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INCREASING PERSONNEL EFFECTIVENESS IN ELECTRONIC SYSTEMS--STATU--ETC(U)

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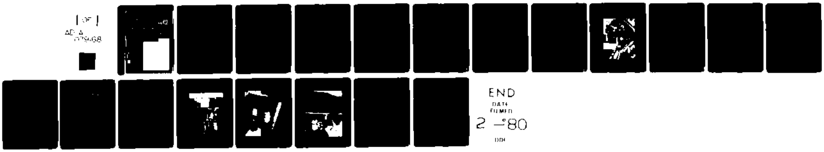

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RESEARCH STUDY 62-5

Increasing Personnel Effectiveness in Electronic Systems -- Status Report, 30 June 62

USAPRO

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Electronics

APRO – Research Study 62-5

INCREASING PERSONNEL EFFECTIVENESS IN ELECTRONIC SYSTEMS-- STATUS REPORT, 30 JUNE 1962

Seymour Ringel

Approved by

J. E. Uhlaner
Director, Research Laboratories

Hubert E. Brogden
Chief Scientist

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Research Studies are special reports to military management. They are usually prepared to meet requests for research results bearing on specific management problems. A limited distribution is made--primarily to the operating agencies directly involved.

BRIEF

INCREASING PERSONNEL EFFECTIVENESS IN ELECTRONIC SYSTEMS-- STATUS REPORT, 30 JUNE 1962

REQUIREMENT:

In response to requirements brought about by the introduction into the Army of unique and complex electronic man-machine systems, the Chief, Research and Development has directed that research be conducted to increase the effectiveness of these systems through improved utilization of electronics manpower.

PROCEDURE:

A comprehensive survey of human factors problems, conducted in weapons and communications systems in CONUS and USAREUR, led to the conclusion that improved utilization of personnel within electronics systems can be accomplished through improved identification and assignment of personnel to critical positions and through the development of optimum work methods and techniques for the operations that must be performed. A program of research has been delineated to include studies on critical functions in Air Defense Systems such as Missile Master, Missile Monitor, and BIRDIE and in automated Tactical Operations Centers. Research on the critical functions will include development of objective performance measures, specification of human performance characteristics, identification of underlying psychological variables, and development of optimum work methods and techniques.

ACCOMPLISHMENTS TO DATE:

An experimental Electronics Selection Battery has been constructed and is being validated against school grades and on-job performance evaluations of several hundred enlisted men in electronics MOS.

Two studies of tracking problems were conducted at the Missile Master installation at Fort Meade, dealing with effects on operator performance of varying load levels (number of targets to be tracked), duration of tracking task, and brief rest periods--problems common to fixed and mobile air defense systems.

UTILIZATION OF FINDINGS:

The Electronics Selection Battery provides a basis for improved identification and utilization of electronics personnel through measures of aptitudes differentially associated with success in MOS of high and low levels of complexity.

The tracking studies are providing realistic data for use of commanders in assigning targets, evaluating the target information furnished by trackers, and improving operational effectiveness.

INCREASING PERSONNEL EFFECTIVENESS IN ELECTRONIC SYSTEMS--
STATUS REPORT, 30 JUNE 1962

TASK OBJECTIVE

New concepts of warfare have brought about the introduction of unique and complex electronic systems into the Army. Various staff and field organizations are charged with responsibility for maximizing the effectiveness of these systems. Since the operation and maintenance of these new electronic man-machine systems depend ultimately on human components, the need for human factors information is paramount. In response to this need, the Electronics Task was approved by the Chief, Research and Development and assigned to the U. S. Army Personnel Research Office.

The Electronics Research Task conducts research directed at increasing the effectiveness of personnel in these systems through improved selection and assignment procedures and through the development of optimum work methods and techniques for the operations that must be performed by individuals and groups. The present publication summarizes research accomplishments of the Task to date.

SELECTION AND CLASSIFICATION RESEARCH EFFORT

BACKGROUND

Rapid growth in military activities requiring the use of electronic equipment has created new military manpower requirements. In the future Army, relatively small units will be operating on a widely dispersed basis. Coordination of the activities of such units will depend heavily upon efficient communications. High-speed data processing is essential to streamlined supply systems. New weapons are critically dependent upon electronic equipment, placing a high premium on personnel capable of developing and applying electronics abilities and skills.

Since 1955, the Army classification system has filled electronics manpower requirements through use of the Electronic Aptitude Area (EL), a composite of scores on the Mechanical Aptitude and Electronics Information tests of the Army Classification Battery (ACB). While the validity of EL has been generally satisfactory, the number of men with EL as one of their higher aptitude area scores has been insufficient to meet Army requirements in the electronics occupational area. In 1957, only 6 percent of the personnel available for assignment had their highest aptitude area score in EL, while requirements for EL manpower reached 10.3 percent. However, not all jobs for which EL was the selector appeared to require ability to acquire high-level technical skills. Utilization of personnel in the EL occupational field could, then, be improved through differentiation in aptitude requirements for high level and low level MOS. An effective increase in the numbers available for electronics operation or maintenance jobs could result from measures of aptitudes and personal characteristics differentially associated with performance in jobs of varying complexity within the occupational area, and from improved differentiation of the electronics job family from other job families.

EARLY RESEARCH

Research psychologists of the ELECTRONICS Task first tackled the problem of increasing the quantity and quality of personnel in electronics maintenance MOS. Analysis of the validity of Army Classification Battery composites for 12 Army school courses in the Electronics and Electrical Maintenance Occupational Areas demonstrated that Aptitude Area EL, the current selector, was substantially valid for nine of the courses studied. Use of the General Maintenance Aptitude Area (GM) appeared to offer promise of higher validity for the remaining three courses containing predominantly electrical content (Helme and White, 1958). The effectiveness of ACB test composites was also studied to determine the relative adequacy of Aptitude Area EL for predicting success in several electronics and electrical equipment repair jobs. Success in the job of Powerman, requiring knowledge of fundamentals of electricity and its application to portable power generator equipment, was better predicted by the Motor Maintenance Aptitude Area (MM) than by EL (Sharp, Helme, and White, 1958). USAPRO scientists therefore concluded that research effort to predict success in electronics courses and jobs should concentrate upon differentiating between requirements for electrical-mechanical skills as contrasted to truly electronics skills. At the same time, the Electronics Occupational Area should be redefined to include only those jobs in which high aptitude in electronics is essential.

A first step in the research effort was an analysis of the skills, knowledge, and motivation important to training and job success in electronics--an analysis accomplished through study of past research, of training methods, of training facilities, and of job demands.

Factors hypothesized to predispose a man to success in an electronics assignment fell into the following categories (Goldstein, 1958):

1. Aptitude and ability factors in addition to those presently measured in the Army Classification Battery.

2. Pertinent information acquired prior to entering the Army. Since possession of information specific to electronics work is a good predictor of both school success and on-job success, development of information tests represents a fruitful avenue of research.

3. Personality, background, and experiential factors. Because personality factors seem to play an important role in electronics job success, development of appropriate personality and other non-aptitude measures was indicated as likely to predict capacity to accept and adjust to the environment of the job.

DEVELOPMENT OF THE ELECTRONICS SELECTION BATTERY (ESB)

Instrument Construction. Instruments used in military selection of electronics personnel were first examined to determine the feasibility of using existing tests in whole or in part. Several complete instruments and a number of items selected from other instruments were felt to be promising for use in the experimental battery. Complete descriptions of the Electronics Selection Battery can be found in Castelnovo and Cook (1960) and in Goldberg and Castelnovo (1960). Tests for the experimental ESB were selected, adapted, or constructed with two important objectives: (1) differentiation between potentialities for electrical versus electronic repair and maintenance; and (2) improvement of prediction of on-job performance.

The following tests make up the experimental Electronics Selection Battery:

- Mathematics
- General Science and Radio
- Object Completion
- Letter Combinations
- Figure Analogies
- Verbal Analogies
- Dial Reading
- Table Reading 1
- Table Reading 2
- Directional Plotting
- Spatial Visualization
- Data Flow Analysis
- Following Directions
- Personal Inventory for Electronics
- General Electrical Information Test

Validation of the ESB. The experimental ESB was administered to approximately 5,000 personnel in Signal, Ordnance, and Combat Arms electronics and electrical courses and to incumbents in MOS of high, intermediate, and low levels of complexity. Emphasis was placed on job performance ratings as well as school grades as criteria for evaluating the tests. Specific on-job criterion measures were developed (Robins and Cook, 1959). Data are currently being analyzed. The effectiveness of these experimental tests will be compared with that of other experimental tests and current ACB tests. On the basis of these comparisons, revision of the ACB may be considered.

TENTATIVE RESULTS

Preliminary findings seem promising and suggest that improvement can be effected in the differential identification of personnel who would benefit most by training in MOS of high levels of complexity (electronics maintenance jobs) as against those who would benefit most by training in MOS of lower levels of complexity (operator and electrical maintenance jobs). Further, improvement in the prediction of on-job performance appears possible of achievement.

One of the more promising instruments for achieving improved differential assignment is the Personal Inventory for Electronics which includes personality and background items. Two keys were developed for the instrument, Key H for MOS of high levels of complexity and Key L for MOS of lesser complexity.

A combination of scores on Key H, the Electronics Information Test, and the Arithmetic Reasoning Test and a combination of Key L and the Automotive Information Test were found to have equivalent or greater absolute validity and greater differential validity for the high and low level MOS, for both school and job performance, than the current EL $\left(\frac{2EL + MA}{3}\right)$.

UTILIZATION RESEARCH EFFORT

A major aspect of the Electronics Task effort is research to improve utilization of human abilities in complex electronic man-machine systems through the development of effective individual and group work methods and techniques. Both military users and research specialists recognized at the outset that only through consideration of both selection and utilization problems would major improvements in systems effectiveness be possible. Training problems and problems dealing with the design or redesign of equipment from a human engineering point of view were explicitly excluded from consideration, however, as falling outside of the mission of the U. S. Army Personnel Research Office.

To initiate the utilization phase of the Task, a comprehensive survey of human factors problems was undertaken in approximately 25 weapons, communications, and related systems in CONUS and USAREUR (Goldstein and Ringel, 1960). Visits were made to operational units in the field, to training centers, schools, USCONARC boards, and proving grounds. APRO research scientists participated in exercises, observed systems in operation, and interviewed personnel knowledgeable in the various systems, associated equipment, and organizations. From among several systems viewed as meriting study, considerations of need, amenability to research, and potential gain focussed attention on problems in air defense fire distribution systems and Tactical Operation Centers.

AIR DEFENSE SYSTEMS

In an era in which high speed and destructive power are bywords of military operations, defense of cities, troops, and equipment from air attack is a prime concern. For this purpose, the Army has developed integrated systems of radar air surveillance, fire distribution and control, and surface-to-air weapons. Examples of such surveillance and fire distribution systems are the Missile Master, BIRDIE and Missile Monitor; the weapons systems are the Nike and Hawk. These air defense systems are designed for employment against low and high flying aircraft in CONUS and the battlefield situation.

In fire distribution systems, personnel are required to detect and monitor targets on radarscopes, track targets, determine their height, identity, and raid size, input this information into computers, retrieve information from the computers, integrate all of this target information with weapons and other information coming from various sources, make decisions on the priorities, distribution, and coordination of fire of a number of batteries at a number of targets, communicate these decisions, see that they are implemented, and maintain control over their sectors of responsibility. All these operations and functions are performed using a large array of displays (scopes, lights, status boards, dials), controls (tracking sticks, buttons, knobs, switches), and symbols. See Figure 1. Duties may have to be performed under a wide variety of conditions ranging from those which induce boredom and apathy to those which strain the limits of human capabilities and endurance. All these operations and functions are performed in higher air defense organizational elements as well as at battalion and battery levels.

Research Approach. The need for human factors research in Air Defense Systems arises out of the very newness of these systems and the demands made on human beings as essential components of the systems. The kind and number of operations that must be performed, the speed and precision with which they must be performed, the conditions under which they must be performed, and the interdependencies among men and equipment leave little room for human inefficiency, error, or failure, giving rise to the following broad human factors research question: What can be done to improve the utilization and performance of human beings in critical positions of Air Defense Systems so that the operational effectiveness of these systems is at a maximum?

To answer this question, a four-pronged research attack has been planned encompassing:

1. Development of performance measures for systems, subsystems, and individuals.

2. Specification and description of human performance characteristics in the systems.

3. Development of optimum work methods and procedures.

4. Identification of appropriate personnel for assignment to critical positions.

This formulation is intended to provide a comprehensive and integrated human factors research approach to such critical air defense functions as 1) detection and monitoring of airborne targets on radarscopes, 2) target tracking and radar data processing, 3) assignment of weapons against airborne targets, and 4) communication and control. Although this research involves systems that are operational or in the user-test phase of development, attention is being focussed on areas and problems of human performance that generalize to future systems.

Studies have been planned dealing with the effect of various target, environmental, and psychological conditions on the performance of critical functions. Through a series of such studies much can be learned about performance degradation and enhancement, human limits and reliability, and the factors which underlie the performance of critical functions.

Figure 1. Example of Operator Console

Additional studies are planned on optimum allocation of functions among individuals and improved work methods and techniques for use by individuals and groups. Experimentation will deal with such problems as the relative effectiveness of splitting or combining such functions as detection, monitoring, tracking, processing, and decision making among one or more individuals; optimum combinations of speed and accuracy; and principles of decision making.

Research Techniques. Some research concepts may be tested by analytical treatment of logical models, with recourse to computer simulation if necessary before initiating a full-scale study. This procedure will serve as a screening process to reduce the number of research studies to be conducted and will permit emphasis on the most important problems. To minimize requirements for and interference with operational systems, laboratory-type simulation equipment and methods will be used. On occasion, an older system (Missile Master) may serve as a simulator for a more advanced system (BIRDIE, Missile Monitor) while the former is being studied in its own right.

A substantial portion of the research will have to be conducted using operational systems and personnel in the field or at training centers, particularly when final testing and validation of research hypotheses must be conducted and a given system cannot be simulated with sufficient fidelity.

Exploratory Studies. Several projects were initiated dealing with target tracking and radar data processing. These functions contribute early input into an air defense fire distribution system and provide important data on the basis of which decisions must be made concerning priorities, distribution, and coordination of fire of a number of batteries at a number of targets.

The first project on tracking performance in the Missile Master (Ringel and Smith, 1962) dealt with some of the capabilities and limits of trackers who monitor and track aircraft picked up by radar. The study was conducted to determine how tracking performance is affected by target load (number of targets assigned to be tracked), duration of tracking time, and proficiency of the tracker as rated by supervisors.

Eighteen qualified trackers--six rated high in tracking proficiency, six average, and six low--were required to track real targets on operational tracking consoles. Complete photographic records were made of tracking performance during six consecutive 10-minute periods. Load levels for the six periods varied from 3 to 18 targets. Accuracy indexes computed were: (1) percentage of instances tracker's "tags" were found to be on assigned targets; and (2) number of targets tracked with perfect accuracy in relation to number of targets assigned.

Findings were as follows:

1. As load level increased, average tracking accuracy decreased. The average number of targets tracked with perfect accuracy increased

(although the percentage of targets tracked with perfect accuracy decreased). In fact, the average number of targets that can be tracked with perfect accuracy when all trackers are tracking is close to the target handling capability of the Missile Master.

2. No statistically significant differences in tracking performance were found among groups differing in rated proficiency.

3. No statistically significant differences in tracking performance were found across time periods. However, within 10-minute periods, a small but statistically significant decrement in mean accuracy score was found.

4. Individual trackers were found to differ appreciably in performance.

On the basis of these findings, three recommendations were made.

1. Commanders should consider assigning individual trackers ten or more targets at a given time as a technique for increasing some aspects of tracker proficiency.

2. It is important that a technique be developed for identifying quickly those few assigned targets that are not being tracked with perfect accuracy. Such identification would eliminate the uncertainty associated with all targets when the location of one or more targets is not being correctly indicated by the tracker's tag.

3. Objective performance measures, rather than ratings, should be used in assigning individuals to specific tracking tasks. Such measures should be developed based on research data.

A second study of tracking performance dealt with increasing the number of targets (up to 24), longer duration of continuous tracking (up to 2 hours), and the relative effectiveness of frequent short breaks (every 12 minutes for 30 seconds) versus no breaks in the tracking task. To date, data have been collected and are undergoing analysis.

Difficulties Encountered in Exploratory Studies. The major problem encountered in carrying out the human factors research program in Air Defense Systems is the inordinate number of man-hours required to reduce film record data to quantitative data that can be statistically treated and analyzed. Simulators and other instrumentation to make automatic or more rapid scoring possible are sorely needed for effective research and timely results. The Task has examined the possibility of adapting existing equipment and devices to research needs, as well as the introduction of consideration of research desiderata in the development of new simulators.

TACTICAL OPERATIONS CENTERS

The TOC is a facility within which are grouped representatives of general and special staff sections concerned with current tactical and tactical support operations. These representatives assist the commander in the tactical operations aspects of his exercise of command by providing current information on the tactical support available and intelligence estimates of enemy actions, making recommendations for command decisions, taking action within established policies, and issuing implementing instructions. Rapid coordination among operational staff elements is essential to expedite staff reactions, command decisions, and implementation of decisions, particularly since the advent of nuclear weapons and increased capabilities in electronic warfare, air defense, and mobility. TOC's are established at field army, independent corps, and corps levels. Major activities taking place in a typical TOC are:

1. Continuous and simultaneous evaluation of available information by affected TOC elements and issuance of timely instructions.

2. Communication of tactical information and requirements to appropriate general staff sections (particularly G1, G4 and G5), and instructions to tactical units and tactical support units or agencies.

3. Continuous transmission of situation information by each element in the TOC to its corresponding element in the alternate TOC.

4. Continuous display and evaluation of intelligence required for current tactical and tactical support operations.

5. Continuous display of data, including essential administrative support data, on the status and operations of the command and friendly forces to permit immediate decisions on tactical and tactical support operations.

The automated TOC (AN/MSQ-19) is designed to assist the TOC staff in the receipt, processing, storage, display, and transmittal of information usually represented in maps, charts, journals, and work sheets. The TOC is also supposed to perform certain computations on call (target analyses, fallout prediction, and troop movements). It does this through human use of input, storage, computing, display, and communication devices.

A TOC receives vast amounts of information. The sources, subjects, forms, and degrees of completeness of this information are many and varied. Further, the information often affects several different staff groups. These raw data require a great deal of handling and processing by humans or humans and equipment. Looking at the system as a whole, there appear to be at least six major critical operations that persons and equipment have to perform:

1. <u>Screen</u> for pertinence, credibility, impact, and routing.

2. <u>Transform</u> the raw data to proper format for input into storage devices.

3. Input the transformed data into storage devices.

4. Display the transformed data for consideration by relevant persons.

5. Decide on courses of action based on information displayed and from other sources.

6. Communicate decisions and other information within and outside of TOC.

These operations and major aspects of information flow are depicted schematically in Figure 2. Figures 3, 4, and 5 show some of the devices and equipment that may be used in the performance of these operations in an automated TOC. Here, too, as in Air Defense Systems, personnel will work under a wide variety of conditions ranging from relatively pressure-free to overwhelmingly burdensome situations.

Research Approach. At a general level, the needs for and approach to human factors research in TOC's are similar to those developed for Air Defense Systems problems within the Electronics Task. Objective performance measures will be developed. Performance of TOC operations will be studied to ascertain human limits and reliability and the factors which underlie the performance of critical functions. Various work methods and techniques will be evaluated. Finally, procedures will be developed for improved identification and assignment of individuals and groups to critical positions.

A number of studies are planned in the various functional areas. The independent variables in these studies will be situational (kind, rate, completeness of information coming to TOC), environmental--physical and social (space layout, degree of independent or group work), and psychological (aptitudes, skills). Examples of dependent variables which can serve as performance measures are accuracy, types of error, completeness, and speed.

One set of studies could be concerned with the display aspects of the system, assuming that the decisions to be made and the information needed to make the decisions are known. These studies would seek to answer such questions as: What is the best format for displaying information to assure that the decision maker receives accurate and complete information in a minimum time? What rate of updating is best for a given purpose? Should sequence of display be in order of increasing complexity or the reverse? In experimentation to find answers to these questions, known information can be presented tachistoscopically for controlled periods of time and measures of accuracy, completeness, and speed can be taken.

Other studies might concern the utilization of personnel in processing information for subsequent display. Questions of interest might be: How can personnel be best utilized in screening and transforming masses

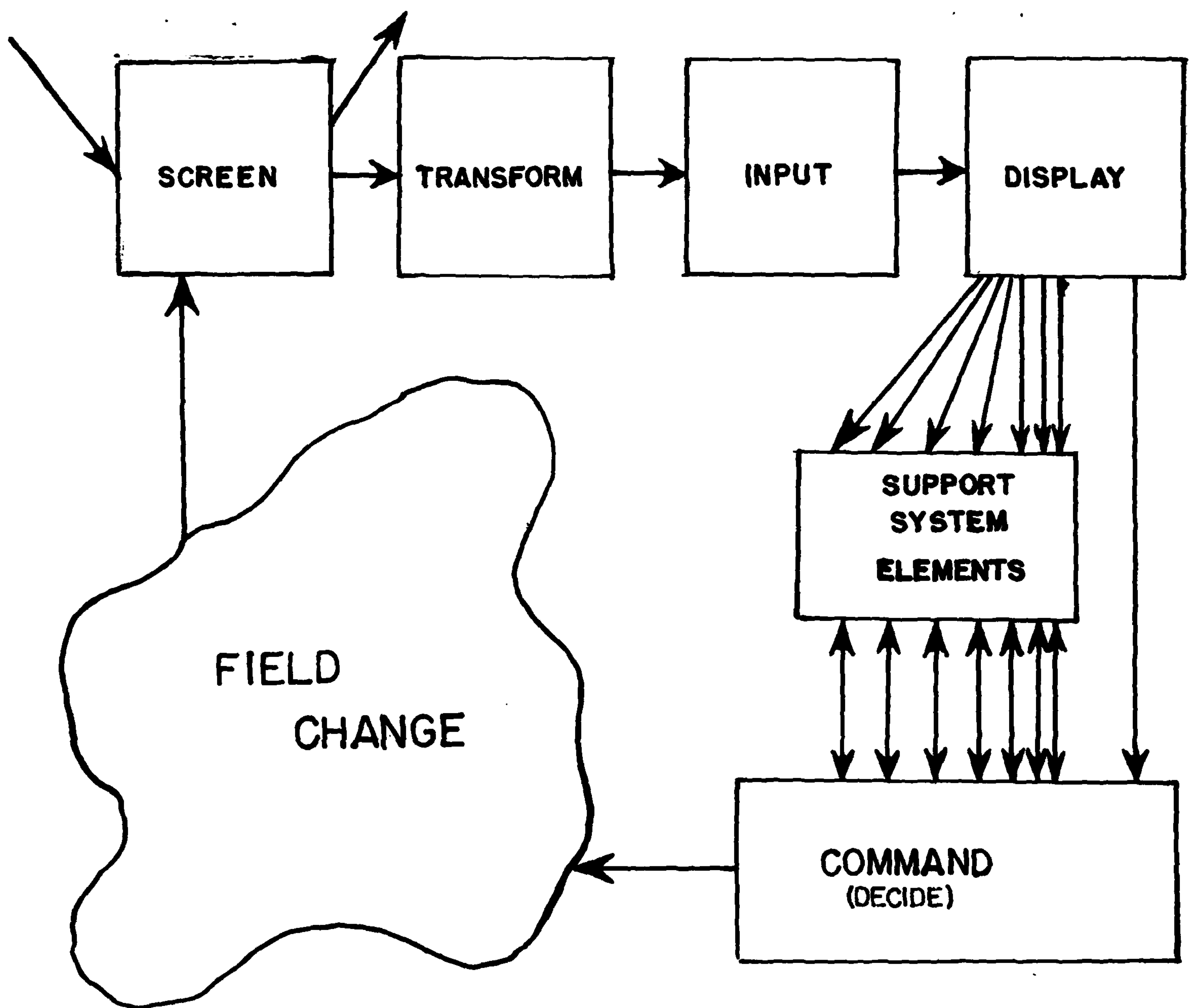

FIGURE 2: SCHEMATIC REPRESENTATION OF OPERATIONS AND INFORMATION FLOW IN AUTOMATED TOC

of information? How many personnel are needed in a given system? Should they work as teams or as individuals? What aptitudes and skills are needed? In a series of studies on these problems, different work methods, techniques, and configurations of groups will be tried out on a given situational task to determine how accuracy, completeness, and speed of information are affected.

Equipment Essential to Research. The human factors research program outlined above will be accomplished primarily through empirical studies. Relatively simple devices and equipment will be necessary, namely, a tachistoscope, slides and means for their production, charts, maps, overlays, tape recorders, an intercom system, capability for motion picture photography and projection, and timers. In addition, 1200 square feet of space, with movable partitions, are required to conduct the research. Finally, appropriate officer and enlisted personnel will be needed to participate in the experiments.

Figure 3. Graphden Prototype

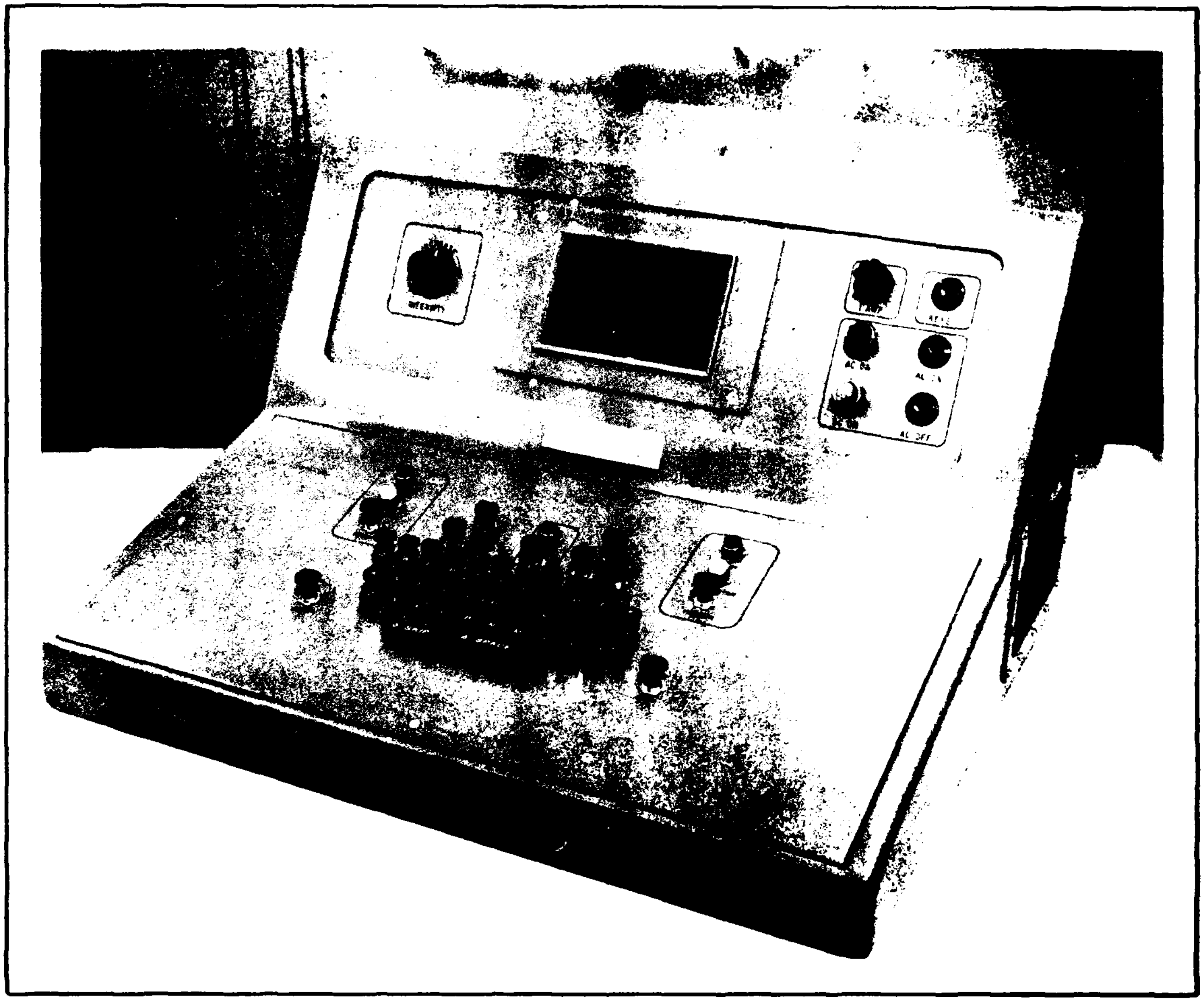

Figure 4. Tacden Operator Console

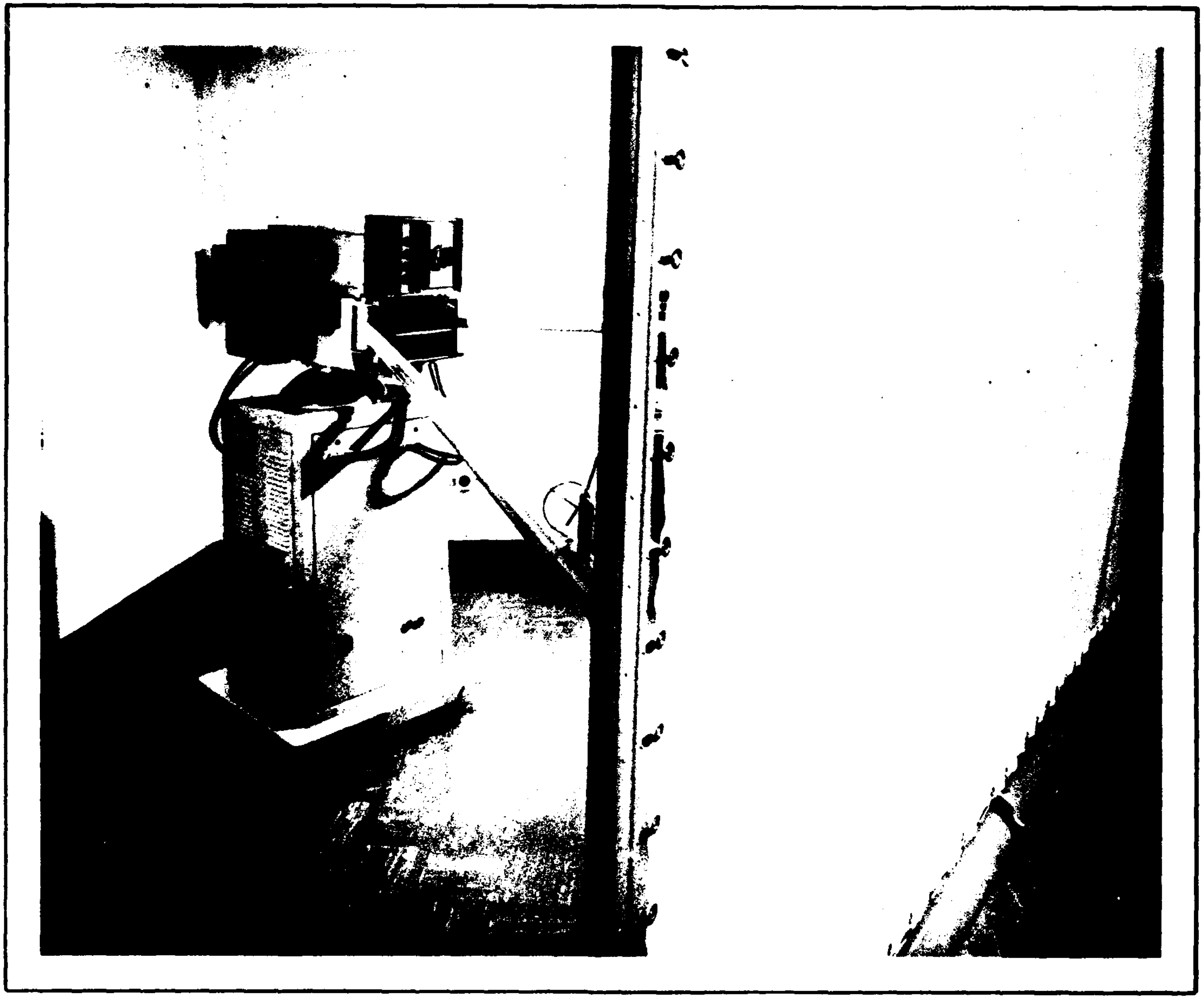

Figure 5. Group Display and Screen Assembly

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