may increase the time requirement for image interpretation.

An information data base (on chips or microfilm) can be used effectively as an interpretation key or in training.

The Mini-Key concept should be used for training and operations.

RECONNAISSANCE RESOURCE MANAGEMENT AND UTILIZATION

Effective reconnaissance resource management is becoming increasingly complex as the number and capability of available resources increase. A comprehensive survey of the present and projected future duties of the G2 Air officer (now the surveillance and reconnaissance officer) and image interpreter personnel was completed. The finding of significant gaps in the training of the G2 Air officer prompted development of the "Aerial Surveillance and Reconnaissance Manager" handbook. A related effort indicated that tactical commanders need a better understanding of the capabilities and limitations of the aerial surveillance and reconnaissance system and the role of the G2 Air officer. The "Combat Commander's Guide to Aerial Surveillance and Reconnaissance Resources" was developed to meet this need. Both publications underwent field evaluations and received largely favorable reviews.

Operational Applications

Both publications have been used in various U.S. Army schools and units for training and reference in aerial surveillance and reconnaissance use.

INTRODUCTION

GENERAL

This report summarizes the image interpretation research conducted by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) between 1970 and 1980. Most research was performed in response to specific military requirements for either operational or developmental image interpretation systems.

FACTORS AFFECTING IMAGE INTERPRETATION COMPLEXITY

A report (Montgomery et al., 1980) describing a model of imagery interpretation processing explains imagery interpretation as follows: "Imagery interpretation is a highly skilled profession with areas of specialization. As in any intelligence field, the interpreter must adapt rapidly to the changing world situation, as well as to the burgeoning imagery collection capabilities and changes in tasking." The following section briefly reviews the increase in collection capabilities.

Remote Sensor Systems

Collection capabilities for the photographic sensor system alone have increased tremendously. During the Civil War, single photographs were taken for surveillance purposes from captive balloons. In World Wars I and II, improved aerial cameras borne by reconnaissance planes flew many aerial missions. In Vietnam, the number of photographic missions flown overloaded interpretation capabilities.

In addition, other sensor systems were used to acquire imagery for intelligence purposes. Infrared scanners--both downward-looking and forward-looking infrared; side-looking airborne radars (SLAR) flown in both the fixed target indicator (FTI) mode and the moving target indicator (MTI) mode; and low-light-level television sensors joined the photographic sensor in the remote sensor inventory. Each added sensor presented unique problems to the image interpreter in analyzing sensor records.

Sensor Displays

Sensor displays changed from being recorded on photographic film only to being on film or displayed as a transient image on a video display. The video displays were often recorded on both film and video formats; however, if real-time interpretation were desired, the video display had to be interpreted. The quality and basic visual characteristics of the video display differed from that of the filmed version, making the interpretation task more difficult. The quality of these transient displays may be further degraded because of bandwidth limitations on transmitting from aerial platforms to the ground terminals. Military operations place great demands on available transmission bandwidth. Broad, clear-channel frequencies for transmitting

sensor acquisitions in analog format will be seldom available. Currently, the use of digitized sensor detections transmitted at compressed bandwidth is being explored.

INTERPRETATION TOOLS AND ASSISTS

The foregoing technological improvements have greatly increased the amount of imagery available for intelligence purposes. The image interpreter is the potential bottleneck in the information acquisition process. A variety of equipment has been developed or proposed to facilitate the interpretation process available.

Manual Facilities

In the manual mode, the interpreter may function with limited aids. Transparencies may be viewed on a backlighted display device equipped with reels for transporting the film over the lighted surface. Tools included in the image interpretation kit--slide rule, magnifiers, pocket stereoscope, measurement scales, reticles--are used in interpretation. The interpretation report may be handwritten or typed and sent to the appropriate headquarters by messenger or phone.

Automated Facilities

Several generations of automated tactical imagery interpretation facilities have been developed and fielded. These facilites speed up the mechanical phases of image interpretation. A computer-linked automated viewing device permits image magnification, rotation, determination of coordinate data, size measurement, and many other features. Reporting can be done by teletypewriter, with format stored in computer memory, or by using a cathode ray tube (CRT) display and typewriter keyboard, with the report sent electronically to the appropriate headquarters. These devices help the interpreter perform the rudimentary tasks involved in image interpretation. Regardless of the mode of interpretation, the actual detection and identification of objects of tactical interest depend on the skill and experience of the interpreter. Sophisticated equipment may facilitate the interpretation process, but it cannot accomplish interpretation at present, nor will it in the near future.

THE IMAGE INTERPRETER

In an automated facility, the assists provided to the interpreter can increase the timeliness of the reports generated, improve the accuracy of measurements and computations, and provide reference materials in a rapid and efficient manner. Perceptual judgments may be enhanced by improved viewing conditions, but the completeness and accuracy of the final report will primarily depend on the interpreter's aptitude, training, experience, and motivation. These human factors contribute to the excellence of the end-product. Thus, the selection of interpreter trainees, formal training in image

interpretation, on-the-job training after assignment to an operational interpretation unit, job satisfaction, and so forth are all viable areas of image interpretation research. Most research efforts described in this review focus on the human factors judged to be important determinants of image interpreter performance.

REVIEW OF ARI IMAGE INTERPRETATION RESEARCH

BACKGROUND

ARI research prior to FY 1970 has been summarized by Birnbaum, Sadacca, Andrews, and Narva (1969). For this review, ARI research investigations between FY 1970 and FY 1980 were grouped into 11 categories. Within a category, each investigation is briefly described and a list of possible operational and research applications is given. The last two sections of the report contain a compilation of all operational applications and research recommendations.

Interpreters participating in much of the ARI research were recent graduates of the Image Interpretation Course at the U.S. Army Intelligence School at Fort Holabird, Md., which is now given at the U.S. Army Intelligence Center and School (USAICS) at Fort Huachuca, Ariz. When interpreters with extensive experience were required, operational units willingly provided them. In this review, the source is stated only when experienced interpreters participated in the experiment.

The research frequently evaluates interpreter performance on the basis of the completeness, accuracy, and speed with which the required information was extracted from the imagery. Speed is measured by time in the normal way. However, completeness and accuracy have specific meanings and are defined as follows:

$$\text{COMPLETENESS} = \frac{\text{Number of Correct Responses}}{\text{Total Number Possible}} \times 100.$$

$$\text{ACCURACY} = \frac{\text{Number of Correct Responses}}{\text{Number of Correct Responses} + \text{Number of Wrong Responses}} \times 100.$$

The objective measurement of the validity of the interpreter's report in terms of accuracy and completeness requires a relatively exact knowledge of what military equipment or other items of tactical interest were actually on the ground during the time the imagery was collected. The aerial reconnaissance mission may have been flown over terrain where exact information was available concerning what was on the ground; this is called "ground truth." When ground truth was not available, several expert interpreters performed a careful, individual interpretation of the imagery. They then checked their results with each other and arrived at a consensual list of objects that are contained on the imagery; this is known as "image truth." Most of the following research depended on this latter method.

RESEARCH AND OPERATIONAL SUPPORT MATERIALS

This category does not concern actual research efforts in image interpretation. The reports reviewed are concerned with the preparation of support materials that facilitated research and/or operational activities.

Interpretation Model

Recent work (Montgomery et al., 1980) has resulted in an Imagery Interpretation (IMINT) Production Model based on published references, site visits to strategic and tactical interpretation facilities, and interviews with operational image interpreters at all levels. The ultimate objective of this investigation was to define functions that take place within interpreters as they develop intelligence information. The mechanical, observable activities interpreters must perform are defined and described in publications, but how they do these tasks has not been defined. Knowledge of these cognitive and judgmental processes will (a) facilitate efforts to evaluate training programs and training doctrine, (b) provide criteria to develop and evaluate advanced system designs, and (c) aid in personnel selection, motivation, and career planning. Research summarized in this review deals primarily with the outward manifestations of these cognitive and judgmental factors, not with the definition of these covert processes.

Target Acquisition Tests

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.

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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) tasks and to train aerial observers to recognize targets and items of equipment in other situations.

Research Recommendations. None.

Development of Research Materials

To support the image interpretation research program, ARI organized and maintained a Technical Support Branch manned by specialists in image interpretation, graphic arts, and other skills. Until recently, this group maintained a film library containing multisensor imagery acquired during various military field exercises and the experimental imagery for specific research efforts developed from the basic multisensor imagery.

Periodically, the Technical Support Branch issues a publication describing the current imagery holdings. The most recent report (Martinek & Bigelow, 1970) lists the holdings as of 1 January 1970. This compendium provides sufficient information so that users can identify measures that are suitable for specific objectives. The imagery was prepared from specifically acquired aerial roll film. Basic roll film was interpreted, and film characteristics were modified in scale, image quality, film format, and so forth to meet the experimental needs. These specially produced imagery rolls are termed "performance measures" because they are prepared to determine the effect of controlled image conditions on interpreter performance.

For each performance measure, the following information is provided: performance measure identification by roll number; number of rolls and number of frames in each roll; appropriate use and reference to relevant ARI publication(s); image content in terms of the exercise on which the imagery was flown, terrain, target areas and types; technical data including format, scale, quality, ground resolution, annotations, stereo/nonstereo, transparencies, positive/negative, how reproduced, and flight information; and form in which available for reproduction and use.

Operational Applications. The imagery and film rolls developed for performance measures have potential utility for future research.

Imagery with known target content and specified image characteristics can be useful for training image interpreters, assessing interpreter proficiency, and identifying training needs.

Research Recommendations. Similar performance measures should be developed for video displays. Such measures are needed for research and performance assessment in the interpretation of transmitted video displays in real-time.

5

Estimating Vertical Photographic Ground Coverage

An ARI memorandum (Jeffrey, 1972) based on data from several image interpretation publications provides tabular information to assist in mission planning and in research. Two tables in the report make it possible to estimate the linear and area coverage obtainable on 25 feet of 70mm film using a vertical camera equipped with one of three specified focal length lenses, at altitudes ranging from 500 feet to a maximum of 21,000 feet. Area coverage is given in square meters 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 coverage for 5-inch film and 9½-inch film can be approximated from the values given for 70mm film by multiplying by 2 and 4, respectively. The report can be used to determine the mission altitude and/or lens focal length required to obtain imagery of a desired scale.

The report also provides estimates of target identifiability as a function of ground resolution. This value, plus system resolution, can be used to determine the combination of altitude and focal length required to establish mission parameters, which provides reasonable assurance that the required targets will be identifiable on the acquired imagery.

Operational Applications. The current presentation has combined the information from several sources into a single source and may be useful to both mission requestors and planners in specifying altitude and focal length to obtain desired coverage of sufficient quality.

Research Recommendations. None.

IMAGE INTERPRETABILITY

Accuracy and Completeness as a Function of Time

Obviously, if the time allotted to interpret imagery containing a large number of targets is very brief, the completeness index will be rather low. On the other hand, the accuracy index could be quite high because the interpreter would find the easy targets first—the hard targets would not be attempted. These relationships will vary depending on image characteristics.

The research objectives of this report were to determine the relationships among accuracy, completeness, and time under selected conditions and to obtain parametric data concerning these variables (Martinek & Hilligoss, 1972). Thirty-six nonstereo, vertical, positive photographic transparencies were used. Nine photographs contained U.S. Army tents and vehicles at each of four scales—1:1,000, 1:2,000, 1:3,000, and 1:5,000. Three levels of target density and three levels of target concealment were represented among the nine photographs so that each photograph had a different combination of target density and target concealment. Image interpreters analyzed this imagery under varying time allowances. Curves for completeness versus time and accuracy versus time were prepared from these data. Empirical quadratic equations were determined to provide the best fit to these data. Curves for the completeness index showed that completeness rapidly increased over time and then leveled off. The curves for accuracy versus time were not as consistent

but generally decreased with time. The results obtained were considered tentative and to be used with caution.

Operational Applications. More precise information concerning the relationship among accuracy, completeness, and time could be used in the following ways:

- If the effects of specific image characteristics on the accuracy, completeness, and time required for interpretation were known, then the interpretation time needed to attain the commander's desired level of accuracy or completeness could be specified for a given mission. Greater precision would be possible if ability parameters for the interpreter doing the task could be included in the prediction.

- Assignment of interpreter personnel to facilities and the number of reconnaissance missions flown could be based on the commander's estimated levels of accuracy and completeness needed within specified response times.

Research Recommendations. Research should continue to study photographic imagery under a wide variety of operational conditions.

Research is needed to determine how interpretation accuracy, completeness, and time are altered by image characteristics for sensor systems other than the photographic sensor.

Estimating Interpretability from Image Quality

Image quality is a central factor in determining how much intelligence information can be extracted from a reconnaissance/surveillance mission. If it were possible to assess the quality of the imagery as soon as it was processed, the intelligence officer could estimate whether the imagery would permit the interpreter to extract the required intelligence information. If not, the mission could be rescheduled without spending time trying to interpret imagery of inferior quality.

Image quality can be assessed empirically using special equipment and computational methods. This equipment is rather bulky and is more often found in laboratories than in field installations. A way to subjectively estimate the quality of the imagery would be more useful. In this section, ARI research toward this end is reviewed.

A previous summary (Birnbaum, Sadacca, Andrews, & Narva, 1969) reported the development of the ARI Image Quality Catalog. This catalog contains 231 photographic transparencies, mounted 11 to a page with all images on the same page at the same image scale. The upper left image on a page is the sharpest; sharpness declines from left-to-right and top-to-bottom of the page. Seven image scales are used, ranging from 1:2,000 to 1:14,000 by even thousands. There is a separate section for each scale in the catalog. There are three scenes and consequently three catalog pages for each image scale. The three scenes differ in scene complexity--low complexity, medium complexity,

and high complexity. Scene complexity refers to the presence of terrain features that might be confused with targets by an interpreter. A flat, arid region without vegetation would be an example of a low-complexity scene. These three scenes, each with 11 images of varying sharpness for each scale, multiplied by seven (the number of image scales) make up the 231 images in the catalog.

Imagery of the quality of each chip was interpreted, and data on the accuracy of target detection and target identification are tabled for use with the catalog. In use, the interpreter determines the scale and scene complexity of the mission imagery so that the proper page of the catalog can be found. The final step is to compare image sharpness of the mission imagery with the 11 catalog chips on the page. Once this is done, the table is used to obtain the accuracy estimates for target detection and target identification. Interpretability estimates based on the comparison with the catalog images were found to correlate substantially with actual performance in discriminating target areas from nontarget areas and in target identification accuracy. For trained interpreters, the correlation coefficients were .77 and .54, respectively. For inexperienced interpreters, the respective coefficients were .70 and .51.

Operational Applications. The Image Quality Catalog can be used to predict the possible accuracy of target detection and identification with considerable effectiveness. Relatively inexperienced interpreters can accomplish this estimation of mission interpretability.

Research Recommendations. Research to refine the catalog procedure for assessing imagery interpretability should be continued, especially for new types of imagery.

Research (Clarke, Welch, & Jeffrey, 1974) extending the above approach sought to isolate additional factors of image quality that are important as determiners of interpretability. Photographic imagery in the film libraries of several agencies was screened to determine the most frequent causes of image degradation. From this survey, three dimensions were selected: image scale, haze (due to atmospheric attenuation), and image motion (resulting from poor image motion compensation or aircraft movement due to turbulence). Four levels of scale, three levels of haze, and four levels of image motion were used in the experiment.

Imagery was prepared, using laboratory manipulation, to represent 13 of the 48 possible experimental image conditions. Thirteen unique scenes, each scene treated to represent each of the 13 experimental conditions, resulted in the production of 169 image variants. GRD estimates for the 13 treatment conditions were computed, and estimates of detection performance were predicted from these data.

In a parallel experiment (Clarke, Welch, & Jeffrey, 1974), a target array was fabricated using geometric shapes positioned on background panels of black, white, and gray. Photographs of this array were degraded with respect to scale, haze, and image motion to the same levels as the imagery in the main experiment. Similar tests were conducted to determine interpretability.

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The use of a model was explored as an inexpensive method of examining several variables under controlled conditions.

As an ancillary experiment, the experimental imagery was rated against the ARI catalog by another group of interpreters, and the detection and identification accuracy were predicted from the catalog data. These predictions were compared with the obtained detection and identification performance of the interpreters. Results included the following:

- The experimental variables--scale, haze, and image motion--over the ranges employed had little effect on image interpreter performance when considered singly. However, these effects were marked when more than one form of photo quality degradation was present on the same photograph.

- A simple detection model based on ground-resolved distance (GRD) fitted observed data quite well. Indexes of interpreter performance yielded correlation coefficients of .84 or higher with the calculated ground-resolved distance model.

- Rank difference correlation coefficient between the ARI image catalog data and detection accuracy was .84, whereas that with target identification accuracy was .81 between predicted and observed scores.

- Imagery using geometric objects as "targets" was demonstrated to be useful for the study of image degradation on interpreter performance and has the advantages of economy, simplicity, and reproducibility.

Operational Applications. The ARI Image Quality Catalog method can be used to predict expected performance. These predictions can be used to determine if new imagery is required to meet the commander's needs, to select which frames in a mission should be interpreted and in what order, and to help the manager of an II facility determine workload requirements.

Mission planners and sensor designers should consider the interactive effects of scale, haze, and image motion on interpretability in initial planning stages.

Research Recommendations. Research should continue on the development of an easily used, subjective measure of image quality that provides estimates of interpreter performance for any imagery obtained under normal operational conditions.

Utility of fabricated target arrays for exploratory research should be evaluated. This low-cost approach will provide a way to achieve control over several troublesome factors. Final validation of promising factors will require operational types of imagery, targets, and image interpreters.

Jeffrey (1973) rescored and reanalyzed the data collected in the previous experiment. The primary purpose of this reanalysis was to obtain data that would permit tests of significance among the various treatment means. Results of this reanalysis revealed the following:

- Unidimensional degradation of photo quality does not significantly reduce the level of detection completeness and accuracy, whereas multidimensional degradation lowers detection performance.

- Any degradation of photo quality, unidimensional or multidimensional, significantly reduces the accuracy and completeness of target identification.

- The effect of degradation of photo quality, by haze or blur, is more pronounced for small-scale imagery than for large-scale imagery.

- Degradation of overall target detection accuracy was due more to erroneous classification of nontargets as targets (errors of invention) than to classification of targets as nontargets (omissions).

Operational Applications. The largest scale imagery practicable should be acquired because image quality degradation produces a greater loss in interpreter performance for small-scale imagery than for large-scale imagery.

In general, target detection and identification performance for imagery degraded on only one dimension is significantly superior to that for imagery degraded on more than one dimension. This may provide guidance in assigning missions to interpreters or in requesting that the mission be flown again.

Research Recommendations. Research on the effect of atmospheric haze as a dimension of photo quality should be defined and quantified; also, its effect in interaction with the quality dimensions of the ARI catalog--image scale, image sharpness, and scene complexity--should be determined so that the haze dimension can be appropriately integrated in the Image Quality Catalog.

Research should be conducted to empirically determine the relative merits of alternative techniques (such as the National Imagery Interpretability Rating System (NIIRS)) for predicting image interpretability. Quantitative and subjective techniques should be included.

Interpretability of Color Photography

The addition of a "dimension" such as color to photography theoretically should improve interpreter performance. However, the added cost and processing time associated with color must be compared to the actual increase in performance to determine the overall cost effectiveness.

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One investigation (Jeffrey & Beck, 1972) explored the usefulness of color photography as reconnaissance imagery. Conventional color imagery was compared to total optical color (TOC) imagery. This second imagery is taken on standard black-and-white film, which eliminates the need for sophisticated processing equipment required for conventional color film. The color information is coded on the black-and-white film using a special grating on the camera, and the color information is then reconstituted by a special viewer.

Five measures of performance were evaluated: (a) identification accuracy, (b) identification completeness, (c) detection accuracy, (d) detection completeness, and (e) mean time per slide. A questionnaire was used to assess interpreter opinion on the desirability of using each of the three ways of acquiring reconnaissance imagery--black and white, conventional color, or total optical color.

The experimental results showed that:

- The only performance index showing significant difference between chromatic and achromatic image quality was the mean time per slide required for interpretation. Conventional color required 89.2 seconds, total optical color required 87.2 seconds, and black and white required 106.4 seconds.

- The questionnaire responses indicated that interpreters believed color was better than TOC and both were better than conventional imagery for interpretation of detail. However, actual performance indicated no difference in interpreter performance, casting some doubt on the use of questionnaire responses in this case.

Operational Applications. System designers should consider that color adds a dimension to image quality that permits interpreters to extract intelligence information from such imagery in less time than is required with black-and-white film.

Research Recommendations. Additional research to validate the usefulness of color reconnaissance imagery should be conducted using a wide range of conditions typical of operational use, e.g., differences in targets, terrain, and weather. A cost-effectiveness analysis comparing interpreter performance, processing costs, viewer costs, etc., should then be made to determine the operational value of the three types of imagery.

Color mixture for the TOC viewer can be set to provide pseudo-color. Research should be undertaken to determine whether this capability has any merit for image interpretation.

Infrared Image Interpretability and Acquisition Parameters

The quality of an infrared image depends upon a different set of acquisition parameters from those important for a photographic image. The recording ability of an infrared sensor system depends upon its thermal sensitivity, spatial resolution, field-of-view, and so forth. The altitude of the sensor platform, the type of target imaged, and environmental conditions (time of day, weather, vegetation, terrain, and so forth) are all important

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determiners of the quality of the imagery obtained. The ultimate test of the usefulness of any sensor system is the ability of an image interpreter to extract intelligence information from the sensor output. Little quantitative information is available on the concomitant changes in interpreter performance as a function of change in acquisition conditions for infrared imagery.

Research (Root, Myers, & Narva, 1974) was conducted to investigate the influence of various factors involved in the acquisition of infrared imagery on its interpretability. Sets of infrared imagery were assembled presenting selected combinations of the acquisition parameters of sensor altitude, time of acquisition, aspect angle, detector, filter, and film format. Other parameters involved, but not subjected to systematic variation, were sensor system, target characteristics, and environmental characteristics. Ninety trained but inexperienced image interpreters were given a brief training course on the interpretation of infrared imagery prior to analyzing the experimental test imagery. For each of four images, each interpreter performed three tasks. The first task required the interpreter to detect and identify as many targets as possible within a 15-minute time limit (the "free search" task). The second task required identifying targets in the image after the targets had been designated to the interpreter (the "directed search" task). The third task required the interpreter to answer detailed questions about designated targets. Interpreter detection and identification completeness and accuracy were determined for the free search task, and identification correctness was determined for the directed search task.

Specific results have a Confidential security classification and cannot be presented in this unclassified summary. The information obtained may be useful in indicating situations where imagery acquisition is useless, where acquisition factors may be varied to obtain the needed level of interpretation performance, or where training is necessary to bring performance to acceptable levels. Reliable information of this type has important ramifications for engineering developments in sensing systems and their components, mission planning, design of interpretation aids, and training.

Operational Applications. The results obtained have implications for planning infrared missions so that the imagery obtained may be effectively interpreted.

Research Recommendations. The investigation of acquisition conditions and their effect on the interpretability of infrared imagery should be expanded to include conditions not varied in the initial experiment—that is, sensor system, target characteristics, and environmental characteristics.

NEAR REAL-TIME IMAGERY INTERPRETATION

General

Currently, most photographic sensor systems do not allow real-time interpretation because of the unavoidable delay in processing the film. Operationally, bandwidth limitations may prohibit the transmission of high-quality inflight processed imagery to ground stations. Degraded imagery may be useful for screening purposes, however.

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Screening Moving Photographic Imagery

Research (Lepkowski, 1978) was conducted to determine the accuracy and thoroughness of interpreter screening performance for moving photographic imagery varying in ground resolution, presentation rate, and scale. Photographic positive transparencies of 70mm format at four known ground resolutions (8 inch, 12 inch, 16 inch, and 24 inch) for two image scales (1:2,000 and 1:4,000) were screened for wheeled and tracked vehicles by 48 image interpreters--eight interpreters screening at each of six different presentation rates (.8, 1, 1.5, 2.0, 4.0, and 6 seconds per frame). The rolls of 70mm imagery contained 50 target and 50 nontarget frames. Interpreters classified each frame as a target or nontarget frame. Performance was evaluated in terms of the number of frames correctly classified in each roll (screening accuracy) and the total number of frames classified--correctly or incorrectly--in each roll (screening thoroughness). Results showed the following:

- For screening accuracy--frames per roll correctly classified:

    - Mean accuracy varied with presentation rate from about 64% at
      .8 seconds/frame to about 73% for 6 seconds/frame.

    - Mean accuracy was about 67% for small-scale imagery and about
      77% for large-scale imagery.

    - For each image scale, two-power image magnification resulted
      in significantly poorer mean accuracy than that obtained
      without magnification.

    - Mean accuracy varied with image resolution from about 67% for
      24-inch resolution to about 74% for 8-inch resolution.

- For screening thoroughness--frames per roll classified (right or
  wrong):

    - The interpreters were able to respond at a near 100% level
      for all presentation rates and at all resolution levels for
      both image scales with and without magnification.

Operational Applications. The factors of image resolution, presentation rate, and scale are important in the design of interpretation displays and related doctrine.

Possible tradeoffs among these factors should be considered also. For example, screening accuracy for poor resolution imagery can be increased for presentation rates in the range from .8 to 2 seconds/frame by increasing viewing time per frame. Beyond 2 seconds/frame, increasing viewing time does not increase screening accuracy.

Research Recommendations. Research conducted in this area should be coordinated with that suggested under real-time interpretation, where the use of bandwidth compression as a technique for cutting bandwidth requirements was evaluated (Martinek & Zarin, 1979).

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Near Real-Time Interpretation of Infrared Imagery

The Joint Inflight Data Transmission System (JIFDATS) provided the real-time transmission of infrared (IR) and side-looking airborne radar (SLAR) detections to ground stations. The time delay from real-time, caused by the film processing, is relatively brief with current rapid film processing techniques. Effective exploitation of this rapid availability of imagery may require new interpretation techniques in order to minimize the elapsed time from receipt of the imagery to the submission of the interpretation report.

Research (Ray, King, & Narva, 1980) was conducted to conceptualize--within the constraints of the JIFDATS and an envisioned advanced Tactical Imagery Interpretation Facility--several promising interpretation methods for deriving intelligence information in near real-time and to test these under load. Specifically, four one-person and four two-person methods were devised and tested, each under two levels of film input rate (.5 and 1.0 inches per second). The one-person method employed different combinations of film speed control (available versus not available), length of viewing window (10 inches versus 20 inches), target designation method (marking on film versus inputting by pushbutton keyboard), and requirement for and method of reporting target location (none, verbal report of target coordinates estimated from UTM coordinates recorded on film margin, or superpositioning measuring reticle over target with automated report). Two-person methods differed on the availability of film speed control and the decision criteria used (governing whether or not the interpreter should report a target) for the initial man of the team and the associated rescreening strategy of the second team member.

Forty-eight image interpreters analyzed three rolls of 5-inch format infrared imagery. Performance was analyzed on the basis of target detection, target identification, and time required. Results indicated the following:

- When interpretation time was disregarded, there were no significant differences among the one-person methods with the exception that target misidentifications were reduced by both the use of the 10-inch viewing window (with no reporting requirements) and the use of a magnifying reticle to report target location.

- Use of a reticle to report target location significantly decreased detection accuracy and completeness achieved per unit time.

- The incorporation of the film speed control option did not significantly affect detection or identification performance for either one- or two-person methods.

- Differential emphasis on interpretation accuracy or completeness for the initial team member produced no significant effects for the two-person methods of interpretation.

Operational Applications. Based on the experimental conditions tested, variable film speed control is not required operationally because it did not affect performance.

A reporting procedure incorporating the placement of a reticle over the target inherently permits greater target location accuracy than that obtained from target location estimates made by the interpreter from coordinate data annotated on the film margin. In addition, use of the reticle decreases target misidentifications. However, the procedure also involves a time lag that may be significant relative to other less accurate target location procedures.

Research Recommendations. Research should be continued in the search for methods to minimize the time required for interpretation and target location using near real-time.

Near Real-Time Interpretation of SLAR Imagery

Directed search and free search tasks were used in research (Kause, Thomas, & Jeffrey, 1973a) on interpreter ability using side-looking airborne radar (SLAR) imagery in near real-time. The interpreter was required to identify the annotated objects in directed search and to determine the map coordinates of these targets. In the free search task, the interpreter had to detect the targets, identify them, and determine their map coordinates. The coordinate determination performance is described in the photogrammetric procedures section of this report. Eight SLAR negative transparencies, each covering an area of about 100 statute miles in length, were used in data collection. Four were acquired by the Army slant range radar (AN/APS-94) and four by the Air Force ground range radar (AN/APQ-102A). Two SLAR runs from each radar system were used for the directed search task, and the remaining four were used for the free search task. Each radar run included the fixed target indicator (FTI) mode and the moving target indicator (MTI) mode.

The Army surveillance aircraft flying at 200 knots equipped with the AN/APS-94 sensor recording an image scale of 1:500,000 along the flight line produces about ½ inch of imagery per minute. A flight run of about 100 statute miles takes about 26 minutes. To simulate the near real-time condition, study interpreters were allowed 25 minutes to analyze each run. These interpreters had an advantage over the airborne sensor operator because they could view the entire run at one time; the airborne sensor operator must view the imagery as it comes from the film processor.

Interpreter performance was evaluated in terms of the accuracy and completeness of target identification for the directed search task and for the accuracy and completeness of target detection and identification for the free search task. Results showed the following:

- The imposed time limitation did not affect performance. The interpreters completed what they could do well within the time limit and then stopped working. Many targets in the directed search task were not identified, and many targets in the free search task were not detected.

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● For the directed search task (target location designated on
imagery):

  - About 47% of the targets identified were correct. These cor-
    rect identifications accounted for 38% of the total number of
    targets annotated on the imagery.

● For the free search task (interpreter detects and identifies
targets):

  - About 53% of the target detections reported were actually
    targets specified on the target list (i.e., 47% were false
    alarms). Of the total number of targets present on the
    imagery, only 22% were detected.

  - Target identification performance was rather low. For the
    total number of targets identified, about 20% were correct.
    Of the total number of targets present on the imagery, less
    than 8% were correctly identified.

Operational Applications. Interpreters require more training and ex-
perience in the interpretation of SLAR imagery to provide useful intelligence
information.

Intelligence analysts should be aware of the accuracy and completeness
of reports based on the present-day interpretation of SLAR and adjust their
intelligence estimates accordingly.

Requirements for information from SLAR should be based on the amount of
detail that interpreters are able to extract accurately and completely.

Research Recommendations. Research should be conducted to develop
training procedures in the use of inductive and deductive cues to determine
whether a specific radar return on SLAR imagery is a target and, if so, the
type of target it is.

The ability of image interpreters to determine the coordinates of SLAR-
imaged objects was of primary interest in the foregoing research (Kause,
Thomas, & Jeffrey, 1973a). Because coordinate determination performance was
not very accurate, research (Kause, Thomas, & Jeffrey, 1973b) was conducted
to determine whether training with knowledge of results would improve inter-
preter performance in coordinate determination. A description of the train-
ing program is given in the training and performance maintenance section of
this report.

Twelve interpreters, the experimental group, took part in the four-phase
instructional program and then performed the directed search and free search
tasks. A control group of six interpreters received a 4-hour review of the
imaging properties of radar systems, and then they also performed the di-
rected and free search tasks. The time allotted for these tasks simulated
the near real-time interpretation of SLAR imagery. Results showed the
following:

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- The imposed time limit did not affect performance.

- For the directed search task:

  - About 47% of the targets identified were correct. These correct identifications accounted for about 37% of the total number of targets annotated on the imagery.

  - The control group was significantly more accurate in target identification than the experimental (trained) group. About 54% of the control group's identifications were correct, whereas only 40% of the experimental group's responses were correct. Since the training given the experimental group was to enhance their coordinate determination performance, it is not obvious why the experimental group performed less well in target identification than did the control group. It is possible that the experimental group devoted greater effort to determining target location as a result of the training and less effort to target identification.

- For the free search task:

  - About 46% of the targets detected by the two groups were correct. However, of the targets available on the imagery, about 20% were detected.

  - Target identification performance was low. About 20% of the targets identified were correct. Of the total number of targets present on the imagery, about 7% were correctly identified.

Interpreter accuracy and completeness performance for target identification in the directed search task and for target detection and identification in the free search task were almost identical for the two experiments (Kause, Thomas, & Jeffrey, 1973a, 1973b). The suggestions made with respect to possible operational applications and research recommendations for the previous research (Kause, Thomas, & Jeffrey, 1973a) apply here and are not repeated.

REAL-TIME IMAGERY INTERPRETATION

General

Real-time information concerning the enemy is essential. The artillery forward observer linked to a fire direction center by phone or by radio is one solution to this problem. Another solution is manned aircraft like the Mohawk (OV-1D) carrying the infrared scanner (AN/AAS-24), which could provide an inflight display of the terrain overflown and, at the same time, telemeter this information to a ground sensor terminal where it could be viewed and interpreted in real-time. Currently, remotely piloted vehicles (RPVs) are being developed for this purpose. These small, unmanned aerial platforms can carry a variety of sensor systems, including television cameras. Personnel

at the ground sensor terminal can maneuver the RPV, change the look angle and field-of-view (FOV) of the television on board the RPV, and extract intelligence information from the fleeting display. A permanent record can be made on videotape.

Narrow bandwidth allocation and/or coding of transmissions are often necessary to avoid problems. ARI has performed research on the real-time interpretability of transmitted displays under bandwidth compression conditions, a potential solution to bandwidth restrictions.

Infrared Interpretation

The Army's surveillance aircraft, Mohawk (OV-1D), when equipped with the AN/AAS-24 infrared scanner, can present sensor detections on a cockpit display in real-time. The airborne sensor operator must scan the display and report the information derived from it to potential users. The operator must detect and identify not only targets but must also provide target location data. Since the display is dynamic, the time available to perform these tasks is limited. The purpose of the experiment (King, Cooper, & Jeffrey, 1980) was to obtain operator performance estimates for extracting information from such dynamic infrared displays.

The factors selected for experimental manipulation were image movement rate and the task to be performed by the observer. Image movement rate depends upon aircraft velocity, scanner FOV, and aircraft altitude. To limit the scope of the experiment, only differences in aircraft velocity and FOV were varied. Three types of surveillance missions were represented in the imagery: (a) a mission in which the targets were distributed along a line of communication, such as a river or road; (b) a mission where the targets were located at designated terrain positions; and (c) a mission where the targets were distributed over a relatively broad area requiring the observer to search the entire display area.

The laboratory simulator used in the experiment employed a light table over which infrared film could be driven at controlled rates of speed in keeping with the aircraft velocities simulated. A closed-circuit television camera scanned the moving imagery and displayed it on a video monitor, which closely simulated the characteristics of the actual cockpit display. The interpreter sat 18 inches from the display and wore a lavaliere microphone connected to a tape recorder. The interpreter used a response-pointer with a microswitch at one end that activated a camera to record the display and the location of the pointer on the screen. When reporting a target, the interpreter pressed the pointer switch against the face of the video monitor screen at the target location and orally identified the target by name. This provided an accurate record of the interpretation for scoring purposes. Figure 1 shows a schematic representation of the laboratory simulator.

Forty-five interpreters (nine were experienced) were given training on each of the interpretation tasks and on the use of the equipment prior to data collection. In scoring interpreter performance, the photo records and tape recordings were correlated and then compared against "image truth." Accuracy and completeness scores were analyzed. Although far from perfect,
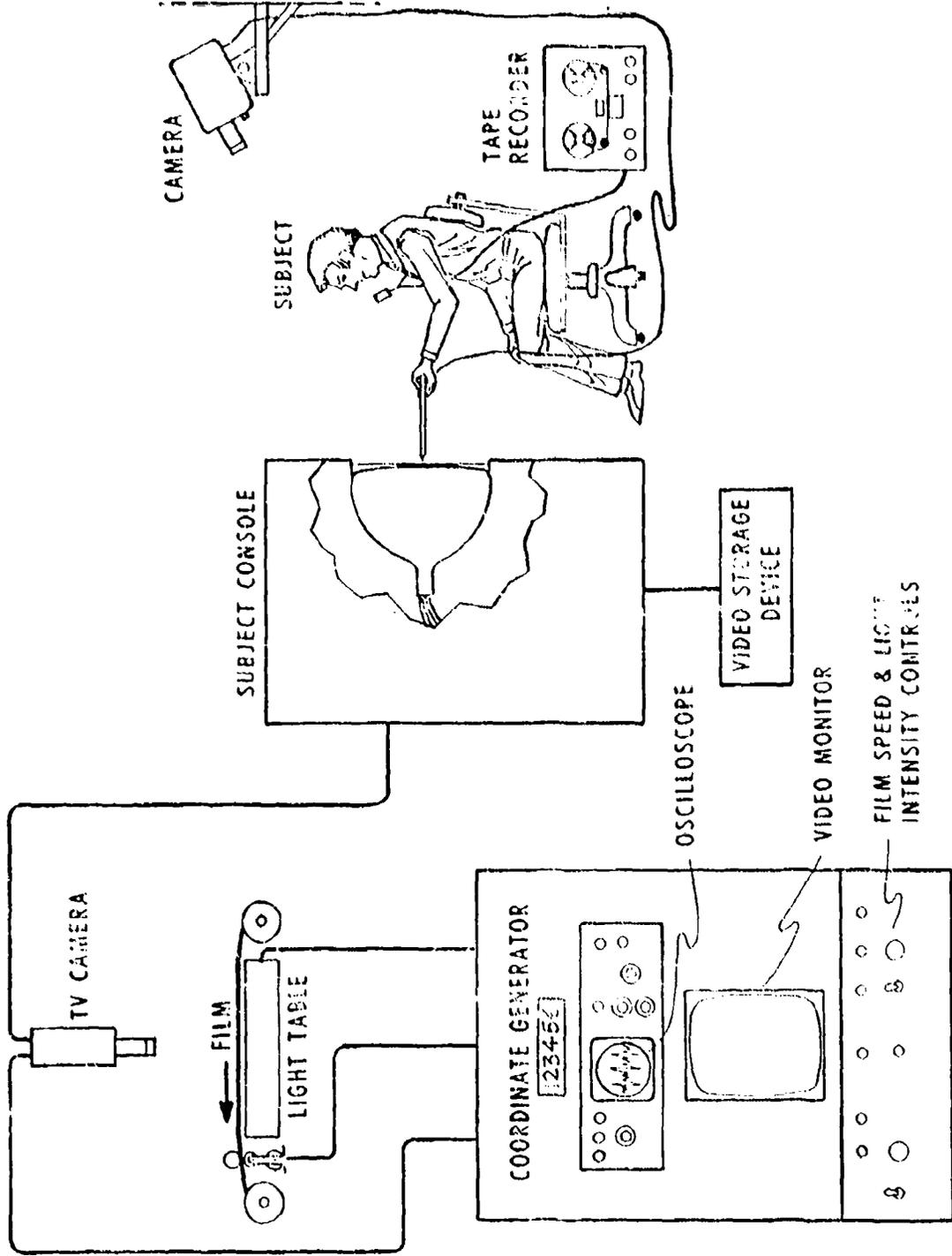
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CAMERA

SUBJECT

TAPE RECORDER

SUBJECT CONSOLE

VIDEO STORAGE DEVICE

OSCILLOSCOPE

VIDEO MONITOR

FILM SPEED & LIGHT INTENSITY CONTROLS

TV CAMERA

FILM

LIGHT TABLE

COORDINATE GENERATOR

23456

EXPERIMENTOR'S CONSOLE

interpreters were able to extract information from video displays of infrared imagery under simulated Mohawk (OV-1D) real-time display conditions.

Operational Applications. Results can be used to indicate training requirements and to specify modifications of operator techniques and procedures to enhance operator performance in the field.

Research Recommendations. Research should develop assists and training techniques to improve completeness and accuracy performance.

Research to improve the target coordinate read-out capability of the operators may be warranted.

For laboratory simulation, videotape recordings should be developed to simplify the procedure.

RPV Systems Problems

Manning requirements for ground stations for RPVs must be known to establish doctrine for determining the cost-effectiveness of the system. Research (Huntoon, Schohan, & Shvern, 1979) was conducted to obtain baseline data on observer target acquisition performance derived from a TV display while performing auxiliary tasks at several task loading levels that might pertain in the use of an RPV as the sensor platform. This research showed the degree of interference when these tasks are performed by a single operator under various conditions.

This simulation study employed a terrain model at scale 1:1,200. The model could be traversed along specific paths by a camera transport system carrying a TV camera viewing tank size targets, which were dispersed in open and clutter backgrounds. The display of this closed circuit TV system was the TV monitor viewed by the "RPV observer."

The simulated RPV flew at a velocity of 100 knots at an altitude of 2,000 feet. Three classes of targets--tanks, trucks, and self-propelled antiaircraft guns--were to be detected and recognized. The television camera look direction could be controlled by the observer in both pitch and yaw, and the camera diagonal field-of-view (FOV) could be set at either 20 degrees or 5 degrees.

Twelve observers participated in a three-phase experiment. Phase A required the observers to detect and recognize the targets in open and clutter backgrounds. Phase B required the observers to perform auxiliary tasks: first, to correct deviations from prescribed RPV course and altitude; second, to take appropriate action to two warning signals--correct video display degradation and actuate simulated electronic countermeasures in response to a warning that the RPV had been acquired by an enemy tracking system. Two levels of task loading were used--one per 10 seconds and three per 10 seconds. Phase C required that Phase A and Phase B tasks be performed simultaneously. Each of the six possible orders of the three phases was assigned to two of the observers to counterbalance for practice and/or fatigue effects.

Results of this experiment showed the following:

- For targets in open background, neither the probability of target detection/recognition nor the slant range to target at detection/recognition was affected by changes in auxiliary task loading.

- For targets in clutter background, both the probability of target detection/recognition and the slant range to target at detection/recognition were significantly reduced by auxiliary task loading.

- The probability of target detection/recognition and the slant range to target at detection/recognition were significantly greater for targets in open background than for targets in clutter background.

- There was a significant interaction between auxiliary task load level and target background conditions (open versus clutter) for the probability of target detection/recognition and slant range to target at detection/recognition.

- Time required to perform auxiliary tasks was unchanged by increase in task load level when auxiliary tasks were performed without target acquisition.

- When target acquisition tasks and auxiliary tasks were performed simultaneously, the time required for performance of auxiliary tasks increased significantly from the moderate to the heavy task load levels.

Operational Applications. To insure optimum performance on either auxiliary tasks or visual search, both tasks should not be assigned concurrently to the RPV observer.

Research Recommendations. Nonvisual, auxiliary tasks in response to tactile or auditory stimulation may be possible for the RPV observer without distracting attention from the primary task. Research to determine techniques to inform the RPV observer when ancillary tasks need to be performed should be conducted. Responses to such stimulation should be sought that do not impose visual requirements on the observer.

Bandwidth Compression of Digitized Imagery

Of considerable importance to systems that depend on the use of transmitted imagery is the research (Martinek & Zarin, 1979) to determine the effect of bandwidth compression on the interpretability of digitized imagery. Bandwidth compression is a technique for reducing the bandwidth requirements for transmitting imagery in digital form to ground terminals in real-time.

Conventional photographic imagery differing in ground-resolved distance (GRD)--8-inch GRD, 16-inch GRD, and 24-inch GRD--was digitized and treated to represent four levels of bandwidth compression--1:1 (no compression), 4:1, 8:1, and 10:1--and interpreted by 12 experienced image interpreters. The interpreters were given 3 hours of training and practice on digitized imagery representative of all of the experimental conditions. Interpreters were instructed to respond to the most detailed level possible for each target detected. A target list showing five different levels of specificity was provided: Category I (Target/Nontarget), Category II (e.g., Wheeled Vehicle), Category III (e.g., Heavy Truck), Category IV (e.g., 2½-ton Truck), Category V (model number from key provided). Interpreters responded to the most precise level they felt was justified. In the case of the example, interpreters might have reported "Heavy Truck," because they were unable to decide if it was a 2½-ton truck or a 5-ton truck. Following this procedure made it possible to score interpreter identifications at five reporting levels (I through V).

Each interpreter analyzed the imagery in the resolution sets: 8-inch GRD, vertical first; 16-inch GRD, vertical second; and 24-inch GRD, oblique last. Each image set was divided into four subsets, one for each bandwidth compression level--1:1, 4:1, 8:1, and 10:1. These materials were given to the interpreters in counterbalanced order to control for biasing effects. Target difficulty was controlled sufficiently for the 24-inch GRD, oblique imagery, to permit a test of the effect of sun angle, image contrast, target obscurity, bandwidth compression, and their interactions on interpreter performance. For the two sets of vertical imagery, sun angle, image contrast, and target obscurity were distributed equally across bandwidth compression levels, but their effects could not be analyzed because of confounding with target differences in the imagery. The number of correct identifications and misidentifications were analyzed for each of the five reporting levels.

The results indicated the following:

- Bandwidth compression of digitized imagery of three different levels of ground-resolved distance--8-inch, 16-inch, and 24-inch--reduced the number of correct responses (for several levels of reporting precision) by experienced image interpreters. The largest decrease in the number of correct responses occurred between the second and third compression levels used (4:1 and 8:1).

- Generally, bandwidth compression reduced the number of wrong responses made by interpreters.

- The following apply for the 24-inch GRD, oblique imagery only:

  - Target detection and identification were best for high sun angle. However, sun angle had no effect on target detection and identification performance for targets in the open under low-contrast conditions.

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- Target detection and identification performance was significantly poorer for targets embedded in vegetation than for targets in the open.

- For the contrast range employed, image contrast produced no effect on interpreter performance.

Operational Applications. Bandwidth compression of digital imagery degrades interpreter performance, particularly beyond a 4:1 compression ratio.

System users should consider the tradeoffs between different amounts of bandwidth compression and levels of reporting precision required—target detection versus precise target identification.

The effects of sun angle should be considered in mission planning.

Research Recommendations. Research is needed to determine the effects of bandwidth compression of digitized imagery under operational conditions, i.e., conditions involving the search and identification functions of image interpreters, trained and experienced in the interpretation of compressed, digitized imagery.

The interaction effects among bandwidth compression, sun angle, and target obscurity should be investigated more thoroughly under typical operational conditions, particularly for 8-inch and 16-inch GRD, vertical imagery.

MAN/COMPUTER DECISION PROCESSES

General

A previous ARI report (Birnbaum, Sadacca, Andrews, & Narva, 1969) presents a summary of research in this area conducted prior to FY 1970. As stated there,

> In a systems context, image interpreters and the system computer can be viewed as components whose task is to perform their functions so as to contribute maximally to the system output. The system output is intended to satisfy levied mission requirements. The study of man/computer decision processes is an attempt to increase the meaningfulness and utility of the interpretation system output by tailoring with the aid of a computer the quality and quantity of interpreter reports to the needs of the military situation.

> Research was conducted to determine whether a general decision model involving the evaluation of action alternatives through the use of payoff matrices and probability estimates could be used to help control interpreter output. The pay-off matrix states the relative value of each action alternative (in this case, making various alternative interpretation report given each possible true state or condition (in this case, t tual targets in the area covered by the photographs). The model is probabilistic in

the sense that it admits that the true state or condition confront-
ing the decision maker is seldom positively known, and it is neces-
sary to hypothesize a set of mutually exclusive and exhaustive true
states and to estimate their relative probability (in this case,
the probability that the object being interpreted is each of the
targets for which the interpreter is searching).

The decision model exploring the utility of payoff matrices and proba-
bility estimates as a means of controlling interpreter output can be de-
scribed most readily by reference to Table 1. Section I of Table 1 shows a
sample payoff or cost matrix consisting of hypothetical data. In this ma-
trix, the "true" state is indicated by the column headings, and the row head-
ings show the possible identifications that might be reported. The "Nothing"
column heading indicates that there was nothing of tactical interest at a
designated point on the image. The "Nothing" row heading indicates that the
interpreter judged that there was nothing of tactical interest at a specific
location. This latter is the equivalent of an omission if an object of in-
terest was actually located at this point. The numbers in the body of Sec-
tion I are estimates of officers in command misidentifying or omitting an ob-
ject on the imagery. As the matrix shows, there is no cost involved in
making a correct identification, and the most serious error is the failure to
report a missile, that is, reporting nothing when in fact a missile is
present.

Cost Matrix

The most recent ARI research in the determination of this cost matrix
was summarized in the earlier report (Birnbaum, Sadacca, Andrews, & Narva,
1969). Several constraints were imposed for practical reasons: (a) the
method used must provide valid costs on an interval scale, (b) it must re-
quire no more than 4 hours of decisionmaker's time to establish all costs, and
(c) it must require neither special equipment nor lengthy training of the de-
cisionmaker for data collection. This method required the direct estimation
of the magnitude of a sample of the possible errors and the prediction of the
remaining errors by multiple regression techniques. The larger number of
errors to be judged and/or predicted and the generation of regression weights
for the multiple regression equation required the use of a computer. Since
computers will be available in automated interpretation facilities, this re-
quirement should not be troublesome.

Probability vector in Table 1, Section II, is an example of the second
basic factor that must be provided for the control of interpretation output
using cost estimates. This probability vector is made directly by the image
interpreter. For each detection, the image interpreter estimates the subjec-
tive probability that the imaged object is one or more of the required tar-
gets. For probability vector (a), the interpreter judged that the probabil-
ity was .40 that the object was a tank, .20 that it was a truck, .30 that it
was a missile, and .10 that it was nothing of tactical interest. The sum of
these probabilities must add to unity.

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Table 1

Abbreviated Sample Matrix Showing Hypothetical Data for
Expected Costs in Image Interpretation Systems

Reported Identification	TRUTH				A	
	Tank	Truck	Missile	Nothing	Probability Vector	Expected Cost
Tank	0	2	5	4	.40	2.3
Truck	3	0	6	2	.20	3.2
Missile	2	2	0	5	.30	1.7
Nothing	8	4	14	0	.10	8.2
Vehicle	3	1	6	2		3.4
Weapon	3	2	4	2		3.0

Section I   Section II

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When the cost matrix is weighted (postmultiplied) by the probability vector, the expected cost column in Table 1, Section II, is obtained. If the decision rule is to take the identification with the smallest cost, the object is identified as a missile even though the interpreter assigned the greatest probability to the tank identification. The G2 may set some minimum cost level and thereby allow a greater number of responses to be reported. If the criterion is set more strictly, no response at all may be possible, and some means of improving the probability estimates would be required-- other interpreters, better imagery, or collateral information.

Operational Applications. The expected cost procedure provides the G2 with control over the number and credibility of the reports received from the interpretation facility. Setting a low acceptable cost level results in fewer reports of greater accuracy, whereas setting a high acceptable cost level results in more reports with a reduction in accuracy. Level set can be changed to correspond to the operational requirements.

Research Recommendations. The shortcut method for assessing subjective costs of large numbers of image interpretation errors should be refined and evaluated in an operational field setting for use in conjunction with the probability vector estimates provided by interpreters.

Estimating the Probability Vector

The estimation of the probability vector has been the subject of several recent research projects. These have centered on the confidence judgment of the image interpreter regarding the accuracy of specific identifications. Previous research has shown that certain interpreters seriously overestimate confidence, and others underestimate. Many use only a small portion of the total scale. To enhance the usefulness of confidence ratings, techniques for increasing their validity are required.

One experiment (Samet, 1969) used a team approach to increase confidence validity. An initial interpreter and a second interpreter performing the role of a checker were used. The checker examined the imaged object for each target reported, noted the initial interpreter's identification of the object and the expressed confidence in the correctness of that identification, then entered a confidence estimate in the correctness of the initial interpreter's identification. The initial interpreter reports used in this research were contrived to represent three levels of identification accuracy and three levels of confidence validity.

Results showed that checkers improved the confidence validity for initial interpreters who were poor or moderately good in estimating confidence but detracted from the confidence validity of excellent initial interpreters. Interpreter confidence statements were more valid when checking than when making initial interpretations. The checker's confidence statements were affected more by variations in identification accuracy of the initial interpreter than by confidence validity.

Operational Applications. In an interpretation facility, the confidence validity of interpreters who are poor or moderately good in stating confidence can be improved by having a second interpreter check the work of the initial interpreter. For target identifications associated with large error costs, checking the confidence statements of some of the interpreters should be routine when time permits.

Research Recommendations. Techniques to enhance the validity of confidence estimates using a team approach should examine the relative importance of selected levels of the checker's demonstrated ability to make valid confidence statements for selected conditions--type of imagery, type of target, image quality, and so forth.

Research (Evans & Swenson, 1979) on three techniques for determining the entire probability vector was conducted. The three judgment techniques were termed Direct Name Vector (DNV), Derived Name Vector-Experimental (DNVE), and Derived Name Vector-Control (DNVC). The characteristics of each technique appear in Figure 2. Results indicate that of the three techniques, the DNV maximized the amount of information that could be obtained from the interpreters. Performance deteriorated for all groups when a free search task was used instead of a directed search task. This suggests that the training given to interpreters should have been given in the free search condition and not the directed search situation. The DNVC was the poorest technique, and this group received no feedback during training. Additional research seems to be indicated; replication of the DNVC technique with feedback should prove informative.

Operational Applications. If use of payoff matrices becomes operational and additior 1 research is not possible, the Direct Name Vector technique shoulJ be used. Training on this technique must include free search.

Research Recommendations. The three techniques for establishing the probability vector--DNV, DNVE, and DNVC--should be reviewed, revised, and evaluated using experienced image interpreters instead of recent interpretation course graduates. Training with feedback should be considered for all techniques, and a free search task for training should be used.

Research on the probability vector development was extended along the lines described in the previous research. This experiment (Levine & Eldridge, 1974) used the DNV technique. Interpreters were given rolls of positive photographic transparencies with one target annotation per frame. A target list of 22 target names plus a "catch all" and "nothing of tactical interest" categories made a total of 24 entries. The interpreter could select up to five target names plus the catch all and nothing of tactical interest for a total of seven possible target identifiers. The probability assigned to one of these had to be greater than that assigned to the others, and the sum of all probabilities assigned had to equal one. Ancillary information was furnished for each annotated target location in probability vector format in two modes--quantitative (probability) or qualitative (verbal). A vector contained information estimates for from two to six categories. Each interpreter received all quantitative or all qualitative ancillary information. Two competing sets of information were furnished--ostensibly from different sources--for each annotation. Four modes of interpretation were used:

Interpreter analyzes object and estimates probability that:	DIRECT NAME VECTOR (DNV)	DERIVED NAME VECTOR-EXPERIMENTAL (DNVE)	DERIVED NAME VECTOR-CONTROL (DNVC)
• Object is a required target (total target probability).	xx	xx	xx
• "First choice" target name is correct.	xx	xx	xx
• Each of alternative target names—judged to have appreciable likelihood of being correct—is the "true" name of target.	xx		
• Remaining target names (all other identifications) include "true" name of target.	xx		
• (Assuming hierarchical target list—CLASS, CATEGORY, NAME.)			
(1) If "first choice" target name is wrong, category includes target name.		xx	
(2) If category does not include target name, class includes target name.		xx	

Figure 2. Characteristics of judgment techniques.

(a) interpretation without information, (b) simultaneous information/image interpretation, (c) post information with reevaluation of previous report, and (d) computer integration of the interpretation without information report with ancillary information.

Ancillary information, provided either simultaneously or post interpretation, enhances the accuracy of interpreter performance regardless of the information format--quantitative or qualitative. Performance accuracy was considerably better for easy targets than for difficult targets. Computer integration of the interpretation report without ancillary information with the relevant information was inferior to that achieved by an interpreter correlating the information with the interpretation task--either simultaneous or post.

Operational Applications. Interpreters preparing probability vectors should be provided with ancillary information from other intelligence sources when assessing the confidence of their reports. Proper indoctrination concerning the utility of this ancillary information should be given.

Research Recommendations. Research to answer the following questions is required:

- Did the enhancement of performance stem from the information content furnished or because the interpreter had to examine the imagery more carefully?

- What is the optimal combination of information parameters and the tradeoff between reduced information quality (less than complete and accurate) and no ancillary information at all?

- What is the relationship between the most influential informational variables and interpreter performance in establishing a probability vector?

Estimating Unit Identification

The final research (Laymon, 1979) in this section deviates from the foregoing efforts in that it does not concern the determination of expected costs associated with misidentifications. The task of the image interpreter in this research was to estimate the probability that a sample set of targets (vehicles) belonged to one of two company- or battalion-sized units (Unit A and Unit B) whose authorized vehicular complements were specified.

Tables of Organization and Equipment (TO&E) for company- and battalion-size units in the Army were used as a source of data on the equipment complement of units for which subjective probabilities were to be estimated. The sample sets of targets were devised and were not the result of interpretation. Each problem presented to the image interpreters consisted of a sample of vehicular targets showing the number of each type present in the sample, along with the number of each vehicular type authorized in the TO&E for two different company- or battalion-size units. The interpreters were trained to

estimate the subjective probability that a given sample was drawn from Unit A and from Unit B. The theoretical probabilities associated with each event were determined by computer.

The task proved too difficult for the interpreters. It was concluded that problems of the type used in the study could not be solved by inexperienced interpreters. A real-time computer program was developed in the later stages of the experiment that could compute the theoretical probabilities for up to six different units simultaneously.

The report suggested that the experiment be repeated using trained and experienced image interpreters. Since computers will be available in future image interpretation facilities, it may be advisable to develop a computer program that compares target samples against known enemy unit equipment composition and computes the theoretical probabilities as well.

Operational Applications. Trained but inexperienced interpreters should not be used to estimate the probability that a sample of targets detected and identified on a surveillance mission came from a specific enemy unit.

An operational computer or man/computer method should be developed to determine the probabilities that a given target sample came from a specific enemy unit or units.

Research Recommendations. Research should be conducted to determine the ability of experienced image interpreters to estimate the subjective probability that a detected configuration of targets came from one or more enemy units.

If valid estimates of the probability of unit identification are found, the use of this knowledge as an interpretation aid in detecting additional targets should be investigated.

CHANGE DETECTION IN IMAGERY INTERPRETATION

General

ARI research has examined some of the problems associated with change detection performance. A summary (Birnbaum, Sadacca, Andrews, & Narva, 1969) of previous research indicates that departure from congruence of early and late coverage results in a degradation of completeness and accuracy of change detection. Congruence refers to the identical nature of the early and late imagery--same scale, same flight path and direction flown, same terrain coverage per image frame, and so forth (however, all characteristics were not studied, e.g., image quality, time of day flown, and weather conditions). Previous research suggested that target reports for each mission be stored in the computer in automated facilities for automatic change detection by coordinate locations and a computer-produced change report.

Image Overlap, Scale, and Orientation

Later research (Epstein, 1970) determined the effects of variation in the amount of image overlap and discrepancies in image scale and orientation on the interpreter's ability to select comparative cover frames. All three types of departure from perfect congruence degraded performance. Departure from 100% overlap and any orientation discrepancy between early and late coverage had parallel effects, with that for overlap being the more severe. Performance degradation was evidenced by increased working time, more erroneous frames selected, decreased completeness in correct frame selection, and lowered interpreter confidence in responses. Scale discrepancy decreased completeness and increased the number of inventive errors but had no significant effect on working time or expressions of confidence in responses.

Operational Applications. Equipment should be provided to permit variable magnification and rotation in order to minimize the effects of scale and orientation differences.

Equivalence of ground area coverage should be partially controlled by mission planning. If late information about specific locations detected in prior coverage is desired, spot cover or area coverage at smaller scale can be requested to insure that the areas of interest are covered.

Research Recommendations. The utility of computerized assistance for change detection in operational facilities should be assessed to reduce the time devoted to this function and to decrease error rates.

Change Detection Methods

Another experiment (Epstein & Jeffrey, 1973) in change detection sought to determine whether change detection performance was improved by (a) demarcation of common areas on early and late imagery, (b) annotation of targets on early imagery, and (c) use of a list of targets appearing on the early imagery. Dependent measures of performance were the number of correct change detections ("unchanged," "gone," and "new"), number of erroneous detections, total working time, and confidence. Results of the research indicated the following:

- Demarcation of common areas did not significantly affect the mean number of correct target detections nor the mean number of erroneous change statements.

- Annotating targets on the early imagery increased the mean number of correct change statements for "unchanged" and "gone" targets but did not affect the number of erroneous change statements (targets detected on noncommon terrain or invented targets on common terrain). The number of target misidentifications increased also, but to a minor degree compared with the increase in correct change statements.

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- Use of target lists for the early imagery increased the mean number of correct change detections but also increased the number of invented targets.

- Use of target lists increased working time by 20%. Working time was not affected by demarcation of common terrain or by annotations of early cover.

Operational Applications. These results suggest the following:

- Prior demarcation of common terrain on early and late imagery does not help the interpreter.

- Target annotations on the early imagery are useful techniques for change detection.

- Combined use of annotations and target lists for the early imagery appears to maximize the number of correct change statements and is recommended if time can be allowed or if used in an automated facility where the computer would reduce the time element.

Research Recommendations. Research should determine the usefulness of team consensus feedback training in improving interpreter change detection performance.

MENSURATION AND COORDINATE DETERMINATION

General

Mensuration is involved in almost all phases of image interpretation: in determining the scale of imagery; in plotting the area covered by a mission; in making the field plot and the master cover trace; in ascertaining the physical size of objects detected on the imagery, thereby helping to corroborate or refute a tentative identification; in providing ground location data to the potential user at some prescribed level of precision; and for many other specific requests for information.

There are at least two ways of regarding the need for human factors research to develop improved techniques and procedures for enhancing measurement performance of image interpreters. The first way is concerned with the feeling that emergent or extant systems will solve, or have solved, most measurement problems by providing automated methods for determining tedious but necessary measurements and computations. The second way considers that the need to make numerous measurements may dictate that some portion of these will have to be accomplished by an interpreter using only the instruments provided in the image interpretation kit. If enough sophisticated imagery interpretation facilities become available so that all interpretation can be accomplished at these installations, the type of human factors research required will change in character, but the need for such research will not cease. Additionally, some of the manual measurement methods still will be needed as backup methods in the event of equipment failures.

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Manual Mensuration Variability

Research (Lepkowski & Jeffrey, 1972) on the variability of interpreter mensuration performance for manual measurements was conducted. The index of variability used was the standard deviation of the groups' measurements of the size of one large object, measured on the imagery, using a 7-power tube magnifier equipped with a reticle graduated in .1 millimeter (mm) units. The results for seven image interpreters--all with 10 or more years of active interpretation experience--showed that the variability of their measurements was .038 mm. The cursor accuracy cited for the automated system (constant error) was .1 mm, and the variable error of .038 mm for measurement variability among the seven interpreters yields a total error that can be as great as .138 mm or as small as .062 mm, depending upon whether man and machine errors sources were additive or compensatory. Converting this range of total error to ground size using an assumed image scale of 1:10,000, the ground error could range from .62 meters to 1.38 meters (2 to 4½ feet).

Other results of this research indicated that for the conditions of the experiment--imagery scale, target size, mensuration task, and measurement tools--the following conclusions appear to be justified:

- Scale graduations--thousandths of a foot or tenths of a millimeter--used on interpreter scales or reticles had no significant effect on mensuration variability.

- Measurement variability did not vary significantly with target ground size.

- Imagery scale had no significant effect on the variability of target measurement.

- Magnification level (2x, 7x, 12x) had no significant effect on mensuration variability.

- Measurements made using reticles appear to be less variable than those made with an interpreter scale.

- Interpreters tend to maintain their relative position from one measurement task to another with respect to the group average.

Operational Applications. Within a particular operational unit, the most accurate interpreters (in terms of measurement) should be determined and used for critical measurement tasks. The reticle scale should be used in preference to the interpreter scale if the object to be measured is smaller than the length of the reticle scale.

Scale graduations--in thousandths of a foot or in tenths of a millimeter on both interpreter scales and magnifier reticles--had no significant effect on measurement variability among interpreters.

Research Recommendations. A standard measurement task should be developed in which a series of fixed known distances are measured by each operational interpreter. Error scores for each interpreter would be determined. For each interpreter, the measured size would be plotted against the true object size for all measurements to obtain a personal equation for the interpreter. This functional relation between measured and actual size could be used to correct the operational measurements made by each interpreter. Error causes could be studied to determine the nature of faulty individual interpreter techniques and procedures that cause measurement errors, and school or on-the-job training could be provided to reduce or eliminate measurement errors.

Coded Reconnaissance Data

For some imaging systems, certain mission characteristics are recorded directly on the imagery in binary coded form. This information includes the coordinates of the nadir point, time of exposure, platform attitude, sensor type, organization flying the mission, date flown, and so forth. It was intended that these coded data would be read by a machine and the information then displayed in clear text. However, the block began to be recorded on imagery before automatic readers became available in the field. As an expedient, the U.S. Army Intelligence Center and School distributed instructions to trainees in their image interpretation course on how to decode the block visually to obtain the necessary information. Even with automatic readers, a manual backup was required in the event of equipment failure.

In an experiment (Birnbaum, Sadacca, Andrews, & Narva, 1969), a training package was developed using the paired-associates learning method to link the 16 unique dot patterns with their noncoded equivalent meanings. Recent graduates of the image interpretation course were taught to recognize the dot patterns using the training materials.

Interpreters required about 1 hour of training to reach the criterion of two errorless trials--recognizing 15 different dot patterns and writing the equivalent meanings without any mistakes. In decoding parts of actual code blocks on operational mission images, the trained interpreters were able to decode, with or without magnification of the block, at a rate of about 16 patterns per minute. Decoding accuracy was about 98 percent. Although this level of performance cannot compete with perfectly functioning automatic readers, it would be invaluable if the equipment is down.

Operational Applications. Interpreters should be trained in visual decoding to insure a backup capability in the event of automated reader failure.

A set of flash cards, as developed for experimental use, can be used operationally to train interpreters in pattern recognition for the decoding process and to help interpreters maintain their proficiency.

There are limitations on the accuracy of the location data reported in the code data block. If precise coordinate location information is required using the code block location data, correction for this source of error will be necessary.

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<u>Research Recommendations</u>. Research should be conducted to determine whether image interpreters learn to decode the reconnaissance data in the code matrix block better by paired-associates training or by learning to decipher the excess-three binary code. Research should determine the comparative levels of skill retention over periods of disuse for the two methods of decoding.

Coordinate Determination

The accurate location of tactical and strategic targets is a key part of the image interpreter's job, particularly if destruction or disruption of these targets is contemplated.

Accurate coordinate determination requires that the interpreter give meticulous attention to the correlation of the reconnaissance image and the topographic map or map substitute being used to determine coordinates. The disparity in scale between imagery and map, the difference in the amount of terrain detail, presence of geometric distortion in the reconnaissance imagery, and so forth magnify the difficulties involved in transferring a critical location from the image to the map. These problems become more severe in areas where the terrain has few mutually identifiable features on the map and on the imagery.

A report of the U.S. Army Engineer Topographic Laboratories (ETL) (Griffin, Barnes, & Stilwell, 1970) indicates that the most stringent field artillery positional requirement is about 25 meters CPE (Circular Probable Error). That is, if the ground plane coordinates of a target are determined and an imaginary circle drawn around this coordinate location with a radius of 25 meters, the probability that this circle includes the actual target location is .50. If greater assurance that the circular area includes the target is desired, a circle with radius of 46 meters drawn around the coordinate location will have a probability of .90 of including the target.

How difficult is it to achieve this level of accuracy when the interpreter must correlate the imagery with a map and determine the coordinates of the target identified on the imagery? Consider the map reference used. Suppose the map scale were 1:250,000, such as that of the Joint Operations Graphics (Ground) Series 1501. If the map position selected for the target location is displaced 1 mm from its actual position, the plane positional error on the ground is 250 meters, or 10 times greater than the accuracy requirement specified above (25 meters CPE). Even if the map scale were 1:50,000, the ground positional error would be 50 meters, or twice the stated acceptable error. Obviously, positional requirements are not this stringent for all objects detected and reported, but the interpreter must have the necessary training and equipment to achieve the level of accuracy required.

Coordinates for SLAR-Imaged Targets

The Army surveillance aircraft, the Mohawk (OV-1), when equipped with the side-looking airborne radar (SLAR) (AN/APS-94), processes the image record inflight which is viewed by the airborne sensor operator in near real-time. A laboratory simulation of the operational employment of this

sensor for near real-time interpretation was described in an ARI report (Krause, Thomas, & Jeffrey, 1973a). The time allowance given to the interpreters participating in this experiment was comparable to the time available to the airborne sensor operator in the operational setting. Flight conditions such as space limitations, work space stability, and ambient light conditions--all of which tend to degrade interpreter performance--were not simulated.

The interpreters participating in the experiment performed a directed search task--the interpreter examined annotated areas on the imagery, identified objects, and determined coordinate locations--and a free search task-- the interpreter searched the imagery, detected targets, identified them, and determined the terrain coordinates of these targets.

The results showed that for the directed search task, coordinates were reported for about 64% of the annotated targets. This failure to report locations for all targets was not due to lack of working time, because many interpreters stopped working before the allotted time had elapsed. Location errors ranged from less than 100 meters to more than 100,000 meters, with a median error of about 5,000 meters. For the free search task, about 22% of the possible targets were detected, and the same targets were not reported by all interpreters. Therefore, there was no common base for determining location accuracy in free search.

It appeared that trained but inexperienced radar interpreters cannot determine coordinate locations for targets on SLAR imagery with usable accuracy. Spot location of targets classified as tactical should be within a terrain location error of 100 meters, even for observed artillery fire (Department of the Army, 1971).

Operational Applications. Only interpreters with the proven ability to locate targets accurately should be used operationally with SLAR imagery.

Research Recommendations. More extensive training programs should be developed and validated.

The feasibility of using reference materials of larger scale should be investigated as a way to improve location accuracy for SLAR-imaged objects.

A baseline research effort is needed to establish the level of coordinate determination accuracy attainable by expert radar interpreters using SLAR mission imagery from both coherent and noncoherent sensor systems.

A Photogrammetric Approach

In 1971, ETL addressed the tactical target location requirements and developed the Analytical Photogrammetric Positioning System (APPS-1) to enhance target location accuracy. The key item of the system is a data base (DB) to provide the reference display. It consists of aerotriangulated stereoscopic pairs of mapping quality photographic imagery and the associated numerical data stored on tape cassettes to provide the ground reference source for

determining three-dimensional coordinates of any location on the overlapping area of the stereoscopic pairs.

Human factors requirements associated with the APPS stimulated three research efforts by ARI to determine the extent to which this system might satisfy coordinate location requirements for targets located on reconnaissance imagery acquired by various sensor systems. The first experiment (Sewell, Bradie, Harabedian, & Jeffrey, 1978) was concerned with determining how accurately experienced image interpreters could transfer annotated points from four types of photographic mission images--vertical, low oblique, low panoramic, and high panoramic--to data base imagery at 1:100,000 scale. Another variable of considerable relevance to the operational situation was the proximity of the targets to identifiable ground objects, e.g., crossroads, bridges, and so forth. Each mission image was marked with 30 numbered points. Half the points were defined as Type A, which were points appearing on identifiable ground objects; the other half were Type B, which were points more than 200 meters distant from an identifiable ground object.

Forty enlisted image interpreters with from 1 to 20 years of interpretation experience participated in the experiment. Each interpreter visually transferred the 30 points annotated on each of the four pieces of mission imagery--two were transparencies and two were paper prints--to the associated data base images. The interpreters did not use the APPS for this purpose but used a stylus to prick the emulsion of the data base imagery to show the point selected. (In APPS operations, no marks are made on the data base imagery.)

Results indicated that Type A points were located more accurately than were Type B points by ratios from 3:1 to 6:1. Oblique or panoramic missions were associated with less accurate location of points in the horizon half of the photo than for points in the near vertical half. For the conditions of the study, transfer errors of less than 20 meters were obtained for 50% of the Type A point transfers for all mission imagery types. Only for the vertical missions were Type B points transferred with this level of accuracy. Transparencies as mission imagery were preferred by the interpreters to paper points, and in several cases performance accuracy was better for transparencies than for paper prints. Type B points were not transferred visually with suitable accuracy. A technique must be devised to improve transfer accuracy of such points.

Operational Applications. The following should be considered in mission planning and standing operating procedures in an II facility:

● In the employment of the APPS, the interpreter/operator depends on the mutual presence of the same detail on the mission image and the data base image in order to accurately correlate the two by visual means.

● The most accurate location data can be determined from vertical or near-vertical photographic mission imagery.

- The reduced resolution of paper prints appeared to reduce location accuracy compared with that obtained with transparencies in some cases.

- Locations remote from terrain features identifiable on both mission and data base images cannot be transferred visually with consistent accuracy.

- Locations on terrain features in vertical, oblique, high panoramic, and low panoramic photographic missions can be transferred to the data base with a ground error of less than 20 meters PCE.

- Locations 200 meters distant, on the ground, from mutually identifiable terrain features on mission and data base imagery can be located within 20 meters CPE on vertical photographic missions only.

- Transfer difficulty is aggravated by the length of elapsed time between the acquisition of the data base imagery and the mission imagery. If appreciable time has elapsed, manmade changes may appear in one and not the other, making correlation more difficult. Attendant changes due to seasonal variations such as crop patterns, flooding, snow cover, and so forth may also make correlation difficult.

Research Recommendations. Research should be conducted to help the APPS interpreter/operator transfer locations on mission imagery to data base imagery when there are no mutually identifiable terrain features nearby.

The second experiment (Sewell, Harabedian, & Jeffrey, 1978) had two objectives: (a) to determine the accuracy and speed with which target locations on SLAR, IR, and static TV mission images could be transferred to a photographic data base; and (b) to develop techniques and procedures to help the operator correlate mission and data base imagery and so enhance transfer accuracy. Mission imagery from three radar systems (AN/APS-94, AN/APQ-97, and AN/APQ-152), two infrared imaging systems (AN/AAS-24 and AN/AAS-27), and a closed-circuit TV display of scale 1:5,000 were used. Twenty points were marked randomly on each mission image. The points were then classified as Type A or Type B points, depending upon their position in relation to identifiable terrain features.

The APPS operators were 11 experienced photogrammetrists who were familiar with photogrammetric mensuration devices but who had no previous APPS experience. Training on the use of the APPS included correlation of mission and data base imagery prior to the beginning of data collection.

In a preliminary phase of the study, alternative transfer techniques were evaluated. Nine operators transferred 20 points from the SLAR and IR images to the data base by the indirect transfer technique and the direct transfer technique separately. Only the direct technique was used for the TV display. The indirect technique was determined to be the most accurate for

transferring target locations from a variety of reconnaissance imagery. Experimental results indicated the following:

- The transfer accuracy for Type A points was accomplished equally well by either the direct or the indirect transfer technique. The median plane error for the six types of sensor displays employed in the experiment ranged from 9 meters to 34 meters, with only the AN/APS-94 and the AN/APQ-97 imagery points having median errors exceeding the 25-meter CPE criterion.

- The median plane error for Type B points transferred by the direct technique ranged from 13 meters to 75 meters; for the indirect technique, the range was from 10 meters to 54 meters. Median accuracy for Type B points imaged by AN/APS-94, AN/APQ-97, and AN/AAS-27 did not fall within the 25-meter CPE criterion, regardless of the transfer technique employed.

- Except for the AN/AAS-27 infrared imagery, the indirect technique for transferring Type B points provided a significant increase in accuracy over that for the direct technique.

- The relative time required for the two transfer methods shows an average time per point for the direct technique to be 1.3 minutes and that for the indirect technique to be 6.5 minutes, or five times longer.

The transfer of targets annotated on AN/APS-94 imagery to a map or map substitute (gridded radar mosaic) both at 1:250,000 scale was found to have a median plane error of about 5,000 meters in one of the experiments described earlier (Kause, Thomas, & Jeffrey, 1973a). In the present study, the maximum median error was 75 meters for transferring annotated target locations from AN/APS-94 imagery to a 1:100,000 scale photographic data base image. Certain differences in the two experiments can be specified that may have caused the magnitude of this disparity.

- Reference System:

    - A map or mosaic at scale 1:250,000 was used in the earlier experiment.

    - An aerotriangulated data base image at scale 1:100,000 was used in the present experiment.

- Mission Imagery:

    - Two images over Phoenix, Ariz., and two images over South Vietnam with MTI and FTI were recorded on all four. Negative transparencies were used.

    - In the present experiment, one image flown over Phoenix was used. MTI and FTI were recorded and reproduced as a glossy print.

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- Mission Imagery Scale:

  - Part of the imagery was at 1:500,000 scale and the remainder at 1:1,000,000 scale in the previous experiment.

  - Image scale was 1:250,000 in the present study.

- Personnel:

  - School-trained but inexperienced image interpreters were used in the early study.

  - Experienced photogrammetrists were used in the present study.

- Motivation:

  - The school-trained interpreters taking part in the previous study performed an experimental task beyond their operational experience. Their drive to do their best was probably not optimal.

  - The experienced photogrammetrists performed a task within their expertise. In addition, several of their peers were conducting the research. Motivation was probably high in the present study.

- Equipment:

  - The interpreters in the earlier study determined coordinates manually using the map or mosaic grid and interpolating between grid lines. A coordinate square was the only equipment available.

  - The photogrammetrists used a programmable calculator that read out the coordinate location of the spot on the data base under the measuring mark (reference dot) of the viewing instrument.

Operational Applications. Under proper conditions, point transfers can be made with useful accuracy to a photo data base from radar and infrared reconnaissance imagery having a wide range of scales and ground resolutions.

The direct transfer technique should be used for Type A points except for AN/APS-94 and AN/APQ-97 imagery if a 25-meter CPE is required.

The indirect transfer technique should be used for Type B points for some types of imagery in order to obtain sufficient accuracy (but an additional 5 minutes/target will be required).

Point transfers can be made by direct transfer with acceptable accuracy from a static TV display of vertical photography to a data base image.

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<u>Research Recommendations</u>. Research should determine the locus and magnitude of errors in APPS operation. This information will pinpoint areas where equipment design changes and operator selection or training are required to reduce output errors.

The third APPS experiment (Sewell, Harabedian, & Jeffrey, 1978b) investigated the amount of time required and the error magnitude involved in the performance of two preliminary tasks and the total task of determining target coordinates using the APPS. The purpose was to determine if sizable errors or excessive time were associated with the performance of these tasks. This research would identify the operations where equipment characteristics and/or operator procedures might be modified to reduce performance time and increase accuracy. The three tasks are described below:

● Task 1: In the preparation of a data base, each photo is marked with six index marks--three near the top edge and three near the bottom edge, as shown in Figure 3. In orienting the stereo pair to the model data stored on the magnetic tape, the four index marks in the overlapping area on the left photo must be positioned under the left reference dot, in turn, and the data grid location of each read into the APPS programmable calculator. The same procedure is repeated for the four index marks in the overlapping area on the right photo. The eight index marks were measured four times by each of 10 operators. Time was recorded for the measurement of each set of eight index marks. Plane error at ground scale was determined for the four measurements about their mean for each of the eight index marks.
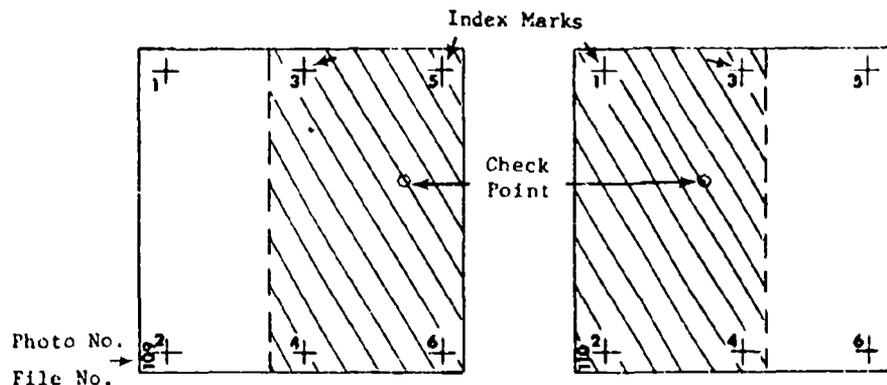
Figure 3. Index marks on data base stereo pair.

- Task 2: After the stereo pair is oriented, the APPS operator can determine the three-dimensional coordinates for any point in the overlapping area of the stereo pair. Eight locations had been marked on the overlapping area, and the coordinates of these points were determined by each of 10 operators. Height error, plane error, total error, and time required were the measures of operator performance.

- Task 3: The final task involved the entire coordinate determination process. All transfers from mission imagery to data base imagery were made using the indirect technique. Ten points were transferred from imagery from an infrared, a radar, and two panoramic sensor systems. Time required, height error, plane error, and total error were determined for each coordinate location.

The results obtained for the three tasks are summarized in Table 2 for error measures and Table 3 for time measures. For the types of mission imagery used in this study, trained APPS operators appear to be able to transfer target locations from mission imagery to data base imagery and determine UTM coordinates and height with respect to the datum plane with median accuracy that meets the most stringent artillery accuracy requirements. The desired positional accuracy of a second generation APPS was set forth in a letter (HQ TRADOC dated 12 June 1975, subject: APPS, Advanced (APPS-2)) that specified the acceptable error bounds by coordinate dimension (Table 4).

Table 2

Summary of Error Measures
(in meters)

Imagery		Type of Error	Centile		
			25th	50th	75th
Data Base Index Marks		Plane	1.0	1.6	2.4
Data Base		Height	1.4	3.0	5.5
		Plane	4.0	6.0	8.6
		Total	5.3	7.5	10.1
Infrared (AAS-24)		Height	3.2	5.7	9.7
		Plane	5.2	9.5	15.5
		Total	8.3	12.3	17.9
Panoramic (KA-77, KA-78)	Within 45°	Height	2.5	5.6	10.1
		Plane	6.2	10.1	15.0
		Total	9.2	13.0	17.8
	Beyond 45°	Height	2.8	5.8	10.3
		Plane	7.2	12.5	19.5
		Total	10.3	15.8	22.7
Radar (APD-10)		Height	2.8	6.2	11.3
		Plane	9.7	14.0	20.5
		Total	12.2	17.0	24.7

Source: Sewell, Harabedian, & Jeffrey, 1978b.

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Table 3

Summary of Time Measures
(in minutes)

Imagery	Number of observations	Centile		
		25th	50th	75th
Mono White Sands DB	8 index marks	1.3	1.5	2.5
Stereo White Sands DB	per point	.6	.8	1.3
AN/AAS-24	per point	4.6	7.0	10.2
KA-77 and KA-78	per point	4.8	6.5	8.9
APD-10	per point	4.8	6.5	9.1

Source: Sewell, Harabedian, & Jeffrey, 1978b.

Table 4

Acceptable Error for APPS-2

Terrain location	Type of error	
	Height error (PE)	Plane error (CPE)
To FEBA	3-8 meters	5-10 meters
Beyond FEBA	5-15 meters	15-25 meters

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For the conditions of the third APPS study, the median height error--similar to the probable error (PE)--statistic is less than the upper bound (8 meters) shown for the allowable error for objects of interest located in friendly territory for all types of mission imagery used. The median plane error--similar to the circular probable error (CPE)--exceeds the specified upper bound (10 meters) for objects of interest in friendly terrain for the radar mission and that portion of the panoramic missions that fell 45 degrees and beyond from the nadir.

Assuming that aerial surveillance beyond the forward edge of the battle area (FEBA) by manned aircraft will be accomplished in a standoff mode, the panoramic cameras (KA-77 and KA-78) and the side-looking radar (APD-10) would be the type of remote sensors used to acquire coverage of enemy-held terrain. The median plane error for these sensors falls well within the bounds specified above (15-25 meters) for objects of interest located beyond the FEBA. The results of this experiment suggest that APPS-1 can meet the accuracy requirements projected for APPS-2.

Operational Applications. An instruction manual for point transfer techniques is available that provides step-by-step instructions for carrying out a direct transfer and an indirect transfer using the APPS.

The use of quick prints of areas of interest, made during the interpretation phase, will permit point transfers to be made with improved accuracy before the image interpreter has completed the mission.

The indirect transfer technique and associated software provide an accurate means for determining ground coordinates of target points located in areas of sparse background detail on photographic, infrared, and radar imagery.

Research Recommendations. Research should determine the utility of APPS for coordinate determination of objects detected in real-time imagery.

TRAINING AND PROFICIENCY MAINTENANCE

General

Training is a continuing process in developing expertness in any area. This is true for the professional image interpreter as described in one report (Montgomery et al., 1980) based on a review of pertinent sources--Army training manuals and field manuals, site visits, and interviews with interpreters at all levels. The image interpretation course at U.S. Army Intelligence Center and School, Fort Huachuca, Ariz., provides training in basic interpretive skills whose mastery the trainee must demonstrate in order to graduate. Novice interpreters (MOS 96D) are not fully qualified image interpreters upon completion of this training, but they have the basic skills; and training will continue from this point.

Upon assignment to an operational unit, training is given in unit schools and/or in the form of interaction with more experienced interpreters, relevant publications, visits to other facilities, and so forth. The

individual interpreter must pursue aggressively all available resources in order to upgrade interpretive skills. Facility supervisors are vitally interested in this process and will provide local training. Certain skills developed by the interpreter may deteriorate during periods of disuse. Interpreters and their supervisors should guard against this contingency by providing training that will maintain proficiency in acquired skills, even though these skills may not be required by the current operational mission.

A series of ARI research projects had as its objective the upgrading of interpreter entry skills and the maintenance of proficiency. The techniques developed have application for on-the-job training but can be applied to more formal training situations as well. In general, the materials used for these efforts were chosen to be those readily available in an operational facility. Elaborate training materials and sophisticated equipment have been avoided.

Target Search Strategies

The target detection performance of experienced image interpreters shows that they will fail to detect a number of the available targets in an image, will fail to search certain areas of the image, will search other portions more than once, will fixate some locations for unwarranted periods of time, and so forth. In an attempt to improve detection performance, research (Birnbaum, Sadacca, Andrews, & Narva, 1969; Powers, Brainard, Abram, & Sadacca, 1973) compared four training techniques as to their relative efficacy in improving the completeness, accuracy, and speed with which interpreters were able to detect targets on photographic transparencies. Two of the training methods and systematic search strategies insured that all areas of the photographs were searched only once. Combined with these search strategies was a "speed-reading" technique designed to reduce fixation time and to increase the size of the photographic area perceived in a single fixation.

In brief, the characteristics of the four training methods were (a) a geometric search strategy--image searched from left-to-right and top-to-bottom, as a page of English text is read; (b) a tactical search strategy--image searched along communication lines (roads, rivers, valleys), areas of tactical deployment, e.g., ridge lines and high ground, and so forth; (c) a speeded search method--free search under time constraint; and (d) a control method--interpreters were given target detection practice under a free search condition without time or procedural constraint. Feedback during practice was provided for the first three methods but not for the fourth method. Target detection performance of four groups of eight interpreters per group--each group trained under a different experimental method--was determined before and after training. Performance data appear in Table 5.

Posttraining results for the two systematic search methods showed a marked improvement in the total number of target detections compared with pretraining results. However, this increase was at the expense of an increase in the number of inventions (nontargets detected as targets). The speeded search method produced the greatest gain. Search time was reduced about 65% with little degradation of other performance aspects.

Table 5

PRETRAINING AND POSTTRAINING PERFORMANCE MEANS

Experimental Groups

Performance Index	Geometric Search		Tactical Search		Speeded Search		Control	
	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post-Training
Total Detections	10.64	13.17	10.31	16.87	11.37	9.97	10.85	9.53
Correct Detections	6.98	7.02	6.89	7.18	7.13	6.19	6.21	5.79
Time (Minutes)	94.20	38.09	85.21	48.12	89.27	31.05	71.26	35.06
Completeness	0.55	0.56	0.55	0.57	0.56	0.50	0.49	0.46
Accuracy	0.67	0.55	0.66	0.44	0.68	0.65	0.62	0.63
Overall Error	9.05	11.51	8.91	14.89	9.51	9.97	10.81	10.34
Inventive Error	3.66	6.14	3.41	9.67	4.25	3.81	4.65	3.72

Source: Powers, Brainard, Abram, & Sadacca, 1973.

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After the research described above was completed, an investigation of error avoidance was conducted and then reported in the appendix to the study. Imagery containing examples of frequently reported nontarget items as targets was analyzed. Expert interpreters judged the cause of erroneous detections to be due to various factors--presence of vehicular tracks, shadows along roads, wet spots or puddles on dirt trails, rectangular or highlighted tree crowns, rocky formations, and so forth. An instructional unit was prepared using examples of those conditions that led to erroneous detections. This type of training is an example of an error key (Martinek, Hilligoss, & Harrington, 1972). Pre- and posttraining performance of eight experienced interpreters trained with this error avoidance material showed a 50% reduction in inventions with no reduction in detection completeness and with a 20% reduction in search time.

Operational Applications. Search time can be reduced by training, but only at the expense of fewer detections or more errors.

The number of false target detections (inventions) can be reduced by error avoidance training using an error key. Systematic development and use in the school and on-the-job should be initiated.

Research Recommendations. Research should determine the effect on the accuracy, completeness, and time required for detection by combining rapid systematic search and error avoidance during training. It should also determine the extent to which such training persists over time.

Team Consensus Feedback

The use of interpretation teams to produce more complete and/or more accurate reports than interpreters working alone was described in a previous ARI research summary (Birnbaum, Sadacca, Andrews, & Narva, 1969). This finding suggested the use of teams in interpretation training, since the team consensual judgment would provide more accurate knowledge of results (feedback) than would be available to the interpreter practicing alone.

The team consensus feedback method offers a simple and inexpensive solution to the problem of training in the field. Imagery available in the interpretation facility can be presented to a team of interpreters; the individual team members make their interpretations and then compare and discuss results with the other team members and resolve any conflicting interpretations.

Research was initiated to investigate, empirically, the most effective methods to be used in training individual interpreters by the team consensus feedback approach. Factors other than work procedures that were varied in these experiments were delay of feedback, size of team, composition of team in terms of initial interpretation proficiency of team members, and the effect of initial proficiency on subsequent learning. In the final experiment, an attempt was made to investigate the nature and extent of the learning that occurs and the shape of the learning curve.

Four experiments were conducted on the use of team consensus feedback. The first two studies were described in separate ARI reports (Birnbaum, Sadacca, Andrews, & Narva, 1969; Cockrell, 1969) and the final two in another ARI report (Cockrell & Sadacca, 1971). Only the final experiment will be summarized, since it used those procedures and conditions shown to be most effective in interpreter training by team consensus feedback in the first three experiments. This final experiment sought to determine the nature and shape of the learning curve involved in team consensus feedback.

Two team consensus feedback procedures were selected--serial consensus feedback and immediate consensus feedback. These are defined as follows:

- Serial Consensus Feedback: Each team member interprets a different stereo pair of photographs annotating and identifying all targets. After all team members are finished, members change position and check the work of another member and then search the imagery for additional targets that may have been missed by the initial interpreter. After all members have completed this step, they discuss the results and attempt to resolve any conflicts.

- Immediate Consensus Feedback: Each team member interprets a copy of the same stereo pair of photographs annotating and identifying all targets. After all members are finished, results are compared and discussed, and conflicts are resolved.

Choice of team size was not clearly defined by significant results from the previous research, but trends seemed to indicate that three-person teams were preferable. Discussion of results among team members during the team's evaluation of results had not been demonstrated to be beneficial but was retained for this experiment. Teams were required to identify all targets at gross name level, e.g., tracked vehicle, wheeled vehicle, and so forth. All teams were heterogeneous in terms of initial interpretation proficiency of the members and were composed of one high, one medium, and one low in proficiency.

Three separate tests were used to assess performance. Each interpreter took one of the three tests as a pretraining test, a different one as the intermediate (midtraining) test, and the remaining one as the posttraining test. These tests were roughly equated but were used in counterbalanced order to insure that any differences in test difficulty would not bias results.

Results for this fourth experiment showed that learning took place during the 3-day practice period and that learning was greater for the team consensus groups than for the control group.

Learning occurred for all measures of interpreter performance used--target identification, number of targets correctly detected, and reduction in the number of false targets detected (inventions). Figure 4 shows the learning curves for the target identification score for all three training methods and for each of the three levels of initial interpretation proficiency of team members.

IDENTIFICATION SCORE
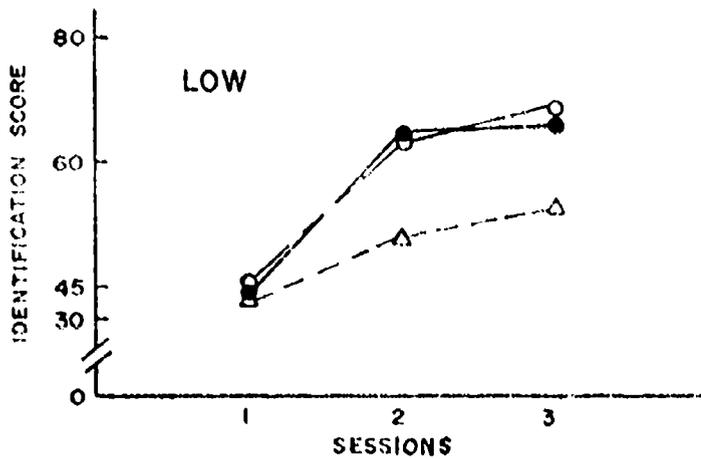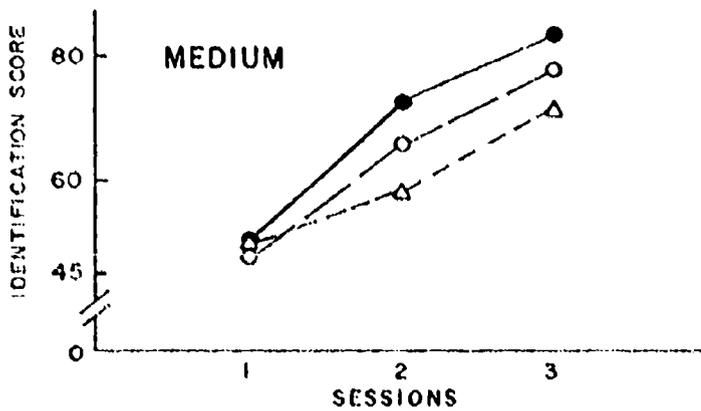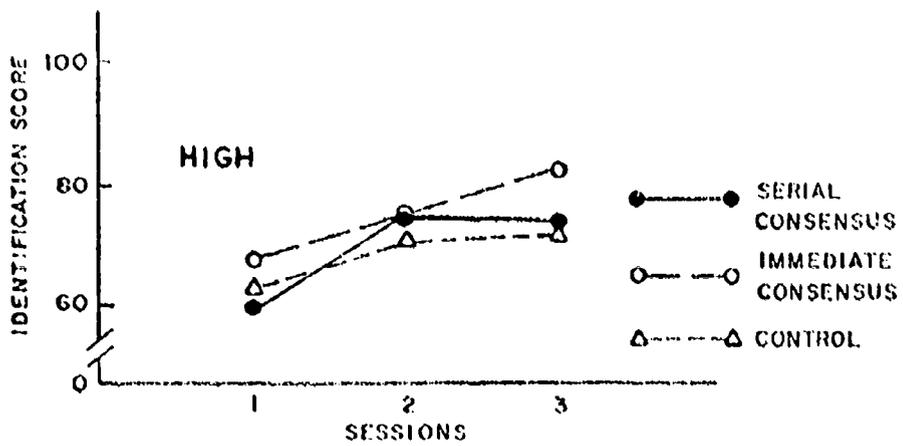
Figure 4. Identification learning curves for three methods used by interpreters of high, medium, and low proficiency.

The immediate consensus feedback procedure was judged to be somewhat superior to the serial consensus feedback method. Learning with serial consensus feedback was initially high and then slowed; learning with the immediate consensus feedback method was steady at a moderate rate. For the no-feedback (control) groups, learning was steady at a low rate.

Operational Applications. The following applications are taken from all four experiments; they can be applied in the field or during formal training:

- Precise feedback was shown to produce greater learning, but this type of feedback is impractical in some operational units. It should be used in formal training and in computerized facilities if information storage capacity is sufficient and if time for on-the-job proficiency training is available.

- Team consensus feedback is an effective way to develop and maintain interpreter proficiency. Consensus feedback can be used by two or more interpreters using operational imagery during normal operations but under little time pressures.

- Teams that are heterogeneous in proficiency learn more than do homogeneous teams. This indicates that team members learn from each other and that without one member who is more proficient than the others, little learning will take place.

Research Recommendations. The results of the team consensus feedback research indicate that this approach has merit for training and proficiency maintenance. Perhaps additional research is not judged necessary. However, the definition of high, medium, and low proficiency in interpretation skill was based on performance on the pretraining tests. The interpreters participating in these experiments were all recent graduates of the Army image interpretation course, and it seems reasonable to assume that the range of interpretive skill among the members of the group was not very large. In one of the team consensus feedback experiments, the mean target detection completeness score for the members with greater proficiency was 48.5 and that for the members with lower proficiency was 37.3. This difference in skill level was sufficient to produce a significant change in performance for the lower skilled group. This observation suggests three other research efforts to answer the following questions:

- How is learning rate of the less proficient team members affected by the skill level of the most proficient member?

- Since the most proficient member of the team has been shown to learn little more than interpreters practicing without feedback, how can the progress of the most proficient member be facilitated? Precise feedback, if available, might be an answer.

- What other factors inherent in the most proficient team member are conducive to increased learning by less proficient team members? Should leadership of the most proficient member be dogmatic, laissez-faire, democratic, or some other personality characteristic?

Structured Training Content

A summary (Birnbaum, Sadacca, Andrews, & Narva, 1969) of research using computer-assisted instruction to teach interpreters to identify U.S. Army cargo trucks and tanks was structured primarily around the method of presenting the training material (linear or branching format) and two types of feedback (response-sensitive and response-insensitive). A linear program presents the training material in fixed order with small incremental steps between instructional increments, whereas a branching program permits the student to skip over easy material. Response-sensitive feedback provides information tailored to the student's response--if the answer is wrong, the correct answer is given along with an explanation of why the student's answer was wrong. Response-insensitive feedback provides the correct answer only. Results of this study showed the branching program to be superior and that there was no difference between the two types of feedback.

The foregoing research used the technique of training the interpreter in the significant features or signatures of each target. However, it may be more advantageous to present pictures of the targets to be learned--at various image scales, different orientations, under various light conditions, at various levels of distinctiveness, and so forth--until the interpreter is able to name the target each time it is presented. This perceptual approach requires less expensive instructional material, and the instructional unit can be prepared without specialized training personnel.

The objective of the follow-up research (Cockrell, 1978) was to evaluate an instructional technique for training interpreters in target identification that would (a) be easy to develop; (b) require only materials that are operational unit would have readily available; (c) require little effort for updating or revision; (d) be flexible in terms of amount of training that could be provided--ranging from a few minutes to a few hours; and (e) allow free choice by the student as to the material to be covered. The four training methods used in the evaluation are described below:

- Unstructured Pictorial Method: This method typified the study objectives. The instructional materials could range from slides to hard-copy photographs. Presentation could be done by computer-controlled displays down to manually turned photos. Key pictures showing targets to be learned were presented, followed by target pictures presented in random order. The interpreter identified each target picture, received the appropriate type of feedback, and proceeded to the next target picture until mastery was achieved.

- Structured Textual Method: Verbal questions with multiple-choice answers were used to teach interpreters to memorize cues associated with each tank or truck to be learned. Schematics and dichotomous cues leading to identification were used. Key pictures and training pictures carried the target identification under each vehicle. The emphasis for the student was to learn and remember cues that distinguished each target and not to passively learn to recognize the target. Appropriate feedback was given after each response.

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- Structured Pictorial Method: This method was similar to the un-
  structured pictorial method except that difficulty was ordered
  to enforce a low error rate. Training progressed from the easy
  to recognize targets to the more difficult. Feedback similar to
  that for the unstructured pictorial method was provided.

- Structured Method (Mixed): The first half of the training under
  this method was given using the structured textual method and
  the second half using the structured pictorial method. Feedback
  provided during the first and second halves of training was con-
  sistent with that of the method used.

Eight interpreters were trained under each of the four methods. Half of
each group received response-sensitive feedback and the other half received
response-insensitive feedback. High and low aptitude (defined by the General
Technical Aptitude Area scores) was balanced across all experimental condi-
tions. Posttests on visual target identification and verbal target cues were
used to evaluate the effectiveness of training methods and feedback condi-
tions for each GT level. The results of the experiment showed the following:

- Target identification performance was significantly poorer for
  the structured textual method and about the same for all three
  methods using pictures.

- Type of feedback given has no significant effect.

- Learning did not vary as a function of GT aptitude. However,
  interpreters with lower aptitude appeared to forget training
  more rapidly.

Operational Applications. Effective school and on-the-job training in
target identification can be provided with a minimum of instructor participa-
tion and relatively simple support, using operational imagery as the basic
instructional material. Immediate feedback on right or wrong answers is vi-
tal but need not be complex.

Research Recommendations. Retention of learned target identification
skill should be evaluated, especially for the lower aptitude interpreters.
Is the learning acquired under pictorial training more or less resistant to
forgetting than that attained under textual only or textual/pictorial mixed
training?

Coordinate Determination Training

Another experiment involving structured training content evolved from a
report (Kause, Thomas, & Jeffrey, 1973a) on the accuracy with which inter-
preters could determine ground coordinates of targets detected on side-
looking airborne radar (SLAR) imagery. The results of this study were dis-
couraging--the median ground plane error (elevation was not determined) was
about 5,000 meters. SLAR imagery from the Army AN/APS-94 with scale of
1:500,000 and 1:1,000,000 and from the Air Force AN/APQ-102A with scale of
1:400,000 was used. Annotated locations on the imagery were to be

transferred to a topographic map of 1:250,000 scale and the coordinates of those locations determined. This is a difficult task because scale of imagery and map are different and the radar image and the map portrayal of the terrain are dissimilar. Because of the magnitude of the error obtained, a training program was needed to help the interpreter correlate the SLAR image with the map to reduce the error.

Because of the above results, a four-phase training program was developed for another experiment (Kause, Thomas, & Jeffrey, 1973b) to improve target location accuracy. The salient features of the four phases were the following:

- Phase I: Correlate imagery with map using imagery and map of the same scale. Prominent targets on both map and imagery were used.

- Phase II: Locate targets by triangulation. Same as Phase I, except that the targets did not appear on the map and their positions had to be obtained by visual triangulation from other points.

- Phase III: Locate and plot position of the SLAR-imaged scene on map of different scale. Scale of map and imagery differed. Imagery was at the natural scale at which it was generated, and the map was at a scale of 1:250,000. A new task was introduced, that of plotting the flight path of the imagery.

- Phase IV: Locate multiple targets by visual triangulation where a scale difference exists between imagery and map. Interpreters were required to block inflight path as well as provide coordinates of each of multiple targets not shown on map.

Feedback was provided at the end of each training exercise.

The experimental group, after training was completed, was given a directed search task in which they determined the location data of targets annotated on the imagery. A control group, which had been given a training lecture but no specific training in determining coordinate location, performed the same tasks as the experimental group.

The experimental group determined location data much more accurately than did the control group. The median error for the experimental group was less than 5,000 meters, while that for the control group was greater than 10,000 meters. The absolute magnitude of these location errors for both groups is still excessive for operational use.

Operational Applications. Training with feedback can improve performance over that achieved by an untrained group. Such training methods have application to many different interpretation tasks.

Research Recommendations. Additional research should explore the ability of experienced and/or expert SLAR interpreters to perform this task. Such information will permit the specification of the accuracy limits attainable.

Use of larger scale maps for determining coordinate data may be beneficial and should be tested empirically.

Computer-Aided Instruction

A feasibility experiment (Narva, 1972) to determine the utility of the AR-85A Viewer-Computer and its peripheral equipment as a computer-aided instructional tool was conducted in the early 1970s. This hardware was part of the Tactical Imagery Interpretation Facility (TIIF), AN/TSQ-43A, and has become outmoded. Continued consideration of this hardware for computer-aided instruction (CAI) in image interpretation is not profitable.

However, ignoring hardware, the basic premises underlying the report have implications for newer systems. Considerations underlying the employment of any computer-based system for CAI include: (a) the instructional objectives to be achieved, (b) the limitations of the computer and the associated input-output capabilities, (c) the instructional strategy and materials required, and (d) the programming required to present the instructional program.

Operational Applications. Factors specified in this research should be given careful study prior to the initiation of a CAI training program in image interpretation that uses equipment in future computer-based interpretation facilities.

Research Recommendations. The design of the next generation of interpretation facility may have given consideration to the potential use of the system for CAI training. If not, as soon as the design specifications are known, a cost analysis of the potential use of the system for CAI should be conducted so that minor modifications can be made, if needed, before the system is fielded.

IMAGERY INTERPRETATION KEY DEVELOPMENT

Error Keys

According to one source (Montgomery et al., 1980), the objective in the development and maintenance of references to the imagery interpretation process is to develop concise and accurate materials for distinguishing items of known or potential military significance. In developing a key for a particular set of objects, special care is devoted to the identification and specification of features that distinguish members of this given set. ARI research (Birnbaum, Sadacca, Andrews, & Narva, 1969) identified a new requirement for keys that involved the use of "error keys" to avoid misidentification of items of military significance as nonmilitary items (an omission error) and, conversely, the misidentification of nonmilitary items as items of military significance (an invention error).

Another error key study (Martinek, Hilligoss, & Harrington, 1972) sought not only to reduce the number of inventive errors made in interpretation but to reduce the number of common omissions among image interpreters as well. The purpose was to develop an error key for use in Vietnam that would (a) increase the number of correct responses--by reducing the number of common omissions and (b) decrease the number of wrong responses--by reducing the number of common inventive errors.

In the first phase of the development of the error key, Vietnamese imagery was interpreted by 50 image interpreters. Their responses were analyzed to determine suspected causes for common inventive errors and common errors of omission. The greatest number of omissions common among interpreters were for vehicles, sampans, and personnel. Objects giving rise to false alarms involved graves, craters, brush, and trees. In the second phase of key development, representative imagery exampling these common causes was selected, assembled into a key, and provided with the necessary instructional material.

Evaluation of the utility of the key was accomplished by using a new sample of 122 inexperienced image interpreters. These interpreters analyzed the same Vietnamese imagery that had been used in the first phase--for error definition--with and without the error key. Interpreter performance was scored for the number of right identifications, the number of wrong identifications (both misidentifications and inventions), and the accuracy of interpretation (R/R+W). Results showed that use of the error key improved performance as follows: (a) number of correct identifications increased by 39%; (b) number of wrong identifications (misidentifications and inventions) decreased by about 26%; (c) interpretation accuracy increased by about 43%. Conclusions drawn include the following:

- Use of an error key produced marked improvement in interpreter performance over that achieved without use of the error key.

- In general, interpretation completeness was low. Even with the error key, only about 10% of the available targets were reported.

- Interpretation accuracy was low also. Even with the error key, only about half of the information reported was correct.

Operational Applications. Error keys can be used in the field to reduce inventive errors and omissions. Error avoidance training should be incorporated in the image interpretation training curriculum.

Error keys should be developed for other geographical areas of potential interest.

Error analysis should be applied to student performance in the image interpretation course and in on-the-job training to help define areas where improvement is needed.

Research Recommendations. Error keys should be developed and validated for other sensor systems besides the photographic sensor (e.g., infrared, video, radar). Photographic error keys should be extended to include different image scales and types of photographs--vertical, oblique, digitized, etc.

Error Avoidance Training

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.

In another experiment (Powers, Brainard, Abram, & Sadacca, 1973) examples of inventive errors were obtained over a range of images. Expert interpreters analyzed these images and inferred the underlying causes for the inventive responses. Their consensual judgment elicited five major error categories:

- Inferring the current presence of vehicles from old track activity.

- Misinterpreting unusual shadow patterns as military targets.

- Attributing target-like features to unfamiliar objects.

- Confusing regularly-shaped tree tops with targets.

- Interpreting natural terrain features (e.g., rock formations) as targets.

Tactical reconnaissance imagery was assembled that contained nontarget objects and situations of the type that might lead to false alarms. Three groups of images were established: (a) a small set of images without annotated objects representing the inventive errors most frequently made; (b) a similar set with annotated objects combined with a descriptive list of the errors commonly made for each annotated object, along with the probable reason for the error (trainees read the pertinent description after first deciding whether or not the annotated object was a target); and (c) an instructional set of 80 images with about 200 annotated targets and nontargets—trainees used the error keys to help them decide whether the annotated objects were targets or nontargets. Matched sets of 27 unannotated images were used to assess the utility of the error key training. Eight experienced (average 2 years) image interpreters searched one set for targets prior to training and the other set after training. The number of inventive errors was reduced by about 50% by training, whereas identification completeness was unchanged. Time required per image was reduced by more than 20% by training.

Operational Applications. Error keys are an effective way to reduce inventive errors in image interpretations, even for experienced interpreters. They should be used in school and on-the-job for proficiency maintenance.

Research Recommendations. A longitudinal study should be conducted to determine whether error avoidance training persists over time or must be periodically reinforced.

Pictorial Characteristics of Interpretation Keys

Conventional image interpretation keys are used to help the interpreter make a more accurate and complete identification of objects detected on the imagery. Such keys may be quite elaborate, showing oblique and vertical photographic views of the objects, giving size dimensions, listing salient and unique characteristics and so forth that differentiate the object from related objects in the same category. In other instances, line drawings (schematics) may be used instead of photographs.

Three related experiments (Narva, 1972) were conducted to investigate 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. In the experiments, selected pictorial characteristics of image interpretation keys were varied, and the effect of

the variations on performance in identifying military vehicles was determined. Each experiment dealt with a different combination of the following: (a) photographs, line drawings, or both; (b) angle of view--vertical, oblique, or both; and (c) scale of image in the key--large or small. In the first experiment, a computer--in response to inputs from the interpreter--derived the three categories most likely to include the vehicle to be identified. The interpreter then referred to the key (in looseleaf notebook form) to make the final identification. In the other two experiments, the interpreter used only the key, which contained no textual material. In each experiment, image interpreters identified 16 vehicles organized into four sets and presented in a balanced research design. Two levels of image 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 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 by presenting more than one viewing angle, nor by presenting photographs and schematic representations together. Reduced scale in the key images required more identification time, but did not affect accuracy. The experiments indicate that greater leeway in the materials included in keys and in the manner of presentation is possible without affecting performance.

Operational Applications. Line drawings and photographs were equally effective. For CRT displays, key information retrieved from memory in line format can be used for interpretation references.

Viewing angle is not a significant factor in interpretation keys. Key pictorials need not match imagery in terms of viewing angle.

Key pictorials at reduced scale may increase time required to use the key because of need to use a magnifier.

Although no increment in identification performance was obtained by using both photographic and schematic representations together, there is some indication that difficulty of identification of certain targets is reduced when both representations are present in the key. The target involved and associated degree of difficulty may dictate which type of presentation should be used or whether it is desirable to present both.

Research Recommendations. Research should be conducted to determine an optimal scale or range of scales to present the appearance of a target adequately and still permit use of the key without magnification.

Further research into how photographic and various schematic presentations may be integrated is needed; the effectiveness of such integrated presentations should be assessed empirically.

Infrared Image Interpretation Keys

Research (Root, Young, & Narva, 1974) was conducted to determine the most effective content of reference keys for use in interpreting infrared imagery. Four experimental keys were developed, differing in type and amount of information presented. The Minimum Information Key presented two representative images--one with the target in the open and the other with the target embedded in vegetation--for each target type acquired under favorable take conditions (i.e., at relatively low altitude and at a time of day when target to background contrast was good). Additionally, for each target type, the cue or cues that help to identify the target uniquely were given. Written information was presented on targets with similar and thus potentially confusing signatures. The Intermediate Information Key included all information given in the Minimum Information Key plus representative images for each target type under variations in two of the most important acquisition parameters--time of acquisition and altitude. The Maximum Information Key included all information provided in the Intermediate Information Key plus representative images showing the effects of selected acquisition parameters and special cues. The Error Key concentrated on presenting information to prevent errors of omission, invention, and misidentification (but not developed like the previous error keys were). Keys of each type were developed for six tactical targets.

Forty image interpreters with little experience in infrared interpretation were divided into five groups of eight each. Four groups had available one of the experimental keys, while the fifth group had no key. After a 3-hour training session on the interpretation of infrared imagery, each interpreter was given a roll of 30 unannotated frames of infrared imagery on which to detect and identify targets. Nine annotated target frames were also analyzed by the interpreters. Performance was scored in terms of target detection, target identification, and the time required to complete the assigned task.

Only the Maximum Information Key had any significant effect on performance. Interpreters using this type of key identified more of the targets they detected than did interpreters not using a key. This indicates that once a target had been detected, its subsequent identification was significantly aided by access to the Maximum Information Key.

Operational Applications. In the development of keys for infrared imagery, emphasis should be placed on the presentations of cues and effects of acquisition parameters specific to the particular type of target being treated, rather than on the presentation of generalized effects of acquisition parameters.

Research Recommendations. The utility of the experimental keys developed in this research should be reevaluated using experienced infrared image interpreters.

Infrared Data Base Design

Research (Root, Ray, Brahosky, & Narva, 1980) was conducted to explore
the feasibility of establishing a single reference information data base to
improve interpreter performance in two ways: (a) the data base would provide
reference materials that the interpreter could use as an interpretation key
during operational interpretation, and (b) the data base could be used for
on-the-job training through systematic exposure of the interpreter to the
available data base materials. The report presents the results of a design
analysis to define a method for establishing and utilizing such a reference
data base to support interpreter functions within a future, computer-based
imagery interpretation facility, as well as the results of experimentation to
test certain aspects of such a data base for its usefulness for on-site
training and operational interpretation.

It was assumed that the future interpretation facility could support in-
put/output equipment such as a CRT/keyboard combination, provide sufficient
memory capacity to store an index of available reference information against
which interpreters could levy information requests, and retrieve a store of
reference information in the form of standard 70 mm x 100 mm chips. Among
reference materials, prior cover, interpreter reports, and maps serve a valu-
able function in assisting interpreters in the accomplishment of their over-
all task. However, this study concentrated on the utilization of the type of
information usually contained in interpretation keys, with primary emphasis
on infrared reference materials.

To determine data base requirements to satisfy the basic study objec-
tives, a detailed questionnaire was prepared to obtain information relevant
to data base content necessary for use both as infrared key material and as
training materials. The questionnaire was administered in two groups:
(a) senior instructors of the Army image interpretation course, and (b) a
group of experienced civilian interpreters with prior service experience. An
analysis was conducted of the organization and content of the infrared data
base for reference purposes, together with a consideration of the mechanics
for the construction and display of such a data base. An indexing scheme and
retrieval methodology were also devised. An experimental data base, based on
the analysis, was developed with appropriate software to empirically test the
concepts developed in the analysis. One test was designed to ascertain
whether structured exposure to data base materials, in the form of slides,
would increase interpreter proficiency; another test studied the efficiency
of such a data base as an aid during interpretation.

Sixty-four image interpreters participated in the empirical assessment
of the utility of the data base. For the training objective, all 64 inter-
preters analyzed a 5-inch roll of infrared film containing 30 frames with one
target annotated on each frame--the pretest. Two matched groups of 32 inter-
preters each were established, and one group was given structured training
with the data base materials while the other group received no training.
After training, both groups analyzed a second infrared roll of film contain-
ing 30 frames with one annotated target per frame. This was the posttest.
For the keys study, trained and nontrained interpreters were distributed
equally among the four key conditions: (a) accession to pictorial key ma-
terial by acquisition parameter only; (b) accession to key material by target

type only; (c) accession to key material by both acquisition parameter and target type; and (d) no key provided. Sixteen interpreters, eight trained and eight not trained, were assigned to each key condition. These interpreters analyzed a third roll of infrared film consisting of 30 frames with one annotated target per frame. Interpreter performance was scored in terms of target identification accuracy and time required for interpretation per roll, and these data then analyzed. Results included the following:

- Three kinds of information were delineated for the reference-information data base. The first kind presented a single image containing each target type under one set of acquisition parameters, providing simultaneous viewing of several targets under one set of acquisition parameters. The second kind presented images of a single target type under all acquisition conditions, permitting analysis of the appearance of a single target type under a range of acquisition conditions. The third kind presented detailed target information, primarily textual material concerning target description, employment, misidentification errors, effects of weather, and effects of imagery degradation.

- An indexing scheme was devised to permit access to keys, prior cover, interpreter reports, and maps.

- Procedures for the use of the keys portion of the data base were suggested and related to operational interpretation as well as initial and refresher training.

- In the empirical investigation of the utility of the data base, it was found that the request formats used on the CRT computer interface could be effectively handled by the interpreters with little training. The information presented on the slides could be utilized easily for training and as keys.

- Structured exposure to the data base in training sessions increased the trained interpreters' proficiency in target identification at the category level. However, target identification performance was unaffected by the key condition used except that more time was required to use keys.

Operational Applications. Reference material that decreases in value with time, such as prior coverage and previously prepared interpreter reports, should be indexed for rapid retrieval but stored in its original form.

Reference material that remains constant in value, such as maps or key material, should be stored in a unit record format (e.g., as a 70 mm x 100 mm chip) for speed of retrieval, rapid access, and minimal bulk of material to be stored.

Microfilm technology, which offers a method of storing large amounts of information on a single piece of film, should be considered for storing reference information.

To be of maximum usefulness, there should be provisions for expansion of the data base and for substitution within the data base. Field units should be able to perform these functions so they can tailor the materials to their own needs.

The empirical demonstration supports the notion that reference information can be indexed, requested, retrieved, and displayed with computer assistance. Although the demonstration was concerned only with the retrieval and display of key information, such a scheme may be used for the retrieval of other types of reference information, such as maps, prior cover, and previous interpreter reports.

Research Recommendations. Further experimentation is required to reach more definitive conclusions concerning the effectiveness of this prototype data base for interpretation purposes.

Additional research should be conducted to develop data bases for sensor systems other than infrared.

Special Keys

ARI designed and developed an image interpretation key to Army tents (Martinek, Bigelow, & Jorgensen, 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.

To make this key current, the key should be changed to reflect changes in Army tents.

Research Recommendations. None.

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.

RECONNAISSANCE RESOURCE MANAGEMENT AND UTILIZATION

General

This section of the review differs from the preceding sections because it is not limited to the image interpretation task. The emphasis here is on the job requirements of the G2 Air and image interpreter personnel within the Army aerial reconnaissance and surveillance (AR&S) system. Changes in surveillance systems as well as changes in military capabilities impose changing requirements on such personnel.

Job Requirements

Research (Youngling, Vecchiotti, Bedarf, & Root, 1974) was conducted to determine the tasks, duties, and associated procedures of G2 Air and image interpreter personnel in the Army's AR&S system as currently performed and as projected for the future, and to identify changes in job duties and training required in the functions comprising these jobs to satisfy the intelligence needs of commanders.

To accomplish this end, data were collected in three ways: (a) by a comprehensive review of source documents; (b) by in-depth interviews with 40 personnel intimately familiar with the Army AR&S system; and (c) by an analysis of responses to mailed questionnaires completed by active duty personnel functioning in the AR&S system. An ARI memorandum (Bedarf, 1972) was prepared listing summary response data on the actual questionnaire forms (Aerial Surveillance and Reconnaissance Questionnaire--G2 Air Personnel and Aerial Surveillance and Reconnaissance Questionnaire--Image Interpretation Personnel) on a question-by-question basis.

Data from these sources were integrated and used to delineate the jobs of aerial surveillance personnel and to identify groups of related tasks performed by G2 Air and image interpretation personnel. Flow diagrams and task analyses of the AR&S system were prepared showing the skills, abilities, and knowledge required of the various personnel. Descriptions were prepared identifying representative duties, job aids, and general qualifications required of incumbents. Such descriptions were prepared for the current system and for projected future air intelligence systems.

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U. S. EQUIPMENT MINI-KEY

Figure 2. Vertical view.
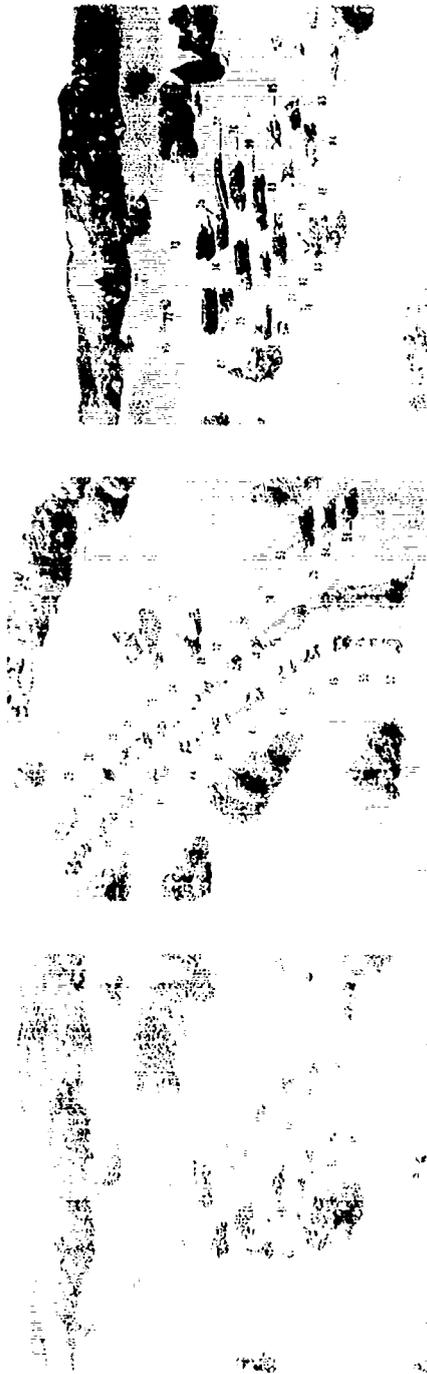
U. S. EQUIPMENT MINI-KEY

Figure 6. Oblique view.

The principal findings of this investigation center on the G2 Air officer and the G2 Air officer position. The G2 Air officer is primarily a resource manager, but the personnel filling this position are inadequately trained for the job. Also, a requirement was found for tactical commanders to gain a better understanding of the capabilities and limitation of the AR&S system and the role of G2 Air personnel.

Other findings suggest that more balance should be given to the subject matter content in the training of image interpreters. Some tasks are given greater emphasis in training than the importance of the task in the operational setting warrants.

Operational Applications. Selected findings of this research have implications for curriculum revisions in Army training courses for aerial surveillance officer and image interpreter personnel.

Research Recommendations. Materials should be developed to provide appropriate resource management training for G2 Air personnel.

Development of Resource Management Materials

Subsequent to the investigation (Youngling, Vecchiotti, Bedarf, & Root, 1974) conducted to determine job requirements for the G2 Air and image interpretation personnel, a follow-up study (Vecchiotti, Berrey, & Bedarf, 1978) was conducted to produce materials that the G2 Air officer could use for on-the-job training and guidance in the performance of operational duties and, in addition, could be used in formal school courses. This dual purpose required the development of a flexible document that could be used in either a classroom or field environment. The specific objectives were (a) to prepare materials to help the G2 Air officer perform management duties; and (b) to conduct limited field evaluation with the materials to determine their usefulness, acceptance, and final structure. At the time this effort was conducted, no specific training was given to an officer assigned from the image interpreter office position to the position of G2 Air officer to prepare him to fulfill the G2 Air duties. The G2 Air officer designee, typically, had to rely on on-the-job training to become familiar with the position requirements.

In preparing the materials, information was gathered on tasks performed by operational aerial surveillance and reconnaissance (AS&R) units. From this, a comprehensive study data base was developed and its accuracy verified by field observation and interviews. A content outline for a handbook was prepared by integrating the field interview data with personnel. The handbook was then prepared, taking into account the various training techniques and aids appropriate for on the-job and school application. The handbook underwent a limited evaluation by instructors and students of the AS&R Division, U.S. Army Intelligence Center and School, to determine its usefulness, acceptance, and final structure; it was then revised. A part of the handbook content was programmed for use in an automated demonstration to explore the potential utility of the handbook content as input for a more sophisticated data base in future systems. The products developed in this effort include the following·

- The handbook, "Aerial Surveillance and Reconnaissance MANAGER," prepared and used for on-the-job and school application.

- An automated demonstration of parts of the handbook, which indicated its potential for future use under computer control.

Operational Applications. The Aerial Surveillance and Reconnaissance MANAGER has been used by instructors in the Aerial Surveillance and Reconnaissance Division of the U.S. Army Intelligence Center and School for lesson planning and practical exercises. The MANAGER has been requested and distributed to operational field units.

Research Recommendations. A more extensive field evaluation of the Aerial Surveillance and Reconnaissance MANAGER should be carried out.

Field Evaluation of the AS&R MANAGER

Research (Bedarf & Potash, 1975) was conducted to obtain a more detailed evaluation of the usefulness of the MANAGER than was obtained previously. A survey technique was employed in this second evaluation. The questionnaire used was designed to permit the respondents to evaluate the AS&R MANAGER as a whole as well as its component parts.

A group of 82 individuals--practicing G2 Air officers, instructors in the Army surveillance officer course, and persons functioning in positions closely related to the G2 Air officer position--were sent copies of the AS&R MANAGER handbook and later sent copies of the questionnaire. Analysis of their responses indicated that overall, the user population sampled considered the AS&R MANAGER to be an acceptable reference book and training aid. The various sections of the MANAGER were rated as being moderately high on accuracy, completeness, and clarity. Respondents thought a major difficulty was that not enough information was presented. This may be partially because the handbook was designed to be both a training document and a reference source.

Operational Applications. The survey indicated that subject matter experts considered MANAGER to be a useful reference and training aid for the G2 Air officer position. It also provided information concerning the factual nature of the material contained in MANAGER.

Because more than 5 years have elapsed since the AS&R MANAGER was prepared, the content of the handbook should be revised and updated to make the reference current.

Research Recommendations. None.

Utilization of Surveillance Resources

An earlier report (Youngling, Vecchiotti, Bedarf, & Root, 1974) indicated that tactical commanders needed a better understanding of the capabilities and limitations of the aerial surveillance and reconnaissance system and the role of the G2 Air personnel. The objectives of an investigation (Vecchiotti, Berrey, & Narva, 1978) conducted to enhance the comprehension of commanders of infantry, armor, and artillery units concerning the capabilities and use of the AS&R system were as follows:

- To summarize and analyze the experiences and training given to combat arms officers relative to the use of AS&R resources, with the purpose of identifying areas where improvements in training may lead to improvements in system use.

- To conceptualize and evolve experimental training materials and/or methods that will increase the probability of more effective use of the AS&R system by combat arms officers.

- To explore the possibility of developing aids that might supplement training and be used on the job for increased effectiveness of AS&R use.

To accomplish these objectives, lesson plans and supplementary AS&R instructions were obtained from the three combat arms schools and the Command and General Staff College. These data were reviewed to determine the scope of AS&R coverage given in training. Another source of information relative to the combat commanders' use of AS&R resources was obtained from the experience and opinions expressed by combat commanders concerning system capabilities and ways to improve it. This information was derived from questionnaires completed by students at the Infantry School, Armor School, Field Artillery School, Intelligence School, Command and General Staff College, and the Army War College.

The results obtained from the curriculum content analysis and the analysis of questionnaire responses were used to define areas where training in the use of AS&R resources was needed. Training materials were developed to provide information for those areas where students expressed a need for more information about AS&R use. The materials developed were organized into a document, the Combat Commander's Guide to Aerial Surveillance and Reconnaissance Resources. The guide was designed to supplement reading materials available during portions of the advanced officer course dealing with intelligence at branch schools.

In addition to the guide prepared for formal school use, job aids were prepared for use in the field--one for each of the three combat arms. These job aids are small, easy to carry, and help tactical commanders obtain benefits from available AS&R resources.

Operational Applications. The Combat Commander's Guide to Aerial Surveillance and Reconnaissance Resources is used worldwide in U.S. Army schools and units for training in AS&R use. The guide material has been divided into a Commander's Field Aid to Aerial Surveillance and Reconnaissance Utilization

for each of the Combat Arms. The job aids are small, easy to carry, and provide officers with ready references in formulating information requests.

Research Recommendations. None.

Field Evaluation of the Combat Commander's Guide to AS&R Resources

The Commander's Guide was evaluated using a survey technique. The questionnaire used in this research (Shvern, 1979) permitted the respondents to rate the Commander's Guide as a whole, rate the major sections, and comment on features not specifically covered in the questionnaire.

About half of the 60 officers who completed the questionnaires were battalion commanders; the rest had experience in G3/S3, G2/S2, or MI areas. The major sections of the Commander's Guide were judged to be useful, accurate, complete, and clear. Many of the raters considered portions of the document too detailed for commanders. A major problem of the Commander's Guide was the obsolescence of many of the references to specific AS&R assets and capabilities.

Operational Applications. The Commander's Guide is generally useful and accurate, although many references to specific AS&R assets have become obsolete and are no longer suitable for training or reference.

The Commander's Guide should be revised to reflect the various changes in AS&R assets. Greater emphasis should be placed on information the commander is likely to use.

Research Recommendations. None.

BASIC RESEARCH: VISUAL SEARCH AND TARGET ACQUISITION

General

Although ARI research in image interpretation is conducted mainly in response to military requirements, a portion of the research effort is devoted to more basic research by ARI research scientists or through grants to qualified institutions with unique research facilities for the conduct of basic research in aerial surveillance. These basic research efforts are selected as having potential long-range significance for military developments, but have less immediate applicability than the main body of ARI research.

Visual Search

Visual search is a central factor in aerial surveillance regardless of whether the observer is looking directly at the environment or is interpreting a remote sensor display. ARI research on the effect of image quality on interpretability was described in an earlier section of this review. However, the nature of the target and its surroundings, combined with observer peripheral visual acuity, was not investigated.

Basic research (Bloomfield, Beckwith, Emerick, Marmurek, Ebo Tei, & Traub, 1978) on the above was conducted with a twofold objective: (a) to determine the relationships among measures of visual search performance, peripheral visual acuity, and ratings of target to background discriminability obtained with embedded targets, and (b) to compare competition and embedded target search tasks. Two principal causes that give rise to a need for research on visual search are (a) the target may be confused with nontarget objects that are within the search area (a competition search situation), and (b) the target may not emerge perceptually from its immediate background because the patterning of the target and background combine in some way (an embedded target search situation). More research has been reported for the competition search situation than for the embedded search situation.

This laboratory research effort used constructed displays for both the embedded and the competition search situations. Several types of displays were used.

For the embedded color display, the background consisted of 1-inch yellow squares, with each square touching the adjoining squares. Any square in the background could be removed and a 1-inch square of another color inserted as a target. Five target colors were used: white, tan, green, blue, and red.

For competition color displays, 1-inch yellow squares were arranged on the displays, but the squares were not contiguous. They were arranged in matrices with equal spacing between squares, as in a lattice. In the embedded situation, any yellow square could be removed and replaced by one of the target squares.

Black-and-white textural displays were used for the embedded search situation only. One-inch squares of a photographic enlargement of expanded mica texture were used as the background, with each background square touching surrounding squares. Any given background square could be replaced by a target square cut from a photographic enlargement of one of the following textures--oriental straw cloth, woolen cloth, pigskin, or beach sand.

The observers participating in this study were all students of Ohio State University with normal vision. The experimental tasks performed included the following:

- Embedded target discrimination--that is, rating the relative ease with which the target square could be distinguished from the background squares--was rated by 28 observers for all five color targets and all four textural targets with each target in three different target locations.

- Several different search tasks were performed. In two tasks using embedded target displays, search time (in seconds) was determined for each of the five color targets and for each of the four black-and-white textural targets.

- In four tasks, with the yellow squares of the color display background separated to varying degrees to create a competitive search situation, search times (in seconds) were recorded for an 11/12-inch yellow target in one task and for two of the color targets (white and tan) in the other three tasks.

- Peripheral visual acuity (in minutes of arc) was measured for embedded and competition color target displays and for the embedded black-and-white display.

For the conditions of the study, the principal findings indicate that--

- Search time is inversely proportional to peripheral visual acuity and to target discriminability, i.e., search time, in seconds, is less for observers with greater peripheral visual acuity and for targets that are more easily distinguished from their backgrounds.

- Embedded search is easier than competition search.

- Two opposing effects appear to affect search time in competition target search tasks. As the separation of background elements increases, the target becomes more difficult to discriminate, thereby increasing search time. However, as separation increases, the number of background elements present decreases in the fixed display area, tending to decrease search time.

Operational Applications. There are no direct operational applications for the findings of this basic research project.

Research Recommendations. Additional research should be conducted to extend this approach to the more complex real-world search tasks. The finding that peripheral visual acuity is a predictor of search time may warrant a full-scale effort to investigate the implications of this factor in selecting observers for visual search and target acquisition tasks.

Prediction of Airborne Observer Object Recognition Performance

Aircrews must locate visually navigational checkpoints, landing and cargo drop areas, and targets of military significance. Although the field commander may have past performance data available on the capabilities for a given aircrew, it would be of much greater value to the commander to be able to have data tailored to the specific situation.

Research (Bonnet & Snyder, 1978) was conducted to develop an objective, field-amenable technique for predicting air-to-ground tactical target-by-target acquisition performance. Although this research was conducted under laboratory conditions, the advent of small special-purpose computers and automatic microdensitometric scanners that are field transportable makes possible automatic mission success prediction, if the following conditions exist:

- Aerial photographic reconnaissance imagery is available and specific targets of interest have been acquired on the imagery;

- One knows what type of and how many scans to make on the imagery;

- One knows which measures to extract from the scans; and

- One knows how to combine these measures into an equation to predict mission success.

The primary objective of this research was to obtain data that could be used to define optimal conditions for the last three requirements listed above.

The aerial reconnaissance imagery used in this research was three black-and-white 35 mm motion picture films recorded over a 3,000:1 scale terrain model. The same path over the model and the same simulated altitude (10,000 feet) was used for all three. The three films differed in terms of the simulated ground speed (500 feet or 3,000 feet per second) and/or camera depression angle from the horizontal (45° or 23°). The camera field-of-view for all three films was 14.2° horizontal and 18.8° vertical.

Microdensitometric scans were made for 12 tactical targets contained in these films. Data from these scans were used to generate 36 photometric and geometric predictor variables that were used in a stepwise linear multiple regression analysis to predict air-to-ground target acquisition performance. These 36 predictors were reduced to 17 by a consistency criterion and the 17 variables used to develop a linear model that predicted ground range to target at the time of acquisition. Three alternative criteria were used: (a) the ground range for correct responses only, (b) the ground range for correct responses plus zero ground range scores for incorrect responses and omitted targets, and (c) the ground range for correct responses plus the minimum ground range for incorrect or omitted responses.

The prediction model was evaluated for accuracy with both one and two different images of the same target and for single and multiple microdensitometric scans through the target in each image. The linear model was developed for targets in one film mission and cross-validated against the same targets in different missions. It appears feasible to predict the ground range at which a given target will be detected by an airborne observer. This prediction can be done automatically, given reconnaissance imagery, a microdensitometer, and a small computer.

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

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Predicted target acquisition range correlated highly with actual performance on the cross-validation missions. This should not be interpreted to mean that the predicted ground range and the actual ground range at target acquisition were equivalent. High correlation between predicted and actual results can be attained if the relative rank orders between the two sets are preserved. However, the commander is interested in predicting the absolute ground range at which a given target will be recognized by the observer under the conditions prevailing when the mission is flown, regardless of how they differ from the conditions existing when the reconnaissance imagery was flown.

In the present research, aircraft groundspeed and camera depression angle were the only differences between the mission from which the prediction model was developed and the missions for which target acquisition ranges were predicted. In this case, a multiplicative and an additive constant could be used to convert predicted range to absolute range to compensate for differences between the two missions.

Operational Applications. There are no direct operational applications for the findings of this basic research project.

Research Recommendations. Additional research should be conducted to determine the corrective constants needed to make the prediction model accurately forecast the absolute ground range at target acquisition. Research should include a larger number of targets to provide greater stability in the results.

Additional research will be required to determine how other differences in mission conditions--weather, time of day, flight parameters, and so forth--affect the accuracy of the prediction model.

COMPILATION OF OPERATIONAL APPLICATIONS

Research and Operational Support Materials

(2)*
- 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 observer (and other) reports and in helping observers recognize targets and items of equipment in other situations.

(29)
- The imagery and film rolls developed for performance measures have potential utility for future research.

- Imagery with known target content and specified image characteristics can be useful for training image interpreters, assessing interpreter proficiency, and identifying training needs.

(19)
- The current presentation has combined the information from several sources into a single source and may be useful to both mission requestors and planners in specifying altitude and focal length to obtain desired coverage of sufficient quality.

Image Interpretability

(6)
- The Image Quality Catalog can be used to predict the possible accuracy of target detection and identification with considerable effectiveness. Relatively inexperienced interpreters can accomplish this estimation of mission interpretability.

(31)
- If the effects of specific image characteristics on the accuracy, completeness, and time required for interpretation were known, then the interpretation time needed to attain the commander's desired level of accuracy or completeness could be specified for a given mission. Greater precision would be possible if ability parameters for the interpreter doing the task could be included in the prediction.

- Assignment of interpreter personnel to facilities and the number of reconnaissance missions flown could be based on the commander's estimated levels of accuracy and completeness needed within specified response times.

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* Numbers here refer to reference list entries.

(9)

- The ARI Image Quality Catalog method can be used to predict expected performance. These predictions can be used to determine if new imagery is required to meet the commander's needs, to select which frames in a mission should be interpreted and in what order, and to help the manager of an II facility determine workload requirements.

- Mission planners and sensor designers should consider the interactive effects of scale, haze, and image motion on interpretability in initial planning stages.

(20)

- The largest scale imagery practicable should be acquired because image quality degradation produces a greater loss in interpreter performance for small-scale imagery than for large-scale imagery.

- In general, target detection and identification performance for imagery degraded on only one dimension is significantly superior to that for imagery degraded on more than one dimension. This may provide guidance in assigning missions to interpreters or in requesting that the mission be flown again.

(21)

- System designers should consider that color adds a dimension to image quality that permits interpreters to extract intelligence information from such imagery in less time than is required with black-and-white film.

(39)

- The results obtained have implications for planning infrared missions so that the imagery obtained may be effectively interpreted.

Near Real-Time Imagery Interpretation

(26)

- The factors of image resolution, presentation rate, and scale are important in the design of interpretation displays and related doctrine.

- Possible trade-offs among these factors also should be considered. For example, screening accuracy for poor resolution imagery can be increased for presentation rates in the range from .8 to 2 seconds/frame by increasing viewing time per frame. Beyond 2 seconds/frame, increasing viewing time does not increase screening accuracy.

(38)

- Based on the experimental conditions tested, variable film speed control is not required operationally because it did not affect performance.

- A reporting procedure incorporating the placement of a reticle over the target inherently permits greater target location accuracy than that obtained from target location estimates made by the interpreter from coordinate data annotated on the film margin. In addition, use of the reticle decreases target misidentifications. However, the procedure also involves a time lag that may be significant relative to other less accurate target location procedures.

(22,23)

- Interpreters require more training and experience in the interpretation of SLAR imagery to provide useful intelligence information.

- Intelligence analysts should be aware of the accuracy and completeness of reports based on the present-day interpretation of SLAR and adjust their intelligence estimates accordingly.

- Requirements for information from SLAR should be based on the amount of detail that interpreters are able to extract accurately and completely.

Real-Time Imagery Interpretation

(18)

- To insure optimum performance on either auxiliary tasks or visual search, both tasks should not be assigned concurrently to the RPV observer.

(24)

- Results can be used to indicate training requirements and to specify modifications of operator techniques and procedures to enhance operator performance in the field.

(33)

- Bandwidth compression of digital imagery degrades interpreter performance, particularly beyond a 4:1 compression ratio.

- System users should consider the trade-offs between different amounts of bandwidth compression and levels of reporting precision required--target detection versus precise target identification.

- The effects of sun angle should be considered in mission planning.

Man/Computer Decision Processes

(6)
- The expected cost procedure provides the G2 with control over the number and credibility of the reports received from the interpretation facility. Setting a low acceptable cost level results in fewer reports of greater accuracy, whereas setting a high acceptable cost level results in more reports with a reduction in accuracy. Level set can be changed to correspond to the operational requirements.

(42)
- In an interpretation facility, the confidence validity of interpreters who are poor or moderately good in stating confidence can be improved by having a second interpreter check the work of the initial interpreter. For target identifications associated with large error costs, checking the confidence statements of some of the interpreters should be routine when time permits.

(16)
- If use of payoff matrices becomes operational and additional research is not possible, the Direct Name Vector technique should be used. Training on this technique must include free search.

(28)
- Interpreters preparing probability vectors should be provided with ancillary information from other intelligence sources when assessing the confidence of their reports. Proper indoctrination concerning the utility of this ancillary information should be given.

(10)
- Trained but inexperienced interpreters should not be used to estimate the probability that a sample of targets detected and identified on a surveillance mission came from a specific enemy unit.

- An operational computer or man/computer method should be developed to determine the probabilities that a given target sample came from a specific enemy unit or units.

Change Detection in Imagery Interpretation

(6,14)
- Equipment should be provided to permit variable magnification and rotation in order to minimize the effects of scale and orientation differences.

- Equivalence of ground area coverage should be partially controlled by mission planning. If late information about specific locations detected in prior coverage is desired, spot cover or area coverage at smaller scale can be requested to insure that the areas of interest are covered.

(15)

- Prior demarcation of common terrain on early and late imagery does not help the interpreter.

- Target annotations on the early imagery is a useful technique for change detection.

- Combined use of annotations and target lists for the early imagery appears to maximize the number of correct change statements and is recommended if time can be allowed or if used in an automated facility where the computer would reduce the time element.

Mensuration and Coordinate Determination

(27)

- Within a particular operational unit, the most accurate interpreters (in measurement) should be determined and used for critical measurement tasks.

- The reticle scale should be used in preference to the interpreter scale if the object to be measured is smaller than the length of the reticle scale.

- Scale graduations--in thousandths of a foot or in tenths of a millimeter on both interpreter scales and magnifier reticles-- had no significant effect on measurement variability among interpreters.

(6)

- Interpreters should be trained in visual decoding to insure a backup capability in the event of automated reader failure.

- A set of flash cards, as developed for experimental use, can be used operationally to train interpreters in pattern recognition for the decoding process and to help interpreters maintain their proficiency.

- There are limitations on the accuracy of the location data reported in the code data block. If precise coordinate location information is required using the code block location data, correction for this source of error will be necessary.

(22)

- Only interpreters with the proven ability to locate targets accurately should be used operationally with SLAR imagery.

(43)

- In the employment of the APPS, the interpreter/operator depends on the mutual presence of the same detail on the mission image and the data base image in order to accurately correlate the two by visual means.

79

- The most accurate location data can be determined from vertical or near-vertical photographic mission imagery.

- The reduced resolution of paper prints appeared to reduce location accuracy compared with that obtained with transparencies in some cases.

- Locations remote from terrain features identifiable on both mission and data base images cannot be transferred visually with consistent accuracy.

- Locations on terrain features in vertical, oblique, high panoramic, and low panoramic photographic missions can be transferred to the data base with a ground error of less than 20 meters CPE.

- Locations 200 meters distant, on the ground, from mutually identifiable terrain features on mission and data base imagery can be located within 20 meters CPE on vertical photographic missions only.

- Transfer difficulty is aggravated by the length of elapsed time between the acquisition of the data base imagery and the mission imagery. If appreciable time has elapsed, manmade changes may appear in one and not the other, making correlation more difficult. Attendant changes due to seasonal variations such as crop patterns, flooding, snow cover, and so forth may also make correlation difficult.

(44)
- Under proper conditions, point transfers can be made with useful accuracy to a photo data base from radar and infrared reconnaissance imagery having a wide range of scales and ground resolutions.

- The direct transfer technique should be used for Type A points except for AN/APS-94 and AN/APQ-97 imagery if a 25-meter CPE is required.

- The indirect transfer technique should be used for Type B points for some types of imagery in order to obtain sufficient accuracy (but an additional 5 minutes/target will be required).

- Point transfers can be made by direct transfer with acceptable accuracy from a static TV display of vertical photography to a data base image.

(45)
- An instruction manual for point transfer techniques is available that provides step-by-step instructions for carrying out a direct transfer and an indirect transfer using the APPS.

80

- The use of quick prints of areas of interest, made during the interpretation phase, will permit point transfers to be made with improved accuracy before the image interpreter has completed the mission.

- The indirect transfer technique and associated software provide an accurate means for determining ground coordinates of target points located in areas of sparse background detail on photographic, infrared, and radar imagery.

Training and Proficiency Maintenance

(6,37)
- Search time can be reduced by training, but only at the expense of fewer detections or more errors.

- The number of false target detections (inventions) can be reduced by error avoidance training using an error key. Systematic development and use in the school and on-the-job should be initiated.

(6,10,12)
- Precise feedback was shown to produce greater learning, but this type of feedback is impractical in some operational units. It should be used in formal training and in computerized facilities if information storage capacity is sufficient and if time for on-the-job proficiency training is available.

- Team consensus feedback is an effective way to develop and maintain interpreter proficiency. Consensus feedback can be used by two or more interpreters using operational imagery during normal operations but under little time pressure.

- Teams that are heterogeneous in proficiency learn more than do homogeneous teams. This indicates that team members learn from each other and that without one member who is more proficient than the others, little learning will take place.

(11)
- Effective school and on-the-job training in target identification can be provided with a minimum of instructor participation and relatively simple support, using operational imagery as the basic instructional material. Immediate feedback on right or wrong answers is vital but need not be complex.

(23)
- Training with feedback can improve performance over that achieved by an untrained group. Such training methods have application to many different interpretation tasks.

(35)
- Factors specified in this research should be given careful study prior to the initiation of a CAI training program in image interpretation that uses equipment in future computer-based interpretation facilities.

Imagery Interpretation Key Development

(32,37)
- Error keys can be used in the field to reduce inventive errors and omissions.

- Error avoidance training should be incorporated in the image interpretation training curriculum.

- Error keys should be developed for other geographical areas of potential interest.

- Error analysis should be applied to student performance in the image interpretation course and in on-the-job training to help define areas where improvement is needed.

- Error keys are an effective way to reduce inventive errors in image interpretation, even for experienced interpreters. They should be used in school and on-the-job for proficiency maintenance.

(1)
- 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.

(36)
- Line drawings and photographs were equally effective. For CRT displays, key information retrieved from memory in line format can be used for interpretation references.

- Viewing angle is not a significant factor in interpretation keys. Key pictorials need not match imagery in terms of viewing angle.

- Key pictorials at reduced scale may increase time required to use the key because of need to use a magnifier.

- Although no increment in identification performance was obtained by using both photographic and schematic representations together, there is some indication that difficulty of identification of certain targets is reduced when both representations are present in the key. The target involved and associated degree of difficulty may dictate which type of presentation should be used or whether it is desirable to present both.

(41)

- In the development of keys for infrared imagery, emphasis should be placed on the presentation of cues and effects of acquisition parameters specific to the particular type of target being treated, rather than on the presentation of generalized effects of acquisition parameters.

(40)

- Reference material that decreases in value with time, such as prior coverage and previously prepared interpreter reports, should be indexed for rapid retrieval but stored in its original form.

- Reference material that remains constant in value, such as maps or key material, should be stored in a unit record format (e.g., as a 70 mm x 100 mm chip) for speed of retrieval, rapid access, and minimal bulk of material to be stored.

- Microfilm technology, which offers a method of storing large amounts of information on a single piece of film, should be considered for storing reference information.

- To be of maximum usefulness, there should be provisions for expansion of the data base and for substitution within the data base. Field units should be able to perform these functions so they can tailor the materials to their own needs.

- The empirical demonstration supports the notion that reference information can be indexed, requested, retrieved, and displayed with computer assistance. Although the demonstration was concerned only with the retrieval and display of key information, such a scheme may be used for the retrieval of other types of reference information, such as maps, prior cover, and previous interpreter reports.

(30)

- 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.

(3)

- The MINI-KEY provides a useful and convenient guide for identifying Army equipment for research and operational use.

Reconnaissance Resource Management and Utilization

(49)

- Selected findings of this research have implications for curriculum revisions in Army training courses for aerial surveillance officer and image interpreter personnel.

83

(47)
- The Aerial Surveillance and Reconnaissance MANAGER has been used by instructors in the Aerial Surveillance and Reconnaissance Division of the U.S. Army Intelligence Center and School for lesson planning and practical exercises.

- The MANAGER has been requested and distributed to operational field units.

(5)
- The survey indicated that subject matter experts considered MANAGER to be a useful reference and training aid for the G2 Air officer position. It also provided information concerning the factual nature of the material contained in MANAGER.

- Because more than 5 years have elapsed since the AS&R MANAGER was prepared, the content of the handbook should be revised and updated to make the reference current.

(48)
- The Combat Commander's Guide to Aerial Surveillance and Reconnaissance Resources is used worldwide in U.S. Army schools and units for training in AS&R use.

- The guide material has been divided into a Commander's Field Aid to Aerial Surveillance and Reconnaissance Utilization for each of the Combat Arms. The job aids are small, easy to carry, and provides officers with ready references in formulating information requests.

(46)
- The Commander's Guide is generally useful and accurate, although many references to specific AS&R assets have become obsolete and are no longer suitable for training or reference.

- The Commander's Guide should be revised to reflect the various changes in AS&R assets. Greater emphasis should be placed on information the commander is likely to use.

COMPILATION OF RESEARCH RECOMMENDATIONS

Research and Operational Support Materials

(31)
- Similar performance measures should be developed for video displays. Such measures are needed for research and performance assessment in the interpretation of transmitted video displays in real time.

Image Interpretability

(6)
- Research should continue to study photographic imagery under a wide variety of operational conditions.

- Research is needed to determine how interpretation accuracy, completeness, and time are altered by image characteristics for sensor systems other than the photographic sensor.

- Research to refine the catalog procedure for assessing imagery interpretability should be continued, especially for new types of imagery.

(9)
- Research should continue on the development of an easily used, subjective measure of image quality that provides estimates of interpreter performance for any imagery obtained under normal operational conditions.

- Utility of fabricated target arrays for exploratory research should be evaluated. This low-cost approach will provide a way to achieve control over several troublesome factors. Final validation of promising factors will require operational types of imagery, targets, and image interpreters.

(20)
- Research on the effect of atmospheric haze as a dimension of photo quality should be defined and quantified; also, its effect in interaction with the quality dimensions of the ARI catalog-- image scale, image sharpness, and scene complexity--should be determined so that the haze dimension can be appropriately integrated in the Image Quality Catalog.

(34)
- Research should be conducted to empirically determine the relative merits of alternative techniques (such as the National Imagery Interpretability Rating System (NIIRS) for predicting image interpretability. Quantitative and subjective techniques should be included.

(21)
- Additional research to validate the usefulness of color reconnaissance imagery should be conducted using a wide range of conditions typical of operational use, e.g., differences in targets, terrain, and weather. A cost-effectiveness analysis comparing interpreter performance, processing costs, viewer costs, etc. should then be made to determine the operational value of the three types of imagery.

- Color mixture for the TOC viewer can be set to provide pseudocolor. Research should be undertaken to determine whether this capability has any merit for image interpretation.

(39)
- The investigation of acquisition conditions and their effect on the interpretability of infrared imagery should be expanded to include conditions not varied in the initial experiment--that is, sensor system, target characteristics, and environmental characteristics.

Near Real-Time Imagery Interpretation

(26)
- Research conducted in this area should be coordinated with that suggested under real-time interpretation, where the use of bandwidth compression as a technique for cutting bandwidth requirements was evaluated (Martinek & Zarin, 1979).

(38)
- Research should be continued in the search for methods to minimize the time required for interpretation and target location using near real-time.

(22,23)
- Research should be conducted to develop training procedures in the use of inductive and deductive cues to determine whether a specific radar return on SLAR imagery is a target and, if so, the type of target it is.

Real-Time Imagery Interpretation

(18)
- Nonvisual, auxiliary tasks in response to tactile or auditory stimulation may be possible for the RPV observer without distracting attention from the primary task. Research to determine techniques to inform the RPV observer when ancillary tasks need to be performed should be conducted. Responses to such stimulation should be sought that do not impose visual requirements on the observer.

(24)

- Research should develop assists and training techniques to improve completeness and accuracy performance.

- Research to improve the target coordinate read-out capability of the operators may be warranted.

- For laboratory simulation, videotape recordings should be developed to simplify the procedure.

(33)

- Research is needed to determine the effects of bandwidth compression of digitized imagery under operational conditions, i.e., conditions involving the search and identification functions of image interpreters, _trained_ and _experienced_ in the interpretation of compressed, digitized imagery.

- The interaction effects among bandwidth compression, sun angle, and target obscurity should be investigated more thoroughly under typical operational conditions, particularly for 8-inch and 16-inch GRD, vertical imagery.

Man/Computer Decision Processes

(6)
- The shortcut method for assessing subjective costs of large numbers of image interpretation errors should be refined and evaluated in an operational field setting for use in conjunction with the probability vector estimates provided by interpreters.

(42)
- Techniques to enhance the validity of confidence estimates using a team approach should examine the relative importance of selected levels of the checker's demonstrated ability to make valid confidence statements for selected conditions--type of imagery, type of target, image quality, and so forth.

(16)
- The three techniques for establishing the probability vector--DNV, DNVE, and DNVC--should be reviewed, revised, and evaluated using experienced image interpreters instead of recent interpretation course graduates. Training with feedback should be considered for all techniques, and a free search task for training should be used.

(28)

- Research to answer the following questions is required:

    1. Did the enhancement of performance stem from the information content furnished or because the interpreter had to examine the imagery more carefully?

    2. What is the optimal combination of information parameters and the trade-off between reduced information quality (less than complete and accurate) and no ancillary information at all?

    3. What is the relationship between the most influential informational variables and interpreter performance in establishing a probability vector?

(25)

- Research should be conducted to determine the ability of experienced image interpreters to estimate the subjective probability that a detected configuration of targets came from one or more enemy units.

- If valid estimates of the probability of unit identification are found, the use of this knowledge as an interpretation aid in detecting additional targets should be investigated.

Change Detection in Imagery Interpretation

(13)
- The utility of computerized assistance for change detection in operational facilities should be assessed to reduce the time devoted to this function and to decrease error rates.

(14)
- Research should determine the usefulness of team consensus feedback training in improving interpreter change detection performance.

Mensuration and Coordinate Determination

(27)
- A standard measurement task should be developed in which a series of fixed known distances are measured by each operational interpreter. Error scores for each interpreter would be determined. For each interpreter, the measured size would be plotted against the true object size for all measurements to obtain a personal equation for the interpreter. This functional relation between measured and actual size could be used to correct the operational measurements made by each interpreter. Error causes could be studied to determine the nature of faulty individual interpreter techniques and procedures that cause measurement errors,

and school or on-the-job training could be provided to reduce or eliminate measurement errors.

(22)
- Research should be conducted to determine whether image interpreters learn to decode the reconnaissance data in the cc.e matrix block better by paired-associates training or by learning to decipher the excess-three binary code. Research should determine the comparative levels of skill retention over periods of disuse for the two methods of decoding.

(23)
- More extensive training programs should be developed and validated.

- The feasibility of using reference materials of larger scale should be investigated as a way to improve location accuracy for SLAR-imaged objects.

- A baseline research effort is needed to establish the level of coordinate determination accuracy attainable by expert radar interpreters using SLAR mission imagery from both coherent and noncoherent sensor systems.

(43)
- Research should be conducted to help the APPS interpreter/operator transfer locations on mission imagery to data base imagery when there are no mutually identifiable terrain features nearby.

(44)
- Research should determine the locus and magnitude of errors in APPS operation. This information will pinpoint areas where equipment design changes and operator selection or training is required to reduce output errors.

(45)
- Research should determine the utility of APPS for coordinate determination of objects detected in real-time imagery.

Training and Proficiency Maintenance

(6,37)
- Research should determine the effect on the accuracy, completeness, and time required for detection by combining rapid systematic search and error avoidance during training.

- Research should also determine the extent to which such training persists over time.

89

(6,10,12)

- The results of the team consensus feedback research indicate that this approach has merit for training and proficiency maintenance. Perhaps additional research is not judged necessary. However, the definition of high, medium, and low proficiency in interpretation skill was based on performance on the pretraining tests. The interpreters participating in these experiments were all recent graduates of the Army image interpretation course, and it seems reasonable to assume that the range of interpretive skill among the members of the group was not very large. In one of the team consensus feedback experiments, the mean target detection completeness score for the members with greater proficiency was 48.5 and that for the members with lower proficiency was 37.3. This difference in skill level was sufficient to produce a significant change in performance for the lower skilled group. This observation suggests three other research efforts to answer the following questions:

  1. How is learning rate of the less proficient team members affected by the skill level of the most proficient member?

  2. Since the most proficient member of the team has been shown to learn little more than interpreters practicing without feedback, how can the progress of the most proficient member be facilitated? Precise feedback, if available, might be an answer.

  3. What other factors inherent in the most proficient team member are conducive to increased learning by less proficient team members? Should leadership of the most proficient member be dogmatic, laissez-faire, democratic, or some other personality characteristic?

(11)

- Retention of learned target identification skill should be evaluated, especially for the lower aptitude interpreters. Is the learning acquired under pictorial training more or less resistant to forgetting than that attained under textual only or textual/pictorial mixed training?

(22)

- Additional research should explore the ability of experienced and/or expert SLAR interpreters to perform this task. Such information will permit the specification of the accuracy limits attainable.

- Use of larger scale maps for determining coordinate data may be beneficial and should be tested empirically.

90

(35)
- The design of the next generation of interpretation facility may have given consideration to the potential use of the system for CAI training. If not, as soon as the design specifications are known, a cost analysis of the potential use of the system for CAI should be conducted so that minor modifications can be made, if needed, before the system is fielded.

Imagery Interpretation Key Development

(37)
- A longitudinal study should be conducted to determine whether error avoidance training persists over time or must be periodically reinforced.

(32)
- Error keys should be developed and validated for other sensor systems besides the photographic sensor (e.g., infrared, video, radar).

- Photographic error keys should be extended to include different image scales and types of photographs--vertical, oblique, digitized, etc.

(1)
- Work should be extended on the development of expanded training units for error avoidance.

(36)
- Research should be conducted to determine an optimal scale or range of scales to present the appearance of a target adequately and still permit use of the key without magnification.

- Further research into how photographic and various schematic presentations may be integrated is needed; the effectiveness of such integrated presentations should be assessed empirically.

(41)
- The utility of the experimental keys developed in this research should be reevaluated using experienced infrared image interpreters.

(40)
- Further experimentation is required to reach more definitive conclusions concerning the effectiveness of this prototype data base for interpretation purposes.

- Additional research should be conducted to develop data bases for sensor systems other than infrared.

(30)
- To make this key current, the key should be changed to reflect changes in Army tents.

Basic Research: Visual Search and Target Acquisition

(37)

- Additional research should be conducted to extend this approach to the more complex real-world search tasks.

- The finding that peripheral visual acuity is a predictor of search time may warrant a full-scale effort to investigate the implications of this factor in selecting observers for visual search and target acquisition tasks.

(7)

- Additional research should be conducted to determine the corrective constants needed to make the prediction model accurately forecast the absolute ground range at target acquisition.

- Research should include a larger number of targets to provide greater stability in the results.

- Additional research will be required to determine how other differences in mission conditions--weather, time of day, flight parameters, and so forth--affect the accuracy of the prediction model.

Reconnaissance Resource Management and Utilization

(49)

- Materials should be developed to provide appropriate resource management training for G2 Air personnel.

(47)

- A more extensive field evaluation of the Aerial Surveillance and Reconnaissance MANAGER should be carried out.

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