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UNITED STATES ARMY

HUMAN FACTORS RESEARCH & DEVELOPMENT

SIXTEENTH ANNUAL CONFERENCE

SPONSOR: CHIEF OF RESEARCH & DEVELOPMENT
DEPARTMENT OF THE ARMY

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U.S. ARMY AIR DEFENSE CENTER
AND FORT BLISS, TEXAS

OCTOBER 1970

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20310

attn Chief, Behavioral Sciences Div.

CRDBES

SUBJECT: Sixteenth Annual Army Human Factors Research and Development Conference - Foreword and Transmittal

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1. This report presents the proceedings of the subject conference sponsored by the US Army Chief of Research and Development and held at the US Army Air Defense Center, Fort Bliss, Texas, on 19-22 October 1970. Theme of the conference was "Human Factors in Command and Control."

2. The site of the conference, Fort Bliss, is in harmony with that theme, for the command and control of air defense systems represent a major technological development and a corresponding challenge to behavioral science respecting the human factors involved.

3. The Chief of Research and Development welcomes the opportunity again to sponsor this conference. The outstanding support provided by the host and all participants contributed greatly to a successful interchange of information concerning the importance of behavioral and social sciences to improved understanding of human factors in military operations. Comments and inquiries respecting the conference may be addressed to the Chief of Research and Development, ATTN: Chief, Behavioral Sciences Division, Department of the Army, Washington, D. C. 20310.

FOR THE CHIEF OF RESEARCH AND DEVELOPMENT:

FRANK H. DUGGINS, JR.
Colonel, GS
Chief, Behavioral
Sciences Division

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SUBJECT: Sixteenth Annual Army Human Factors Research and Development Conference: Foreword and Transmittal

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REPORT OF THE SIXTEENTH ANNUAL U.S. ARMY HUMAN FACTORS RESEARCH AND DEVELOPMENT CONFERENCE

20-22 October 1970
U.S. Army Air Defense Center
and Fort Bliss, Texas

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CHAPTER 1
KEYNOTE SESSION

General Chairman: Lynn E. Baker
U.S. Army Chief Psychologist
Office of the Chief of Research and Development
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Washington, D.C. 20310

1A. BACKGROUND

References:

a. Conference Report, "Army Human Engineering Conference," The Pentagon, 14-15 December 1955.

b. Report, "Second Annual Army Engineering Psychology Conference," Army Medical Research Lab, Fort Knox, Kentucky, 7-9 November 1956.

c. Report, Third Annual Army Human Factors Engineering Conference," Quartermaster Research and Engineering Command, Natick, Massachusetts, 2-4 October 1957.

d. Report, "Fourth Annual Army Human Factors Engineering Conference," U.S. Army Chemical Center, Maryland, 9-11 September 1958.

e. Report, "Fifth Annual Army Human Factors Engineering Conference," Redstone Arsenal, Alabama, 22-24 September 1959.

f. Report, "Sixth Annual Army Human Factors Engineering Conference," Fort Belvoir, Virginia, 3-6 October 1960.

g. Report, "Seventh Annual Army Human Factors Engineering Conference," University of Michigan, 3-6 October 1961.

h. Report, "Eighth Annual Army Human Factors Engineering Conference," U.S. Army Infantry Center, and U.S. Army Infantry School, Fort Benning, Georgia, 16-19 October 1962.

i. Report, "Ninth Annual Army Human Factors Research and Development Conference," Walter Reed Army Medical Center, Washington, D.C., 14-17 October 1963.

j. Report, "Tenth Annual Army Human Factors Research and Development Conference," U.S. Army Aviation Center, Fort Rucker, Alabama, 5-8 October 1964.

k. Report, "Eleventh Annual Army Human Factors Research and Development Conference," U.S. Army John F. Kennedy Center for Special Warfare, Fort Bragg, North Carolina, 3-6 October 1965.

l. Report, "Twelfth Annual Army Human Factors Research and Development Conference," U.S. Army Infantry Center, Fort Benning, Georgia, 2-5 October 1966.

m. Report, "Thirteenth Annual Army Human Factors Research and Development Conference," U.S. Army Signal Center and School, Fort Monmouth, New Jersey, 25-27 October 1967.

n. Report, "Fourteenth Annual Army Human Factors Research and Development Conference," U.S. Army Tank-Automotive Command, Warren, Michigan, 23-25 October 1968.

o. Report, "Fifteenth Annual Army Human Factors Research and Development Conference, U.S. Army Training Center, Infantry, and Fort Ord, California 4-6 November 1969.

p. Army Regulation 70-8, Behavioral and Social Sciences Research and Development, dated 28 April 1969.

q. Army Regulation 602-1, Human Factors Engineering Program, dated 2 March 1968.

Sponsorship and Planning of the Conference:

The annual U.S. Army Human Factors Research and Development Conference is sponsored annually by the Chief of Research and Development (OCRD), Department of the Army. This Conference is the sixteenth in the series. The Conference includes programs in all areas of human factors research of interest to the Army.

Previous Conferences have been reported in references a through o above.

In accordance with references, planning for the Conference and follow-up of suggestions and recommendations are accomplished by an ad hoc USA Human Factors Research and Development Conference Committee. The committee is composed of representatives of the Chief of Research and Development (Chairman), The Surgeon General U.S. Continental Army Command, U.S. Army Computer Systems Command, U.S. Army Materiel Command, the U.S. Army Behavior and Systems Research Laboratory, and the Human Resources Research Organization, Inc.(HumRRO).

Purposes of the Conference are:

a. To provide direct exchange of information on human factors research and development among personnel of U.S. Army development agencies and between these and representatives of user agencies and other qualified individuals.

b. To provide recommendations and suggestions to be followed up by the U.S. Army Behavioral and Social Science Research and Development Committee to assure exploitation of all opportunities for improving the effectiveness of the U.S. Army soldier, his training and his equipment.

c. To provide a conference report which will serve as a useful, authoritative, and complete compendium of current work programs and related information concerning all U.S. Army human factors research and development activities.

Chairman"s Summary and Forecast:

Technological advances in air defense artillery materiel and data processing capabilities, coupled with the awesome destructive potential of our weapons, force attention to the relation between human and hardware components of air defense and other command and control systems.

Respecting Computer-Based Command and Control Systems, BG Reed, CG, U.S. Army Computer Systems Command, described: special requirements imposed by battlefield conditions on ADP systems (must be rugged and mobile, operable and maintainable by non-technical troops) goals of battlefield data automation for the 1980's (gather, process, integrate, and disseminate information in time to permit commanders to influence the action); current battlefield information systems (information overload with consequent lost opportunities for action and re-action);Army's response (Project ADSAF automation in TOS, TACFIRE CS_3); roles for human factors technology to (a) maximize usefulness of information available from an automated system, and (b) reduce maintenance and operational burdens of automated systems on the battlefield user.

BG Adamson, ODCSPER, in the Sponsor's Charge, presented vivid contrast of technical versus human environments and challenged research to take account of inter-personal problems (e.g. "age polarization" between troops and non-coms, junior and senior officers) in command and control.

Banquet Address of Dr. Clark (MG, USA-ret.) cited example of 1850 circular of Sec Nav to which replies from 84 naval officers showed less than 1% felt that abolition of flogging would be critically destructive to Navy discipline. To the contrary, displacement of flogging as a keystone of naval discipline presented serious new challenge, called for the best qualities of leadership and a new test in which the men in the ranks could prove themselves, and (with other changes) laid the foundations for a career enlisted service. Similar challenge to long-range planning for research in the social sciences is presented to the military today.

Sessions II-VII covered human functions and training considerations for automated command and control systems in general and for SAFEGUARD in particular; and CONARC's interaction with the scientific community. Emphasizes: how much of what to give a soldier and how to make him effective in combat as part of a team -- to be situationally responsive, militarily well motivated, and disciplined against drug abuse, racial discrimination and mission-disruptive activities; the commander's desires and needs to couple advancing technology with military know-how.

FORECAST: New Army human factors R&D facility -- Manpower Resources Research and Development Center -- will provide in-house capability for research and development of unit training principles and procedures and for realization of career enlisted service for the American soldier of the future.

1B. ADDRESS OF WELCOME

Richard T. Cassidy, Major General
Commanding General
Army Air Defense Center and Fort Bliss, Texas 79916

I was particularly pleased to be asked to host the 16th Annual Army Human Factors Research and Development Conference. Because this year's Conference is emphasizing the behavioral science and human factors aspects of Army command and control systems, I consider Fort Bliss, the U.S. Army Air Defense Center, a most appropriate location.

Technological breakthroughs in air defense artillery materiel and in data processing capabilities coupled with the awesome destructive potential of the weapons in our arsenal focus attention on the relationship between the human element and the command and control system.

Since the beginning of recorded history, military men have had reason to complain about the quantity, quality, and timeliness of data provided them as they evaluated critical tactical or strategic information. In spite of the earlier slow pace of events, information about the enemy and about one's own forces tended to be unreliable. In part, this was due to the necessary reliance on fallible humans for the observation of enemy action and for the transmission and summarization of such observations. Prior to WW II, equipment, available technology and its utilization were not particularly complex. Today, the situation is far different. Weaponry, technology, and as a result, the conditions of battle have all undergone revolutionary change.

The growth of technology has at once increased the amount of information that a commander must consider in making a decision and has reduced the time available for him to do so. However many people have reasoned that more of the technology which has caused the increase in complexities of the military environment could be exmployed to solve some of the command and control problems. I am confident that this Conference will contribute to the speedy solution to many of these problems.

During the course of the Conference the Air Defense School will make presentations which will provide some insight into the employment of air defense artillery. There will be a briefing on air defense in the field army covering the mission, objectives, history and development of air defense to include tactics and future developments. Additionally, you will see an engagement scenario called "Nike

in the Attack." The Safeguard Central Training Facility will present an unclassified briefing explaining the Safeguard system, its deployment, and our training concepts.

Again, it is my pleasure to welcome you to Fort Bliss and the sunny southwest. The Air Defense Center stands ready to assist you in any way possible, and I wish you success in your Conference.

1C. SPONSOR'S CHARGE

James B. Adamson, Brigadier General
Office, Deputy Chief of Staff/Personnel
Washington, D.C. 20310

General Betts, General Cassidy, Ladies and Gentlemen:

The charge I deliver to you this year is designed to enlist your efforts in developing a practical approach to some very serious Army problems. We are experiencing these problems now and expect them to continue. They affect Army operations on a broad front and in my judgment are relevant to the development and operation of command and control systems. They constitute the real environment of the Army and should be included as first priority in all of our research approaches. These problems are the communications gap at the face-to-face level, drug abuse and race relations. Such roadblocks to effective human relationships must be analyzed for their affects upon the command and control of Army operations.

Recently, I have had the opportunity of traveling to many areas of the world where our troops are deployed. My purpose has been to discuss the feasibility of actions which my staff and I believe are necessary in order to move from our current reliance on the draft to an all-volunteer Army. In my trips, a secondary mission has been to observe the Army's people.

As a result of this mission, I feel that complete examination of the soldier of today, his attitudes and his environment, are basic to such a major change as the volunteer Army. My travels have led me to many interesting conclusions. Let me share a few of them with you.

In the Army today, manpower is being pretty well managed -- perhaps better than ever. But it is only with great difficulty that the soldier of today is being <u>led</u>. I cannot but draw a parallel with the once great Roman Empire, which in its day was better equipped and better managed than any empire in the world. The empire crumbled before the might of less sophisticated peoples who were less well equipped and rather poorly managed. They were merely led. The Romans of that day were imbedded in the culture of an affluent society, one which allowed time for each person to do his thing. When the chips were down, it developed that the nature of each individual's thing did not contribute to adequate collective defense.

Today, in the Army, we have serious problems in spite of all the scientific advances we have made. We have a communications gap at

the face-to-face level. To be sure, we have communications equipment, computers to program our options, and more technological improvements are under development. Important as they are, these are sometimes not the most crucial aspects of communication. We have the problem of the private comunicating with his squad leader. It just isn't being done adequately. And, the platoon sergeant and first sergeant are even more removed from the thoughts and insights of the private. This communications gap is paralleled by the distance between the junior officer and the senior officer. Communications are polarized by the age of the soldiers. On the one hand, the senior officers and the noncommissioned officers have rapport. On the other hand, the junior officers and enlisted men communicate. There are age and cultural differences to overcome between groups before a unified Army society can be achieved. Undoubtedly, you realize that this condition is a mirror image of American society. We are facing this same problem in the environment of our families.

A second problem is that of drug abuse. Aside from the outwardly visible excuses such as easy access to drugs overseas and acquired habits before entering the Army, it is apparent that drug abuse is a sign of a vacuum of values or a lack of personal goals. Could inspirational leadership create values which would challenge today's youth to the point where they would not seek escape through drugs? How can the on-duty operational situation provide or support these goals while achieving mission performance? How can the off-duty situation reinforce these goals?

Still another problem, although not unrelated with the previous two, is the racial problem. In spite of enlightened leadership in the field of race relations for a quarter of a century, the Army is faced daily with charges of real and imagined discrimination against minority groups. How can the Army inspire and utilize the best efforts of all of its soldiers? What environmental changes, command actions, job designs and career systems are needed?

It would be easy to attribute these and other problems to the existence of the war in Vietnam, but this war is not the cause. It is merely a convenient happening to which we are tempted to attribute our problems. Our problems are much deeper than any specific political or military act upon which objections are voiced. We face the problems of monumental social change which accompanies scientific revolution. The change promises to be equally traumatic as that of the industrial revolution some years ago.

From my own parochial standpoint, I need to know what changes must be made in the Army now in order that it will become known as a good place to live and work. If our soldiers are to be voluntary recruits, this is fundamental.

The design and development of new command and control systems must appreciate the individuals and groups who operate and support these systems. Job design must challenge and satisfy the goals of individuals as well as meet technical requirements. Job aids, tools and test equipment must be realistic in terms of the skills and abilities of our soldiers. Units must be designed to enhance individual development and leadership as well as mission performance.

From a larger standpoint, we must concentrate upon developing, through systematic general studies, blueprints for dynamic enlightened leadership to bridge the gaps and overcome the barriers presently found among the Army's major groups. This leadership reform is an absolute must if our Army is to endure and remain capable of responsibly answering the demands of our nation's defense. One approach to this reform is described by Major John D. Elliot in his article in this month's Military Review. He sees the need for what he calls an "open military society." Face-to-face communication to encourage free expression of opinion. Innovative change would be expected rather than feared. The nation's youth would be challenged to become the building blocks and provide a basis for establishing an Army on what General Westmoreland has called a new "thinking plateau."

I charge you to devote your thoughts to developing a sound blueprint for the changes which must be made. It is from the talents of you assembled here today that such guidelines must come. We have here at stake an issue for which today's solutions are rapidly showing themselves to be inadequate. Our problem is not so much to change the young to values of the old, but to adapt the leadership to meet the challenges found in the present environment. What we need is a transition from the leadership practices of yesterday to those which will be required in the near future. This task requires the best efforts of the human factors research community. Development of a useful solution to this problem may be one of the greatest challenges you have ever undertaken.

1D. KEYNOTE ADDRESS

Austin W. Betts, Lieutenant General
Chief of Research and Development
Department of the Army
Washington, D.C. 20310

INTRODUCTION

The theme of this conference is "Human Factors in Command and Control." Back in the days when I was a second lieutenant - and on into the 40's and 50's - such a theme so worded would have been so obviously redundant as to be almost meaningless. In those days we'd have said that the words "command and control" could refer to nothing else but human factors. It's a sign of the times that C^2=ADP (command and control equates to automatic data processing)!

To be sure we knew a lot about automatic controls even then. James Watt, in the late 18th century, had developed the centrifugal governor to control the speed of the steam engine. We also knew that Clark Maxwell and others in the 19th century were concerned with developing studies of the theory of control.

But it was not until the 1930's that engineering practice began to reflect some of the common principles that operate in a wide variety of regulating mechanisms. The term "automation" was first used by D.S. Harder, in 1936, to refer to "the automatic handling of parts between progressive production processes" in the General Motors Corporation. Twenty years later, in 1956, L. Landon Goodman was able to say that the purpose of automation is "to utilize the mechanization of thought and effort to achieve an automatic and in some cases a self-regulating chain of processes." -- Note the words "utilize the mechanization of thought."

Recent history of the technology of modern industrial operations finds its application not only in the production of military materiel, but, particularly with the advent of computer technology, also in design, doctrine, and tactics for employment of that materiel with the Army in the field. General Reed, Computer Systems Command, will have more to say on that subject later this morning when he speaks of the development of computer-based command and control information systems. Following General Reed's presentation the conference will deal in some detail with Human Functions and Interfaces in Command and Control Systems, with Problems of Night Observation, with Air Defense in

the Field Army, and with a number of major aspects of development, test and evaluation, as well as training for such systems as TAC-FIRE and SAFEGUARD.

R&D OF MANPOWER QUALITY AND QUANTITY

You may or may not believe in the ultimate possibility of the "mechanization of thought," to use again L. Landon Goodman's expression. If you are concerned, you are not along. I just read a review of a new book, Risk, Survival and Power, by R.K. Mueller. He says...."the danger of a computer is not the science fiction fear that machines will begin to think like men, but the more realistic apprehension that men will begin to think like machines." They say that "garbage in, garbage out" still remains the basic rule of automatic data processing and computer applications. I do not quarrel with that rule, but I would rather see us more concerned that men may use machines to avoid thinking for themselves. I'd like to see us applying machines to address a first principle of military manpower development: That in an Army of decreasing size, and perhaps even all volunteer, quality becomes all the more important. That goes for the quality of the men, the quality of their materiel, and the quality of their leadership. Let's use machines to enhance that quality, not supplant it.

Now what about quanitity? Our research and development programs must equally be motivated by the fact that the substitution of materiel for men can realize appreciable manpower savings. Let me give you some examples taken from current development programs:

Let's start with aircraft engine development. Use of the best of advanced technology in an engine for the Army's utility helicopter should result in sizeable savings in support requirements. Specific fuel consumption on gallons per horsepower output should be reduced by 20%, which should be immediately reflected in the logistic stream. In addition, maintenance man-hours per hour of flight should be reduced by 50%, which means a reduction of almost 500 maintenance man-hours per flight hour per month of support for each assault helicopter company.

In a similar vein, we hope for considerable savings in man-hours of effort by development of a diagnostic and prognostic system for Army aircraft maintenance. The goal is a system somewhat like those now in operation for automobile maintenance. -- one simply drives a car in, and for a fee of $7 to $10 the car is given a pretty thorough going over. The diagnostic instruments can tell what is wrong and, to an extent, predict where trouble may be expected in the future.

In Vietnam, where we have large fleets of rotary wing aircraft, we have to spend much too much manpower on maintenance. We know that we can improve on this considerably with resultant manpower savings associated with reductions in unwarranted re-work, secondary part damage, spare part consumption, and fault isolation. This should make possible an overall reduction in training and skill level required of forward echelon maintenance personnel in a future Army that will probably be highly mobile.

The current COBRA gunship is a fine weapon system, but we can and must do better. If we can keep Congress on our side, it will be

augmented by the CHEYENNE. This remarkably effective gun-ship will incorporate a number of advances in the human factors field relating to maintenance. The CHEYENNE was designed from the beginning to be capable of being supported in the forward area of the battlefield. It includes such things as: built-in maintenance ramps, built-in test equipment, and modularized components of solid state circuitry. These design features should result in a higher availability rate than COBRA because of human factors consideration being given early in the design phase.

We have not yet begun development of a system we call UTTAS - for Utility Tactical Transport Aircraft System - to replace the current HUEYS. Again, as I have noted, current maintenance requirements of the HUEY technology are high. Those aircraft demand about 6 hours of maintenance for every hour of flight. For UTTAS we are confident that we can cut this to 3:8 to 1. Equating this to dollars, even if the flying hours for UTTAS were the same as for HUEY, we estimate that the Army will save about $20 million annually. Actually, mission capabilities of the UTTAS should be reflected in other savings. -- UTTAS is faster, hence can accomplish more missions per flight hour.

Other systems that enhance manpower effectiveness in a somewhat different way are the TOW and DRAGON anti-tank weapon systems. Both reflect a considerable upgrading in operational capability at no increase in manpower over the current crew requirements of the 106mm and 90 mm recoilless rifles.

Backing up TOW and DRAGON in the anti-tank role is an automatic anti-tank mine dispenser. This is a device manned by 3 men, towed by a truck or personnel carrier. It can dispense up to 525 M-15 anti-tank mines per hour under ideal soil conditions. The previous method, as I'm sure many of you know from painful experience, was to use G.I. manpower digging the mines in by hand tools.

The scatterable anti-personnel mine is another example. Here the scattering may be done by cannon, missile, aircraft, and ground vehicle. We believe the savings in manpower for equal minefield effectiveness can be measured in battalions.

There are developments in artillery that can save precious manpower. Current nuclear cannon projectiles come in pieces that must be carefully handled and meticulously assembled by highly trained personnel. One type of round requires from 30 to 60 minutes for assembly. To change the yield requires dissassembly and reassembly. Projectiles in development will be shipped and stored completely assembled. They will require only a relatively few minutes to prepare for firing. There should be no maintenance needed while in storage.

Another system designed to save manpower is the SAM-D, a future air defense system. Today's world-wide, all-weather air defense requirements total approximately 44,000 active Army and National Guard soldiers to man all of the Army's HERCULES and HAWK units. To replace these two systems, and at the same time provide qualitatively improved air defense with about the same area coverage, SAM-D manpower savings will be quite significant, although not predictable until current study is completed.

It is quite clear that the re-

duction from a 4-man to a 3-man crew in the MBT-70 will save combat manpower, but the expected savings in crew size will in part be offset by the necessity for increased maintenance support. Even so, in this, as in many other cases, any manning increase for backup will be in elements not committed directly to combat. These support elements will not be likely to suffer quite as many casualties as the combat crews. Hence, they should require replacement at a much lower rate. This much-discussed example may well illustrate a second implicit principle of military manpower utilization: Technology that puts increased power and precision at the cutting edge justifies the acceptance of some increases in manpower support requirements.

NEW EMPHASIS IN HUMAN FACTORS R&D

The Army'c current experience with the fluidity of warfare on the ground and the resulting problems of command and control (note, for instance, the concept of the airborne CP) indicate that a significant research effort is warranted in the area of combat arms unit training. In view of increased public concern with ecology, it appears that the availability of training areas will be an increasing problem in CONUS just as it has long been in Europe. Add to this the increasing costs of the use of tactical equipment, and the requirements for increase of command skill and proficiency at all combat arms levels from squad to division. These considerations would dictate that our traditional field exercises, and even CPX problems are not likely to provide the degree of unit combat readiness in the future that they have in the past. In short, combat arms unit training must have a high priority for applied behavioral and social science affecting human factors in military operations. Specific benefits needed are:

a. Improved criteria for evaluation and measurement of unit training and performance effectiveness.

b. Improved information systems for reporting and supervising training.

c. Improved integration of training cycles as they relate to deployment demands and performance capabilities rather than to arbitrary fiscal year or calendar year cycles.

d. Training simulators and devices that reduce maneuver costs, area, time, and personnel support requirements.

I am aware that developments are already under way that will play a role in providing these needed benefits. As respects aviation, for instance, we already at work to produce a system that will enable aviation manpower managers to predict more accurately, during their individual traing, which men are most likely to complete the flight training program; - or which aviators will be effective at helicopter gunnery; - or which ones will perform effectively in combat and which will not; - or which aviators will remain in service and which will leave.

Similarly, to use another aviation example, I am acquainted with work to develop the helicopter training simulator that you refer to as the Synthetic Flight Training System (SFTS). The SFTS will provide advances in the automation of training, computer monitoring and the evaluation of performance, "adaptive" training that is gaited to the progress of the individual

trainee, and improved training systems management. In short, we expect SFTS to provide devices and procedures that have been conceived and designed as a complete training system rather than as a collection of separate, discrete devices each independent of the other.

But these benefits for individual selection for capabilities assessment, and for training must also be realized for command and control of combat units at the squad, platoon, battalion, and even the division level. Let's look at the three pieces of this problem. One third relates to tactical operations; another to combat support, and the third to what we may call - for simplicity's sake - intelligence. In support of each of these broad areas we have a variety of programs - such as TACFIRE for the operations side; CS_3 for the support side, and for the intelligence third perhaps we should list Project MASSTER. It is in the integration of these three that I believe human factors can make a major contribution. Technology tells us that it is conceivable that a commander can receive with the push of a button, literally miles of detailed photographic coverage. Simultaneously, a mix of other sensors can provide him with additional real time data. Thus we have a very real human problem - that of prompt, real time intelligence processing and evaluation. How do we solve this?

Another human factors problem - this at the unit level. Behavioral science must take account of the fact that it is as obvious as the rising sun that major sociological changes are occurring in the nation with ever-increasing momentum. Since the Army is in major degree a reflection of the nation, it is imperative that the longer-range effects of these changes be understood and taken into account in Army programs and policies of (a) individual recruitment, selection, and training: and (b) our doctrine and practice of the arts of unit command, leadership, and control.

Commencing early in World War II a major sociological research effort titled The American Soldier was undertaken by the Army. This project involved over one hundred and thirty behavioral scientists. It was initiated with the personal approval of General George C. Marshall and the support of the General Officer Corps. Research detachments were established in Europe, the Mediterranean, Central Pacific, and India-Burma with smaller units in Philippines, Panama, Alaska and the Southwest Pacific. For four years this massive effort recorded the attitudes and values of a half-million American youths toward a variety of military topics. Major policy and legislative decisions were based on this eminently useful research; its best known achievements were the "Point System" of demobilization and "GI Bill" cost estimates. The range of research topics was very broad indeed, and included, for example, analysis of: psychiatric casualties (combat motivation and control of fear), winter clothing preferences, medical care, fraternization policies; attitudes toward WAC, special assignments, promotion policies, job assignment policies, and weapons preferences.

A monumental four-volume work was issued from the research effort dealing with adjustment to Army life, special problems of combat and its aftermath, experimental studies of communication, and methodological problems of attitude measurement and prediction. With demobilization, the social

scientists returned to their campuses and the study of military attitudes and values was allowed to lapse. It must now be revived.

For these and other reasons, we have recently established, as a Class II activity of the Office of the Chief of Research and Development, a new agency to be known as the Manpower Resources Research and Development Center (MRRDC). It will be the function of this new agency to build upon and complement the advances that you are already providing with respect to the individual soldier by comparable advances in unit training, unit performance assessment, unit motivation and leadership.

SUMMARY

In summary, I must emphasize the importance for Army R&D affecting human factors in command and control of the principles that:

a. In an Army of decreasing size, and perhaps all volunteer, quality becomes increasingly important.

b. The substitution of materiel for men can realize appreciable manpower savings, but, it is the increased power and precision at the cutting edge that justifies acceptance of calculated increases in manpower support requirements.

c. Our advances from behavioral science applications to individual selection, classification, and training must now be extended and complemented by advances in unit training, unit performance assessment, and unit motivation and leadership.

Gentlemen, I thank you for the privilege of talking with you this morning, and for allowing me to communicate to you some of my philosophy of what the future holds for the Army. You people have the capacity and the capability to assist the Army materially in the years ahead as it changes in composition. There are a number of unknowns, in terms of the skill levels, quantities and qualities of a future all-volunteer Army. You can assist the country and the U.S. Army in a very great way if you devote your efforts wholeheartedly and realistically to the future problems as well as today's problems.

Now, if there are any questions any of you would like to ask me, I'll be glad to try to answer them.

1E. COMPUTER-BASED COMMAND AND CONTROL INFORMATION SYSTEMS

Wilson R. Reed, Brigadier General
Commanding General
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Fort Belvoir, Virginia 22060

It is a real pleasure for me to be here this morning, to tell you about my business, a business in which we are developing new concepts every week, new policies every day, and new procedures every hour.

First, let me put this whole business into some sort of perspective for you.

Commanders base their decisions on information such as personnel statistics, POL stockage, maintenance statistics, ammunition levels, combat information, and so on.

Information through the ages has been all but completely lacking. At best it has been expensive, late, and quite unreliable. Most people in responsible positions today, whether in government, in hospitals, in research laboratories or in business, spend most of their time scratching to get a little incorrect and unreliable information on what happened yesterday.

An old friend of mine, General Bill Reeder has said, "The art of command consists of issuing orders based on inaccurate, incomplete and archaic data, to meet a situation which is dimly understood, and which will frequently be misinterpreted and often ignored, to accomplish a purpose about which many of the personnel are not enthusiastic".

Other things being equal, the commander or manager with the greatest amount of accurate information at his command has the greatest competitive edge over his rivals -- be they friendly or enemy.

An automatic data processing system is comprised of four major components: Management; People; Software; and Hardware. Obviously, the human is the major factor in the system. Since management is human, humans develop the software, and humans operate and maintain the hardware. But so the human has always been key in our command and control systems.

On the battlefield mobility and frequent movement are literally a way of life; communications are seldom ideal; the weather is either overhead or underfoot. None of these conditions apply to the usual computer installation with its tile floor, filtered air-conditioning and AT&T communications. While data processing in

the field is similar to general purpose data processing for business and scientific applications, there are two added dimensions of great significance.

First, the equipment must be rugged enough to withstand the rigors of a battlefield environment; mobility over rugged terrain, and exposure to extremes of temperature and humidity (as well as sand and dust) require equipment more complex mechanically than commercial computers, although they may otherwise be the same. Second, the equipment must be useable by soldiers who are primarily fighting men, not full-time computer technologists.

So much for the physical demands which the tactical environment places on the equipment. Now, bear in mind, we don't want this expensive and vulnerable gear up front unless it pulls its weight. So, just what do we envision in the future tactical situation that makes battlefield data automation necessary?

General Westmoreland highlighted the goal for the 70's in his speech to the AUSA annual luncheon just one year ago:

"In summary, I see an Army built into and around an integrated area control system that exploits the advanced technology of communication, sensors, fire direction, and the required automatic data processing -- a system that is sensitive to the dynamics of the ever-changing battlefield -- a system that materially assists the tactical commander in making sound and timely decisions...

"Hundreds of years were required to achieve the mobility of the Armored Division. A little over two decades later we had the Airmobile Division. With cooperative effort, no more than 10 years should separate us from the automated battlefield".

Now, with that as the goal for 1980, where are we starting from in 1970?

Well, on the one hand, the Army currently has available to it for use on the battlefield something in excess of 250 types of sensors. These range from the small seismic detector, through radar and infrared sensors, to satellites of various types, each with its data link to our command and control centers. As Leonard Sullivan, the Deputy Director of Defense Research & Engineering for Southeast Asia Matters, has said, "One can now perceive an evolving capability to locate and track in real time, anything that moves, perspires, broadcasts, makes a noise, shakes the ground, runs an engine, shoots a weapon, or is hotter or colder than its surroundings."

On the other hand, the Army currently has available to it for use on the battlefield billions of dollars worth of reaction means, ranging from infantry and armor, through artillery and rockets, to aircraft and missiles of every description, each with its communications net to our command and control centers.

And what is in our command and control centers?

A handful of harassed, fatigued, forgetful but dedicated men; working with grease pencil and acetate, message form and lead pencil, field

desk and telephone; trying to turn information into intelligence and produce order from chaos. A number of our studies indicate that about 1/3 of the battlefield information that is sensed reaches the tactical operations center; the tactical operations center is able to assimilate for use about 1/2 of the information received; thus the commander ends up basing his decisions on something less than 15% of ground truth, a sorry situation.

So now we have a defined goal and a starting point, and the question remains, "How do we get from our current situation to General Westmoreland's goal in the seventies?" The Army's answer, of course, is by automation of selected battlefield functions through PROJECT ADSAF.

When the computer is applied to a tactical force, it does not act simply to add an incremental improvement to a part of the force: Rather, it acts as a multiplier, increasing the effectiveness of the entire force two -- five -- ten times. And it provides additional options for design of the functional system. I am persuaded that is both "cost effective" and "combat effective".

Since the potential for useful applications of data automation on the battlefield is enormous, the Army has underway a major effort to accelerate the process of putting these machines on wheels and designing them to survive in a tactical environment.

We started some years ago with a stated requirement for just over 1,000 functional applications for ADP for the Army in the field. Perhaps the prime achievement of my command in this area has been development of the ADSAF concept which packaged these requirements in three logical subsystems conforming to the organization and communications of the Army in the field.

So now let us take a look at the basic systems which make up the Army's tactical ADP family: The Tactical Fire Direction System, "TACFIRE", for control of supporting artillery fires; the Tactical Operations System, "TOS", for intelligence activities and control of the maneuver elements; and the Combat Service Support System, "CS3", for control of the logistical and administrative support of the Army in the field.

All of our tactical systems utilize digital computers. Perhaps there is some historical significance in the fact that the first message to an American Army in the field was digital. A simple code devised by a patriotic silversmith, "One if by land and two if by sea".

Today that message wouldn't tell a field commander nearly enough. He wants to know: How many? What direction? Their weapons? Vehicles?

So now let me describe TACFIRE and TOS, the two systems which will provide combat information to the commander, and do much more.

TACFIRE is a completely integrated system of computers located at battalion, division artillery and corps artillery, within the Army in the field after 1971. This system will provide for receipt, storage, processing, display, retrieval and control of artillery information on targets, survey and metro. In addition, and most important, it will generate and disseminate orders, information and intelligence

essential for the conduct of field artillery fire support.

Here are the objectives of the TACFIRE system. (Chart 1) In achieving them we expect to just about double our artillery effectiveness.

The computers at battalion and division artillery will perform these functions: (Chart 2)

I should like to show you how TACFIRE will operate in the execution of a typical artillery mission -- engaging a battalion target of opportunity.

At a battalion fire direction center equipped with TACFIRE, the battalion commander and the operations officer can review the tactical situation in their sector of responsibility, on a computer driven digital plotter map.

Meanwhile, all along the front, artillery forward observers are operating, each equipped with a TACFIRE message entry device and a radio or wire link back to the fire direction center, which in turn is in communication with the firing batteries. Many forward observers can, of course, report in to each fire direction center.

When one of our forward observers sights a target, he fixes its location using well-proven conventional techniques. But now, with the help of his message entry device, he uses a relatively new method of getting the word back.

On the keyboard of the message entry device, he sets up a message in a fixed format, checks and verifies his dial settings, and pushes a button to transmit the information. The message is transmitted over conventional voice circuits. But because it is digital in nature, it contains error correction data and requires far less time to send.

The message is received at the battalion fire direction center and enters the TACFIRE computer. The computer displays the message, in this case a request for fire, on TACFIRE'S artillery control console.

Simultaneously, the computer locates the target coordinates on the digital plotter map and enters a symbol at the exact point on the map to identify the target. At the same time a hard copy printout is displayed on the TACFIRE printer, for record purposes. Both a gunnery officer fire order and battery fire commands are automatically developed, and they may include a recommendation as to which of his batteries is best positioned and best equipped to execute the fire.

The fire order is now displayed on the artillery control console for the gunnery officer to examine. Elapsed time from the pressing of the transmit button by the forward observer to the display of the fire order on the artillery control console is less than 7 seconds. Satisfied that they are the proper responses to the situation, the gunnery officer, not the computer, makes the decision to fire.

He orders transmission of the fire commands to the battery designated, where they are displayed visually, to reduce the chance of error. Firing commences. First round accuracy is likely to be improved by use of the computer-calculated firing orders. But after the first round the complete TACFIRE cycle can rapidly be repeated with the forward observer

U.S. ARMY COMPUTER SYSTEMS COMMAND

OBJECTIVES

THRU ADP

- [illegible]ED ACCURACY
- BETTER AND MORE RAPID USE OF TARGET INFORMATION
- FASTER REACTION TIMES
- GREATER EFFICIENCY IN:
  - DETERMINATION OF FIRE CAPABILITIES
  - ALLOCATION OF FIRE UNITS TO TARGETS

CHART 1

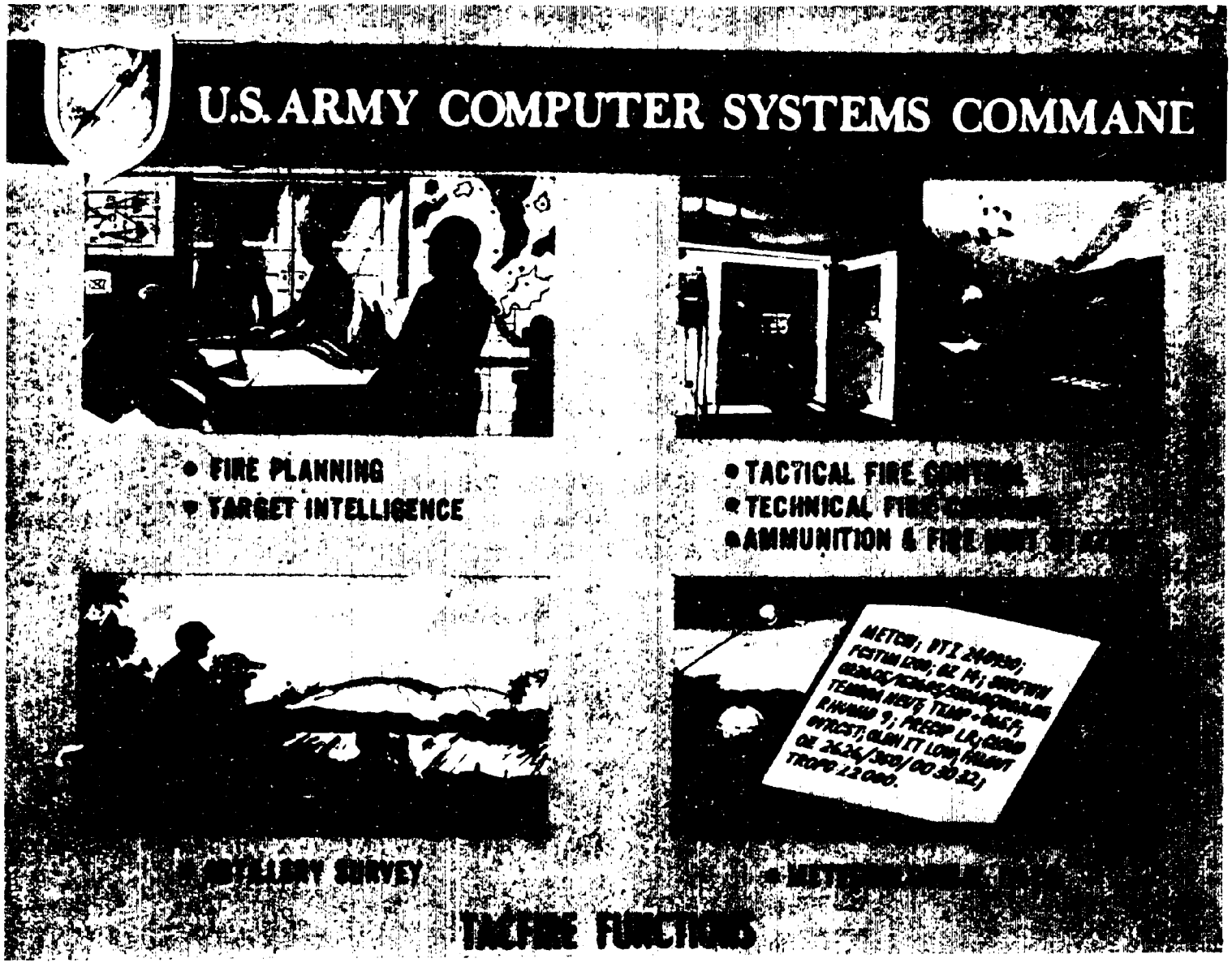

U.S. ARMY COMPUTER SYSTEMS COMMAND
• FIRE PLANNING
• TARGET INTELLIGENCE
• TACTICAL FIRE
• TECHNICAL FIRE
• AMMUNITION & FIRE
• ARTILLERY SURVEY
TACFIRE FUNCTIONS

CHART 2

calling for adjustments if necessary.

The forward observer now calls for "Fire For Effect". In response to this message the battalion computer brings in all fire units designated to fire, then automatically composes and forwards a message to the division artillery fire direction center, updating the records on artillery targets.

Finally, the forward observer, observing the results, uses his message entry device to report on the successful completion of the mission. From the firing batteries information is entered on ammunition consumed, and status files at the battalion and division artillery computers are updated accordingly, assuring the commander of accurate status reports when next he needs them.

Of the three ADSAF systems, TACFIRE is the most advanced and is expected to ease the way considerably for the other systems.

The second major system of ADSAF is the Tactical Operations System (TOS). The system is being designed as an on-line, near real-time, militarized ADP system to be fielded at division, corps, and army levels within the Army in the field about 1977. This system will, to the maximum extent, use equipment identical to that procured for TACFIRE. The ultimate Army TOS will provide tactical commanders with an automated information gathering, processing, and dissemination system. It will provide timely and accurate handling and processing of the large volume of intelligence, operations, and fire support coordination data flowing into the tactical operations center for use in making tactical decisions.

So here are the objectives of TOS. (Chart 3)

We are performing extensive testing on an experimental TOS system using an interim, transportable, "ruggedized", commercial system.

Here are the five functional areas we have tested so far in field exercises in U.S. Army, Europe. (Chart 4)

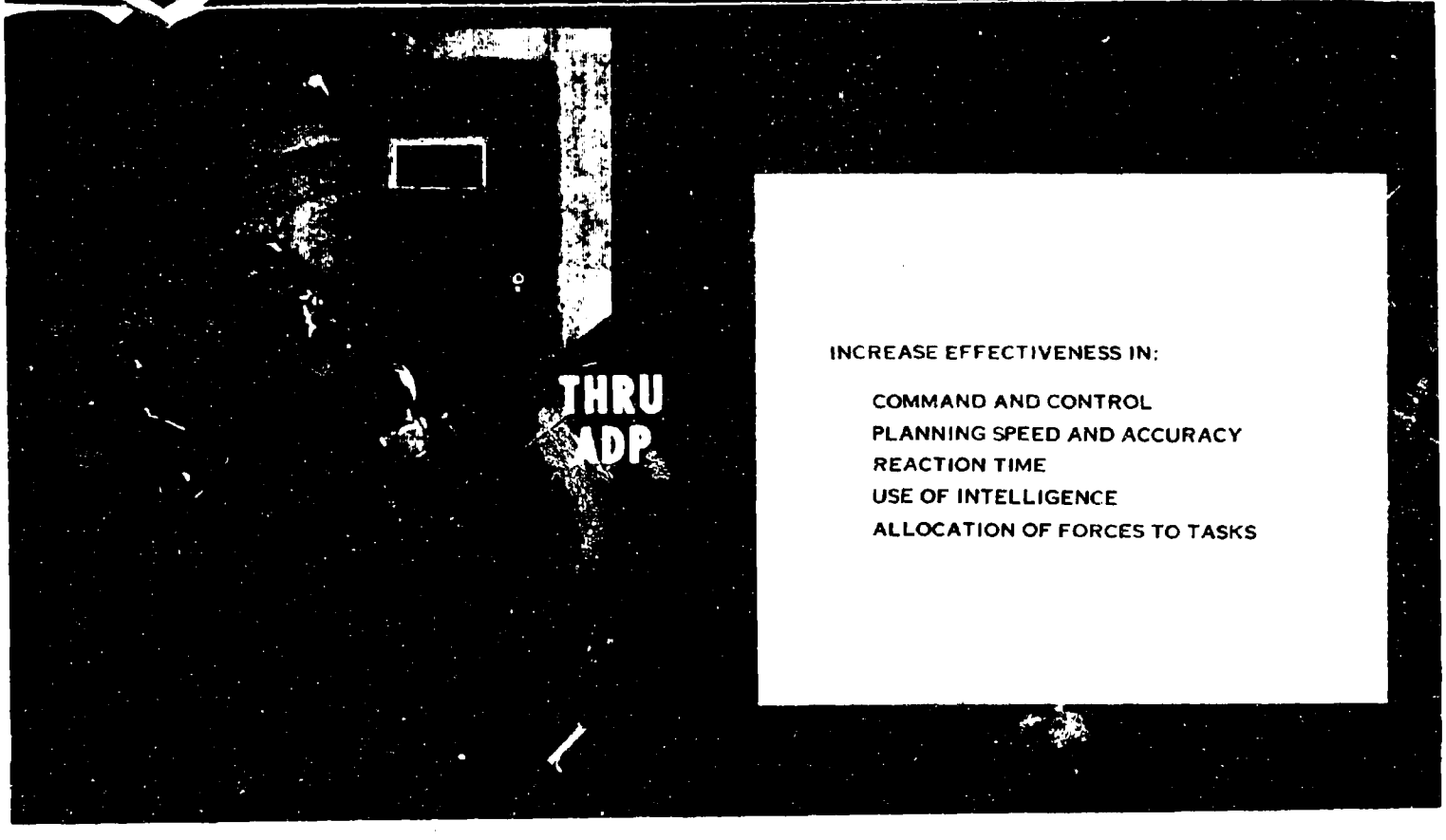
And here are the first 18 areas we plan to develop. (Chart 5)

Concurrently, a study effort is underway to identify additional user areas for automation for Army-wide TOS. At the present, it looks as though we could end up with a total of 30-35 functional areas on TOS.

Our experimental TOS consists of a Central Computing Center (CCC) in a four-van configuration, with five magnetic tape units and the usual printer, card reader and card punch. It can be located anywhere that provides access to the communications system, most likely at the signal center nearest the echelon which it supports. Thus, this group of vehicles would not be added to the congestion in a command post.

The CCC is fed by four smaller, remotely located shelter-mounted "Remote Station Data Terminals" (RSDT), each composed of a computer, typewriter, controller, and COMSEC equipment. These are the local information processing points for data. The RSDT stores the messages as they are prepared for transmission, or when received, encrypts and decrypts the data, and acts as a multiplexer so that all eight users can share one communication line to the CCC.

U.S. ARMY COMPUTER SYSTEMS COMMAND



INCREASE EFFECTIVENESS IN:

- COMMAND AND CONTROL
- PLANNING SPEED AND ACCURACY
- REACTION TIME
- USE OF INTELLIGENCE
- ALLOCATION OF FORCES TO TASKS

CHART 3

U.S. ARMY COMPUTER SYSTEMS COMMAND
EFFECTS OF ENEMY
NUCLEAR STRIKES

CHART 4

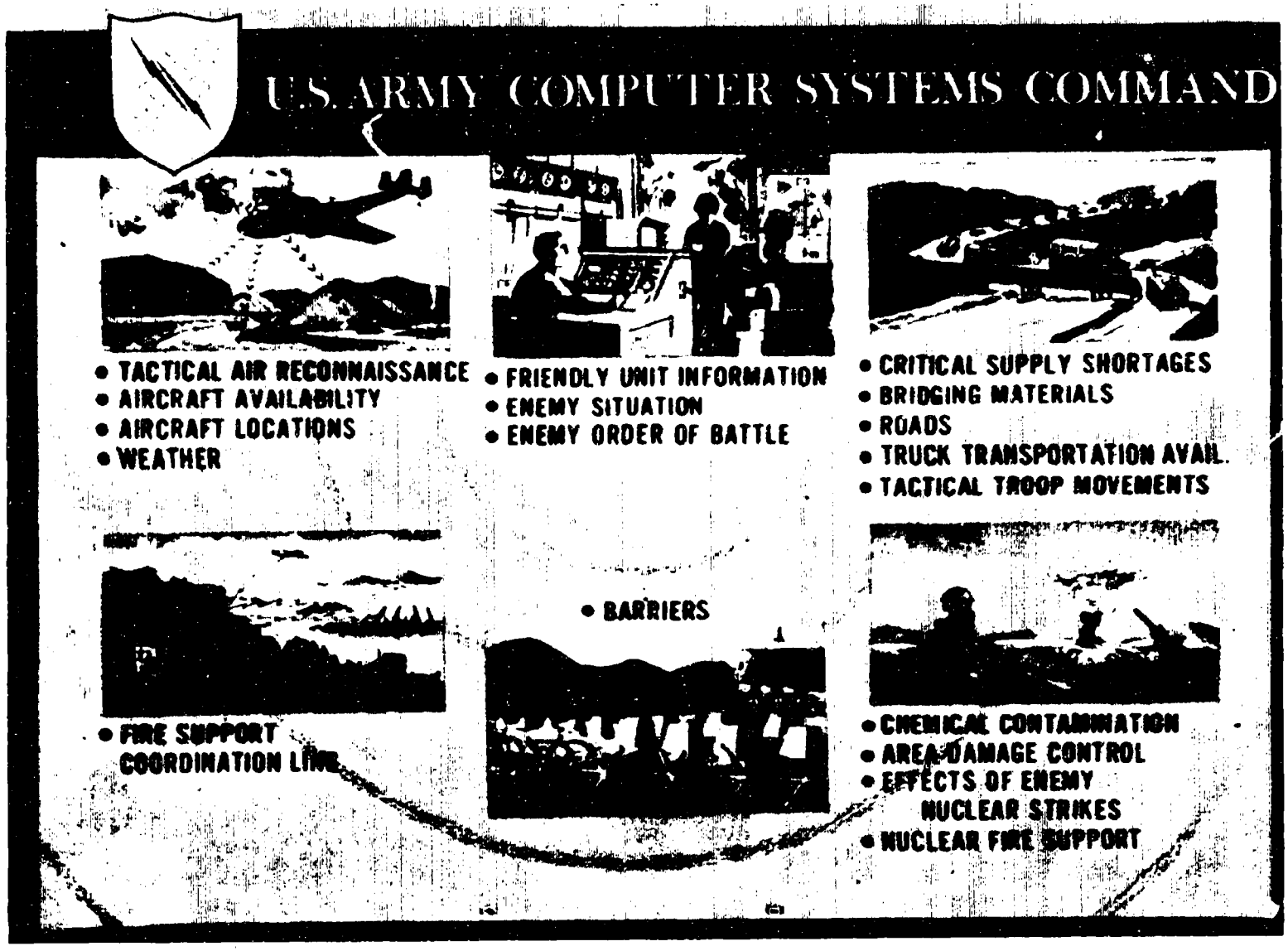

U.S. ARMY COMPUTER SYSTEMS COMMAND
• TACTICAL AIR RECONNAISSANCE
• AIRCRAFT AVAILABILITY
• AIRCRAFT LOCATIONS
• WEATHER
• FRIENDLY UNIT INFORMATION
• ENEMY SITUATION
• ENEMY ORDER OF BATTLE
• CRITICAL SUPPLY SHORTAGES
• BRIDGING MATERIALS
• ROADS
• TRUCK TRANSPORTATION AVAIL.
• TACTICAL TROOP MOVEMENTS
• BARRIERS
• FIRE SUPPORT COORDINATION LINE
• CHEMICAL CONTAMINATION
• AREA DAMAGE CONTROL
• EFFECTS OF ENEMY NUCLEAR STRIKES
• NUCLEAR FIRE SUPPORT

CHART 5

Information is put into and received from each RSDT by eight User Input/Output Devices (UIOD) located with the users of the system. The UIOD, connected to the RSDT by a 300 foot cable, consists of two desk-type devices -- a typewriter station which will be used mainly for receipt of messages, and an entry and display station used for input of messages. The user will usually be located within the tactical operations centers at army, corps and division level. One of the objectives of the experimental TOS is to determine the optimum locations of the UIOD's within the tactical operations center.

In operation, essential information is entered onto the screen of the video display (UIOD), where it is visually verified and then transmitted to the RSDT. These computers forward the information to the higher level CCC where the information updates the master data base. The information can then be retrieved by any user of the system at any echelon.

One important manner of data retrieval in the system is the Standing Request for Information (SRI). The user prestates his requirements for information, and when that type of information is received, the CCC automatically forwards it to the user.

Now, where does human factors technology fit into the development of computer based command and control systems? The Computer Systems Command, as a systems developer, is a consumer, rather than a developer of human factors technology. Human factors specialists participate in a dual role in our system development process. In the first role, they seek to maximize the usefulness of the massive amount of information which is potentially available from an ADP system. To begin with, information requirements must be determined and explicitly stated in language understood by both computer technicians and operational users. Since we have great difficulty in getting the user to say what he wants, it may be that we have been asking the users the wrong question. Instead of asking what information is wanted, perhaps we should ask "What is your job? -- What do you do?" Then we, the information experts, could provide the information needed. Thus, instead of simply using the computer for data retrieval for manual decision making, we might be able to produce much of the solution, leaving only the truly exceptional for human decision. Achievement of this advance will require the participation of the human factors community.

Closely related to information requirements are system performance objectives. As with any other type of system, we must be able to make performance measurements of an automated system in terms of operational parameters as well as technical parameters. I'm reminded of the airline reservation system that almost failed because it wasn't trusted. The confirmation of a request for a seat came back to the clerk so fast that they wouldn't trust it without a few repeats, which quickly produced a system overload. It was probably a human factors man that solved the problem by programming a 19 second delay into every reply.

Human factors technology is already being applied to some of these specific problems. BESRL lived with TOS on-site in Europe for 2-1/2 years of its stay there. On-site participation on a daily basis provided human factors in-

fluence in both hardware and software design. However, because of the operational environment in Europe, the TOS effort was necessarily observation and design analysis rather than research and experimentation. In order to bridge this gap, BESRL developed a CONUS facility for system simulation. During the BESRL session this afternoon, Mr. James Baker will describe some of the specific results of his efforts on TOS in Europe. And then Mr. Richard Krumm will describe some of the on-going simulation work.

The second human factors role is to seek to reduce the maintenance and operational burdens of these complex systems on the military personnel who must use them in the adverse environment of a tactical situation. So it involves the care and feeding of a computer in the tactical environment. The TACFIRE system attacks the problem through its design. First echelon hardware troubleshooting uses automatic fault isolation at the modular level, and direct replacement of the faulty module. Most failures are repairable in minutes by the operational personnel. This, when combined with high system reliability, minimizes the basic hardware maintenance problem. On Thursday, Dr. Hertzka of Litton Industries will describe the extensive involvement of human factors specialists in the design of TACFIRE.

In summary, we at the Computer Systems Command have recognized the importance of introducing a human factors influence early in the development cycle. We intend to keep it there throughout the cycle. We appreciate your support in the past and will seek it for the future.

CHAPTER 2
FROM DATA TO DECISION: HUMAN FACTORS AND INTERFACES IN COMMAND DECISIONS

Chairman: Robert S. Andrews
U.S. Army Behavior and Systems Research Laboratory
Arlington, Virginia 22209

2A. ACORNS IN FLOWERPOTS/PSYCHOLOGISTS IN THE FIELD

James D. Baker
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INTRODUCTION

Typically, human factors research in military systems is concerned with determining the effects of different variables operating upon a system on the speed and accuracy of human's processing information within that system. For example, input load may be varied while a man retrieves data from some analog of a storage point in the system (as in display research), or processes data (e.g., in transform studies), or inputs data (e.g., in keyboard studies). Meanwhile, the human factors researcher is measuring how long it took the man to do this and how many errors he made in the process. The results of the study are documented and the findings are sent to actual and potential users so that these findings can be related, in some philosophic or logical way, toward satisfying needs of that individual or organization. The degree of success in implementing research findings this way is a moot point.

Mackie (1) suggests that the linkage between laboratory research in human behavior and applied research and development is weak and proposes a reason why. In his words:

"The scarcest quantity in the United States at the present time are professionals who operate at the interface between research and applications. The university system, preoccupied as it is with intrinsically motivated basic research, is not yet producing the kind of hybrid individual required for these kinds of engineering tasks. Only continued pressure from Government and industry for applications from psychological research is likely to change this situation. The 'translator' or 'learning engineer', or whatever we may choose to call him, requires training both as an expert observer of real-world problems and as an experimental psychologist. He must understand two worlds at once--a technical subject matter area related to some equipment development--and the methodology and technical language of the basic researcher, but he must be capable of recognizing its implications and limitations."

Can one, in actuality, achieve this ideal state proposed by Mackie? We at the Behavior and Systems Research Laboratory (BESRL) think the answer is yes. In fact, the BESRL COMMAND SYSTEMS program achieved something approaching this ideal state. The purpose of this paper is to sketch in broadly how this was accomplished, to describe some of the resultant products, and to touch upon the successes and failures encountered.

BRIEF DESCRIPTION OF THE SETTING

The COMMAND SYSTEMS Program of BESRL is concerned with improving the effectiveness of command information processing systems through the most efficient use of human abilities. In studies conducted under the Work Unit, specific aspects of information processing systems are examined with respect to requirements for the handling and presentation of information to human users of the system. These studies seek to improve the quality, speed, and completeness of information processing, information assimilation, and decision making.

Coincidental with BESRL research interests, the Computer Systems Command, Headquarters U.S. Army Europe and Seventh Army, initiated plans for the design verification of an automated tactical operations system (TOS) planned for incorporation in the Automatic Data Systems within the Army in the Field (ADSAF). This program was aimed at verifying the efficacy of the design of a field system conceptually representative of the operations and intelligence aspects of the ADSAF master plan. To design and test such a system, the TOS Development Group was formed and assigned the task of developing a field version of the TOS for ADSAF.

To provide for the melding of effort to support both BESRL research and human performance evaluation in the TOS (2), BESRL established a Command Systems Field Branch in September 1967 which was collocated with the TOS Development Group. The Field Branch remained in Europe throughout the life-span of the Seventh Army version of the TOS Development. The Field Branch was headed by myself, with Douglas J. Mace and Dr. James M. McKendry, both of HRB-Singer, Inc., comprising the remaining scientific members of the team. Four basic Field Branch activities, or tasks, were established: First, make inputs to the system development decisions and approaches through application of expertise in human performance. Second, review and contribute to test plans and other evaluative efforts from the aspect of human performance capabilities. Third, field validate major BESRL laboratory research findings and results in an operational setting. Fourth, develop in the operational setting research questions which could be used to update and further orient the laboratory research toward field problems in command and control.

DESCRIPTION OF TOS

To insure that we are all operating from the same "data base," it may be beneficial at this point to describe the particular TOS configuration within which this research was conducted.[1] The Seventh Army Tactical Operations System (TOS) was an automated, secure information processing system designed to assist military commanders and their staffs

[1] A large portion of what follows in this section was taken from briefing materials prepared by the TOS Development Group for orientation training of Seventh Army users.

at Field Army, Corps, and Division levels in the conduct of tactical operations. The TOS provided a central repository of information into which remote users could enter data, update the data as required, have the data processed, and, as an end result, be provided with up-to-date dynamic information which could be used by commanders concerned as a basis for tactical decisions.

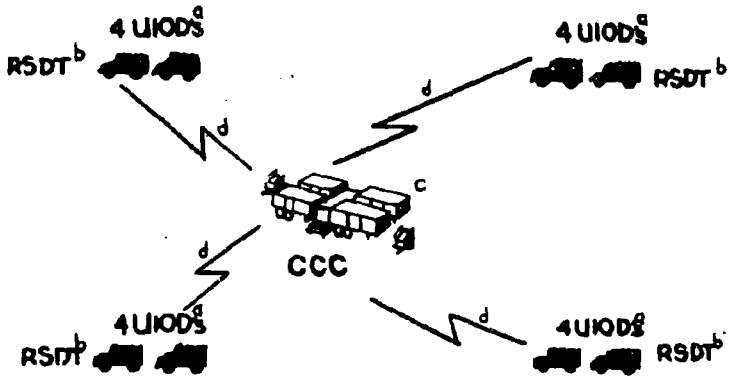
The Seventh Army TOS was geared to handle five functional areas -- friendly unit; enemy situation; nuclear fire support; effects of enemy nuclear strikes, and enemy order of battle. The friendly unit area provided basic information concerning significant changes in organization, disposition, activities and status of combat and combat support units of an Army in the field. The enemy situation area provided basic information pertaining to the identification, description, location, activities and capabilities of the enemy force. The nuclear fire support area was concerned with the cycle of nuclear fire support activities from the receipt of a target nomination through the consolidation of post strike results and required nuclear fire scenarios. The effects of enemy nuclear strikes area provided basic information concerning the potential and actual effects of enemy nuclear burst. The enemy order of battle area consisted of evaluated information regarding composition, deployment, strength, training, tactics, logistics, and combat effectiveness with respect to enemy military forces.

In this setting there were three basic types of data processing equipment: User Input/Output Devices (UIOD), Remote Station Data Terminals (RSDT), and a Central Computing Center (CCC). The general configuration for the TOS and a brief description of the equipment functions is presented in Figure 1. The Seventh Army units it serviced are shown in Figure 2. The major point of focus for our effort was on the actual user interface, the UIOD, with somewhat less attention given to the controller interfaces at the RSDTs and CCC.

The users communicated with the system via the UIOD which consisted of a desktop display unit and a typewriter printer. The display unit, with its keyboard and TV-like screen, were used primarily to compose and transmit messages, whereas the typewriter was used for printing messages and other data coming from the computer. Input messages first were composed on selected message worksheets, and then were transcribed via the input keyboard, to similarly selected formats which were displayed on the display unit screen. The message input into the device was displayed on the screen; verified for correctness, and then entered into the system by means of a "send" key on the keyboard. Output messages to the user were routed to the UIOD and printed automatically on the typewriter.

TOS users were concerned principally with two types of messages: operational messages and relay messages. Operational messages were used for entering and retrieving tactical information from the TOS data base. The operational messages constitutes the major portion of the TOS data volume. Relay messages were free-text messages generated by one user for transmission to one or more other users and this type of message did not affect the data base.

Operational messages consisted of four basic types: data messages, query messages, special process requests, and standing requests for



a. The User Input/Output Device (UIOD) is the device which enables a number of remotely located military users to communicate with the system and to interchange information with each other.
b. The Remote Station Data Terminal (RSDT) is an intermediate message processor/transmitter between the UIODs and a central computing facility. The RSDT, which includes a computer, computer peripheral equipment and secure communication equipment is contained in shelters mounted on two 2-1/2-ton trucks. Each RSDT will service one major unit at Field Army, Corps, or Division level.
c. The Central Computing Center (CCC) stores the TOS data base, processes all incoming messages transmitted by the RSDTs, performs TOS computations and transmits output messages to the RSDTs. One 40-foot van and three 35-foot vans house the CCC, which includes the computer, computer peripheral equipment, secure communications equipment and power distribution.
d. TOS utilizes existing Seventh Army tactical communications.

Figure 1. Configuration for first increment of transportable hardware for the Seventh Army TOS

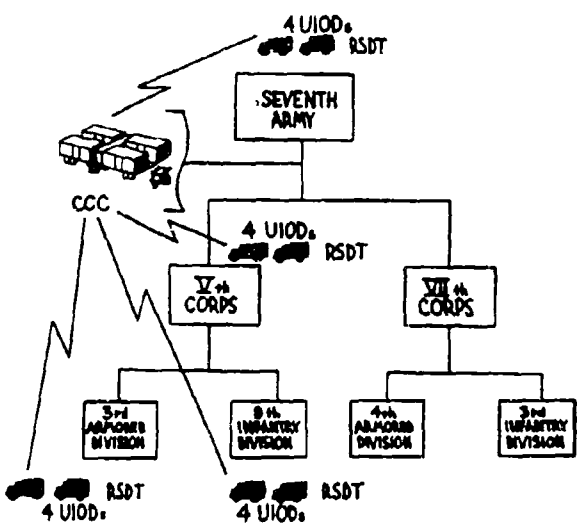


Figure 2. Designated Seventh Army users for the first increment of transportable TOS hardware

information. Data messages allowed the user to enter data into the system, and to add, change or delete information already stored in the data base. Query messages initialized a search of the data base to supply the specific information requested. The user could request certain special calculations or summarization of a particular type of information in the data base by submitting a special process request (SPR). The standing request for information (SRI) message permitted the user to establish the capability for automatic dissemination of selected TOS output data to his UIOD station and/or to other designated stations, e.g., the G2 could establish an SRI which would automatically output data concerning enemy armor whenever such data were input by other users of the system.

This, in essence, was the on-line, near real-time automated data processing system, TOS, which served as the vehicle for the human factors research which subsequently will be described.

THE RESEARCH FRAMEWORK

Given an organizational setting within which to conduct field research, and given a developmental system to serve as a research vehicle, one more ingredient was required before we could successfully bridge the gap between the real-world, and the laboratory, namely, a common research paradigm. As noted earlier, while a portion of our activities were directed toward direct support of on-the-spot evaluation of human performance in a TOS setting, part of the team's effort also was focused toward the enrichment of the BESRL in-house program by introducing operationally oriented concepts and approaches to research problems while, simultaneously, attempting to apply BESRL's laboratory findings in an operational setting. A common research paradigm would insure that even with an ocean separating us, all of the people involved in the COMMAND SYSTEMS work unit would be operating within the same framework and that we would all be communicating about the same thing.

In laying out the COMMAND SYSTEMS research program (3), it was speculated that at least five critical human performance areas requiring experimental attention would accompany the advent of the TOS. To quote from the program documentation (p. 2):

> "An automated TOS will receive vast amounts of information of many and varied sources. The information will vary widely in content, form, and degree of completeness... The raw data will require a great deal of handling and processing by man and equipment...Looking at the system as a whole, there appear to be five critical operations that man and equipment will have to perform: Screen incoming data for pertinence, credibility, impact, priority, and routine; Transform the raw data for input storage devices; Input the transformed data into storage devices for subsequent computation and display; Assimilate data displayed, and Decide on courses of action based on information displayed and information from other sources."

The flow of these operations is diagrammed in Figure 3 and this framework served as the common referent for the COMMAND SYSTEM's work which was being done in BESRL's laboratory in Washington, D. C., as well as our own efforts in Europe.

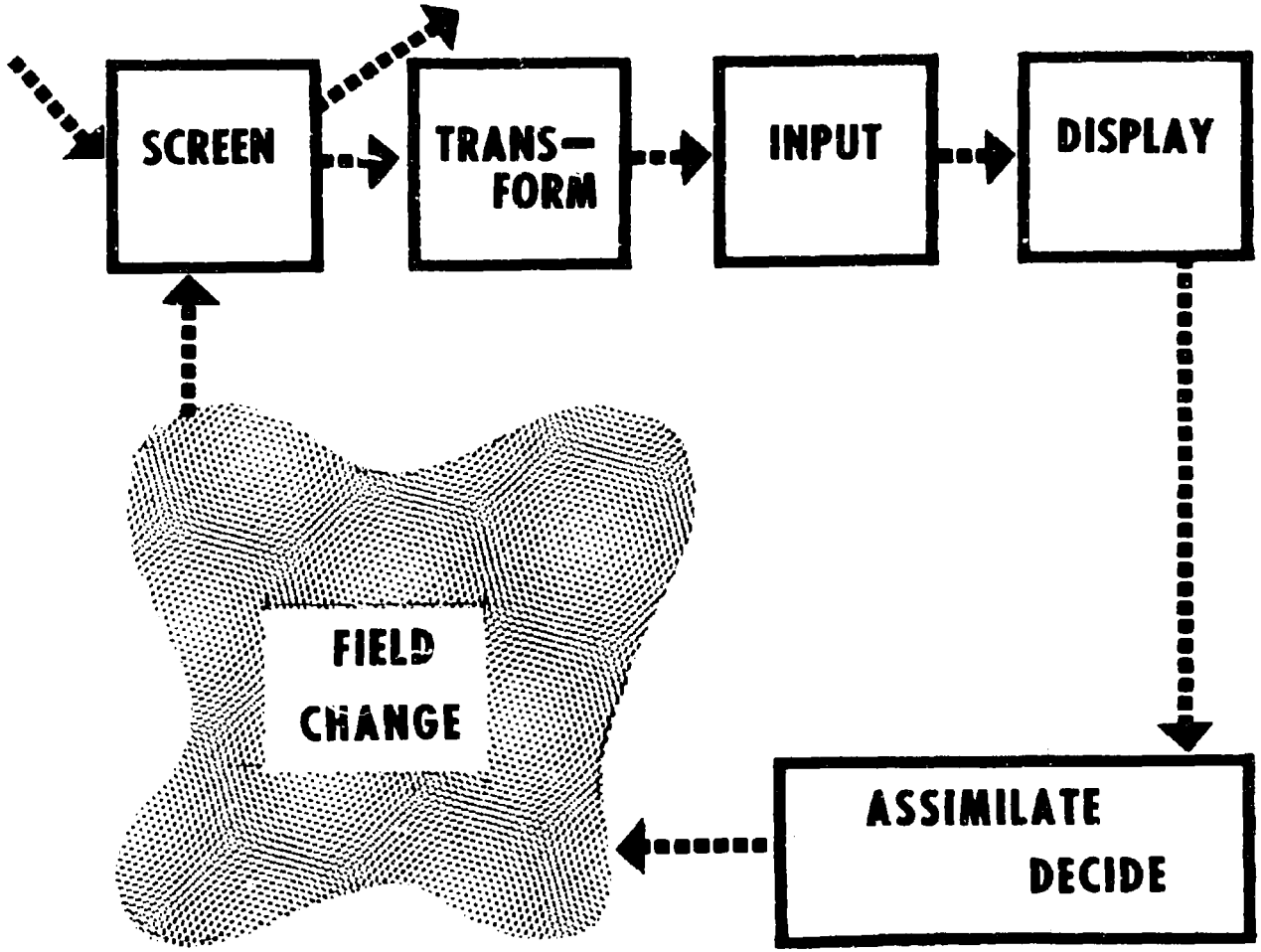


Figure 3. Schematic representation of operations and information flow in an automated TOS *(Taken from Ringel, S. Command information processing systems--A human factors research program. BESRL Technical Research Report 1148. June 1966.)*

It will now serve as the background for the following descriptions of representative studies conducted in the operational environment.

SOME REPRESENTATIVE STUDIES

In an automated information system such as TOS large numbers of messages of varied content and from diverse sources are received. These incoming messages must first be screened for system relevance. Irrelevant information must not be allowed to enter the system. But the problem of screening was given limited attention by us in the field setting. One reason for bypassing this problem area was that field exercise observations did not yield good information about screening. The scenarios used in most command post and field training exercises employ only relevant messages. Ambiguous data, purposefully deceiving data, and data without historical continuity are rarely included. The rationale given is that the training problem in field exercises is difficult enough without adding this confusion factor. There are other reasons, not to be delineated here, for directing our efforts in the field away from this area, but all things considered it appeared to us that research addressed to the screening problem could better be conducted in a laboratory setting.

The process of transforming information for input into TOS, required taking typically unconstrained free-English text that characterizes a manual system message and converting it to equivalent symbolic notation, entered in specific format fields (particular alpha-numeric character locations) for the particular class of information in the computer's data base that was to be acted upon. All information contained in the TOS data base had to be entered and retrieved via formats. If the appropriate format and/or entries were not selected, the information would usually be rejected by the system, thereby introducing delays in updating the data base. In some instances, however, the information could be introduced into the system using an inappropriate format; in which case the information was to all intents and purposes irretrievable since it would not be in the correct data base location.

In contrast to the screening problem area, the transform problem area proved to be a ripe candidate for research in the field setting. For example, in one study (4), a job-aid was developed in an attempt to assist action officers who had to decide which format was appropriate for each incoming message. Fourteen subjects processed 47 messages. The main concern was the method of format selection: half the subjects used the job-aid while the other half used a "menu" type listing of available formats. The job-aid developed was ineffective in improving the accuracy of format selection. The more important finding, however, was that incorrect formats were selected 22% of the time, with and without the aid. Thus, the transform operation represented a definite bottleneck in the system; during periods of heavy message traffic information could queue for a considerable length of of time before being entered into the system. Further research was undertaken, and is continuing, to develop effective ways to reduce human error in the transform area, since the transform process is essentially a new experience for TOC personnel and problems associated with the process will arise every time we introduce automatic data processing techniques into what are now manual operations.

Once the information was recorded on the appropriate format, it was entered into the TOS. The input device, as noted earlier, was a display unit with a keyboard and TV-like screen. The input keyboard, cathode ray tube (CRT) display and the typewriter output that constituted this station were "given" in the Seventh Army TOS and, therefore, not amenable to modification for field experimentation. We did find, however, that insufficient planning had been done in the initial system design with regard to optimizing the man-machine interface workspace layout. For example, when the UIOD's were delivered they came in sturdy, metal packing cases for use in transporting them in a field environment. In very short order the rumbles began to trickle-in from the people who were operating this equipment. If one tried to use them on an "as is" basis (Figure 4), the results were disastrous. Employing available props hardly solved the problem, e.g., in Figure 5 we see a valiant attempt to ACK (i.e., acknowledge receipt of) an incoming message on the typewriter using the UIOD in one of the initial configurations. In keeping with our previously mentioned charter to "make inputs to the system development decisions and approaches through application of expertise in human performance," we prepared a detailed technical memorandum (5) which delineated relevant human factors principles, translated these principles into well defined recommendations for on-the-spot implementation, and submitted our recommendations to the developer of the system. Further interaction between ourselves and several "midnight requisition experts" from the TOS Development Group resulted in the alternative interface configurations depicted in Figure 6. It was not the ultimate solution to the problem, but even this "quick and dirty" solution represented a considerable improvement in the existing state of affairs.

In the Seventh Army TOS, the principal computer-driven equipment employed was the CRT with keyboard input and typewriter output. No computer generated displays of the vector drawing or big-board, group shared variety were employed. The reasons for not undertaking the task of providing such a display capability in the early stages of fielding a TOS have been adequately presented elsewhere (6), but our observations in the field (7) suggest that the largest amount of human information processing time in a field army operation is spent continuously updating the situation map displays within a tactical operations center (TOC). In the hope of alleviating the situation, a study was undertaken--commensurate with our charter to "field validate some of the major laboratory research findings and results in an operational setting"--to examine the implications of the COMMAND SYSTEMS in-house research for displays in an actual, tactical information processing setting.

Some of the early BESRL in-house display and information assimilation research had been undertaken with the realization that the then current and planned automated devices transmitted mainly alpha-numeric information. Therefore, the question was asked: To what extent would information assimilation be degraded by the translation of map symbols and other information to alpha-numeric equivalents? If the degradation was negligible, then much of the information displayed symbolically on maps could be handled alpha-numerically by the computer. The results from two different studies (8), (9) indicated no difference in decision perform-

Figure 4. User Input/Output Device (UIOD) set up using the packing containers to structure the workspace layout. The "work surface" was so low in this configuration that the seated operator could not read the critical, operator field (format designator) which was displayed in the upper left hand corner of the CRT.

Figure 5. Attempt to type ACK on output device. Side-by-side arrangement was within tolerable horizontal reach limits, but the keyboard surface was so high in this configuration that most of the characters on the keys could not be read when the operator was in a normal, seated position.

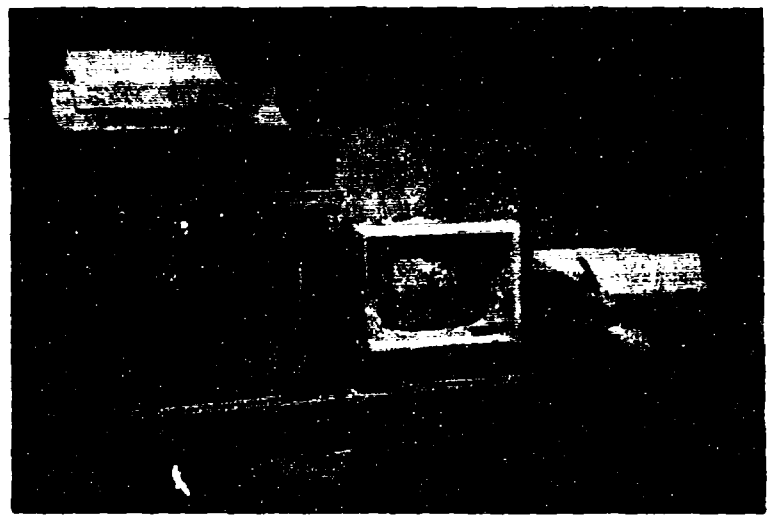


Figure 6. Interim solution to User Input/Output Device (UIOD) workspace layout. This picture shows two possible configurations. On the left is a stacked configuration. Stacking was considered for space-saving reasons. ACK could be located next to the CRT keyboard. On the right is a side-by-side layout. The latter configuration was the one generally chosen by the user.

ance between alpha-numeric and graphic presentation of data. These results suggested that much of the information being posted manually on maps in symbolic form could be stored in the computer, making possible the automatic updating of enemy and friendly unit identification and locations. A study was undertaken, therefore, to determine if the implications from the in-house research were valid in an actual tactical information processing setting (10). One of the conclusions drawn from that study was that the potential of TOTE-type displays[2] for facilitating information display and assimilation appeared substantial, especially since TOTES could be generated by the existing automatic data processing systems immediately, while awaiting the appearance of computer generated big-board displays. It was suggested that proper use of such TOTES could reduce reliance on situation maps and save the time of staff officers who prepare summary reports.

[2]The term TOTE, as used here, originated in the early design days of computer-based command and control systems. At that time, it was realized that basically two types of computer-generated displays were evolving: 1) the graphic vector-drawn display of the situation map variety, and 2) the tabular alphanumeric display. The latter was called a TOTE because it resembled the tote board at race tracks on which number and amount of bets and other data are displayed. In a command and control context, a TOTE shows the totals, averages, and/or summaries of measurements in the form of tables.

The decision process, like the screening process, is difficult to study in an operational setting. The human factors researcher is rarely in a position to specify completely all of the conditions for experimentation in a field exercise. Further, a field exercise is usually serving some other function while the experimentation is taking place. For example, an exercise quite often is a dual-knowledge/training evaluation at the same time that it is being used as a vehicle for system evaluation. Consequently, the commander and his staff are reticent about having a research team intrude into what Krumm (11) calls the "private experience of decision making." Hence, we concluded very early that much of command and staff level decision-making behavior is better studied in something like BESRL's simulated tactical operations system (SIMTOS)--which, incidentally also happens to be a less threatening, non-OER related setting (12), (13).

This is not to say that we did not conduct research in the field setting which dealt with the decision process. A series of studies was undertaken which was concerned with discovering how decision making ability could be enhanced or aided by tools available within the decision environment (14). Attention was devoted to devloping aids for the evaluation of G2 spot reports.

The standard NATO schema used in the Seventh Army requires that each spot report contain two complex ratings, an accuracy rating on a six-point numeric scale and a reliability rating on a six-point alphabetic scale. Our first research effort was concentrated on job-aids. Two job-aids were developed, one following the Field Manual text, the other incorporating suggestions from the faculty at the G2 Intelli-

gence School located in Oberammergau, Germany. The job-aids were variants of a decision process flow chart consisting of a series of yes-no questions leading to the appropriate evaluations. When the results of job-aided groups were compared with results of control groups using no job-aids, no differences were found either in speed or accuracy of evaluations. This finding, coupled with conversation with school faculty and data from student questionnaires, led to the following conclusion: A job-aid is not the solution to the G2's evaluation problems; he does not have time for such a rating schema even when the necessary decision process is flow charted for him.

However, the above conclusion does not imply that an underlying evaluation process does not operate. A second study[3] demonstrated a definite utility of spot reports. Intelligence school students were asked to select from among 16 spot reports the most important set of four messages, followed by the second and third sets of four. The results yielded significant agreement among students. If students do rank order spot reports according to a perceived utility but do not have time to use a job-aid, perhaps the evaluation process could be improved by changing the rating schema itself. Consequently, research is now under way in the laboratory to determine the extent to which G2 personnel can assign subjective probabilities to the reliability of source and accuracy of a report and whether these probabilities correlate with the six-point scales currently used. If this approach is successful, we will have made some progress toward the goal (3, p.20) of structuring the computer as an aid to the user in information assimilation and decision making, since a number of models currently exist for efficiently manipulating subjective probabilities. These models could then be embedded in the computer and called up as tools when needed.

The studies described so far by no means exhaust the effort undertaken in the field to support each of the functional areas in our research paradigm, but, rather, these particular studies are presented as being representative of the sort of thing that a human factors researcher can do in the field. It should be commented also that some of our efforts cannot be as neatly pidgeonholed in our research framework as those just noted. Such efforts encompassed more than one, or in some cases all, of these functional areas. For example, our initial efforts to develop an appropriate human factors test and evaluation plan for TOS design verification testing (15) eventually culminated in the development of a general model for quantifying human performance in various types of information systems (16)--a concept which encompasses all of the human performance functional areas just discussed.

SPECIFIC EXAMPLE OF HUMAN FACTORS IMPACT ON THE TOTAL SYSTEM

I would like now to take one human factors problem we encountered in the field and discuss it in detail. This study will serve to illustrate how apparently subtle human factors problems can have considerable impact on total system performance.

In order to prepare the Seventh Army users for their part in the

[3]The reports from which these findings were culled, are in the final stages of preparation for publication.

TOS design verification field test, a vehicle for familiarizing and training the user was needed. The solution for fulfilling this need was logical and straightforward: collect the messages and the scenario from a prior Seventh Army field exercise and re-run it as an in-garrison training exercise using the TOS equipment. To this end, sufficient materials were extracted from a prior field army exercise to provide a training session which could be run twenty-four hours a day for approximately five days. A master incident list was prepared which included the typical entry time/date groups for inserting required messages into the exercise. This particular master incident list differed from the usual list of this type in one respect--associated with each of the messages were recommended message formats for inserting this data into the TOS. This latter segment of the master incident list was prepared for each of the TOS functional areas by TOS Development Group subject matter experts.

When the user training exercise (UTREX) was undertaken, there were the usual bugs and snafus to iron out. But even discounting the delays encountered from the expected hardware and software bugs, the realization began to dawn on those involved[4] in the exercise that the system was not keeping up with the load. Granted, the Seventh Army TOS was not intended to operate as a truly real-time system;[5] however, it had been assumed all along that it would be capable of running in a near real-time capacity.

Why was the system lagging behind? The TOS, even at that stage of its development, was considered capable of handling up to 60 messages an hour. The TOS master incident list had been modified from the original field exercise list to insure balanced play among all participants. But, while so doing, care also was taken to insure that the message insertion rate did not exceed the system's capacity to handle them. Still, the system could not keep up with the load. What was going on?

The answer was rooted in the fact that, in keeping with the current trend in information systems, the TOS designers went out of their way to allow the user to communicate with the computer on-line and to influence system operations. Presently, the only way this can be done efficiently is to develop a rigidly defined user/computer language. As Nickerson (18) has noted: "No one has yet succeeded in developing a translator program that will accept as input a program written in 'human language' if that term is taken to mean the language of every day speech." Therefore, such user/computer languages are, and within the current state-of-the-art must be, most precise. They are intolerant of errors. Errors, even if slight, usually result in the com-

[4]The author would like to take this opportunity to acknowledge the role played in this study by COL Frank Romano. COL Romano was, at that time, the UTREX Test Director (now Chief, Command Systems Support Division, Headquarters, U.S. Army Europe). He first became aware of the acuteness of this problem; tasked our human factors group to delineate it, and then provided the data and help necessary to resolve it.

[5]Real-time normally is defined as the period during which it is possible to influence or control a physical operation. Real time operation is a procedure in which information obtained from a physical process is processed to influ- or control the physical process.

puter's rejecting a message. Taking this situation into account requires defining the human factors realities likely to be encountered in the various organizational and operational environments and then limiting design complexity accordingly. According to Ely (17)"....such a process...(was)...intuitively applied, for example, in designing the developmental TOS in Seventh Army to favor pre-formatted reports and queries by user input-output stations. It...(had)...been presumed in this case that to plan the use of complex procedures needed for a more sophisticated approach would not be realistic."

The answer to why the system was lagging behind was simply this: the collaborative team of system and scenario developers assumed a one-to-one correlation between the messages to be handled and the messages to be fed into the computer. In reality, this situation did not obtain. It took more messages to communicate man-to-machine than it did to communicate man-to-man in the original exercise.

Let me show you the data that led to this realization. In Figure 7 you see graphed the TOS format messages suggested as the "school solution" by the TOS Development Group subject matter experts. A simple "eyeball fit" of these data suggests that the rate will be higher than the then system limit of 60 messages per hour. These data can be dealt with in a slightly different, and I think more meaningful way, by graphing them as a cumulative function (Figure 8). That is, if the system can handle 60 messages the first hour, then 60 more the second, etc.--the points plotted at each hour will be 60, 120, 180, etc. cumulatively. Likewise, if the system is really processing 40 the first hour, 65 the second and 50 the third--the plot points would be 40, 105, and 155, respectively. This has been done in Figure 8 for 48 hours of actual UTREX data and it immediately becomes evident why the system was lagging behind during the conduct of the training exercise.

When this situation was realized, the initial reaction was that the most expeditious way to overcome this problem would be to "stretch real time" by some factor. That is, stretch each hour of scenario play, by modifying the time/date group insertion times, to where an hour of scenario time was actually being played in 1 hour and 15 minutes blocks (a factor of .25). Figure 9 shows this stretch factor would bring the UTREX "school solution" TOS format input rate into line with the load handling limit. Theoretically the exercise should have been able to run in near real time. In actuality, this did not prove out, because of another human factors oversight.

In Figure 10, you see graphed that segment of the UTREX exercise (designated UTREX B) which was actually run in "stretched time." Besides showing that the exercise was terminated after 25 hours--because of some technical problems in stretching time in the data base, in addition to which this approach tended to bore the user--the data shown in Figure 10 explain why the attempt to solve the system lag problem this way was not successful. In the lower right hand corner of Figure 10 you see that the actual user queried the system about 3% more than the school solution called for; likewise the actual users communicated with each other through the relay message feature about 4% more often than the subject matter experts thought they would. The net result was about 6% (rounding error differences) higher message traffic,

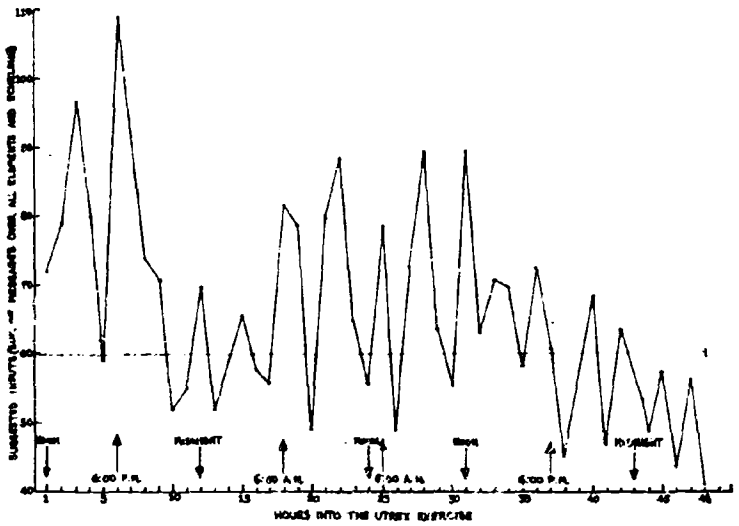


Figure 7. Fluctuations in the formatted "school solution" for 48 hours of the UTREX exercise

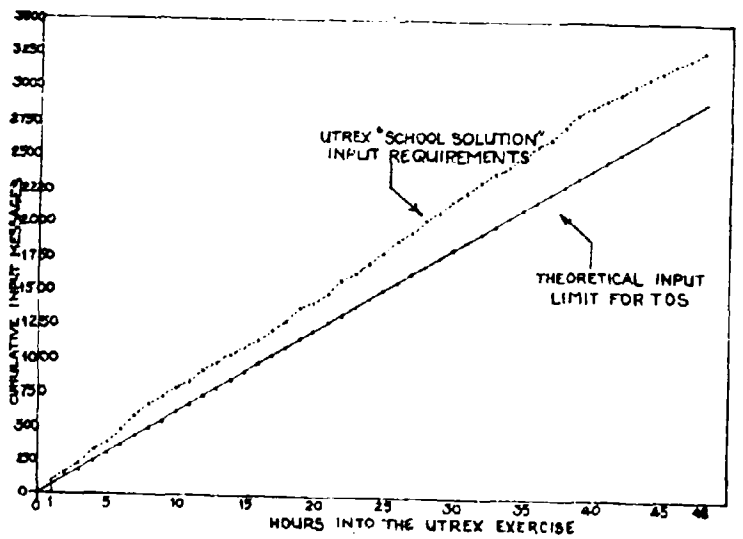


Figure 8. Cumulative inputs, both theoretical limit and the UTREX "school solution," for the first 48 hours of the UTREX exercise

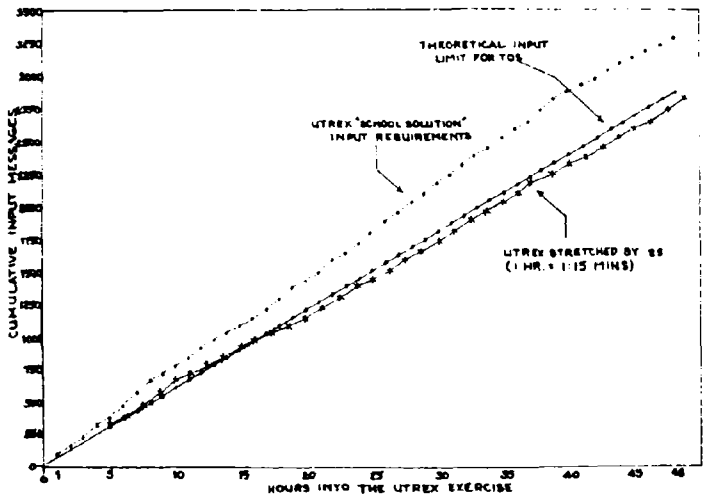


Figure 9. Stretch factor which, theoretically, would bring the UTREX "school solution" into line with the TOS load handling limit.

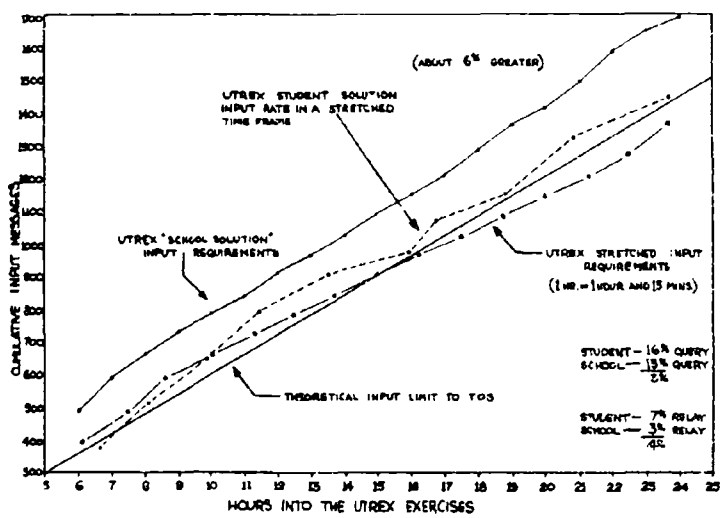


Figure 10. Shows the theoretical limit for TOS inputs; the "school solution" inputs in stretched time (where 1 hour equals 1 hour and 15 minutes of actual run) and the actual cumulative inputs of the users during 25 hours of stretched run.

even in stretched time, which once again pushed the load above the system handling capacity. Thus, the reason stretched time did not succeed was because it failed to take into account a second facet of human behavior--the users' curiosity about, and his tendency to use, new tools.

What was required, then, was some way of determining what the expected load of TOS format messages would be for a scenario constituted of normal, free-English text messages. As a result of extensive analyses, not to be discussed here, we managed to develop a weighting scale (Figure 11) which met the need. For example, Figure 11 shows that if your scenario calls for four pure English messages to be handled by the G-3, then you know that it will take ten message formats for the G-3 to communicate this to the machine. Interestingly enough, the CBRE traffic was found to be on a one-to-one basis. Given that you have derived the true number of messages to be handled, you must still increase this message volume by some factor (5-6%) to account for the users' utilization of the tools (e.g., query capability) which you have provided him. To provide closure for this salty tale, when the scenario was screened and culled accordingly--plus some over the shoulder caveats to the various users using the tools only when you need to--the exercise (UTREX C) ran according to expectations.

There are several morals to be drawn from this experience. Nickerson (18), for example, points out that a key problem in any computer-based information system is that of determining how the data base should be organized within the computer. He notes that with some types of organization it is quite possible for the organizational data to require more storage than the operational data. If one has significantly underestimated the quantity of operational data to be handled by failing to take into account the human factors associated with the man-machine communication, and the software approach has been one of emphasizing the organizational data, the system can soon become swamped. The resolution of such a problem may necessitate acquiring more hardware to store the additional data, or it may take the form of radical renovation of the initial software to take into account this unanticipated operating environment. Add to this the failure to consider seriously the fact that humans will use tools when they are provided and the result is likely to be a system that is choked-up anyway because all of the designer's "whistles-and-bells" are being used at the same time.

Therefore, it behooves the system developer to get help as early as possible by, for example, having human factors people provide specific input for system design and technical advice concerning the Qualitative Material Requirements (QMR) and the Functional System Design Requirements (FSDR). Human factors help should be sought on a continuing basis throughout the research-development-production-distribution gamut. Otherwise, the system developer should not be at all surprised when the system is placed in the hands of the users and the damned thing doesn't work the way he thought it would.

PROS AND CONS

The effort I have just described is without precedent, for no U.S. Field Army has ever had a computerized command and control system plunked down in its midst and then been run out into the field with it. That is, no field army until the

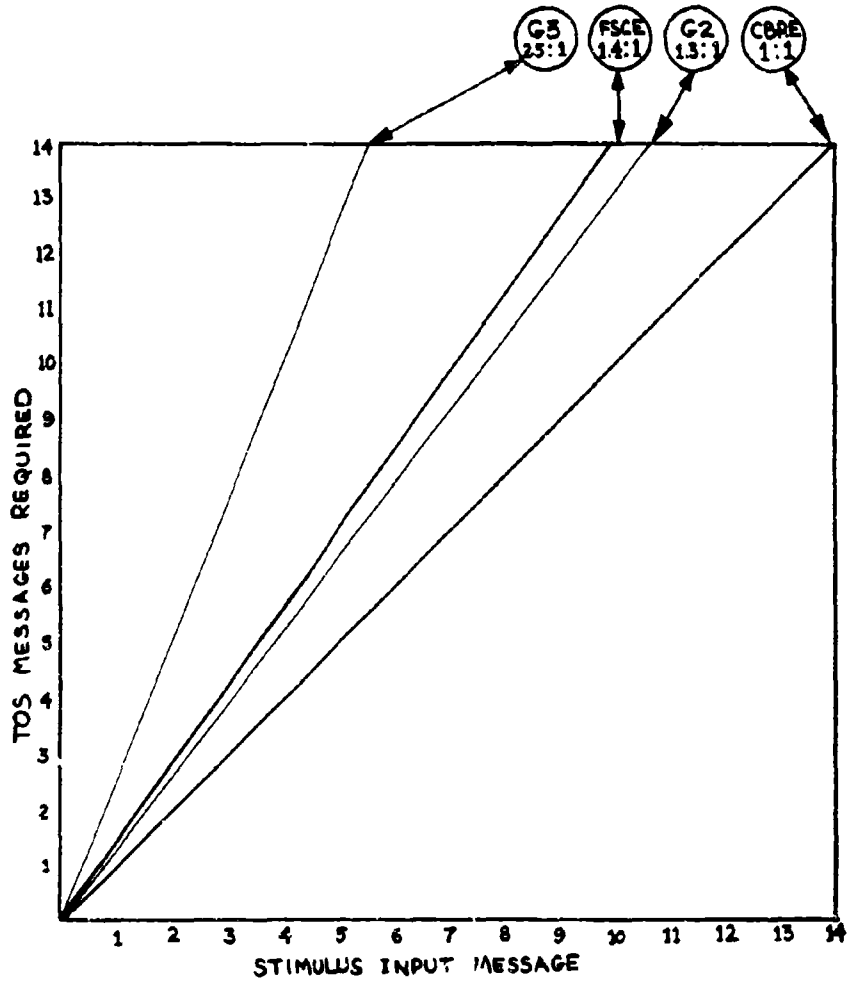


Figure 11. Weighting scale for the number of TOS formatted messages required to accommodate the free-text English messages used in the manual system.

Seventh Army TOS made its appearance. It follows, then, that the U.S. Army has never had psychologists in the field during the evolutionary development of a computerized command and control system until we came onto the scene. What lessons can be learned from our unique experience, then, that may be of value for future developments, such as IBCS?

In thinking about pros and cons of this endeavor many things come tumbling to mind, but they are such a hodgepodge of personal experiences and general principles that they need some sorting out. For example, the temptation exists to mention the real feeling of satisfaction that comes from sitting around in sweaty fatigues translating findings into recommendations to the user and finding out that not only does he understand what you are talking about--but also that he heartily indorses them! One also could dwell on the seemingly shortsightedness and stubborness of some individuals or groups which proved to be frustrating as hell at the time. But the latter is nothing new to any of us, and the former is more of a personal experience than a general principle. However, some insights did evolve that may benefit future endeavors of this sort.

Among the advantages to this approach is that it bridges the gap between the user and the laboratory in several ways that would please Mackie.[6] The user can directly express and delineate the problems that he thinks are critical in his day to day operations. The user also knows that the researcher to whom he is presenting these problems understands his operations and can interpret his notions meaningfully into a research program. Likewise, the user can have the benefits of laboratory findings directly translated into comprehensive inputs for his daily activities when he has on board a research oriented human factors person, who also understands his operations. The user also benefits by having in his midst a trained professional, with a different perspective, who can see things from a vantage point which is not colored by "doing things this way, because we always did things this way." The human factors researcher is not encumbered by operating tradition,and, additionally, has the skills and methods for "quick and dirty" testing of alternatives for immediate fixes to intolerable situations. The workspace layout problem previously described is an example of such an instance.

But the "quick and dirty" approach has the potential to blossom into a disadvantage. One disadvantage is that the psychologist working in the field is often required to stretch standard scientific methodology to encompass the problems as he finds them. He may be unable to define independent or dependent variables, while holding all others constant, as he would have done in the laboratory. Consequently, his results, while adequate for that special purpose, have only limited power of generalization. Unfortunately, this is not recognized by many people and you hear the statement that long range research is "behind the power curve." To this I can only say--nonsense! The second disadvantage arising from this situation, is that the danger exists that an adequate ex post facto solution to one problem may be used as an ad hoc requirement for other, similar system problems. The previously described pre-formatted approach to user/system communication is a case in point. Another disadvantage is that the psychologist in the field is constantly caught in the crunch of management trying to

[6]See the quote by Mackie in the introduction to this paper.

seize him and use him as just one more helping hand to do quick and dirty studies. If this does occur, the very people he is intended to help may then be deprived of the full value of his professional capabilities.

The pros and cons cited do not, by any means, exhaust the possibilities inherent in having a human factors team directly involved in system development in the field. They are presented as being representative of the sort of tradeoffs one must consider in taking this approach. But one strong warning must be stated concerning this approach: it will never replace long range research, nor was it ever intended that way! The two, on the spot assistance and longer range laboratory research, are not mutually exclusive but, rather, mutually enhancing. No number of one-shot, methodologically weak studies will ever replace the predictive power of the findings resulting from an integrated, well controlled long range research program.

AND NOW A WORD ABOUT ACORNS

The presentation is coming to an end and still no light has been shed on why this paper was entitled: "Acorns in flower pots/Psychologists in the field." The psychologists in the field aspect of the title has been discussed at length, but what of acorns? Flower pots? I must admit that the title reflects a notion propounded by one of my favorite authors--Oliver Wendel Holmes (19). He summarized his lack of blind faith in things working themselves out over time without any effort on man's part with the statement: "I don't believe in planting oaks in flower pots!"

I am not proposing that the field unit is necessarily the ultimate or only solution to the problem of bridging the gap between psychological research and human factors applications. But while awaiting a better solution, I cannot blindly trust that the system designer or system user will effectively implement human factors findings without some cooperative effort on my part. Since it is impossible to bring giant systems and their concomitant problems directly into the laboratory (oaks in flower pots), I propose for the time being, that the best approach is one of bringing realistic samples of problems from the field into the laboratory. There they can germinate into fresh and meaningful solutions (acorns in flower pots) which eventually can be replanted in the operational setting by psychologists in the field.

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2B. HUMAN DECISION-MAKING BEHAVIOR AS A PREDICTOR OF DECISION QUALITY

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INTRODUCTION

The ultimate purpose of any information system is, of course, to improve the quality of decisions made by the system users. Since management information systems are now proliferating at a rapid rate, we might all confidently assume that managerial wisdom will enjoy a corresponding growth. This is a shaky assumption, however, based upon the equally shaky premise that if a little information is good then a lot of information must necessarily be better.

Fortunately, for all of us perhaps, there are skeptics. Some potential customers are becoming interested in evaluating the effectiveness of proposed systems prior to installing them on a large scale. Inevitably these evaluations of system effectiveness will have to include an appraisal of whether human decision making behavior has in fact been improved.

To date there have been relatively few field evaluations of information systems. Those which have been conducted have assessed system performance largely in terms of message volume, message throughput time, and such system efficiency measures as information accuracy and completeness. The question of the degree to which changes in these make any real difference in terms of user decisions has received scant attention. This is so primarily because of the enormous difficulties involved in conducting controlled studies in a field environment. Some of these difficulties have been discussed today by the previous speaker, Mr. Baker.

In addition to the difficulties imposed by a field environment I believe there are other reasons that study of the impact of information systems upon decision making behavior has been largely ignored. For non-trivial situations, (i.e., "real life" problems) the decision process can be enormously complex. More importantly, it is a private experience.

It is complex in that it may involve dozens of identifiable steps. These

include recognizing that a problem exists, identifying the nature of the problem, considering whether action is required, alternative actions which are possible, feasibility of alternatives, etc.

It is a private experience in that an observer has no way of conveniently determining, for example, whether a decision maker is considering particular alternatives, or whether the presence or absence of certain data is even noticed by the decision maker.

In recognition of the difficulties involved in controlling field studies of information system effectiveness, the U. S. Army Behavior and Systems Research Laboratory (BESRL) has instituted a series of laboratory studies of human decision making behavior. These studies include a simulated military information system. Interestingly, although the simulated information system was intended to provide the independent variables for decision making experiments, it developed that the system also afforded opportunities for insights into the complex and private decision process itself.

I should like today to acquaint you with one part of the research which has thus far been conducted. Specifically, we have been able to observe four behavioral aspects of the decision process which related significantly to decision quality. With some modification, three of these behavioral aspects held up under replication despite substantial changes in the test procedure.

BACKGROUND

The two studies I should like to discuss today were conducted at the BESRL Information Systems Laboratory, which includes a CDC-3300 computer system with six input/output data channels. Connected to the six input/output channels are a card reader, a punch unit, a high-speed printer, three disk pack units, two magnetic tape units, six cathode ray tube (CRT) CDC-211 display devices, and sixteen IBM-1050 terminal stations.

Each test subject cubicle was equipped with one CRT display device and keyboard, wall map displays, and a telephone to communicate with the experimenter. The entire test scenario was stored on one disk pack.

For each study, the subjects consisted of twenty colonels and lieutenant colonels, all of whom had combat experience: three reported combat experience during World War II, ten in Korea, and eighteen in Viet-Nam. The majority had served in mechanized infantry units, had held staff positions in tactical operations centers, and were graduates of the U. S. Command and General Staff College (CGSC).

The task assigned to each subject was to deploy a mechanized infantry division to defend an assigned sector in the event of an attack by an initial force of two motorized infantry divisions. The friendly unit was shown in assembly areas

(hostilities had not yet commenced). The subject was to indicate enemy avenues of approach into the division sector, to identify key terrain features and to recommend a form of defense. He then allocated maneuver elements to the general outpost line, forward defense area, and reserve and recommended a form of resistance to be offered by each echelon. He was then requested to sketch on a situation map overlay his recommended location of the general outpost, combat outpost coordination point, brigade boundaries, forward defense area battalion positions, reserve force location, visualized allowable penetrations, and blocking positions. Finally, he was requested to write out his recommended task organization and to write mission statements to subordinate units.

In solving the above problem the subject required access to information concerning friendly and enemy unit task organizations, dispositions, activities, and status, as well as information concerning weather, terrain, and civil affairs. During the first study the subject obtained information by telephoning the experimenter who then searched the index of the scenario data base, retrieved the requested information from the computer, and transferred the retrieved data to the CRT in the subject's cubicle. This resulted in a number of inefficiencies. Consequently, during the second study the test subject accessed the data base directly. A split screen technique was used. The upper ten lines of the CRT were used to display data and/or indexes of subordinate data categories which the subject could then access if he so desired. The lower ten lines of the CRT were used to have the subject instruct the computer to provide additional information or to return to an earlier display.

When the subject completed his task organization and his mission statements, he notified the experimenter and the test was terminated. Subjects varied substantially in terms of time to complete the exercise. One required less than two hours and some required four or more. There was a significant negative correlation between test time and test score on the first study. On the second study the correlation was also negative but did not reach statistical significance at the .05 level.

The subjects responses were scored in terms of standards established by CGSC. The present scenario was based upon a lesson plan in use at CGSC. Since the lesson had been meticulously developed over a several year period by combat experienced military instructors we felt that objective scoring standards could be developed which would have a high probable degree of validity. Internal consistency estimates of test reliability were satisfactorily high. Application of the Kuder-Richardson KR-21 formula gave a value of .91.

It was hypothesized that the total score a subject received on a decision making test would be a function of four major variables: his experience, his ability, the amount of information he possessed which was relevant to the problem, and

the pattern of behavior he exhibited in arriving at a problem solution. It is this last variable, the decision process pattern, which is the central topic of this paper. Consequently, I shall only mention briefly the nature of the other predictors.

The Experience Score

A subject's "experience" score was an arithmetic mean of three component scores, each of which was converted to a standard score based on the unit normal curve: (1) a score related to the date that the subject attended the U. S. Army Command and General Staff College at Fort Leavenworth, (2) the amount of experience the subject had in mechanized infantry units, (3) the number of field exercises he had participated in. The product moment correlation of this composite score with the criterion was .49.

The Ability Score

Two scores comprised this variable. The first represented the subject's class standing at graduation from CGSC, expressed as a percentage score based on the number of students in his class. The second "score" was an overall final grade which had been assigned by CGSC regarding the subject's ability to express himself. The two sets of scores were normalized and averaged to derive the composite score of "ability". The composite correlated .53 with the criterion measure.

Fact Possessed Score

Calculation of the "Facts" score was based upon discrepancies between obtained and predicted scores on the criterion measure. A multiple regression equation had been developed which combined the Experience Score, the Ability Score, and a Decision Process Pattern Score (to be explained below). This equation was used to predict the criterion test score each subject could be expected to obtain on the basis of his three predictor scores. It was then hypothesized that subjects who achieved scores substantially higher than predicted may have accessed different information in the data base than was accessed by subjects who scored substantially lower than their predicted score. It was found that there were indeed many data elements which differentiated these two extreme groups. Consequently, the entire subject sample was scored in terms of the number of such "significant" facts each subject had accessed. This Fact score correlated .56 with the criterion. There is, of course, some circularity in this procedure since a substantial portion of the sample comprised the groups which were used to develop the scoring technique.

DECISION PROCESS PATTERN

This score was a composite of four normalized pattern scores: request dyad sequence, data request runs, request slope, and terminal pause. Each of these is defined below.

Request Dyad Sequence

The following procedure was used to identify and to score the request dyad sequence pattern. The

subjects' requests for information which had been transcribed by the observer during the test were assigned a code number in terms of the following eleven categories:

1. Friendly Unit Task Organization

   Request concerning:
   Attachment, support, and operational control

2. Friendly Unit Tactical Dispositions

   Requests concerning:
   Front line trace
   Command post locations
   Center of mass
   Unit boundaries
   Reserve locations
   Objective locations
   Supporting troop locations

3. Friendly Unit Operational Activities

   Requests concerning:
   Current activities
   Planned activities
   Summary of activities

4. Friendly Unit Status Information

   Requests concerning:
   Strength
   Casualties
   Morale
   Combat effectiveness
   Critical supply items

5. Weather

   Requests concerning:
   Visibility
   Precipitation

6. Terrain

   Requests concerning:
   Cover and concealment
   Fields of fire
   Roads and nets and status
   Soil trafficability
   River fordability
   Presence of bridges and their status

7. Enemy Unit Task Organization*

8. Enemy Unit Tactical Disposition*

9. Enemy Unit Operational Activities*

10. Enemy Unit Status Information*

11. Miscellaneous (primarily civil affairs)

Each subject's requests were organized along a time base (in five-minute time blocks) so that a string of numerical codes represented the sequence and nature of each subject's requests for information. Each successive set of two numbers was then studied. A tabulation was made of the frequency with which each numerically coded request category followed another. In other words, each set of two successive numbers (dyads) was studied to determine whether a particular request category was more likely to be followed by one request category than by another. Such a relationship was, in fact, discovered. An 11 x 11 matrix of successive cate-

*These categories have the same contents as those noted above for Friendly Units.

gory tabulations (with the first number of a dyad entered on the rows and the second term indicated in the appropriate column(yielded a contingency coefficient of .73, and a Chi-square value beyond the .001 level of probability. Examination of the cell contingencies in the matrix indicated that the entries in the diagonal were largely responsible for the discovered relationship. Many subjects, having accessed, for example, the "terrain" category would ask additional questions in that category before turning to a different topic. Thus, the derived score for sequence for each test subject became simply the number of his dyads whose category numbers were identical, divided by his total number of dyads. This measure correlated .53 with the criterion.

Data Request Runs

The score for data request runs was developed using the same definition that is used for the nonparametric statistic called "Wald-Wolfowitz Runs Test". The numerical codes indicating each subject's request category had been entered in their appropriate five-minute time blocks. One or more requests in a time block signified that the time block was "filled". One or more consecutive filled blocks is defined as a "run". Similarly, one or more consecutive unfilled blocks is a "run". A subject's score was the total number of such runs prior to the time block in which he stated his final decision. "Desirable" scores were found to be the lower scores on the first study; therefore, the number of runs was subtracted from a constant prior to normalizing. Correlation with the criterion was .49.

Request Slope

The analyses of the subjects' timing in requesting data included calculating their cumulative percentage of requests as a function of time. A monotonic relationship was found between this variable and total decision quality test score. The top quartile had made 80 percent of their requests in the first 75 minutes of the problem. Mean times for successive quartiles to reach the 80 percent point were 115, 125, and 142 minutes, respectively, for quartiles two, three, and four. Similarly, the 90 percent point was reached by the four quartile groups after 120, 150, 165, and 200 minutes, respectively. Consequently, we endeavored to develop a measurement technique which would reflect this tendency for "effective" decision makers to build their information base early in the problem solving period. Several methods were tried and they all worked about equally well. The simplest and most direct is to score the subjects in terms of the percentage of their total requests which were made in the first thirty minutes after they started. The subjects who scored high on the criterion measure tended to build their data base quite rapidly and this initial percentage of total requests reflected this tendency quite well. Correlation of this measure with the criterion was .44.

Terminal Pause

The "terminal pause" score is the

number of minutes which elapsed from the time of the subject's final request for data and the time he submitted his decision. This measure ranged from less than one minute to 150 minutes, with a mean value of 40 minutes. "Desirable" scores were believed to be the brief times; therefore, the scores were subtracted from a constant. This score, as was the case with each of the foregoing, was normalized prior to conducting subsequent analyses. A correlation of .23 was obtained between this measure and the criterion.

REPLICATION

It is important at this time to draw attention to the change in experimental procedure which was introduced in the second study. During the initial study, it will be recalled, the subject obtained information by telephoning the experimenter. The manner in which he organized his requests related significantly to the criterion measure. In the second study, indexes of the data base contents were available to the subjects and the indexes were organized in terms of subject matter categories. Consequently, there was much less skipping around among categories, and the Request Sequence score reflected this change. On the second study the correlation between the Request Sequence score and the criterion was essentially zero. Consequently, it was not included in subsequent analyses. However, we did explore for possible effects of the changed procedures upon this score. Inspection of the work patterns of the subjects indicated that it was possible to identify two "methods". One identifiable group of subjects progressed uniformly through each category of frames on most of the major indexes. The others appeared to be much more "selective", accessing a few specific frames and not in the order in which they were listed on the index. For this latter group (which represented half the test subjects) the Request Sequence score correlated with the criterion at approximately the same value as during the first study. This finding confirmed our suspicion that presentation of the indexes affected the subjects' data accession patterns.

The Request Slope score correlated .40 with the second study criterion, as contrasted with .44 on the first study. The Terminal Pause score yielded a .29 correlation with the second study criterion, contrasted with .23 for the first study. The Request Runs score, however, was also apparently influenced by the change in procedure. During the second study the subjects averaged 300 data requests per man, whereas the mean number of data requests was well below 100 during the first study. During the second study there was a significant tendency for subjects scoring high on the criterion measure to space their requests, rather than clumping them as in the first study.

As on the first study, the above scores were converted to standard scores, were averaged, and were correlated with the criterion measure. The mean of the Request Slope and Terminal Pause scores correlated .53 with the criterion, a value which is significant at the

.05 level. If we are permitted to include the Request Runs score in the DPP composite, the correlation becomes .60. When the Facts Possessed score is combined in a multiple prediction equation with the Decision Process Pattern score a correlation of .73 results. Addition of the Experience and Ability scores could be expected to raise the multiple correlation to a value close to that of the earlier study but, since these scores are not presently available, this can only be regarded as conjecture at this time.

DISCUSSION

There are one or two features of this research which appear to merit some emphasis. The first concerns the central point of the paper that one's approach to problem solution is predictive of the quality of the solution.

In the first study, four patterns of behavior were identified which when expressed as a composite score, yielded a substantial correlation with the criterion measure. The four scores comprising the DPP composite score had extremely low intercorrelations yet they seem to suggest that they are measuring a common characteristic. It would appear that what they may be measuring is the degree to which a subject systematically develops a data base necessary to solve a problem. "Systematic" thought processes may be reflected by sequences of related questions (high Sequence Score), which are developed relatively quickly (high Slope Score), which are asked in groups of questions as contrasted with questions distributed throughout the test period (low Runs Score), and which lead to a decision relatively soon after the data base is developed (low Terminal Pause Score).

Two of the DPP scores continued to relate significantly when the study was repeated using changed procedures for accessing the data bank. One score (the Runs Score) reversed its direction apparently because the subjects who scored low on the criterion measure had a tendency to access very large numbers of frames. This necessarily reduced the elapsed time between accessions and, therefore, lowered the number of Request Runs for these subjects. At the present time, the Runs score may tentatively be accepted (pending later verification) as a potentially useful predictor of decision quality. Interpretation of the score is contingent upon whether a subject interacts directly with a computerized data bank or places his data requests through an intermediary.

The failure of the Request Sequence score to hold up in the second study does not necessarily invalidate the score for use in other decision tests which are similar in procedure to the first study. Evidence is available that the cueing in the second study (by displaying indexes which influenced subsequent questions) removed scoring differences which would otherwise have pertained. This would seem to merit further attention.

The differences in test procedure for the two studies illustrate other interesting aspects with respect to

influences upon individuals' work patterns. In the second study, fourteen subjects were tested in groups of two or three, and six were tested individually. When subjects were tested simultaneously the average deviation of test time was exactly half the average deviation of the subjects tested individually. Mean test times were nearly identical. Even though the subjects tested simultaneously were working in separate cubicles there was an apparent mutual influence upon the time they required to arrive at their final decision point. Since some of the DPP scores are sensitive to work pace it would appear logical to assume that the scores would, therefore, be affected by whether individual or simultaneous test procedures were used.

The behavior patterns identified in these studies are not the only patterns potentially available. The value of the second study was that it confirmed that behavior patterns during decision making could be reliably identified and would be related to criterion measures of performance. Additional exploration would now seem to be indicated to identify additional behavioral patterns and to refine further those measures which appear to have merit In this iterative manner we may be able to gain a clearer understanding of the "complex and private" nature of human problem solving.

If the DPP score actually does measure a systematic, orderly, logical way of acquiring knowledge relevant to problem solution, and if it is consistently found to relate to decision quality, the factor has implications beyond the scope of the present study. BESRL's research interests include effects on decision making performance of such independent variables as work load, conflict, information presentation mode, work methods, and system configuration. The subjects' decision process patterns would appear to have some influence upon each of these variables. Therefore, a better understanding of such patterns and their influence upon these variables should lead to a better understanding of the effects of the independent variables upon decision making performance.

Additionally, it may be possible to develop procedural guidelines relevant to efficient problem solving behavior. Such guidelines might deal with hypothesis formulation, data gathering, and maintaining a manageable and organized data base. A beneficial effect of such problem solving procedures might well be improved problem solving in personal and business areas. One does not have to be a division commander to benefit from an orderly approach to problem solving.

2C. DATA INPUT AND MODIFICATION

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ABSTRACT

This report presents a view of the data entry process; reviews some of the operator actions, encoding mechanisms, input devices, and operator functions and tasks in manual data input and data base modification; and presents the results of selected human factors studies of operator performance in data input tasks.

INTRODUCTION

The fuel of computer-based systems is data. But data are elusive, and must be fed into a computer or its data base before they are useful. Occasionally, some of the data in the base must be added to, modified or deleted.

The purposes of this report are to (a) present a view of the data entry process, (b) review some of the operator actions, encoding mechanisms, input devices, operator functions and tasks in manual data input and data base modification, and (c) present the results of selected human factors studies of operator performance in data input tasks. The report emphasizes human operator considerations in using equipment and performing tasks. It does not deal with device descriptions since these change frequently, and at the time this is being written, a new device is introduced nearly every day.

Data Entry

Figure 1 presents major routes that data can follow from their point of origin to the computer and data base. Physical events occur which create raw or source data. The events can be recorded by: (a) direct measurement in real-time by analog instruments, conversion to digital form, and automatic entry into the data system, (b) direct capture on some form of media, with automatic or human operator conversion into appropriate digital code, or (c) capture by a human operator, who either directly encodes the data, or puts them in a form that another human operator can work from in performing the encoding process. Some of the operator actions and types of devices utilized for the recording and input tasks are shown in Figure 1.

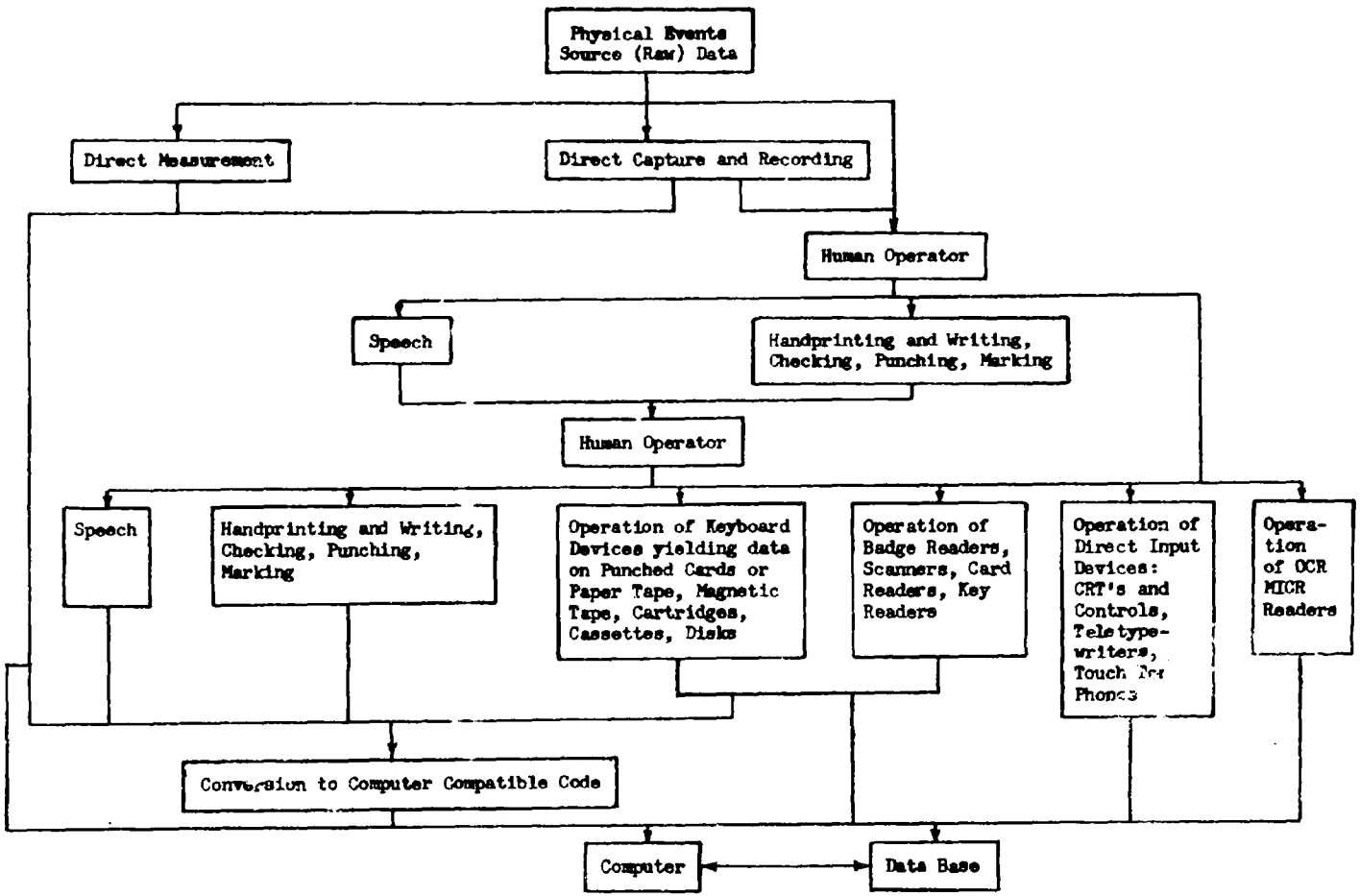

Figure 1. Alternative Routes From Source Data To Computer and Data Base.

The entire process for providing computers and data bases with data has been defined as data entry by Stender (1). He identifies eight functions which may characterize data entry:

(a) Capture or recording of human- or nonhuman-sensible data at their source of origin.
(b) Transmission of these data to data conversion equipment.
(c) Conversion of data to machine-sensible form.
(d) Transmission of the converted data to some intermediate memory media.
(e) Recording of the machine-sensible data on the intermediate media.
(f) Data and communications error checking, and data verification and validation to insure that valid data are ready for preprocessing.
(g) Preprocessing, which includes editing, reformatting, merging, sorting, collating and further field, batch, hash and applications error checking.
(h) Transfer of these preprocessed data to intermediate memory.

The term data input is a subset of data entry; it describes putting data into a computer-readable form, and recording them on some form of intermediate memory (1). This report is primarily concerned with the data input part of the data entry process. The reason is that the other activities are less dependent on direct human operator participation.

Data Modification

Occasionally, some of the data stored in intermediate memory, in computer memory, or in the data base must be modified, added to, or deleted. This process can be defined as data modification.

There are at least two possible approaches to accomplish the data modification process. One technique involves preparation of a complete new record which is substituted for the original record. Another approach is to retrieve the old record, add to, delete from, or modify it as required, and re-enter the revised material. The major routes that data can follow during the modification process are the same as the ones followed during data input (Figure 1). A major difference is that data modification may involve retrieval of and work with a record from the data base or from some point in the data entry procedure. More will be said about data modification in a later section of this report.

MANUAL DATA INPUT

Manual data input consists of a human operator obtaining data from the original source, or as recorded, and operating one or several encoding mechanisms which transform the operator actions into signals capable of being accepted by an appropriate input device. The input device records the data on some form of intermediate memory. The input device, or that to which it is connected, may or may not perform checks on the data encoded by the operator, and may or may not require re-entries when errors are detected. The capability to detect errors, and to require operator correction before a data input job is complete, is system-dependent.

Table 1 presents possible operator actions and associated encoding mechanisms. To date, keyboards operated by finger movements have encoded the majority of data found in data bases. Other approaches are becoming more significant as advances in technology make alternative techniques more economical.

The "Eye Movement" and "Thinking" entries in Table 1 are included for completeness; practical encoding mechanisms are not now, and will not be available for many years.

Table 2 presents most of the major types of input devices available or under development at the present time. One or several of the encoding mechanisms shown in Table 1 either are an integral part of each input device listed in Table 2, or produce media which can be read by one of the input devices.

Operator Functions

The functions required of an operator are determined by the respective system. Major functions may include media insertion or data transcription, verification, validation and formatting.

Media insertion is a major human operator activity associated with optical character recognition (OCR) and magnetic ink character recognition (MICR) systems. Operators take the coded items from a storage area, container, or wherever, and insert them into the reading mechanism. In some systems it is necessary for an operator to use a keyboard to enter non-machine-readable data.

Data transcription is the initial encoding of data into machine-readable form. It may involve encoding of both alphanumeric and graphic data. Major tasks associated with transcription may include manual keying; operation of switches, knobs, dials and levers; movement of hand-held scanners over coded surfaces; handprinting and writing, checking, punching and marking; operation of light pens, joysticks, trackballs, etc.; and speaking. Data transcription may result in media which require insertion in an appropriate media reader.

In some systems it is necessary to check that the data have been correctly entered. This function can be defined as verification. Systems relying on manual keyboard transcription sometimes require an operator to rekey part or all of the original data. Comparison is performed between the original and the rekeyed data, and corrections made. Non-keyboard systems have their own unique techniques for verification, if such checking is required.

Data validation involves checking the encoded information to determine if the data in each of the fields are valid according to some set of rules. In many systems this checking is performed by the machine element at the time the data are transcribed, or as part of an edit run on a computer. Check digits, range-checking of numeric fields, and checking that characters are within a well-defined subset of acceptable characters for a field are examples of validation procedures. Detected errors may be brought to the attention of an operator for immediate or later manual correction. Some systems may require some form of manual validation.

OPERATOR ACTIONS	ENCODING MECHANISMS	
Finger Movement	Keyboards Block Alpha Typewriter Chord Ten-Key Numeric Matrix Numeric Preset Function Overlay Function	Switches Rotary Slide Lever Toggle Rocker Thumbwheel Pushbutton
Hand Movement	Knobs and Dials Push-Pull Pointer Wheel Crank Two-Dimensional Pantograph Stylus Tablet Light Pen and Gun Joystick (Track Stick) Trackball (Rolling Ball) Mouse Touch Display	Direct Handprinting Handwriting Check Marks Hand Punching Marking Stylus Punching Scanners Movable Fixed
Other Body Movements	Switches Pedals Levers	
Speech	Voice Recognition	
Eye Movement	Eye Position Monitoring	
Thinking	Neurological Sensing	

Table 1. Operator Actions and Related Encoding Mechanisms.

Data Recording Devices
- Keypunch
- Paper Tape Punch
- Keyboard-to-Tape
- Keyboard-to-Cartridge
- Keyboard-to-Cassette
- Keyboard-to-Disk

Direct Input Devices
- Cathode Ray Tube and Associated Controls
- Teletypewriter
- Touch-Tone Telephone

Optical Character Recognition
- Multifont Reader
  - Handprint and Writing Reader
  - Printed Font Reader
- Stylized Font Reader
- Bar Code Reader

Magnetic Ink Character Recognition

Source Data Collection Devices: On-Line or Recording on Tape, Cartridge or Cassette
- Badge Reader
- Scanner, Mark Sense, and Card Reader
  - Punched Holes Reader
  - Magnetic Encoding Reader
  - Optical Encoding Reader
- Encoded Key Reader

Voice Recognition Devices

Table 2. Input Devices

Data often have to be ordered in certain ways, fields sometimes have to be zero-filled or skipped, and records sometimes have to be rearranged and merged before computer processing or data base entry. This process is called data formatting. The human operator may be involved in this function and/or the formatting may be accomplished during an edit run on a computer.

Operator Tasks

Each of the major functions consists of many operator tasks, the nature of which are dependent on equipment characteristics, nature and form of the data, and manipulation and storage requirements for the data. It is not possible in this report to consider the wide range of tasks associated with data input. For illustrative purposes, however, one example of some of the major tasks required of an operator in utilizing a keypunch to perform data transcription are presented in Table 3. Each of the entries shown in the table could be further analyzed, e.g., the "Insertion of Program Cards" task consists of (a) removal of the program drum, (b) removal of the previous program card from the drum, (c) insertion of the new program card onto the drum, and (d) insertion of the drum into the keypunch.

Operator Performance

Many investigations have shown that design features and operating characteristics of encoding mechanisms and input devices can significantly influence operator performance. A large number of these studies have been described and summarized in reports by Pollock and Gildner (2), Devoe, Eisenstadt and Brown (3), and Alden, Daniels and Kanarick (4). It is not necessary to review the literature since the referenced documents are comprehensive. Rather, results are presented of several studies which have not appeared in the general literature.

Keypunch Studies. The keypunch has probably encoded more data for entry into computers and data bases than any other input device. Certain characteristics of most keypunches, however, prevent skilled operators from operating at maximum input rates. The keypunch inhibits punching during card feeding and releasing, duplicating, and skipping. Keypunch replacements, such as keyboard-to-tape units, perform the operations mentioned in significantly less time, thus freeing the keyboard for data entry. Error correction on the keypunch involves release of the punched card, duplicate to the error, and rekey the mistake. Error correction on a keyboard-to-tape unit simply involves depressing a backspace key and then the correct key. Cards used with a keypunch can contain only 80 characters of data. Records consisting of more than 80 characters must utilize more than one card, with the attendant delays associated with card feed and release. Most of the keypunch replacements provide capability for significantly larger records.

The National Cash Register Co. (NCR) Human Factors group conducted a limited comparison of operator performance between a keypunch and a keyboard-cathode ray tube (CRT) device which simulated a keyboard-to-disk or on-line system (5). The task of the operator was to transcribe alphanumeric data from Form 1040 income tax returns. The results showed the keyboard-CRT device required

Preparation of Program Cards

Insertion of Program Cards

Insertion of Cards into the Hopper

Removal of Cards from the Stacker

Replacement of Ribbons on Printing Models

Transcription

- Keying of alpha and/or numeric data from the source document
- Duplication and skipping
- Error correction
- Manual card insertion and removal

Table 3. Representative Operator Tasks Associated With Keypunching.

20.1 percent less time to encode a return than the keypunch. It was found under the conditions of this comparison that 17.3 percent additional characters had to be keyed with the keypunch. This was due to the limit of 80 characters per punched card; fields larger than 80 characters required a second card, which required document identification characters. A record was kept of the number of cards redone because of operator detected error. The results show a card spoilage rate of about 6 percent. In one test, about 3.8 percent of the total time to transcribe the returns was attributable to correction of erroneous cards.

The NCR Human Factors group also compared keypunching performance with two different device configurations (6). One configuration (called "non-buffered") would not accept a key depression unless more than about 90 milliseconds (ms.) had elapsed since a previous depression. The minimum inter-key interval was less than 30 ms. with the other configuration (called "buffered").

The task of each subject was to key alpha and numeric material as rapidly and accurately as possible with each of the keypunch configurations. The results showed: (a) a significant 14 percent increase in average keying rate of alpha material by the most proficient operator with the buffered device; less proficient operators showed little or no difference between the two configurations, (b) no difference in keying rate between the buffered and non-buffered keypunches with entry of numerics, and (c) no difference in error rates between the two devices.

Typical distributions of digram times (times between two successive keystrokes) for the most proficient operator keying alpha material and numeric material are presented in Figures 2 and 3, respectively. It can be seen in Figure 2 that the operator was able to establish a faster keying rhythm with the buffered keypunch. She apparently encountered the keyboard lockout with the non-buffered device, and therefore established a pace slow enough to avoid the lockout. Entry of numeric data was by one hand, and no operator was able to develop a fast enough rhythm to encounter the lockout with the non-buffered configuration (Figure 3). The less proficient operators, when keying alpha material, did not develop a keying rate fast enough to encounter the lockout. Figure 4 shows typical digram results for such a subject.

Scanners. Hand-held scanners capable of sensing data located on various types of media have been developed in recent years. These devices are held in one hand, and either passed across the data field to obtain the read, or positioned directly above the data and held stationary during the read. Such devices provide a very attractive alternative to keyboard encoding in situations where a significant (e.g., more than three) number of digits must be entered, and the source data can be provided in machine-readable form.

Several scanners have been announced and others are known to be under development. NCR, for example, has developed a hand-held pencil-like sensing device capable of reading coded bars. The NCR Human Factors group has conducted a number of experiments with this device.

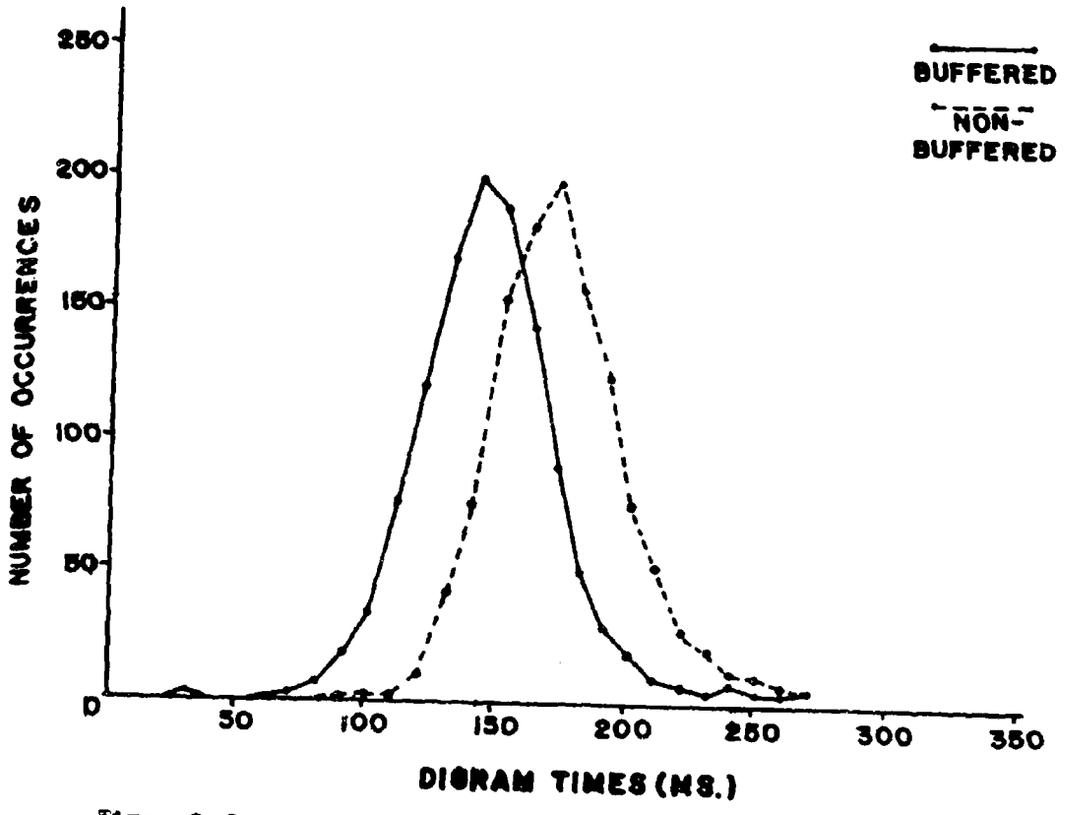

Figure 2. Distribution of Digram Times with Alpha Material for a Proficient Subject.

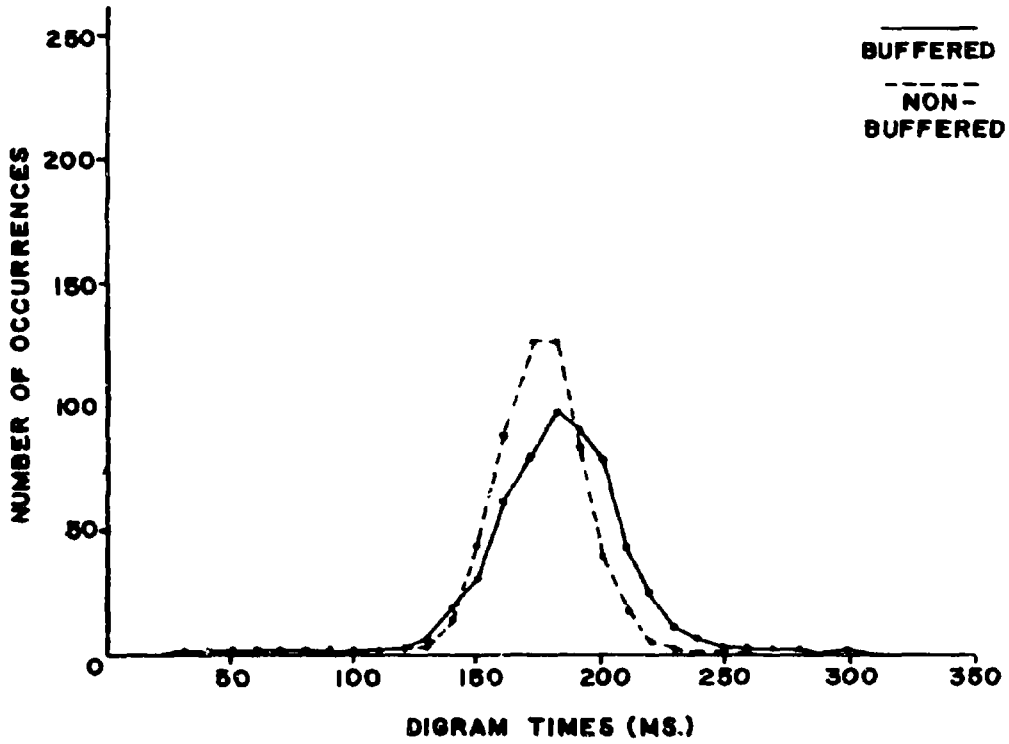

Figure 3. Distribution of Digram Times with Numeric Material for a Proficient Subject.

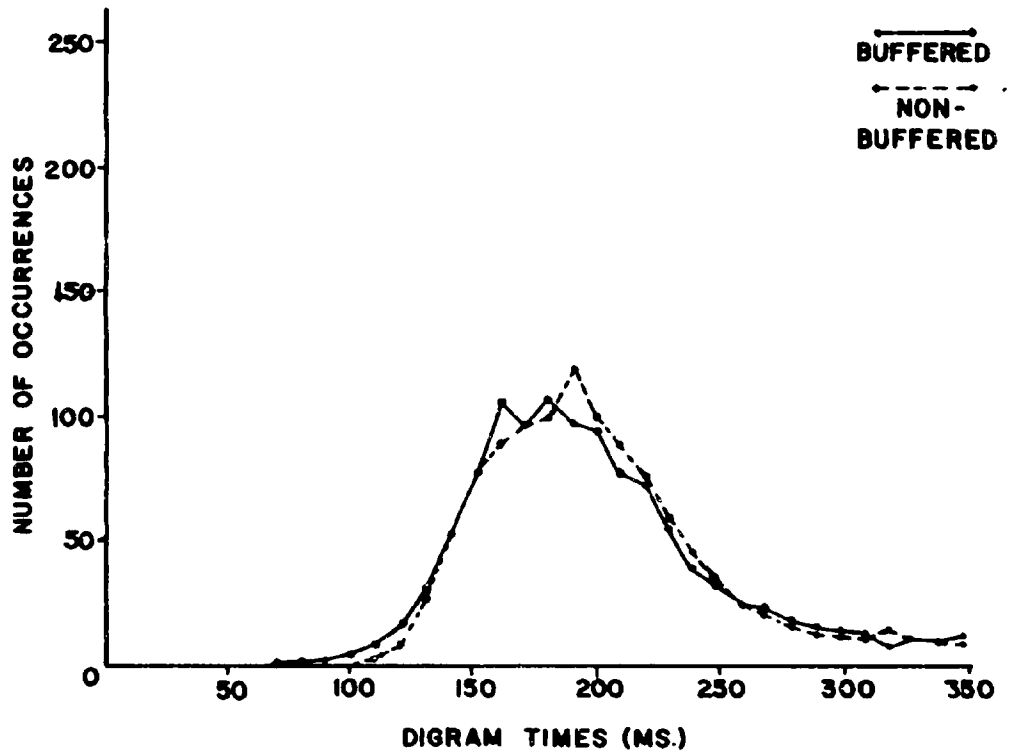

Figure 4. Distribution of Digram Times with Alpha Material for a Non-Skilled Subject.

One of interest (7) compared entry and accuracy rates between a keyboard and the scanner. The operator's task with the keyboard was to obtain various numbers of digits from a label attached to a grocery item, key the digits, and pass the item to the rear of a checkstand. The task of the scanner operator was the same except instead of keying she passed the hand-held scanner over a coded label. The results of the time comparison are presented in Figure 5, and the accuracy comparison in Figure 6. It can be seen in these Figures, for the experimental task, that little performance advantage exists for scanner entries consisting of three digits. There are significant speed and accuracy advantages for the scanner for larger entries, however.

The NCR Human Factors group, in a limited test to determine maximum rate of scanning labels, measured the time to scan a page of coded labels, and found it took about one-half second per label (8). Another type of hand-held scanner was found to require about 1.3 seconds per label to perform the same task. The reason for citing these results is to emphasize that scanner design and operation can have a significant effect on operator performance.

Operator acceptance of the scanner was found to be very high. Some of the reasons are that minimum special operator skills are required, a high level of proficiency is achieved with little practice (compared to learning to operate a keyboard), and the operator requires less concentration while using the scanner. Because of these, and performance reasons, it is anticipated that scanners represent one of the fastest growing areas of data input.

Speech. Interest has been shown through the years in data capturing systems based on speech recognition. This method of data entry has intuitive appeal since minimum special skills and training should be required of the operator.

Lea (9, 10) has listed some of the advantages of speech input. These include: (a) increased physical mobility to the operator because of the elimination of physical contact between speaker and equipment, (b) ability of the operator to use his hands and eyes for other tasks while speaking, (c) ability to use speech with other modalities, such as tactile, for more efficient communications, and (d) possibility for data entry for those who are physically unable to use standard tactile input devices. Major disadvantages of speech input include the difficulty of recognition in high ambient noise environments, and the technical and economic problems associated with speech recognition.

Technical problems have prevented the development of general speech recognition equipment. Pierce (11), in a letter highly critical of the potential for general speech recognition, notes that recognition around 95 percent correct can be achieved for clearly pronounced, isolated words from a chosen small vocabulary (such as the digits) spoken by a few chosen talkers. Performance has decreased drastically as the vocabulary, number, and variety of talkers were increased. Pierce concludes, "It is not easy to see a practical, economically sound application for speech recognition with this capability."

Review of the literature reveals limited empirical data

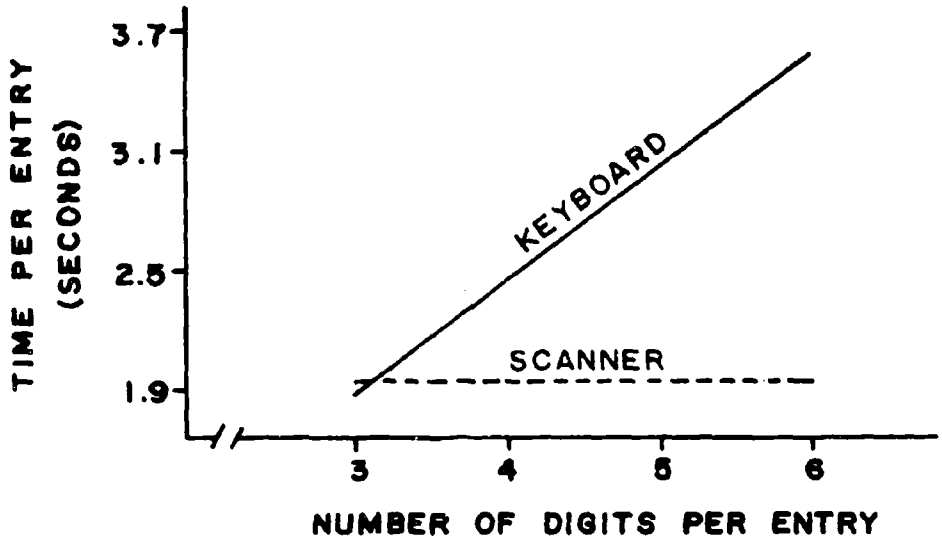

Figure 5. Comparison of Keyboard and Scanner Entry Times.

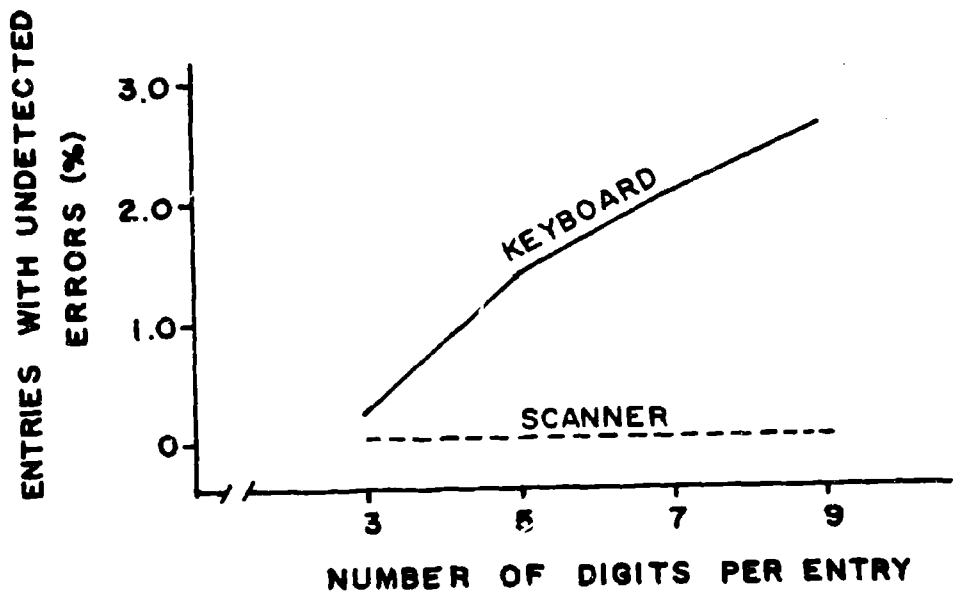

Figure 6. Comparison of Keyboard and Scanner Accuracy.

regarding rates of transmission and misreading errors with speech input. Braunstein and Anderson (12), in a study which dealt with the question, compared speed, accuracy and preference for reading digits aloud and keypunching. The results for inexperienced subjects showed the punch entry rate to be about half that of speech (1.44 versus 3.01 digits per second on the day performance was best for each). An experienced keypunch operator punched and spoke at a rate of 2.80 digits per second. The error rates were similar for the two methods of entry; undetected errors per digit were .0036 for punching and .0023 for speaking on the day accuracy was best for each. In the preference study, four of the five inexperienced subjects chose to punch rather than read 1050 digits, even though punching took nearly twice as long.

Bezdel (13), in another study, found that 43 female subjects uttered words (selected from the 10 digits and 5 command words) at an average rate of 1.33 words per second. Bezdel (13) reported the words were "separated by gaps of silence." He found the mean uncorrected misreading rate was approximately .001, with the standard deviation about as large as the mean value.

Although the first experiment described above was limited in scope, it suggests for tasks involving extended numeric data entry that speaking is initially faster than punching, but this difference disappears with experience; that error rates are essentially equivalent; and that operator preference is in favor of punching. Additional studies are required before any conclusions can be drawn.

There are other data entry tasks which may be more amenable to speech. As an example, nontypists might prefer speaking instead of keying limited amounts of textual material. The time for typing should be significantly longer; possibly an order of magnitude greater than with verbal entry. This estimate of time difference is based on the study of Devoe, et al. (3), who found unskilled operators keyed alphanumeric text at a rate of 0.86 characters per second, and the analysis by Miller (14) which showed the rate of utterance to be about 3 words per second (based on an average word length of 1.7 syllables, and an estimate of 5 syllables per second as the speed at which the speech musculature works). It would require about 4.3 seconds to type one word, assuming 5 characters per word. In the same time, 12.9 words could be spoken.

Error Detection and Correction. The NCR Human Factors group conducted a limited comparison of three methods of error detection and correction (5). Two of the techniques involved the operator pointing at the correct entry on the face of a CRT display. The third method consisted of the operator transcribing from a 1040 tax return a field identified on the CRT. The time required to accomplish the task was the measure of performance.

Figure 7 shows examples of the display presentation associated with each technique . In the Field Comparison method, the characters of an entire field where shown on a line of the CRT. Immediately below was shown the same field as it was transcribed at a different time. In every instance,

TECHNIQUE	DISPLAY PRESENTATION
Field Comparison	41 LAST NAME SMITH SMITT
Mismatch	41 LAST NAME SMITH T
Re-entry	41 ENTER LAST NAME

Figure 7. Examples of Display Presentations for Error Detection and Correction.

one or more of the characters on a line did not match with characters in the line below. In the Figure, the 41 refers to the tax return on which the field was found, and LAST NAME identifies the field. The task of the operator was to check the appropriate tax return to determine which entry was correct, and then point at the correct entry.

The Mismatch technique (Figure 7) was the same as the Field Comparison method except only the characters in the second line that did not match were displayed.

The Re-entry approach required the operator to transcribe the entire field identified on the CRT display (Figure 7). With this method, the system would compare the keyed characters with the two previously transcribed fields in an attempt to find a match.

The results indicated that point-in techniques (Field Comparison and Mismatch) to choose between two alternatives on a CRT display were 40 to 45 percent faster than the technique requiring rekeying of a field. No significant difference in time was found between the two point-in methods, although it is expected that a more extensive test would identify differences in speed and accuracy. The reason for the difference between keying and point-in was probably the many more operator control movements associated with the former task. The study described was very limited in scope; it is likely that the difference between point-in and rekeying is very sensitive to the number of characters in a field.

System Performance

Data input is concerned with rapid, accurate and economical encoding of data. Estimates of how rapidly, accurately and economically data can be encoded are influenced by a number of factors, including (a) the amount and nature of the data, (b) transformations required of the data by the operator prior to using the encoding mechanism, (c) characteristics of the input device and hardware-software system beyond, (d) corrections required on the data after initial encoding, and (e) characteristics of the operator. Unfortunately, most of the published comparisons between alternative data input systems are based on nonscientific observations. Research is needed in this area to establish good bases for comparison.

DATA MODIFICATION

Data modification is similar in many respects to data input since the same operator actions, encoding mechanisms and input devices are used. A major difference is that data modification usually involves reference not only to source data, but also to records already in the data entry process or data base. Therefore, there is greater operator reliance on visual and auditory presentation of the data contained in the existing records.

The transcription, verification, validation, and formatting functions mentioned in the Data Input section also must be accomplished during data modification. A very important operator activity in performing data modification is insuring that the correct record is being added to, modified or deleted.

Each of the data manipulation functions consists of many operator

tasks. The nature and performance of the tasks are dependent on many factors, including amount and nature of the data, transformations required of the data by the operator prior to using the encoding mechanism to update the record, characteristics of the input device and equipment in which the records to be updated are located, and characteristics of the operator.

The published literature regarding human factors aspects of data modification is very limited. Research is required to provide information relating to operator performance in the manipulation function.

CONCLUSIONS

The model proposed in Figure 1 can provide a useful conceptual framework in which to view man's role in the data entry process. The listings of operator actions and encoding mechanisms (Table 1), input devices (Table 2), and descriptions of operator functions and tasks emphasize the diversity of this role.

The studies presented show significant differences in operator performance between alternative input devices, and between different designs of the same device. Many additional studies showing the same type of results are reviewed in reports by Pollock, et al. (2), Devoe, et al. (3), and Alden, et al. (4). Even so, additional investigations are required to generate a pool of quantitative knowledge regarding operator performance in the data input and modification processes. The availability of such information is required to permit more meaningful overall comparisons between alternative data entry systems.

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2D. STATE OF THE DISPLAY TECHNOLOGY

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Display technology is about to enter its second decade with insight and new challenges. Despite the fact that command and control abounds with untested fact and theory, the contributions of display technology in command and control particularly the hardware aspects are formidable and significant. We are now on the threshold of developing new display capabilities which are inherent in such things as the holograph, the laser, fiber optics, etc.

Yet there is evidence that the acceptance of display technology is far from what it should be. Some claim that display systems are a nice show piece for visiting fireman - nothing more. Others claim that the expense of displays bars them from usage in the school room, in the management office, in surgery, etc. An examination of these claims would soon reveal some underlying motives which are related to a lack of understanding as to what displays can do and how they can be used - rather than such considerations as cost.

So we have the situation where a resource is available and yet there is a minimum of its utilization. What is the problem? Is it because the Human Factors were not considered in the design of the display initially so that the user was reluctant to expose himself to discomfort, error, etc? Is it because the user resents being pushed with technology that he didn't ask for in the first place? In 1970 these are important questions, more important than ever for Display Technology. The reason they are now more important than ever is because Display Technology is facing new markets, new needs and new challenges.

Last year, the Department of Health, Education and Welfare awarded several contracts to several cities located in different sections of the United States to design and implement several municipal management information systems. These systems are essentially command and control systems applied to the civic sector. There is a particular danger that the experiences gained from military command and control will be lost to system designers of these public command and control systems unless these experiences are reviewed and an attempt made to understand them so that the advances and pitfalls of the command and control development at large can be applied to them.

The challenge to display technology does not rest alone with the emerging municipal management information systems. The military services are projecting new communication technology, new ways of conducting logistics. Weapon capabilities will demand new decision disciplines from our strategic and tactical commanders. The needs from the educational sector will increase in importance and intensity. The shifts in educational philosophy we are now experiencing will impose greater demands for technology which allow the individual learner to procede at his pace, while freeing the professional for research and other academic pursuits. Libraries as we now know them will become data centers as well as knowledge centers permitting considerable data exploration and manipulation for scholarly and other purposes. All these activities will germinate new interests and new needs in Display Science and Technology.

So it its time for us to become quite serious about what we know and what we do not know - and to come to some agreement as to the priorities as far as display science and technology are concerned. Of course, the time provided will permit an examination of only a few of the underlying factors that are involved.

First lets examine some of our capabilities. Displays serve primarily two major functions in command and control, namely, the alerting function and problem solving. Subsumed under these two functions is the capability of the user to manipulate the data presented to him through the data processing capabilities inherent in the computer. In addition, through the manipulation and the ability to see the results of the manipulation, the user can project and test alternatives; in other words to attempt problem solution and to arrive at decisions. Lets examine some of our understanding of data processing and problem solving in brief detail.

The Data Processing element is taken to mean aspects connected with the clerical/mechanical typing, classification and storage of data and subsequent retrieval of same. Mechanical or hardware problems in this area have centered on efficient low-cost storage systems, preferably with multi-accessibility and large volume permanent memory. C. A. Steinberg (1) describes an example of such a system, "VIDEO-FILE" in which television techniques are used to achieve high storage efficiency, instantaneous filing, update, add or delete information, instantaneous retrieval, remote TV display or readout, all with reusable magnetic tape. Little reference is found concerning human-machine interaction at the clerical/input or transcription phase of the system where it is assumed that no decision making or problem solving functions are being performed. At this level, we are merely inputing data for future use by higher level decision-makers. R. T. Root and R. Sadacca (2) indicate that fastest throughput time may be achieved using a direct entry procedure where information is directly fed via a free-response keyboard as compared with written transcriptions or audio taped transcriptions subsequently encoded by a second person. This procedure may apply to facets of command and control data dealing with real-time evaluation and survey by a specific individual, who must then transcribe his data to the computing facility.

The problem solving aspect is

assumed to deal with a high level decision maker, or team of decision makers. Three functions come to mind: 1) Planning for existing and future methods to overcome specific problems. 2) Deciding on a specific method for handling a situation in real time. 3) Controlling subordinate functioning and dealing with unexpected "emergency" situations. It is assumed that the executive about which we speak has a fairly well established force of subordinates who take care of the "nitty-gritty" so to speak. Provision must be provided, however, for availability of sufficient information to assure executive's cognizance with emergency situations by-passing his normal clerical procedures. The decision maker must have at his disposal the ability to recognize the specific nature of the problem, must be able to display the data he requires, must be aware of both human and mechanical/environmental limitations and resources, and should have some means to simulate the impact or effect of a certain course of action, and should have the ability to monitor the progression of an implemented decision.

Mechanical/hardware considerations for the decision maker are varied, but among them may be: 1) Ready accessibility of relevant data, 2) Capability for high density display, 3) Real time interaction with system 4) Simple and efficient coding capability for ease of display comprehensibility. From the strict hardware angle, H. C. Hendrickson (3) notes that RASTER systems with all digital techniques for video syntheses are capable of outperforming the older ANALOG deflection techniques. The RASTER systems enables a much greater density of data presentation without deterioration of image. I suspect that this changeover has come about because of the cheapness and availability of digital MOS Logic in vastly compact and vastly large storage capabilities.

The human aspects the decision maker faces are several. Firstly, there is the problem of data display - how can data most effectively be presented to the individual. J. D. Baker and Ira Goldstein (4) state that there is no value in displaying material which may contain only potential value. The presentation of extraneous data delays problem solving by increasing search time. On the other hand, C. H. Hammer and Seymore Ringel (5) say a) accuracy of performance increases from 46% to 81% with the presentation of more information, and judgements of confidence from 52% to 68%. I assume they are speaking here of pertinent data, which does not contradict Baker's assertions. "Coding" of data for fast scanning is treated by W. D. Hitt (6) of five different coding methods; numeral, letter, geometric shape, color, configuration; numeral and color were superior in that order. Similarly, H. G. Schutz (7) finds line type trend formats superior to vertical or horizontal bar formats, and likewise, C. M. Williams (8) finds horizontal presentations of numbers are superior to vertical presentation - the vertical required 66% more time to perform the task.

The problem solving aspect may involve several individuals, a staff, or board arrangement. S. L. Smith & B. C. Duggar (9) treat large displays shared in common by group members as compared to individual displays. The large displays are judged 15% faster in performance time; frequency of errors being the same for both (10).

Finally, the overall efficiency of the system will be due, in part to the man-machine compatibility and credibility. G. V. Barrett et al (11) discuss three factors which influence individuals satisfaction with the information system: 1) training and level of proficiency. 2) Amount of information in the system to meet task requirements. 3) Individuals tolerance for irrelevant material.

This leads me to discuss what I consider to be the two fundamental issues facing future display hardware, namely, need for the display and their use.

The issue of need on the surface appears straight forward. With availability comes need but the validity of the need we should remember should not be based solely on availability. Needs suggests that there is an insufficiency of some sort, but the nature of the insufficiency is very often a very complex thing; particularly where the human is concerned. The danger always exists with technology that insufficiency is rationalized for the technology rather than the result of it. The most probing question under display technology is the need for it. The reason for this state is that the human insufficiencies have not all been clearly identified or exposed, with the consequence that display technology stands bare of apparent need.

With the capability of processing quickly large amount of data through the computer there is a requirement for quick updating of presentation. Hard copy readouts soon become voluminous and unmanageable. Electronic means of presenting the data, with option for hardcopy then seems reasonable. With greater data packages, the inclination to require access to such packages for decision making increases. Displays make possible access to such data packages stored in computers. With individuation of training the coupling of the individual with the computer becomes central to the training scenario. The coupling very often requires the display. All these are obvious needs for a display technology. To me there is one bug in the ointment. Namely, the need emerges after the individual is interfaced with the display rather than before it. Our whole problem has been in assuming that we can't live without the display. It so happens that the assumption may be partially right. Because of our technology and the complex nature of our environment we need displays for us to function efficiently intellectually. But, we need the display after we have learned to use it. As with the automobile, transportation is facilitated by the automobile, but only after we learn to use it properly. What is claimed here is that a need for displays is directly tied to its use and particularly to the training that is related to its use. Very often display technologists have totally ignored the training aspects in the development of the display hardware systems.

The question of how a display is and should be used is tied to need as discussed previously, but there may be a more over-riding factor which should concern us here. When a display technology is introduced to the user, - trained to use the equipment to accomplish the job - the display is inclined to change his whole way of looking at his job in the manner in which he relates to others. Consequently the display in the command and control area precipitates new sociological constructs which influence his role as a decision maker, as a user of data,

just like the printing press changed the whole complex of the society and the culture in the 15th century. Why is this so important to display technology? This use of displays will change man's estimates of his capabilities, of his roles - the way that he relates to others and these factors will decidely extend or limit the course of display technology in the next decade.

I consider the foregoing as an important factor, but of course there are other aspects of usage which cannot be denied - these are those that we usually associate with human factors. Some thought must be given to these in this paper. First, the fact that display systems will be essentially part of social systems require that the interactive factors in usage be better understood than at present. Much of the human factors literature overlooks the fact that display systems are used in a consortium of functions and people. A display system that is presented to a decision maker for use should be harmonious not only to his needs, but also to a number of co-decision makers who will need to share or collaborate in the decision function.

A display system or sub-system should constitute an integrated environment very much like an orchestration - the purpose of which is to facilitate function and decision making. The principles of orchestration are very seldom talked about in the function of a display system.

The second aspect of displays which relate to human factors involves the business of getting the most out of the capabilities we now have in displays - specifically, 3-D, color and computer graphics. It is surprising to me how long we have remained fascinated with these capabilities without capitalizing on them. Now and then I get a call asking about 3-D displays - what we know about using them. How often have I uttered the fact that we know little about them - except possibly that there are differences in individual's capabilities to respond to depth, that 2-D may be better with displays in which reading of alphanumerics provides greater accuracy than extrapolating measurements given in 3-D. But this is not very much indeed. Our experiments should deal directly with the individual difference problem and to uncover what these differences are all about and under what conditions.

What applies to 3-D's can also apply to computer graphics and to color. We have reasonable capabilities in all these areas. Recently, I surveyed the literature that would be pertinent to computer graphics and color and was disappointed to discover that much of the literature provided nothing more than an academic understanding of the problem and little that would be of help in providing direct assistance in a specific practical problem. I realize the danger of this admonition. I recognize that extrapolation of data from one or two parameter experiments is a matter of professional skill more than experimental inclusiveness. Yet, I also recognize the danger of false validity that may be harboring around conclusions which are based on such data. I'm not too sure we are giving this sufficient considera tion and serious thought.

In light of what has been said then what can we conclude about the future of command and control display technology? I believe that there is considerable hope

for further expansion and development of display science and technology in the next decade. New challenges in the area of municipal management information systems. New areas in military command and control will provide new requirements for data for the display of information. Much of the applications of displays will need to stress the understanding of how displays can be put together in well formulated integrated environments. There is a need for expansion of current display resources which we now possess so that they can be used to their ultimate extent. I refer specifically to 3-D, color, computer graphics.

Finally, the training for the use of displays has largely been ignored in the past decade. Displays will not become accepted until people learn how to use them and to know exactly what displays can do for them. If indeed displays are the interface between human intellect and a highly versatile computer system we need to know how we can get the individual to use such displays most effectively and efficiently. Its on this acceptance, I believe that the future of display hardware technology rests. Training, therefore, cannot be stressed sufficiently.

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2E. SOME COMMENTS ON SOFTWARE DEVELOPMENT

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The basic trends on the hardware side of computer technology are fairly easy to see: increasing speed, reliability, and memory capacity, accompanied by decreasing size and component costs. Kahn and Wiener (1) point out that the ratio of memory capacity to memory cycle time (which may be used as a rough indication of processing power) has been increasing at the rate of about a factor of 10 every two or three years. How long this rate of growth can be maintained before being curbed by fundamental physical limitations is not yet clear. However, there can be little doubt that we will see significant hardware developments for many years to come.

Hardware is only half of the picture, however; the most pressing need for the near future is for the development of software that will permit fuller exploitation of the potential computing power that already exists. What is needed to advance the state of the art of information systems, for example, is not so much additional processing speed and storage capacity but the development of procedures for organizing, manipulating, interrogating, evaluating, and retrieving data.

This paper discusses, in an informal way, several aspects of the problem of software development. It touches briefly on a variety of software-related topics, ranging from the development of programming languages to the problem of programming for information systems.

TYPES OF PROGRAMS

Programs and programming activities can be categorized in a variety of ways. Distinctions are sometimes made, for example, between systems programs and applications programs, scientific programs and business programs, operations programs and utility programs, etc. My purpose here is not to present a taxonomy of types of programs or programming activity, but to suggest that any such taxonomy should differentiate at least the following.

- Programs whose function is to facilitate the development of other programs. Translator programs (assemblers, compilers, interpreters) fall in this category, as do editors and debugging aids. Such programs may be thought of as tools for programmers.

- Programs that are intended to be used as components in other programs. Subroutines (procedures, macros) that are written in such a way that the user need not concern himself with the details of their operation, but only with how to call them into action and to supply them with the information they need to perform their tasks, comprise this category.

- Programs that are to be used by non-programmers in their work on substantive problems. Examples include ECAP, a program for on-line design or analysis of electronic circuits (2), NLS, an on-line text-handling system (3), and PROPHET, a chemical/biological information-handling system for pharmacologists (4). Such programs may be thought of as tools for non-programmer computer users.

- Programs that are to be used to accomplish (relatively automatically) recurring jobs. A university, for example, might maintain a collection of programs, each designed to perform a particular task, such as admissions, registration, class scheduling, student records, payroll, and billing.

- Programs that are written to solve immediate, and relatively unique problems. For example, an experimental psychologist wants to use his computer to control the data-collecting process in an experiment to determine the relative intelligibility of each of a set of words when masked by various types of acoustic noise. So he develops a program to accomplish that specific task on his particular machine. He may, of course, make use of programs of the first type mentioned above and of subroutines that have already been written by himself or others in connection with other—not necessarily similar—computer applications. However, the program that he will generate will be specific to his problem and quite possibly of use to no one but himself.

- Integrated special-purpose-system software, as, for example, the total package of programs that controls the day-to-day operation of a special-purpose system such as SAGE, TIPI or TOS.

Each of the types of programming mentioned imposes somewhat different demands on the programmer. Programs that are to be used as on-line tools by non-programmers must either be especially well-documented or self-teaching. Programs that are to be used repetitively on production-type jobs must be coded so as to minimize running time. The main requirement for a program that is written to solve an immediate problem is that it produce the results required; elegance and coding efficiency are of little concern. The development of large-scale-system software involves complex problems of file organization, resource allocation, and scheduling. Perhaps the most difficult problems in this case have to do with planning, coordinating and integrating the many individual programming efforts that the implementation of such a system requires. Licklider (5) points out, for example, that the programming of the SAGE system "took roughly a thousand man-years, and the average output for the entire staff was between one and ten 'debugged' and final machine instructions per day" not because of ineptness on the part of individual programmers but because of the inherent difficulty of the undertaking and the "essential incoherence, insofar as complex and highly interactive procedures are concerned, of large, hierarchical staffs of people."

THE DEVELOPMENT OF COMPUTER LANGUAGES

Computer programming may be divided into two rather different types of activity: (a) developing effective procedures for performing tasks, and (b) expressing those procedures in a code suitable for machine execution. The second activity is considerably less interesting than the first and is necessary only because of the fact that the "ones and zeros" symbology that is used to represent information within the machine is different than that in terms of which a man is accustomed to think. Thus, if a man is to communicate effectively with the computer, and vice versa, a translation, or transformation from one symbology to another, must take place. The history of the evolution of computer languages may be summarized by saying that the burden of this translation process, which originally rested entirely on the man, has been shifted more and more onto the machine.

No one has yet succeeded in developing a translator program[1] that will accept as input a program written in "human language" if that term is taken to mean the language of everyday speech. However, numerous languages have been invented that have more in common with natural language than do the binary codes in which information is represented within the machine. If we were to trace the history of these languages, we would see a number of developments, each of which tended to decrease the disparity between the type of symbology in terms of which a man likes to think and that which the translator is able to accept as its input.

Perhaps the first step that was taken in this direction was that of representing programs with octal, instead of binary, numbers. Trivial as this step may seem, it was a significant move in the direction of naturalizing the symbology with which the programmer must deal. Consider the problem of writing a program for a computer that has, say, an 18-bit word comprised of a 6-bit operation code and a 12-bit address. It is much easier for a man to remember that "42" means "add" and "43" means "subtract" than for him to remember that these operations are coded as "100010" "100011". Similarly, it is easier for him to write 3214 to refer to a particular memory register than to write 011010001100.

The next logical step was to do away with the numerical representation of instructions entirely and replace them with a symbology that was still easier for the programmer to use. If the octal number 42 could be used to signify "add," why could not the letters a d d? This meant developing a program that could accept a d d as an input, consult a table of such symbols for an interpretation of that particular one and make the appropriate machine

1. A distinction should be made between a language and its associated translator program(s). The language is defined by its symbols and its rules of composition. A translator program is a program used to translate a program that is written in a computer language into a functionally equivalent program expressed in machine code. A computer language is relatively machine-free (when one writes a program in FORTRAN-4, he—theoretically—should not have to be concerned about the machine on which the program will run); a translator program is not (the program that would translate FORTRAN-4 for an XDS Sigma-7 would be very different from one that would do the same job for an IBM-1130).

code substitution. Thus, mnemonic codes made their appearance on the scene, and programmers started talking to the computer with words such as lac (load accumulator), dac (depos't accumulator), add, sub, mul, and, not, and jmp.

Clearly

```
lac 3214
add 3215
dac 3604
```

is a more convenient code to deal with than

```
203214
403215
243604
```

If mnemonic codes could be used to represent instructions, then why not use them to represent addresses as well? Would it not be helpful to be able to say

```
lac A
add B
dac C ?
```

This capability, although more difficult to implement than were mnemonic instruction codes, was developed in due course. The use of mnemonic operation codes and symbolic addressing were characteristics of the type of translator referred to as an assembler. Another defining feature of an assembler was that the transformation from symbolic to machine code was made on a one-for-one basis: one symbolic statement translated into one machine code statement.

The next significant advance was the departure from the one-for-one translation principle, a step that opened up the door to the development of translators that would be far more convenient and powerful than assemblers could be made to be. Now it became possible to forget about "lacs" and "dacs" and such things, and write simply C = A + B, which, translated into English means "add the value of (the variable called) B to the value of (the variable called) A and set the value of (the variable called) C equal to the result." With this sort of symbology the translator program must be able to transform a single symbolic statement into several machine code statements. Translators that had this capability became known as compilers. (The term compiler now has a more precise meaning, because there have been developed other types of many-for-one translators from which compilers must be distinguished.)

Subsequent innovations have been too numerous and diverse to permit tracing them here. Perhaps a reasonable way to get some appreciation for how languages that are currently used differ from each other is to look at the same program expressed in several of them. I asked several individuals[2] to write a short program in a language with which they were familiar, to generate a table of factorials starting with 0! and ending with N! where N is a number to be obtained from the user. Specifically, the program was to request from the user the value of N, make sure that N is a positive integer (and return an error message and start over if it is not), skip two lines, type a table heading, skip another line, generate the table (without using a preprogrammed factorial function if one was available), skip two more lines and stop. Figure 1 shows several of the resulting programs.

This selection of languages is somewhat arbitrary and dictated mainly by the availability of programmers. It should also be

2. I am indebted to Douglas Dodds, Elaine Thomas and Jim Goodwin for their help in producing these examples.

```
FORTRAN IV
**********

          DOUBLE PRECISION KFACT
C
C
1000      FORMAT (I4)
1001      FORMAT ('*N MUST BE A POSITIVE INTEGER')
1002      FORMAT ('-  K          K!')
1003      FORMAT (1K )
1004      FORMAT (1H ,I4,2X,D15.9)
1005      FORMAT (1H-)
1006      FORMAT ('-N=',$)
C
1         TYPE 1006
          ACCEPT 1000,N
          IF (N.GE.0) GO TO 10
          TYPE 1001
          GO TO 1
10        TYPE 1002
          TYPE 1003
          K=0
          KFACT=1.
          TYPE 1004,K,KFACT
          DO 20 K=1,N,1
          KFACT=KFACT*K
20        TYPE 1004,K,KFACT
          TYPE 1005
          TYPE 1005
          STOP
C
C
          END
```

```
ALGOL 68
********

          START
          INTEGER N, K, KFACT;

INIT:     PRINT ('N=');
          READ N;
          IF N=0 THEN
             BEGIN
             PRINT ('N MUST BE A POSITIVE INTEGER');
             GO TO INIT;
             END
          NCLR; NCLR; PRINT ('K'); TAB; PRINT ('K!'); NCLR;
          PRINT ('0'); TAB; PRINT ('1'); NCLR;
          KFACT:=1;
          FOR K:=1 STEP 1 THRU N DO
             BEGIN
             KFACT:=KFACT*K;
             PRINT (K); TAB; PRINT (KFACT); NCLR;
             END
          NCLR; NCLR;
          FINISH
```

```
BASIC
*****

10 INPUT N
20 IF N<0 THEN 200
30 IF N-INT(N)<>0 THEN 200
31 PRINT
32 PRINT
40 PRINT "K        K!"
41 PRINT
50 PRINT 0, TAB(7), 1
60 IF N=0 THEN 300
70 LET F=1
80 FOR K=1 TO N
90 LET F=F*K
100 PRINT K, TAB(7), F
110 NEXT K
120 GO TO 300
200 PRINT "N MUST BE A POSITIVE NUMBER"
210 GO TO 10
300 PRINT
301 PRINT


RUN
```

```
TELCOMP
*******

1-01 DEMAND N
1-02 TO PART 2 IF N<0 OR FP(N)<0
1-03 TYPE #, #, "  K        K!", #
1-04 TYPE 0, 1 IN FORM 1
1-05 TYPE K, KFACT IN FORM 1 FOR KFACT=KFACT*K FOR N=1:1:N FOR KFACT=1
1-06 TYPE #, #

2-01 TYPE "N MUST BE A POSITIVE INTEGER"
2-02 TO STEP 1-01

FORM 1
###   #.##########

DO PART 1
```

```
LISP
****

  (FACTABLE
    (LAMBDA NIL
      (PROG ((K 0)
             (K! 1)
             N)
        TOP (PRINT (QUOTE N=)
                   1)
            (COND
              (TAND (FIXP (SETQ N (READ T)))
                    (IGREATERP N -1))
               (TERPRI T)
               (TERPRI T)
               (PRINT (QUOTE K"        K!")
                      T)
               (TERPRI T)
               (TERPRI T))
              (T (PRINT (QUOTE N" MUST BE A POSITIVE INTEGER")
                      T)
                 (TERPRI T)
                 (GO TOP)))
        LOOP(PRINT K T)
            (TAB 7 NIL T)
            (PRINT K! T)
            (COND
              ((EQ N K)
               (TERPRI T)
               (TERPRI T)
               (RETURN (QUOTE DONE)))
              (T
                (SETQ K! (TIMES K! (SETQ K (ADD1 K)
                (GO LOOP))

  FACTABLE())
```

```
COBOL
*****

    IDENTIFICATION DIVISION.
    PROGRAM-ID. K-FACTORIAL.
    DATE-WRITTEN. 23 JULY 1978.

    ENVIRONMENT DIVISION.
    SOURCE-COMPUTER. PDP-10.
    OBJECT-COMPUTER. PDP-10.

    DATA DIVISION.
    WORKING-STORAGE.
    77 N PICTURE IS 9999.
    77 K PICTURE IS 9999.
    77 KE PICTURE IS ZZZ9.
    77 K-FACTORIAL PICTURE IS 9(18).
    77 KEFACT PICTURE IS Z(9)9.

    PROCEDURE DIVISION.
    BEGINR. ACCEPT N.
      IF N IS NOT POSITIVE,
        DISPLAY "N MUST BE A POSITIVE INTEGER",
        GO TO BEGINR.
      DISPLAY " ".
      DISPLAY " ".
      DISPLAY " K          K!".
      DISPLAY " ".
      DISPLAY "   0            1".
      MOVE 1 TO K-FACTORIAL.
      PERFORM KUPHT VARYING K FROM 1 BY 1 THRU N.
    ENDR. DISPLAY " ".
      DISPLAY " ".
      STOP.
    KUPHT. MULTIPLY K-FACTORIAL BY K GIVING K-FACTORIAL,
      ON SIZE ERROR GO TO ENDR.
      MOVE K TO KE
      MOVE K-FACTORIAL TO KEFACT.
      DISPLAY KE, "  ", KEFACT.
    END COBOL
```

Fig. 1. Sample programs for generating a table of factorials.

pointed out that the particular problem chosen tends to show algebraic languages to advantage. By a different selection one could show LISP, or perhaps COBOL, in a more favorable light. The point of this comparison, however, is not to permit a critical evaluation of the languages, but simply to provide some appreciation for the variety of ways in which the same procedure can be represented. Although the examples do not reveal all or even most of the ways in which these particular languages differ, they do make it clear that from the user's point of view there are differences and they are substantial ones.

LANGUAGE EVALUATION

The development of computer languages has reached near-epidemic proportions during the past ten years. As a consequence, there is now a sufficient number available to present the fledgling computer user with a bewildering selection problem. Would it not be better to have fewer languages, each more carefully designed? To be sure, one can argue that it may be unrealistic to expect that one language could be developed that would be well-suited to all applications. Surely, however, we do not need the several hundred that now exist. It seems clear that a tremendous amount of programming effort today is spent on writing procedures that have already been written—albeit perhaps in different languages. If fewer languages existed, would it not be easier for programmers to complement each other's efforts more and duplicate them less?

The problem is that we do not know enough about what constitutes a good language. Assuming that some modicum of standardization may be a desirable thing, who is to say what the standards will be? Not only can we not say, in detail, what constitutes an ideal language for a particular type of application, we do not even know how to evaluate, in any very satisfactory way, the languages that exist.

Consider, for example, the problem of comparing any two of the languages represented in Fig. 1. Among the factors that one would want to take into account would be the following: the basic operations that are allowed, the rules of syntax, the conventions for handling subscripted variables and arrays, output formatting techniques, provisions for subroutine (procedure, macro, function) definitions and use, program segmentation and organization conventions, provision of preprogrammed functions and procedures, error detecting and editing capabilities, language modification possibilities, and many others. But how does one determine the relative importance of such factors—and, even more basically, who decides such things as what basic operations <u>should</u> be provided, what conventions for handling subscripted variables <u>should</u> be adopted, etc?

One might get judgmental ratings from experienced programmers. But, how does one control for biases and the importance of the programmer's own idiosyncratic experience? Or, one might teach novices how to program in different languages and obtain objective performance measures, such as time required to write and/or debug a program, or number of errors made. But language features that are advantageous for the novice will not necessarily be so for the expert. And so on.

In short, the problem of evaluation is a difficult one. However, the great disparity between the

amount of effort that has been, and is being, devoted to the development of new computer languages and that being devoted to the development of methodologies for evaluating languages that exist is unfortunate. This is not to argue that creative activities on the part of language developers should be discouraged, but simply to suggest that the evaluation problem is being neglected and, quite probably, to everyone's loss.

THE PRINCIPLE OF SUBROUTINIZATION

A subroutine may be thought of as a program segment that has a name and performs a particular task. The use of closed subroutines accomplishes three important things for the computer user. First, it simplifies the problem of thinking about and constructing complex programs. Most computers have a relatively small set of very simple operations that they can perform, such as copying the contents of a specified memory register into the "accumulator," copying the contents of the accumulator into a specified memory register, comparing the contents of two registers, adding the contents of two registers, and shifting the contents of the accumulator left or right a specified number of bits. One gets the computer to do complicated things by putting together an incredibly large number of such simple operations in an appropriate order. But the step from such basic operations to a complex program, such as would be required to operate the TOS system, for example, is a very large one. The trick that programmers use when faced with the problem of developing a program that will perform a complicated task is to attempt to break the task into subtasks, and to try to develop subroutines that will accomplish the latter. If the subtasks that result from this decomposition are not themselves manageable, then they are broken down still further. This process is continued until tasks are discovered for which subroutines can be written. Once a small task is programmed, the subroutine for it can be used as an element in the solution for the larger problem. And one goes back up the same path he came down. In short, the use of subroutines makes it natural for the programmer to attempt to break the difficult problem apart, find ways to solve the easier component problems and then put these solutions together in an effort to solve the composite problem.

A second thing that the use of closed subroutines accomplishes is a very significant economizing of computer storage. It is invariably true in complex programs that some tasks will have to be performed on several occasions. For example, in a program for performing a statistical analysis, it might be necessary to compute a mean or a standard deviation many times, each time with a different set of data. One can see the implications for storage requirements if the coding for accomplishing this task appeared in the body of the program at every point that the computation was required. If a subroutine is used to perform the task, however, it need appear only once, and it may be used as many times as necessary. The requirement that the subroutine be written in general or closed form is clear from this example. A routine written specifically to compute the mean or standard deviation of 360 scores stored beginning with memory register 1726 would be of very limited use.

A third advantage that comes with the use of closed subroutines is the possibility of building a library of procedures that is

specifically tailored to one's own computational needs. Once a subroutine is properly written it need never be written again (at least as long as one works with the same computer system). The user need only remember what the routine does and how it is called into action. Thus, by enlarging his program library, a programmer acquires a more and more powerful bag of tools. Each time that he writes a new applications program, he will have more preprogrammed subroutines to call than he had before. In many cases, writing a new program may mean little more than producing a sequence of "calls" to existing subroutines.

A user's subroutine-library acquisitions need not be limited to routines that he himself writes. Conversely, when he develops a generally useful routine, he could be enlarging other libraries than his own. Unfortunately, subroutine sharing has proven to be more difficult than one might expect. There are the problems of communication (letting potential users know that a particular procedure exists), of documentation (letting users know how to use it), of verification (determining that a procedure works properly under all contingencies), and of language and/or system compatibility (adapting procedures that were developed for one language or system so they work with another).

The Association for Computing Machinery has taken steps to facilitate the sharing of subroutines. As of June 1970, the Communications had published 384 algorithms that have been submitted by the journal readership. The procedures are published in ALGOL. The problem of verification is handled by the subsequent publication of "certifications" and "remarks" by users.

THE ACTIVITY OF PROGRAMMING

Textbooks on programming often give one the impression that programmers are paragons of efficiency and that programming is a by-the-numbers operation. First, we are told, one defines the task that the program is to perform. Second, he develops a flow diagram in which he identifies the program's major functional components. Third, he elaborates the initial flowchart by developing each of the boxes on this chart into a flowchart which details the ingredients of that box. (If the program is sufficiently complex, this step may be iterated, carrying the flowcharting down to one more level of detail each time.) Fourth, when the flowcharting is complete, the composition of the symbolic program is begun. The lowest order flowcharts are used to guide the writing of code in the language (e.g., FORTRAN, COBOL, LISP) appropriate to the system, the task and the programmer. Fifth, when the writing is finished compilation is attempted and, if successful, the program is loaded and run. If compilation fails, the necessary syntactic corrections are made and compilation is attempted again. Sixth, logical errors are identified and corrected (the program is "debugged"), and the programmer's job is done. So the textbooks say.

Don't believe it. Programming is a fluid and highly individualized activity, the essence of which can not be captured in a by-the-numbers procedure. Each programmer brings to his task his own style of thinking about a problem and of working toward a solution. As often as not, the very first objective thing he does is to write a program statement. He is likely to begin in the middle of a program (where the work gets

done) and proceed toward both ends. Flowcharting is very likely to be done after the program is written, if at all, and then only for the sake of documentation. Writing programs is fun; documenting them is not. (Failure to document, however, can create problems for the author of a program, as well as for other users. It is not unusual for a programmer, while in a fit of devious creativity, to produce such a "clever" code that he cannot understand it himself when looking at the program six months later.) Coding changes and program reorganizations will be made more or less continuously as the programmer discovers ways to improve or "elegantize" his work.

It is obvious that no one would begin to write a program without knowing, in a general way at least, some of the things he wants the program to be able to do; what is not apparent to people who have done no programming is that programmers frequently begin developing a program with only a very fuzzy idea of what the final product will be. This is not because of impatience or an innate inability to plan, but rather because it is often the case that one cannot see a goal clearly until he has moved some distance towards it. Thus, for example, one might want to develop an interactive graphics-oriented program to help teach a course on the behavior of random variables. He does not know, to begin with, which concepts will be most effectively taught with dynamic graphical displays nor precisely what the displays should look like that he does think the system should have. But he perhaps does know, say, that it will be important to display various probability distributions, and this is enough to get him started. So he writes programs that will display on command, and for specified parameter values, binomial, normal, exponential, Poisson, hypergeometric distributions. He then discovers that for certain parameter values a distribution can look very flat when scaled on a graph whose ordinate goes from 0 to 1. So he decides to add a y-axis scaling module to his package, thus giving the user the option of seeing the distribution on a graph that goes from 0 to 1 or from 0 to the maximum value represented in the distribution. A user comments that he would like to have the ability to convolute distributions, or to mix them in specified proportions and observe the composite distributions that result. So the programmer begins to extend his package in that direction. And so it goes. The point is that in many programming situations, one learns by doing. One begins by getting the computer to do something that is at least remotely related to what one thinks he wants it to do eventually. He then gets insights as he goes along, not only about program organization and the details of coding, but also about goals and objectives. Evolution is at least as important a factor in the development of complex programs as is design.

What is true of the individual programmer in this regard is equally true of team programming efforts. Computer-based systems are invariably developed in a dynamic milieu. The state of the art is advancing as the system is being developed; and, hopefully, the development of the system is contributing to that advancement. If one does not want to end up with a system that is a museum piece by the time it is operational, sufficient flexibility must be maintained to permit developers to capitalize on state-of-the-art advances that occur and insights that are gained as the work progresses. One does, of course,

attempt to identify user requirements insofar as possible before launching a development project. What seems to be proving true time and time again, however, is that it is not possible to specify in advance the details of the operation of the final system. It is mainly through the use of a functioning system that one becomes acutely aware of other capabilities that it would be useful for the system to have. If this is an accurate observation, the implication is clear: The most reasonable approach to the development of a computer-based system is an evolutionary one. The strategy should be to produce a system quickly that will do some of the things that the final system, as initially envisaged, will be able to do, and to build incrementally upon that.

This approach has two distinct advantages. First, the work of actually programming a system is the best antedote there is to the overly ambitious flights of fancy that a system designer may find it easy to take when too far removed from day-to-day implementation of his plans. Secondly, a functioning system, or functioning system components, are made available to users very early in the system development process. Both planning and development can profit from the insights that can come only from the interaction that this makes possible. The considerations that will determine whether or not the system will in fact be useful have a chance to force themselves on the system developers, while there is time to act constructively upon them.

SOFTWARE FOR INFORMATION SYSTEMS

The function of an information system is to provide a user with information that he wants, when he wants it, and in such a form that he can make effective use of it. In order to perform this function the system must not only possess the information that the user wants, but it must have ways of getting that information before the user. The first problem is the problem of acquisition, and is beyond the scope of this paper. The second one, however, is largely a software problem, two important aspects of which are: (a) data organization, and (b) data manipulation and query procedures.

Data Organization

A key problem in any computer-based information system is that of determining how the data base should be organized within the computer. The problem is particularly acute when one aspires to use the computer to aid the process of inductive thinking in a context in which the data are largely non-quantitative, diverse in subject matter, of uncertain reliability and time varying. How does one arrange such a data base to facilitate the discovery of important but non-obvious relationships?

Before considering briefly some data-organizing techniques, two distinctions should be made. First, we should distinguish between the logical or "natural" structure of data and the organization that is imposed on data for the purpose of storing them within

a machine. It is the latter with which we are concerned here; however, it will be recognized that the two are not entirely independent.[3] Second, we should distinguish between two types of data: (a) operational data (the data that the system is designed to manage, and (b) organizational data (data that are used to accomplish the management). An example of organizational data would be a directory or dictionary that lists the addresses of data items (see section on Inverted Lists below). The directory does not constitute a part of the operational data base, but contains data about the way in which the operational data are organized. The ratio of organizational to operational data might be an interesting measure with which to compare different organizational schemes. With some types of organization, it is quite possible for the organizational data to require more storage than the operational data. (Minimum storage requirement is not necessarily a desirable goal. One may choose to use up more storage in order to increase the accessibility of information.)

Considerable attention has been given to the problem of data organization in the recent past, and this area is likely to remain a very active one for some time to come. The following are illustrative of the many organizational schemes that have been used in various applications.

Property Sets. Often a file can be thought of as a collection of atoms, each of which has associated with it a set of properties (attributes, descriptors). For example, a phone book may be thought of this way: the atom in this case is the name of an individual; the properties are street addresses and phone numbers. A census file might well be organized in this fashion, the name of an individual again being the atom, and such things as age, sex, residence, occupation and education, being properties.

This organizational scheme is economical in terms of storage use. It facilitates retrieval on atoms, i.e., the reporting of properties of specified atoms. Retrieval on properties (reporting atoms fitting specified descriptions) requires a search. Algorithms are easily developed, however, to conduct such a search, e.g., to determine the educational or occupational profile of a community, to investigate the ratio of male to female workers, or the age distribution for various occupations. Listings of subsets of the data base, e.g., names of female dentists in a specified geographical region, of all college professors under 30 years of age, are readily produced.

At least certain parts of a tactical intelligence data base might be effectively organized in this fashion. For example, one way to conceptualize a tactical data base is in terms of a geometric model, each atom being represented as a point in space time. (What this means in terms of data

3. There is still another aspect of the problem of data organization, namely the question of what sorts of conceptual data structures are optimal from the point of view of thinking about data and the relationships between them. More generally, the question of what sorts of conceptual models a programmer uses to represent both the organization and the dynamics of his program is a particularly interesting one for the cognitive psychologist to consider.

representation within the computer is that each atom has associated with it a time tag and a pair of spatial coordinates.) A slice through this space, orthogonal to the time dimension, would produce a set of points which could be the basis of a map overlay representing a tactical situation at a particular point in time. In addition to the position and time tags, with each atom, there could be associated a set of descriptors; for example, in the case of armored vehicle sightings, such descriptors might include vehicle type, direction of movement, and, in general, any property appropriate to the description of armored vehicles.

Such a data-base organization should be particularly well suited to the interactive generation of situation displays. The man and the computer in collaboration could essentially construct "overlays" in terms of space-time boundaries and any of the other descriptors in terms of which the data are tagged. Thus, if one wanted to get a picture of trends with respect to vehicle activity over some time period, and within some geographical region, he could have the computer generate and display a sequence of "overlays", each of which showed sightings of specified vehicle types during successive time periods of a specified duration.

Lists. In a simple list structure, each item "points" to the next item in the list to which it belongs. Thus, items that are contiguous in a logical sense need not be stored in contiguous regions of the computer's memory. The simple list structure has several advantages. It permits one to make use of small storage regions that may be available throughout the computer's memory. Records need not be of uniform length. Modification of an existing list is straightforward. Space that becomes available as a result of data becoming obsolete is readily recovered for use in new or active lists. These advantages are not obtained without some cost, however. The necessity for storing a pointer with each list item can make a significant demand on storage space if the list items themselves tend to be very short, i.e., if the lists tend to be composed of many very short (single computer word, say) items vs. a few longer ones. Also, unless the entire data base is organized as one long list, some bookkeeping is necessary to keep track of where lists begin and/or end.

The simple list structure can be elaborated in a variety of ways. For example, by storing several pointers with each data item, one can treat any given item as a member of several lists. Thus, pointer #1 might determine its position in one list, and pointer #2, its position in another.

A data item itself may be organized as an atom with a property set (see preceding section). The properties of a given atom could, of course, be stored as a simple list, but need not be. In addition to being associated with its atom, a property might be an item in a list that cuts across atoms. Thus, one could think of lists running through the property sets.

In the simplest list structures, pointers go in only one direction; however, it is possible, and sometimes advisable, to have them going in both directions—to have each item point to its predecessor as well as to its successor. This is particularly helpful when items are allowed to be members of more than one list. One deletes an item from a list by simply changing the pointer of the item that precedes it in the list so that that

item no longer points to the one that is to be deleted, but to its successor. When an item that is a member of more than one list is to be deleted from the data base, it is necessary to make this change with respect to all the lists of which it is a member. Since, normally, one gets to a particular item on a list by following the pointers from the beginning of that list, it will always be easy to identify an item's predecessor on the list that was followed in getting to that item, but, how does one then find the location of the items that precede it on other lists to which it may belong? Without backward pointers, this can be difficult.

Another variation of a list structure is a ring—which is a list that closes on itself. The last item in the ring points to the first. Thus, with a ring structure, one can get from any item to any other item on the ring —including preceding items. The ring is more economical of storage than is the use of two-way pointers, however, it is more demanding of the computer's time. Finding the immediately preceding item in a ring is like traveling east to get to the town immediately to the west.

Inverted Lists. What is sometimes called an inverted list organization is a variation - an inversion - of the property set organization described above. Instead of storing a set of properties along with each atom, one stores all of the properties that are descriptive of any of the atoms in one place—an index. To each property one then attaches the addresses of (pointers to) the names of the atoms for which that property is descriptive. The index then is comprised of a set of properties (key words) with each of which is associated one or more addresses of data atoms.

This sort of organization can facilitate the search for topical information; one need simply scan the index, assuming that the index is sufficiently well developed to constitute an adequate description of the contents of the data base. Disjunctions and conjunctions of data sets are readily identified by simply combining the pointers associated with two or more properties, or taking those that they have in common.

A data base that is organized as an inverted list is easy to add to, but difficult to purge.

Choosing A Data Organization

Two major questions should be asked when trying to identify or develop an organization that will be well suited to a particular application: (a) what is the nature of the data, and (b) what operations are to be performed on them? Both of these questions subsume a host of others.

Regarding the Nature of the Data. Are the data quantitative? Do they have an obvious inherent structure? Are they readily partitionable into categories? Are the categories overlapping? (As examples of overlapping categories, consider a file that contains several items of information—e.g., age, sex, occupation, annual income, education, state of residence—on some segment of the United States populace. One might want to be able to categorize the file entries in terms of any one

or combination of these properties.) What will constitute an item—or atom—in the data base? Will it be feasible or convenient to put all data entries into one or a few standard formats? How stable is the data base likely to be; will items want to be retained for long periods of time, or will they tend to become rapidly obsolete, so that purging and updating will be critical problems?

Re the Operations that are to be Performed. What is to be done with the data once they have been entered into the data base? Will it be sufficient to be able to retrieve them in precisely the form in which they were entered (as, for example, one could do in a card file), or is some ability to manipulate, reorganize, aggregate and interpret data a requirement? Will it be desirable to be able to answer questions that cannot be anticipated?

Data Manipulation and Query Procedures

It is one thing to get data into a computer, and quite another to be able to do something interesting with them once they are there. Storing the contents of the Encyclopedia Britannica inside a machine would not be a difficult task, but what can one do with them once they are stored? Clearly not much, unless he has available some useful interrogation procedures. But what constitutes a useful interrogation procedure?

The difficult problem is to provide one the capability for obtaining answers to questions that are not anticipated by the designers of the system. This observation is equally true when applied to the process of manually extracting information from a library. Suppose, for example, that I want to know who was president of the United States in 1843. Such information is easily obtained, because people who write U. S. history books assume that readers are interested in such things as terms of office of presidents, and they make such information easy to find. Or, suppose that I want to know which U. S. presidents became president via the vice presidency. Still relatively easy. Even if I cannot locate an explicit answer to the question, I can obtain one at the cost of the effort required to conduct a straightforward search. I would probably consult a reference, or history, book, that I would consider to be likely to have a list of presidents and their terms of office. Having found such a list, I would then scan it, applying the knowledge that the term of office for the president of the United States is four years, that a term normally starts on the year following a year that is divisible by four, and that no president has been removed from office before his term expired, except by death. Again, what makes the problem simple is the fact that data regarding presidents are often organized on the assumption that people are interested in dates. Now suppose that I want to find out how many U. S. Secretaries of State were fluent in some language other than English, or had at least one foreign-born parent, or failed to finish college. The answer to these questions will quite probably prove to be somewhat more difficult to find, because history books are not commonly designed with such questions in mind.

The information-retrieval techniques that have been developed to date are, for the most part, limited to retrieving answers to questions similar to the first, or possibly second, example. Few, if any, can cope effectively with

questions that were not at least implicitly anticipated by those who developed the system's data manipulation techniques.

ESTIMATING THE COST OF SOFTWARE DEVELOPMENT

Perhaps the greatest danger in planning the development of computer software, particularly systems software, is that of underestimating costs. The tendency to underestimate the magnitude of the problem of developing a new computer system seems to be a nearly universal failing among system developers. Even extensive experience is no guarantee of accurate estimates. Licklider (6) points out, for example, that "IBM's announced aspirations for TSS (its time-sharing supervisor for the 360/67 computer), once scheduled for initial release in September 1967, were markedly reduced, with some features being dropped altogether and others deferred. The MULTICS system, originally scheduled for limited operation in a GE 645 computer during the summer of 1967, ran for the first time— in a slow and faltering way with a single typewriter console— on December 5. GE evidently closed out its effort to develop interactive multi-access hospital information systems based on its Series 400 computers." Note that in each of the cases the machinery existed; the major problems were "soft" ones.

Other testimonies to the difficulty of accurately estimating the costs of computer-based systems are easy to find. For example, Wolf (7) notes that to have costs exceed estimates by several hundred percent has not been unusual. He claims, referring to military command-information systems, that "no major system was developed within the original cost and schedule estimates and still met its original performance objectives" (p. 5). And Armer (8) supports the idea that the major problems have been related to software: "For large systems the largest single factor contributing to long lead times is most probably the computer program itself, even when fairly complex hardware must be developed and produced" (emphasis his).

I did not intend, by calling attention to costs, to end this paper on a negative note. What I want to emphasize is not software costs per se, but the apparently universal tendency to underestimate them. The question of why we have not been able to arrive at more accurate estimates is an interesting one, from a psychological point of view, but not one we will attempt to answer here. One thing about software, however, is certain: if one intends to use the computer, he cannot do without it.

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CHAPTER 3
HOST SESSION

Chairman: Richard T. Cassidy, Major General
Commanding General, U.S. Army Air Defense Center
and Fort Bliss, Texas 79916

3A. AIR DEFENSE IN THE FIELD ARMY

(Unclassified Abstract)

Harry B. Stoudemire, Lieutenant Colonel; Francis C. Collins,
Major, and Thomas J. LeClair, Major
U.S. Army Air Defense School
Fort Bliss, Texas 79916

INTRODUCTION

Mission and objective of air defense; history and development of air defense.

THE THREAT

Aircraft inventory of communist countries; communist air defense organization; air defense in North Vietnam.

WORLD-WIDE DEPLOYMENT

Locations in oversea areas and in the United States Army Air Defense Command (ARADCOM); air defense systems in the inventory.

AIR DEFENSE TACTICS

Types of defenses; Nike-Hercules equipment and tactics; Hawk equipment and tactics; Chaparral/Vulcan equipment and tactics; Redeye equipment and tactics; family of weapons concept.

SAFEGUARD

Major subsystems; deployment options and tentative locations; scheme of operations.

FUTURE DEVELOPMENTS

SAM-D; outlook for air defense; summary of presentation.

QUESTIONS AND ANSWERS

Team members will answer questions by the audience.

3B. THE EFFECTS OF HUMAN ERRORS IN ARTILLERY ON COMMAND AND CONTROL

(Unclassified Abstract)
Gary L. Horley
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Aberdeen Proving Ground, Maryland 21005

The acquisition, communication, application and interpretation of information are important aspects of the command and control of any military organization in accomplishing its mission. A recent field study by the Human Engineering Laboratories (HEL) at Aberdeen Proving Ground, Maryland, revealed that information management ranks with training, discipline, morale and administration in its effect on how well an artillery unit can accomplish a surprise-fire mission.

This investigation determined the ability of a battalion of self-propelled howitzers (M-109) to deliver surprise fire to a point target. The performance of three artillery battalions of M-109 self-propelled 155mm howitzers from the 1st Armored Division at Fort Hood, Texas, was measured. The total system and subsystem accuracies were computed, analyzed and compared with results from previous studies.

CHAPTER 4
HUMAN FACTORS IN TRAINING

Chairman: Edward M. Hudak, Colonel
Headquarters, U.S. Continental Army Command
Fort Monroe, Virginia 23351

4A. INTRODUCTION

Edward M. Hudak, Colonel
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INTRODUCTION

A most appropriate beginning for the CONARC sessions lies in the thoughts of the CONARC Commanding General, General James K. Woolnough, as he closed his address to the conferees at the 13th annual Army Human Factors Research and Development Conference: "...in your accomplishments - in terms of our achievements - lies the basis for CONARC's continuing interest in the behavioral and social sciences R&D program and of our continuous search for ways and means to improve our training ability.

"But, just because the past record looks good, we are not satisfied to sit on our backsides and view with pride that which has already been accomplished. We must find ways to exploit more fully research results, and to guide new research along lines most valuable in meeting the Army's objectives. Permit me to quote from a report prepared by the Army Research Council which was published in late spring of this year:

"Active involvement of the Army in science and research should assure that the results of research, where done, are applied to solve Army problems. Individuals are needed who are experts in scientific and military fields. They bridge the gap between research results and ideas and practical military applications.

"Such experts minimize the lead time between the generation of a scientific concept and its Army application. They must continually make critical evaluations of new ideas or research results to determine their applicability to Army problems."

"This statement is perhaps a good one on which to terminate my keynote remarks to this distinguished audience. I think it is a pretty fair summary of what should be expected of the military experts in this field and I will not attempt to embroider on it. But I can assure you, military and civilian alike, of CONARC's full support of your projects which could lead to a better accomplishment of the people-oriented CONARC mission."

This then is our thesis for today - how to increase and improve the rapport between the researcher and the user, the soldier-scientist

team. This soldier-scientist team has achieved notable improvements for the individual, in the field of both training and combat performance. Increased interaction will assure a constant and dynamic military effort supported by timely and diligent research to meet the challenge of maximizing America's most potent weapon and precious resource - man himself.

CONARC offers the most unique and complete research laboratory in the whole people business. It becomes the most productive when a sense of urgency and need for a close union is reflected between those charged with advancing knowledge and those charged with applying this knowledge as quickly as possible.

The soldier-scientist interaction has made the U.S. Army of today a powerful weapon - better equipped and better trained than ever before in the history of warfare. This interaction begins with an identification and isolation of the military equipment - by the soldier-scientist team: What is the knowledge gap? What is the obstacle to progress? The interaction continues as the research and study progresses. This interaction assures early identification of improvements and promising training, training device innovations and results in timely translation of research findings into militarily usable products. Application of research findings actually begins long before the report is written and published. Thus, soldier-scientist interaction steers science and technology to a better payoff. Such interaction assures to the fullest the advancement of military expertise through an interactive, knowledgeable coupling of the scientific state-of-the-art - and it will meet Congress dictum: The research funds will be approved only to the extent it supports a validated military service objective.

The CONARC sessions represent the span of such consideration. Using the Safeguard system as our vehicle, we will examine the whole system by way of an orientation and exposure to the full expanse of the command and control problems. The next phase will provide you a detailed exposure of difficulties encountered in developing the manning and operation, operation of the system and the training planning - and the critical need for your type support and assistance. Then finally, a still closer look at the scientific effort now on-going which will make a major contribution to evoking the Safeguard into a more potent, effective weapon system.

It is abundantly evident that we prefer to think in terms that communications gaps do not exist, either between members of our soldier-scientist team or along our command and control systems. Rather we adopted a more positive attack in the form of thinking of avenues and barriers to communication. Some of the avenues are one way and should be two. And if the command and control messages are not getting through, we search for and identify the barrier - and clear the way for understandable and mutually receptive communication. Additionally, we address the matter of advanced technology, from a commander's viewpoint - to say that commanders fear technology is patently ridiculous.

In discussing the "Battlefield of the Future," the U.S. Army Chief of Staff, General William C. Westmoreland, said:

"In summary, I see an Army

built into and around an integrated area control system that exploits the advanced technology of communications, sensors, fire direction and the required automatic data processing - a system that is sensitive to the dynamics of the ever-changing battlefield - a system that materially assists the tactical commander in making sound and timely decisions....to succeed in this effort we need the scientific and engineering support of both the military and scientific communities....I believe our future path has been clearly blazed."

4B. DESCRIPTION OF SAFEGUARD SYSTEM AND PLANS FOR TRAINING

Harold C. Ferguson, Lieutenant Colonel
SAFEGUARD Training Facility
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The Safeguard System now being deployed by the United States is not a new system. It is the outgrowth of 15 years of ballistic missile defense research and development work by the Army and its contractors. It represents the most sophisticated and highly automated weapon system ever undertaken for deployment by the Army and is designed to counter incoming ballistic missile warheads.

The continued and evolving ballistic missile threat to the Continental United States from the Soviets and the continued nuclear weapons program of Communist China highlights the need for deployment of the Safeguard System.

The ballistic missile defense development program began in 1955 with the advent of the Nike Zeus. Under the Nike Zeus program, the Army developed a large acquisition radar, smaller target tracking and missile tracking radars, a discrimination radar to sort the real warheads from decoys, and the Zeus interceptor missile. By 1963, the Nike Zeus concept could no longer meet the evolving and postulated threat. It was reoriented to the Nike-X project. The Nike-X system was to consist of a new family of radars, phased array radars, which are extremely fast in operation and able to handle numerous targets simultaneously. The Nike-X system also included a second interceptor, the "high acceleration" Sprint. This system promised to be more effective against a sophisticated missile attack employing penetration aids and much less susceptible to saturation.

In September 1967, Secretary of Defense McNamara announced a decision to deploy the ballistic missile defense system. It was an extract from the Nike-X effort and was called Sentinel. Sentinel was to be deployed against the potential Chinese Communist ICBM threat to our cities and urban areas.

In March 1969, President Nixon announced a modified, phased deployment concept. The components of the system, the radars and missiles, are basically the same as before, but the manner in which they will be deployed is different. The name "Safeguard" was given to the new system to denote a basic change in its concept of deployment and to assure that this change was widely recognized and understood.

The objectives for the Safeguard system as announced by President Nixon are as follows.

1. Protection of our land based retaliatory forces against a direct attack by the Soviet Union.

2. Defense of the American people against the kind of nuclear attack which Communist China is likely to mount within the decade.

3. Protection against the possibility of accidental attacks from any source.

The system must be capable of meeting such requirements as handling multiple targets, target discrimination, adapting to changes, high fire power, and flexibility.

To provide these capabilities, Safeguard will use two phased array radars, data processing systems, and two interceptors. The first radar is a Perimeter Acquisition Radar called "PAR." The second is a Missile Site Radar, or simply "MSR." The two missile interceptors are called Spartan and Sprint. These four basic components are tied together by a high-speed computer system which permits man to control the entire system.

PERIMETER ACQUISITION RADAR

The Perimeter Acquisition Radar (PAR) is designed for early detection of incoming warheads at ranges in excess of 1000 nautical miles. The radar will be housed in a concrete structure some 200 feet on each side and 130 feet tall. It is a phased array radar which means that beam steering is accomplished electronically and the beam can be steered in any direction in a matter of a few millionths of a second. Instead of a conventional dish-type moving antenna, this phased array radar has thousands of small antennas built into the face of the PAR building.

MISSILE SITE RADAR

The other phased array radar employed by the system is the Missile Site Radar (MSR). This radar has a detection range of several hundred miles. It operates in a manner similar to the PAR but provides much more precise target data. The MSR also readies interceptors for launch and guides them to intercept. Generally, Spartan and Sprint missiles are located at the MSR site. The MSR and its data processing equipment will be housed in an underground building about 230 feet square. A turret approximately 77 feet tall housing the radar faces will project above ground. The MSR will have an underground power plant and other support facilities associated with it. A prototype MSR has been installed at Kwajalein Missile Range in the Marshall Islands, where operational tests are being conducted.

SPARTAN

The Spartan is a long range, defensive missile designed for intercept at very high altitudes. It is a 55 foot long, three stage solid propellant missile and is launched from an underground silo. Spartan will carry a nuclear warhead and its intercepts will occur at altitudes sufficiently high above the ground to preclude any damage to personnel or equipment.

SPRINT

Sprint is a 27 foot long, two stage, solid propellant missile designed to make intercepts at a closer range. It has an extremely high acceleration and is able to reach intercept altitude within seconds after launch. It is also guided to its target by the MSR and system computers. The Sprint is ejected from an underground silo by a gas propelled piston and its booster ignites once the missile is in the air. The Sprint

will have a nuclear warhead in the kiloton range.

DATA PROCESSING EQUIPMENT

Each MSR and PAR will have large capacity data processing centers. These high speed, digital computers process and evaluate the vast amount of information accumulated by the radars and provide the means for man to control the system. A significant part of the Safeguard development is the formulation of so-called "software" or computer programs.

SAFEGUARD DEFENSE

The Safeguard System can provide two types of defense: area defense and terminal defense.

--Area defense is accomplished by intercepting warheads above the atmosphere at ranges of several hundred miles. Hence, each site can protect large areas of the country, hundreds of miles across.

--Terminal defense is a concentrated defense of a small area such as a group of Minuteman silos or a bomber base.

A SAFEGUARD ENGAGEMENT

The first element of the Safeguard system to detect an attack would be the PAR. This radar would provide initial track data for Safeguard firing units. The MSR would review this tracking data if required, and control the flight of Spartan missiles to intercept the incoming warheads. The Spartan's kill, a nuclear explosion to destroy or disable the incoming warhead, would occur well out of the atmosphere (area defense). A second type of missile, the Sprint, would be launched to destroy warheads which have penetrated the Spartan defense or which may have been allowed to pass it for sorting purposes (terminal defense). Engagements would be almost entirely automated except for the necessary human decisions which must be made by command authority. All engagement activities are subject to manual human intervention at any time.

The nuclear warheads used in the Spartan and Sprint missiles have elaborate safety devices to prevent a nuclear explosion until after the missile is launched and reaches a safe altitude.

SAFEGUARD DEPLOYMENT

As announced by President Nixon in March 1969, Safeguard is to be deployed in phases dependent on the development of the threat by either or both the Soviet Union and the Chinese People's Republic.

The initial phase, Phase 1, was approved for deployment by Congress in the FY 70 budget. It consists of two tactical sites: one near Grand Forks AFB, North Dakota, and the other near Malmstrom AFB, Montana. Phase 2 includes twelve tactical sites and represents the maximum number of sites thus far considered for deployment. There are many deployment options which could be deployed in lieu of Phase 2 or as steps in achieving Phase 2. Secretary of Defense Laird announced in February 1970 a recommendation by President Nixon to expand the Safeguard deployment. This expansion is called "Modified Phase 2." It included a request for authorization to deploy one additional site at Whiteman AFB, Missouri; additional Sprints at the original Phase 1 sites; and authorization to undertake advanced preparation work at five more sites: Upper Northwest; Warren AFB, Wyoming; Michigan/Ohio Area; Washington, D.C. Area; and in the Northeast.

This option was passed by the House but modified somewhat by the Senate Armed Services Committee. Their proposal for modified Phase 2 was to delete four of the sites earmarked for long lead-time preparation: Northeast, Northwest, Michigan/Ohio; and the Washington, D.C. Area. The balance of the original modified Phase 2 would remain. There were three amendments offered but were defeated. The Senate/House Conference Committee agreed on a compromise providing for the deployment as voted earlier by the Senate, and as just described. It is now awaiting ratification and signature by the President.

PERSONNEL DEVELOPMENT PROGRAM

The deployment of the Safeguard System will introduce into the Army a new and highly complex weapon system which requires support by thoroughly trained, highly skilled personnel in new as well as existing military and civilian skills. The personnel development program for the operation, support, and maintenance of this weapon system will be implemented and accomplished in three phases: New Equipment Training (NET), Resident Training, and On-Site Training.

New Equipment Training is the responsibility of the Safeguard System Command and will provide the initial transfer of system technical information from the weapon system contractor to key military and civilian personnel. New Equipment Training is further divided into three areas: Engineer Service Test Courses, Key Personnel Courses, and New Equipment Training Teams. Engineer Service Test Courses are conducted at Fort Bliss by the Weapon System Contractor (WSC) and are designed primarily for the Safeguard System Evaluation Agency (SAFSEA) personnel. Key Personnel Courses (KPC) are to be developed and conducted by the WSC and began in September 1970. They provide for the initial transfer of technical information on the system to instructor personnel. New Equipment Training Teams, consisting of contractor, Army Air Defense Command (ARADCOM), United States Army Material Command (USAMC), and/or Continental Army Command (CONARC) instructors as required, will provide maximum training on equipment changes and major modifications prior to installation on site.

The Resident Training Phase is designed to provide qualified personnel in new Safeguard skills as well as existing skills to support, operate, and maintain the tactical sites. Resident Training is the responsibility of CONARC. The Safeguard Central Training Facility (SAFCTF) at Fort Bliss, Texas, was established as a part of the US Army Air Defense School (USAADS) and will provide all resident training for personnel in new Safeguard skills. The Central Training Facility is a unique organization and represents a departure from the usual role of the Air Defense School in support of Air Defense Weapon Systems. It will train Engineer and Ordnance personnel as well as Air Defense artillerymen to support Safeguard deployment.

The deployment of the Safeguard system will require participation by 15 existing CONARC service schools and training centers in providing support personnel in 58 existing MOSs.

The Safeguard Central Training Facility is responsible for developing instructional material and conducting 29 separate courses, 25 of which will be MOS-producing. Two of the MOS-producing courses are ordnance and engineer officer qualification courses. These

officers will have received branch training at their respective branch schools prior to arriving here at the Central Training Facility for instruction.

The Central Training Facility presently conducts a Safeguard Staff Planners Course (SSPC) on a quarterly basis. This is currently the only course being taught on Safeguard that provides general information on the entire system.

That, generally, is the concept of the Resident Training phase of personnel development. It is significant, however, that there will not be a complete tactical site available at the Central Training Facility for resident instruction. Training will be conducted using selected training devices (or part task trainers, as they are currently defined) and other standard training aids. This will result in the need for hands-on equipment training on-site.

The Commanding General, Army Air Defense Command, is responsible for planning and executing the on-site training program.

This training will be conducted to fully qualify personnel possessing Safeguard peculiar MOSs and to familiarize personnel possessing common MOSs with Safeguard site operations.

Safeguard represents the most sophisticated and highly automated weapon system ever undertaken for deployment by the Army. In the final analysis, this high degree of automation is directly dependent upon man's ability to maintain the system at the high level of operational readiness required by design specifications. The Safeguard Central Training Facility must provide these personnel with a sound foundation in the necessary skills if the system is to function as it has been designed. Should it be required, the full 12-site deployment would provide substantial protection for our strategic offensive forces and thereby accomplish the major objectives as stated by the President.

4C. HUMAN FACTOR CONSIDERATIONS IN SAFEGUARD

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Fort Monroe, Virginia 23351

Now that LTC Ferguson has described the SAFEGUARD System and plans for training, I will review some of the human factor efforts that have contributed to the development of these training plans and personnel requirements. My major purpose will be to emphasize the difficulties that we have encountered with obtaining human factors information and incorporating it into planning efforts.

The Army has two programs which make provisions for and require human factor considerations in the development of new training programs. These are the Life Cycle Development Model which is described in DA Pam 11-25 and System Engineering of Training (Course Design) which is described in CONARC Regulation 350-100-1. Before getting into a discussion of SAFEGUARD unique considerations, I will briefly review these programs and their relationship to each other.

Although it is not the only category of human factors information, the Task and Skill Analysis (TASA) is of primary concern to the training efforts, therefore, the remainder of this presentation emphasizes the collection and utilization of TASA data.

AR 700-51 defines TASA as the process of analyzing materiel, hardware, items, or systems to identify all tasks necessary for proper operation, maintenance, and repair of materiel in accordance with the mission, employment doctrine, and support concept. The process includes an analysis of the tasks to provide specified data such as skill demand, frequency, time, personnel required, location, etc., plus a description of the task steps required to complete the performance of the task.

Figure 1 shows the normal relationship of human factors and behavioral information to MOS decisions and the combined relationship of these two categories of information to development of a training program. Provisions for early identification of human factors and behavioral information are provided for during Concept Formulation. The Provisional Quantitative and Qualitative Personnel Requirements Information (PQQPRI) report is based upon human factors and behavioral

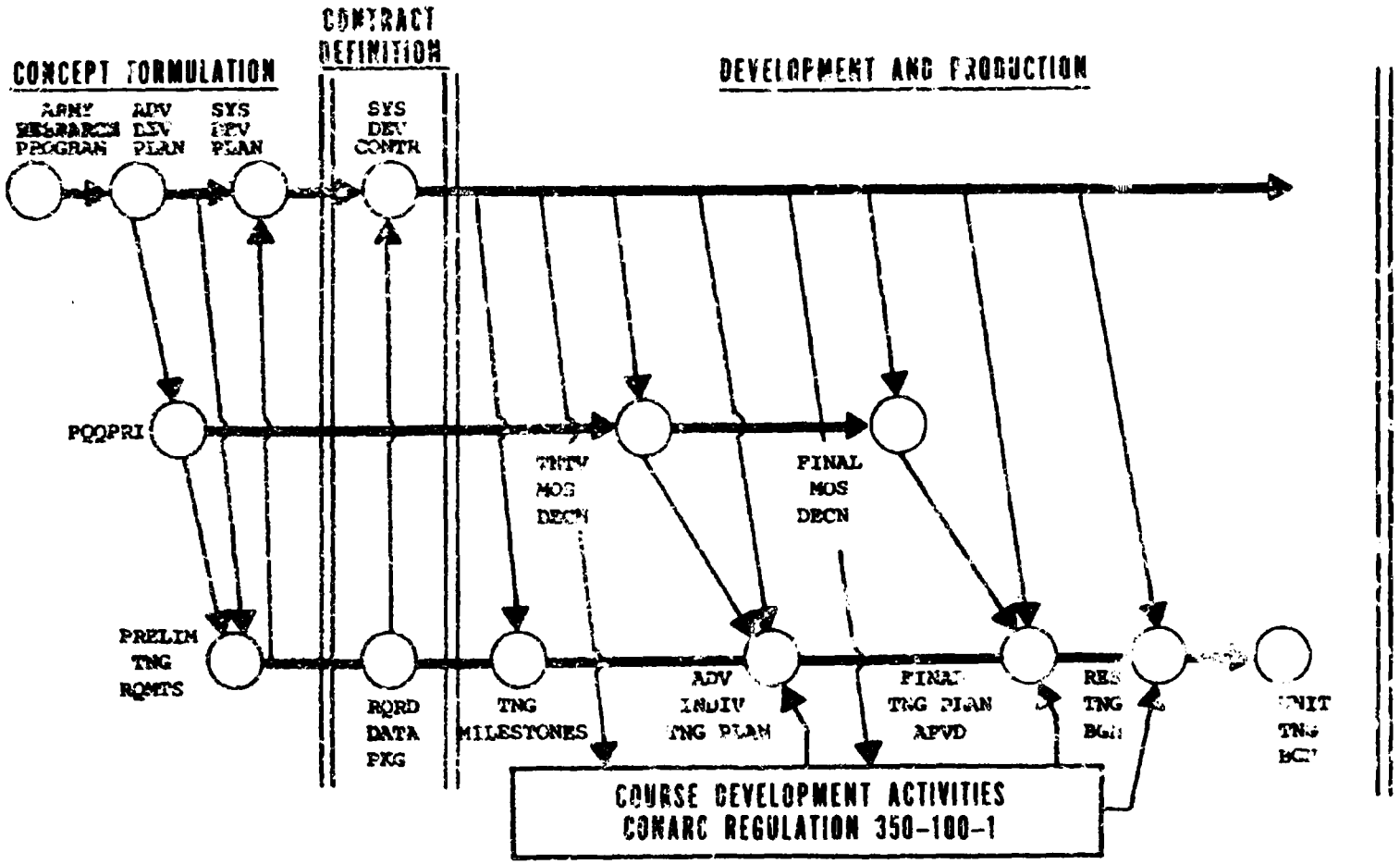

FIGURE 1. RELATIONSHIP OF HUMAN FACTORS AND BEHAVIORAL SCIENCE INFORMATION TO DEVELOPMENT OF TRAINING PROGRAMS

studies performed as a part of material research, exploratory development, and advanced development phases. This same information provides the basis for identification of preliminary training requirements for inclusion into the System Development Plan. The need for TASA should be specifically identified at this time and a specific data package requirement included in the System Development Contract Plan.

Providing that the requirement for TASA is identified and contracting is accomplished, the TASA data should be available to support the follow on training activities as outlined in the training milestones. These milestones are developed early in the development and production phase and should include:

1. Quantitative and scheduling data for training aids and devices and end-item training equipment.

2. Inputs to required data packages such as technical literature, delivery schedules and cost estimates.

3. Advanced and refined training plan submissions including New Equipment Training (NET) requirements.

4. Submission of Military Construction Army (MCA) requirements and modification to Tables of Organization and Equipment (TOE), Tables of Allowances (TA) and Technical/Supply Bulletins.

5. Publication schedule for training literature.

An updated QQPRI report is forwarded to Department of the Army (DA) approximately 33 months prior to fielding of the system. The purpose of this report is to obtain a tentative MOS decision which serves as the basis for preparation of the Advance Individual Training Plan. In addition, development and maintenance of the training plan requires that detailed TASA data, as specified in the required data package, be continuously updated and provided to the training agency.

The Advance Individual Training Plan includes a schedule and description of NET and resident training. The resident portion includes a list of proposed courses, estimated quotas and course lengths, responsible schools, and a description of required training aids and devices. In the absence of adequate TASA information, the training agency can do little more than rely solely on tactical equipment for use in the training program. The NET portion of the plan includes a schedule of NET courses for transfer of knowledge from the developer to the training and other using personnel.

Final QQPRIs are forwarded to DA approximately 15 months prior to fielding of the system, with a final MOS decision scheduled within three months. This MOS decision is the basis for the Final Individual Training Plan which includes a schedule of classes, projected class quotas, a list of training equipment, aids, and devices. The last two dedicated training steps in the Life Cycle Model are "begin resident training" and "begin unit training." If all goes well, training and course materials will be developed, facilities completed,

equipment installed, and instructors trained so that training can begin on schedule.

Concurrently with and providing inputs to the training and personnel activities just described are the course development activities prescribed by CONARC Regulation 350-100-1, System Engineering of Training. Referring back to Figure 1, attention is directed to the continuous inputs of TASA data into the course development and training planning activities.

Figure 2 identifies the course development activities required by CONARC Regulation 350-100-1. This figure is included to identify that an orderly and prescribed procedure exists for the development of training programs. It is emphasized that the success of this process is directly proportional to the availability and quality of TASA information.

Now that I have described the normal situation, or maybe I should say the hoped for situation, I will describe some real time considerations and problems as they apply to SAFEGUARD.

From the records, it would appear that we got TASA off to a good start in SAFEGUARD. The first TASA effort was initiated during May 1966 and the first product was delivered approximately 18 months later. Two significant items will be highlighted regarding this initial TASA effort.

The first is that necessary behavioral science "know-how" was not provided for and as a result the product was certainly less than adequate. For example, critical skill requirements were generalized into broad categories of fixed procedure, variable procedure, physical skill, discrimination, system analysis, and circuit analysis. In addition, knowledges were similarly categorized into mechanical, hydraulic, pneumatic, electrical, electronic, digital and other.

A couple of examples should serve to emphasize the magnitude of these deficiencies. In one sampling of the TASA data, the same skill and knowledge code was assigned to 474 out of a total of 493 equipment units. The units to which this single code was assigned included a wide variety of items from electronic components to empty cabinets. Since the TASA made no distinction in skill and knowledge requirements across such a wide range of equipment items, little useful information was being provided.

Figure 3 illustrates that in addition, some of the TASA information was actually misleading. As shown in this figure, it was concluded that "electronic knowledge" is required for determining whether any of the three lights on a control panel are illuminated, and inferring from an illuminated light that a fault exists in the corresponding power supply. In this connection, "electronic knowledge" indicates a requirement for an understanding of the application or theory of phenomena such as the movement of free elections or ions in election tubes, transistors, and semiconductor devices. From Figure 3, it should be apparent that "electronic knowledge" may not be required to judge whether any of the three lights are "on" or "off" or to read the labels on the lights.

In all fairness to the people involved, they were, in fact, following current regulatory requirements. This highlights the

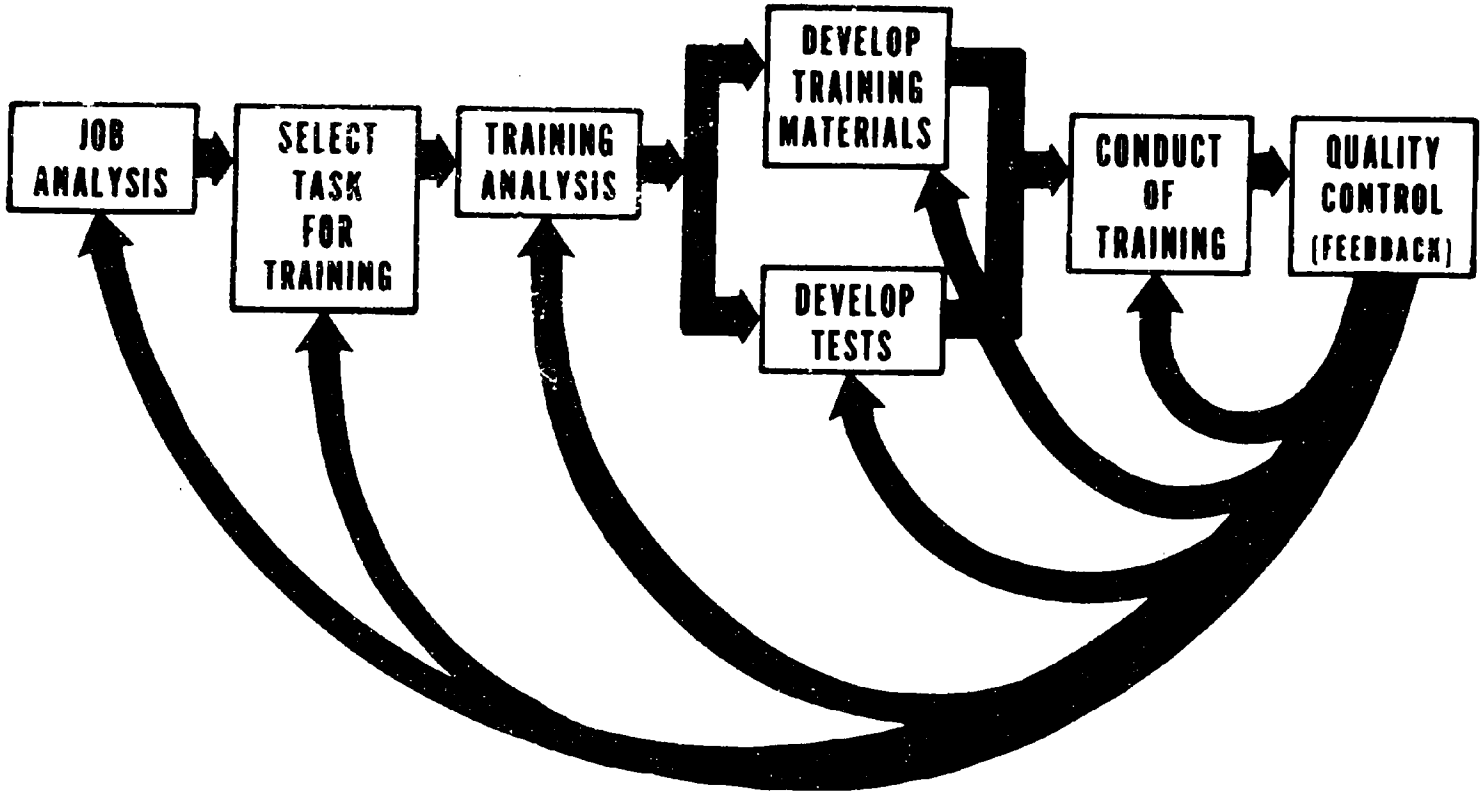

Figure 2. Systems Engineering of Training

REFERENCE:

GRAPHIC AIDS SERVICE CENTER
FORT MONROE, VIRGINIA

June 15, 1967

PHASE Preliminary	LOCATION MSR - Electronics Area - Transmitter (1) - Buffer Control Monitor (1)	TASK NUMBER 23-BBCA-G1B
SECTION III		TASK TYPE Fault Locating
PERSONNEL 1		
TIME 0.01		
FREQUENCY	NOMENCLATURE	NUMBER
EQUIP STATUS 3	Test Equipment Control Panel (1)	
PRIORITY CODE 3		

KNOWLEDGE AREA							SKILL	TOOLS, EQUIPMENT, MATERIAL
MECHANICAL	HYDRAULIC	PNEUMATIC	ELECTRICAL	ELECTRONIC	DIGITAL	OTHER	F Fixed Procedure	NA

STEP NUMBER AND PROCEDURE

HAZARD: NA

NOTES

x

This procedure describes the action required to locate faults in the Buffer Control Monitor.

1-With the Low Level Transmitter energized, observe the following fault lights on the Test Equipment Control Panel

Fault Light	Normal Indication	Fault Indication
-48V PWR SUP	Lamp extinguished	Lamp illuminated (red)
-5V PWR SUP	Lamp extinguished	Lamp illuminated (red)
+12V PWR SUP	Lamp extinguished	Lamp illuminated (red)

FIGURE 3. SAMPLE TASK AND SKILL ANALYSIS FORM

problem that existing regulations do not provide sufficient guidance for initiation of a TASA effort and definition of its contents.

The second significant item regrading the initial TASA effort stems from the deficiency just discussed. Since the TASA was solely an engineering effort consisting of very general information, the true value of a need for a TASA was not recognized and the contract was cancelled in September 1967. Some elements of the initial TASA contract were incorporated into the Technical Logistical Data program. This was an attempt to save money but resulted in a further deterioration of the TASA effort.

So instead of being on-schedule with a TASA program, this false start resulted in considerable delay. The situation was further compounded by a reduced time span in which to develop a training program and identify resource requirements. The normal schedule of events described earlier in this presentation is based on a five year production program. With SAFEGUARD, the training agency must operate within a four year interval due to a requirement for approximately one year of on-site training prior to equipment readiness date of the system. This means that the training community is deprived of that time element when the maximum amount of detailed information is available. As a result, many training decisions are made in a less than desirable environment.

During June 1968, CONARC requested that the TASA effort be revived with certain changes. The major change being that the contract provide for a behavioral science capability to insure completeness of the TASA product. Approximately four months later, this request was approved. It was directed that the overall TASA contract would be awarded to the prime weapon system contractor with the stipulation that a TASA subcontractor would be utilized to provide the behavioral science expertise. The prime contractor's initial proposal was to proceed with a basic engineering analysis with minimum involvement of behavioral science personnel. The Army objected to this approach and insisted that the behaviorist personnel participate in all phases of the effort and actually prepare the TASA products. The major difficulty centered around contractor reluctance to allow "outsiders" into their plants. In addition, the absence of behavioral science expertise in the contractor's training organization created communication difficulties. Unfortunately, TASA is still an art and it is not now possible to prepare specifications that can be translated into the desired product by engineers. The differences over the role of the TASA subcontractor were resolved to the Army's satisfaction and a contract was awarded during March 1969.

The contracting method for SAFEGUARD TASA produced further complications. The TASA contractor was under contract to the prime weapon system contractor and any direction or dialogue between the Army and the TASA contractor was through the prime. This lengthy channel of communications coupled with the absence of TASA "know how" within the weapon system contractor organization created additional problems. In future efforts of this nature, it would be desirable to have the TASA contractor report directly to the

Army. However, we learned that this is a very touchy matter.

Thus far, I have made the weapon system contractor out to be the guys with the "black hats." In all fairness, I must admit that we had our share of in-house difficulties. A major cause of many in-house problems was related to the lateness of TASA information. In the absence of this data, some agencies took certain positions based on what they considered the best information available. When preliminary TASA data produced indications that these positions were susceptible to modification, there was natural resistance on the part of some. In fact, some of this resistance reached the point of being an attack on the credibility of the TASA program and the TASA contractor. Fortunately, most of that is now behind us.

The first TASA product was delivered during August 1969 and we have received two additional deliveries since that time. Currently, we have a high quality program underway, but due to RDT&E funding constraints, the level of effort is somewhat lower than desired.

A second and separate TASA effort to provide data in the tactical support equipment area was initiated during July 1969. Tactical support equipment refers to those items of mechanical, electrical, and environmental equipment which provides support to the tactical equipment.

Our major difficulty in this effort has been the lack of equipment identification. By this, I mean that the contract has not been awarded for many of the items. Until contracts are awarded, we do not know the make and model that will be incorporated into the system, i.e., we do not know whether the chillers will be purchased from Carrier, Trane, or some other supplier. To get around this, we have identified typical systems that will be analyzed. In using this approach, we are "betting" that the selected items will require tasks, skills, and knowledges similar to those required by the typical systems.

Another difficulty has been in the data collection. In this instance, the behavioral science personnel are in more of an advisory role with engineering personnel actually completing the data collection forms. With this arrangement, it is difficult to insure that all data meets or exceeds minimum requirements. In addition, lengthy channels of communications and the absence of personnel knowledgeable in TASA techniques has made the job even more difficult.

In spite of the previously mentioned difficulties, we have been able to revive the TASA effort and get it on a firm footing. However, in many respects it has been a case of "too little too late." The three year period from initiation of the first ill-fated TASA effort in 1966 until the program was underway again in 1969 has proven to be very critical. During this period, planning for training devices proceded on the belief that tactical hardware provided the best vehicle for training. As a result, proposed training devices were governed by engineering considerations and approached the tactical hardware in cost, configuration, and complexity. Estimated cost of three major devices to support training for the Missile Site Radar, Perimeter Acquisition

SUBSYSTEM	EVAL NO.	REV.	SAFEGUARD TRAINER	TRAINING SCOPE
MSR	204-12	A	Receiver Group (TXE0001)	Check and troubleshoot keep-alive power supply in the microwave receiver
DATES 30 June 1970		7/11/70	(Subject equipment is actually missing from Receiver Group)	

POI NOS.	TDCF NOS.
024	13876, 12110

TOOLS & TEST EQUIPMENT

Simpson multimeter

APPL. TDCF		LEARNING ELEMENTS	TRAINER LOCATION	RESULTS OF ANALYSIS
13876	1	Locate keep-alive power supply and appropriate MDS frames		Training cannot be accommodated, owing to the absence in the trainer of the Keep-Alive Power Supply Assembly.
	2	Check keep-alive power supply by observing built-in voltmeters		
12110	3	Troubleshoot keep-alive power supply assembly		Recommendation: Add appropriate trainer equipment.

FIGURE 4. TRAINER EVALUATION FORM

Radar and Data Processing System exceeded $100 million.

Since firm justification in terms of training objectives and student handling capabilities was not available, the need for these high dollar value items was not fully accepted by the SAFEGUARD community. In fact, a major reason for reviving the TASA effort in 1968 was to obtain sufficient information to support a production decision regarding training devices.

This decision was aided somewhat by the Presidential announcement to abandon the SENTINEL deployment in favor of SAFEGUARD which initially consisted of two sites. This deployment change resulted in a revised training concept which limited training devices and equipment for resident training to those items required to conduct only that training which could not be conducted on-site without unacceptable degredation of the tactical equipment.

Since sufficient TASA data was not available for identification of needed training devices for SAFEGUARD, initial estimates were based on engineering proposals provided by the weapon system contractor. The initial contractor proposal has been modified considerably and we are now looking at a cost figure in the order of $60 million for the three major areas identified previously. I wish to emphasize that certain of these modifications have resulted from information obtained from the TASA program. In addition, the weapons system contractor has been directed to utilize the TASA data in a continuing evaluation of training device capabilities. Figure 4 is a sample evaluation prepared by the TASA contractor. Currently, this is our most reliable technique for identifying the capabilities and limitations of current plans for resident training.

Since TASA data is now available in meaningful quantities we are in a position to identify requirements with greater accuracy and confidence. For example, during 1968 it was thought that the major training devices, the ones that approximated tactical equipment, would satisfy all resident training requirements and handle the student loads for the large SENTINEL deployment. With what we know today, it is questionable that these devices as originally designed could have handled the student loads for the current two site deployment. So with that, I will end this presentation by paraphrasing a high ranking officer who said "Thank you for not letting us buy the major devices." This statement is doubly significant, since the officer was at one time the staunchest supporter of the major training devices.

Hopefully, this series of experiences will serve to illustrate some of the difficulties encountered in implementing regulatory requirements relating to TASA within real time constraints that exist during development and production of a major weapon system.

CHAPTER 5
COMMAND AND CONTROL FOR SAFEGUARD ABM

Chairman: Edward M. Hudak, Colonel
Headquarters, U.S. Continental Army Command
Fort Monroe, Virginia 23351

5A. INTRODUCTION

Albert R. Kubala
Human Resources Research Organization, Division 5
Fort Bliss, Texas 79916

Good afternoon, Gentlemen. HumRRO Division No. 5, located here at Fort Bliss, initiated its command and control studies in 1964. Just prior to that time, we had been asked to provide some advisory services by the agency that is now known as SAFSEA, or, the Safeguard System Evaluation Agency. During the course of providing these advisory services, we came to the conclusion that we might make a real contribution with more extensive studies in the command and control area. And, as a result, we initiated our first exploratory research in the area in December 1964. The command and control area continued to appear to be fruitful. So, beginning in Fiscal Year 1967, a full-scale Work Unit was initiated, and we have been actively involved since that time. Although SAFSEA is our sponsor, we have tried to keep our efforts general in nature. That is, we have tried to look at man's role in command and control in any highly motivated system, rather than tieing ourselves specifically to Safeguard. Hopefully, then, our command and control concepts will be generalizable to any complex man-machine system.

One of the speakers in this session, Dr. W. H. Melching, worked in this area from the time of the initiation of the exploratory research until mid-1969. Dr. Melching obtained his Ph.D. degree in psychology from the University of California at Los Angeles in 1953. Before coming to HumRRO in 1961, Dr. Melching worked at the Primate Lab in Austin, Texas, and also taught at Texas Technological University in Lubbock, Texas.

The paper being presented by Dr. Melching is co-authored by Dr. H. L. Ammerman, also of HumRRO.

The other speaker in this session, Dr. G. L. Neal, obtained his Ph.D. degree in psychology from the University of Oklahoma in 1966. Dr. Neal has a long history of association with HumRRO. He has held positions in three of HumRRO's seven Divisions. Upon graduation from the University of Oklahoma, he was employed by HumRRO Division No. 5 here at Fort Bliss. While at Division No. 5, Dr. Neal spent his last year working in the area of command and control. He left HumRRO in the summer of 1968 to take a position with SAFSEA, where he is now employed.

The paper presented by Dr. Neal is co-authored by Mr. Robert O. Wood. Mr. Wood is also an alumnus of HumRRO, now employed at SAFSEA.

I give you Dr. Melching.

5B. MAN IN CONTROL

Harry L. Ammerman and William H. Melching
Human Resources Research Organization, Division 5
Fort Bliss, Texas 79916

INTRODUCTION

I would like to discuss with you today a topic of growing importance in the human factors field. The general area involves a continuing concern over what man should do in complex highly-automated man-machine systems to exercise his prerogatives of command and control. The importance of this general topic area is evident by the number of papers being presented at this conference concerning the role of man in such systems. While many of us have developed our concerns and ideas in relation to one specific weapon system, such as SAFEGUARD, the concern goes beyond a particular system. It involves the whole issue of what man can do, what should man do, in controlling highly automated systems, particularly during tactical operations.

Today I will discuss some ideas that have evolved out of HumRRO's work with the Nike-X/Sentinel/Safeguard systems over the past five years.

First, I will outline the human factors considerations that guided our planning efforts. Next, will be a discussion of concepts for defining man's command and control functions or role. Some training considerations will be mentioned briefly. All of these conceptual frameworks provided the basis for preparing an early detailed description of operator jobs. My concluding remarks will describe the format and nature of one descriptive analysis that helps pinpoint a variety of human factors considerations.

These notions apply to any newly evolving highly automated man-machine system that is concerned with situation uncertainties and should apply to any reasonably complex man-machine system in the development stage. Our concern was to conceptualize a role for man in advance of an operational system and to examine training appropriate to such role. Obviously, maintenance of a system will be a major manual function, but significant concern for the command and control aspects of system operation are also highly critical.

HUMAN FACTORS CONSIDERATIONS FOR COMMAND AND CONTROL

Our human factors considerations with respect to command and control

training revolved about six major issues. They are shown in Figure 1.

1. Meaningfulness of Manual Roles
2. Training for Performance Reliability
3. Contingency Operations
4. Control Decisions
5. Information for Decision Making
6. Control Devices

Figure 1. Manual Performance Issues

Item 1: The Meaningfulness of Manual Roles. That is, the basic functions that are to be performed by man should be intrinsically of significant value in the accomplishment of the system mission.

Item 2: Training for Performance Reliability, with concern for things such as:

a. Error rate,

b. Criticalness of potential errors, and

c. Ease of learning.

Item 3: Definition of contingency operations to include autonomous and emergency operations, as well as special system missions.

Item 4: Definition of operational decisions for each controller position and level of command.

Item 5: Needs and availability of information for decision-making performance.

Item 6: Needs and availability of control devices for implementing decisions.

While important, we were not directly concerned for such human factors considerations as knob and dial shapes, stress, discrimination, sensory thresholds, target tracking, etc.

In newly evolving man-machine systems, one of the initial problems is the tentative identification of what man should do as a decision-maker and controller within the system operations. Constraints on analyses that can be performed include such things as: (1) very little information exists as to precisely how the hardware system will operate, (2) the equipment configuration frequently changes until the system goes into the production stage, and (3) no experienced personnel exist to observe or who can describe how they perform their jobs. Thus, human factors specialists and others concerned with the system operation are faced with the difficult chore of determining what tasks and functions man will perform, in relation to the system operations.

MAN'S ROLE IN COMMAND AND CONTROL FUNCTIONS

All too frequently the discouraging conclusion is heard that man has almost no command and control role in highly-automated systems. Rather, he is expected to keep the system in an operational state, and the system will carry out its own tactical operations without man's intervention. This relegates man to a purely maintenance function. Despite the apparent reasonableness of such a conclusion, that conclusion is generally unacceptable to those who are charged with the responsibility for the system mission. They desire a meaningful command and

control role for man. Thus, it is up to the human factors specialists and other decision makers to create such a role.

Now let me briefly outline some notions which are evolving with regard to the nature of such roles, as they have been visualized in one work effort. This certainly will not represent any final answer to the problem, but it is hoped that these concepts may help stimulate useful discussion of the matter.

In Figure 2 are four basic functional concepts used to define the decision roles of man in command and control.[1] The first is a fa-

1. Facilitate System Functioning
2. Override (Bypass) System Malfunctions
3. Control System Degradation
4. Permit System to Operate

Figure 2. Functional Command and Control Roles

cilitating function, the next is an overriding activity, the third represents anticipatory control, and the fourth is a permissive function.

The role of facilitating system functioning (Figure 3) is basically

a. Manual augmentation

b. Enhance system capability

c. Monitor trends and patterns

Figure 3. Role 1: Facilitate System Functioning

one of augmenting an otherwise adequately functioning system by providing important information and directives to it. Man would essentially monitor the system for trends toward out-of-tolerance conditions and evolving patterns or conditions, taking advantage of his unique capability in such areas as pattern recognition, data relationships, unprogrammed items, recent information updating in real time, and knowledge of events that the system can not sense.

The second role (Figure 4) is essentially a maintenance-monitoring function, in which man would

a. Maintenance monitoring

b. Manual bypass of malfunctions

Figure 4. Role 2: Override (Bypass) System Malfunctions

monitor for gross errors of computer output with respect to important system actions and decisions. His control is exercised by allowing for manual bypass of the system malfunction for those machine errors that do not require immediate maintenance.

The third role (Figure 5) serves to prevent system destruction by

a. Allow for "graceful degradation"

b. Anticipatory monitoring

c. Preferential treatment

d. Traffic management (reassign functions)

Figure 5. Role 3: Control System Degradation

allowing for a graceful degradation of system operations in lieu of a complete system or subsystem collapse. It

[1] Melching, William H. A Concept of the Role of Man in Automated Systems. HumRRO Professional Paper 14-68, May 1968.

represents the anticipatory monitoring of system functions to detect and prevent system overloads and subsequent deteriorations, and to allow man to institute a program of preferential treatment. This could be viewed as a traffic management task in which man might reassign manual or automatic functions to other portions of the system as requirements exceed programmed limits.

The fourth and final decision role (Figure 6) for man is a permissive one, wherein man decides on

a. Determine need for system performance

b. Determine level of operation needed

c. Force system to function

Figure 6. Role 4: Permit System to Operate

the need for the system to operate to accomplish the primary mission. Man may allow or force the system to operate at a level consistent with the threat status of an opponent. Additionally, he might enable the system so that it can handle a situation that it is not anticipating, or had not intended to handle.

These role concepts are defined so that work assignments may incorporate more than just monitoring of events and maintenance of the system. They provide the underlying rationale for postulating specific manual functions.

In addition to the four manual command and control concepts, there are other considerations which aid in the preliminary designing of job positions. Some of these are briefly cited in Figure 7.

1. Task value

2. Level of responsibility

3. Work load balance between personnel

4. System restrictions and requirements

5. Homogeneity of task purpose

6. Control devices provided

7. Minimal crew coordination needed

8. Minimal voice communication

9. Comparable functions at each command level

10. Reasonable task loads across time

11. Means available for exercising control

Figure 7. Some Job Design Considerations

It is assumed that command and control personnel should be assigned work tasks having a value and degree of responsibility consistent with the rank and command level of the person filling the position. The manual tasks should have value in the sense that their performance does directly influence system operations. They should contribute significantly to the probability of system success in attaining its mission goals.

In the process of designing command and control job positions, it is necessary to allocate specific tasks to each operator with due consideration for balance of work load, system restrictions and

requirements relevant to the command level at which the job exists, and homogeneity of purpose of assigned tasks. With respect to work load, it is probably best to give each controller a few meaningful long-duration tasks as well as a variety of short-duration infrequently-performed task activities. Monitoring of events or system status should be avoided unless specific control devices are provided by which the person could do something about the situation he is monitoring. Where operational time is short and critical, there should be little or no requirement for close or rapid coordination between command centers or crew personnel. Voice communication should be minimal or eliminated for normal tactical functions, reserving such interaction for emergencies and special missions. Not only would this conserve operational time, but it should decrease the amount of team training needed. Creation of reasonably comparable functions in different levels of command centers would be beneficial when personnel are transferred between system locations. Various kinds of operational situations or tactical engagements need to be analyzed to assure reasonable task loads for each operator across critical time intervals.

If man is to function effectively as a system controller, he must be provided with the means by which to exercise his control. For example, he needs information that will tell him what the machine is doing, how well it is performing, what it is planning to do next, where it is operating adequately, where it may be in need of assistance, and predictions of future states of affairs. He also needs to be provided with appropriate sets of procedures, decision rules, and control devices. These are necessary to enable him to act upon the information that he has been given. And, obviously, this information is also needed for development of effective training programs.

TRAINING CONSIDERATIONS

Let us consider for a moment some training considerations for command and control personnel. (See Figure 8.) To simplify training and allow

1. Minimize need for non-decision types of skills
2. Pushbuttons and light pens--versus--teletype
3. Homogeneous task groupings
4. Information displays:
   a. Organized and summarized
   b. Useful
   c. Timely availability
   d. Consistent symbology
   e. Meaningful symbology
5. Describe manual tasks

Figure 8. Some Training Considerations

a concentration on those things which are most essential, it appears that skill requirements other than for decision-making skills, should be minimized in the job and in the formal training program. This would allow for easier development of simulation exercises using lower-fidelity and less-expensive training aids and equipment for a significant portion of the training. Interaction with the computer should be generally of the pushbutton or light pen type, reserving the use of the teletype only for specially-trained

technicians. Tasks grouped together to form each operator position should be based on relatively homogeneous sets of tasks, requiring a minimum of differential kinds of skill training for a given operator on the job.

The identification and use of information to be displayed or presented to an operator is also of concern. Obviously in a highly-automated system there are great masses of data within the system which could be made available to a commander or controller. Such data need to be organized and presented to the controller in a most useful and timely manner so as not to overburden the individual with unnecessary information during times of highly-critical activity. Information presented in the form of display symbology needs to be used in a consistent manner on the various control consoles, and, to the extent possible, the symbology needs to be meaningful to the operator. There should be a minimal amount of color coding since there are likely to be many other codings already presented on consoles and visual displays, such as shape coding, location coding, symbol codes, and sequence codings.

If training goals are to be stated in terms of student performance objectives (that is, in terms of job actions, performance conditions, and proficiency standards), then early in the design of command and control positions it appears most useful to formulate initial basic descriptions of the manual tasks involved. These task descriptions serve to establish display and control requirements, and they serve as a framework for fitting new ideas into the command and control scheme as they may evolve from growth and modification of system knowledge.

POSITION ANALYSIS

This formulation of basic task descriptions leads me into the last topic I wish to discuss. That is, the analysis of individual positions. Given the preceding efforts to conceptualize man's role in a complex system, there is then a subsequent need to clarify the specific activities assigned to each job position within the command and control subsystem. One such clarification can be accomplished by the procedure we have labeled as a Position Analysis. This form of analysis aids in pinpointing a variety of human factors problems for further study.

Once a number of functions are postulated for performance by controllers within command centers, it is then possible to group these functions by hypothetical operator positions. It is most likely that various such groupings will be postulated during the development of a system. A position analysis format that I will describe represents one way of keeping track of such tentative plans, and of providing a foundation for revisions as they occur. It is a rather simplified format for readily describing each job position. (See Figure 9.)

1. Decision-Making Actions
2. Information-Gathering Actions
3. Controlling Actions

Figure 9. Types of Manual Activities

Three main types of activities are recognized within each position: (1) decision-making actions, (2) information-gathering actions, and (3) controlling actions. It is assumed for many, if not all, command positions that decision-making

functions are most critical manual functions for mission success. Therefore, these decision actions tend to serve as the focal points of the analyses. For each decision identified, an attempt is made to determine the information that would be available for use in making that decision, and to identify the controlling action that would follow the decision. In other words, decision actions are related both to prior and to succeeding manual events. The first step in analyzing a position consists in recording all actions assumed to be performed by a controller in that position, plus a listing of all items of information available to him or used by him in performing his job. These materials provide the basic data for the analysis of each position.

In Figure 10 are four statements depicting decision actions that might be made by a commander.

1. Select one of four possible readiness levels at which the system is to operate. [READINESS LEVEL switch]

2. Estimate the time required to prepare for a tactical engagement.

3. Determine when to give a firing unit permission to launch. [PERMIT switch]

4. Select one of three possible tactics to use in combating a given attack. [TACTICS switch]

Figure 10. Examples of Decision-Making Actions

Where a given decision is preceded or followed by use of a particular console switch, this additional information is given in brackets following the statement. The examples in Figure 10 show he might select an option, estimate time, or determine when to operate.

In Figure 11 are four statements of information-gathering actions that a commander might perform.

1. Monitor the CRT Engagement Display.
   (To aid in establishing an appropriate readiness level for the system.)

2. Depress INTELLIGENCE switchlight.

   (To display on CRT the latest intelligence information available to the system.)

3. Tag a given land area on the CRT display and depress MAGNIFY switchlight FULL.

   (To obtain an enlarged view of a given land area.)

4. Communicate orally with other console operators, either directly or by telephone headset.

   (To coordinate site actions.)

Figure 11. Examples of Information-Gathering Actions

When the action involves the use of a particular switchlight on his console, this switch is again identified. For further clarification, the purpose of each physical action is given in parenthesis following the statement. Information gathering includes such things as monitoring displays, calling up new information, and obtaining information by oral communications.

Figure 12 shows four statements of controlling actions. In addition to naming relevant switch controls, the purpose of the physical action is stated in parentheses

1. Depress TACTICS switch A, B, or C.

   (To instruct a firing unit regarding the tactics it is to employ in engaging targets.)

2. Depress the PERMIT switch for a selected firing unit.

   (To inform a firing unit that it has been given permission to launch.)

3. Depress the switch for the present readiness level.

   (To inhibit an increase in readiness level as requested by a subordinate firing unit.)

4. Tag an object on the CRT and depress DESIGNATE TARGET switch.

   (To indicate a target to the system computer.)

Figure 12. Examples of Controlling Actions

following the statement. For the most part, these actions represent the giving of orders to the automatic system by means of depressing appropriate console switchlights.

Figure 13 shows one means of listing the information that could be made available to a commander or controller. Because there is such a wide variety of diverse information, it is useful to indicate where the information might most likely be presented man. Thus,

<u>Engagement Display (CRT)</u>

1. Location of each enemy penetration.
2. Type of defense target being attacked.
   a. Area defense.
   b. Fire unit sites.
   c. Other military areas.

<u>Data Display (CRT)</u>

3. Value of defense targets in defended area.
4. Intelligence data being circulated to all commands.

<u>Console Indicator Lights</u>

5. Readiness level.
   a. Present level in which system is operating.
   b. Level requested by a subordinate firing unit.
6. Subsystem status.

<u>Other Information</u>

7. Weather data.
8. Missile stockpiles.

Figure 13. Examples of Information Items

we have information provided on a cathode ray tube, either showing the engagement map or providing digital data tabulations. Banks of indicator lights also may be useful to display readiness and status. Other information may come from teletypewriters, printed materials, and voice communications.

The four listings of actions and information items provide the basic description of a position, but there are several second-level products then possible to be derived. (See Figure 14 below.)

Job Position: XYZ Controller

Decision Action 1: Select one of four readiness levels at which the system is to operate.

Controlling Actions:

1. Depress the switch for the present readiness level.
   (Function: To inhibit an increase in readiness level.)

Decision Occasion: When a subordinate firing unit has requested an increase in its readiness level.

Decision Rules: None yet available.

Decision Information:
4. Intelligence data
5. Readiness level requested by subordinate site
10. Readiness level desired by higher headquarters
17. Nature of enemy threat

Information-Gathering Actions:

1. Monitor the CRT Engagement Display.
   (Function: To aid in establishing an appropriate readiness level.)
2. Depress INTELLIGENCE switchlight.
   (Function: To display on CRT the latest intelligence information.)

Figure 14. Decision Outline

For example, to provide an integrated picture of how decision actions are related both to information and controlling actions a special "decision outline" may be prepared on the basis of available information. Such a decision outline may record the following facts about a given decision. (1) The identification of the controlling action that would immediately follow the decision. (2) A statement of the function accomplished by the controlling action. (3) The occasion upon which the decision would be made. (4) The rules that are to be used to guide the making of the decision. (5) The information to be used in making the decision. (6) The identification of what information-gathering actions are associated with that decision.

Another second-level product that may be prepared from the basic list is a "matrix of information-decision relationships." An example of a hypothetical matrix is presented in Figure 15. In this matrix are tabulated all instances in which a given item of information is used or needed to arrive at a decision. The matrix assists in identifying those decisions on which information bases have not been adequately established. In addition, it will quickly show what information items serve no, few, or many decisions.

Information Item	Decision 1	2	3	4	5	6	.	.	.	.
1. Loc of enemy penet		x								
2. Type def tgt										
a. Area		x								
b. Fire unit sites				x						
c. Other mil sites										
3. Val def tgts			x							
4. Intell circulated	x	x								
5. Readiness level										
a. Present		x								
b. Req by sub	x									
6. Subsys status			x	x						
7. Weather data						x				
8. Msl stockpiles			x	x						
.										
.										
.										

Figure 15. Matrix of Information-Decision Relationships

Given that the previous listings and analyses have been accomplished, it is then possible to structure the various command and control activities into operator functional positions. This also permits the expansion of the analyses to include a number of other aspects. One of these additional analyses plots individual manual activites as they might likely be performed across time. (See Figure 16 below.)

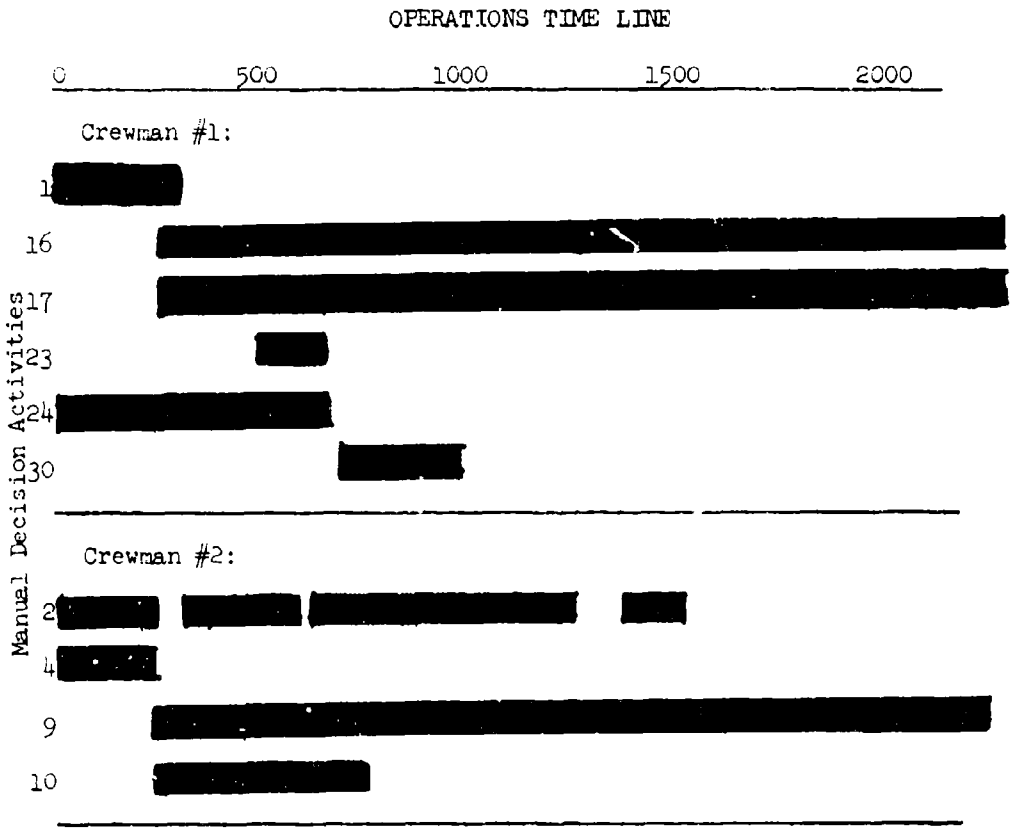

Figure 16. Position Activity Across Time

By hypothesizing a series of likely operational situations, the analyst can plot the time frame during which it is possible to perform the activity. Beginning and ending points of the activities are quite frequently dependent upon key operational points defined by the hardware system. Figure 16 shows a hypothetical time line for tasks assigned to two different controller positions, as they might be performed over 2,000 units of time. Within each position, a number of tasks need to be performed in rather short time frames. Quite often this represents activites or decisions that would be performed at the beginning of the tactical engagement. Additionally, one or two long-duration tasks are assigned to the individual, but typically he would not be assigned very many of these. By plotting a number of such time frames across a variety of typical gaming situations, the analyst can obtain some basis for judging the feasibility and balance of work assignments to each operator.

With these and other descriptive analyses, agencies responsible for development, testing, and operation of the system may then examine the descriptions of commander and controller roles for completeness, adequacy, and feasibility of assigned manual functions. The job descriptions prepared over time represent a series of approximations to the final command and control functions.

The Position Analysis, particularly in later versions, can serve three important needs: (Figure 17) (1) The intended user of the system can review the description and assess it for its completeness. (2) The designer of display and control consoles can evaluate present plans for consoles with regard to adequacy of location usefulness,

1. Review and assessment by system user.

2. Evaluation of control console plans by system designer.

3. Accumulation of task information by training agency.

Figure 17. Uses for Position Analyses

information, and availability of control devices. (3) The agency responsible for developing a program to train personnel to operate the system can accumulate and organize the information necessary to support an appropriate training program.

Various versions of the descriptions are likely to be incomplete and erroneous. Numerous omissions, incompatibilities, and inadequacies will probably be present. However, unless the job descriptions have been prepared in a thorough and rigorous manner, and reported in appropriate format, it may be extremely difficult for these omissions and inadequacies to be readily perceived.

Some specific questions that a reviewer may seek answers to are these: (See Figure 18.) (1) Are the decision actions that man must take clearly identified and stated? (2) Is the information man will need to make these decisions available in a form that he can use at the time

1. Are decision actions clearly identified and stated?

2. Is information needed by man available:

   a. In a form man can use?

   b. At the time it is needed?

3. Does man need information not provided to him?

4. Does system provide man unneeded information?

5. Are necessary control devices present?

6. Are control devices easy to operate?

7. Does system design utilize man's capabilities to a maximum extent?

Figure 18. Specific Questions to Aid Analysis

he needs it? (3) Does the system require man to use information that has not been provided as yet? (4) Does the system provide information to man that he does not need? (5) Are certain controlling actions required for which there are no appropriate control devices? (6) Are control devices easy to operate and conveniently located? (7) Has the system been designed so that man's capabilities can be utilized to a maximum extent? This last question is obviously of a different order than the others, and it can be evaluated only in light of the rationale underlying the overall system concept of command and control.

To answer these concerns, each decision, information-gathering, and control action may be evaluated using an explicit set of criteria.

Similarly, an evaluation may be made of each item of system information. Once each actions and information item has been judged, it is then possible to tally the judgments, and to summarize the findings for each of the several positions.

It should be noted that the several analyses are not only of value for what they contain, but for what they lack. The identification of an area of incompleteness or vagueness can be useful in understanding the status of a system.

One immediate use of such analyses, therefore, consists in providing an agency with a reservoir of questions about the functions postulated for system controllers. Tabulation of these functions in a comprehensive and systematic manner permits inconsistencies and possible inadequacies to be readily exposed and examined.

Finally, let me comment briefly upon the use of these analyses by training agencies. The primary use of the material would most likely be for the construction of statements of student performance objectives, in accordance with CONARC Pamphlet 350-14. The analyses, after being reviewed by relevant agencies, provide the justification for curriculum content and goals, particularly with respect to the need for student learning of background information and technical theory.

PRESENTATION OVERVIEW

With the series of concepts presented here today I have tried to present an integrated flow of some human factors considerations and procedures that might be helpful in the early stages of the development of a complex man-machine system. My discussion began with the underlying basic functions of man's role in command and control. This was supplemented by some considerations for training and the design of operational job positions. Subsequently, these issues led into the actual statement of the task activities for individual job positions. A variety of practical formats were presented by which interested agencies might analyze each position for completeness of description, adequacy of task allocations, and feasibility of assignments during various operational contingencies.

Obviously, there are many other analyses that need to follow these initial descriptions of manual functions before the man-machine relationships are finally established. It is particularly essential that investigations be made of the actual ability of man to perform the job tasks with respect to time for accomplishment and reliability of performance accuracy under various operational contingencies. To perform such evaluations, the next speaker, Dr. Neal, will describe the design of information displays and control devices by which man will likely interface with the machine system to implement his command and control activities in one specific system.

5C. MANUAL INTERVENTION FACILITY FOR CONDUCTING HUMAN FACTORS EVALUATIONS

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INTRODUCTION

Today I'm going to describe the SAFEGUARD System Evaluation Agency's (SAFSEA) Manual Intervention Facility (MIF) and its utilization.

The mission of SAFSEA is to perform an evaluation of the SAFEGUARD Ballistic Missile Defense System, independent of the SAFEGUARD System Command, its contractor organization and participating organizations. The MIF or Manual Intervention Facility is one of the tools we are using to conduct human factor evaluations of SAFEGUARD Command and Control subsystem.

In our presentations we shall (a) describe the purpose of the MIF: (b) describe the rationale for its design; (c) present a brief overview of our test and evaluation program; and, (d) describe the MIF design.

The HumRRO presentation described some of the early human factors work that HumRRO Division 5 performed in support of the NIKE-X and SENTINEL command and control studies conducted by SAFSEA under its earlier designations of SENSEA[1] and ESTO[2]. The MIF conceptualization is an outgrowth of these studies.

As a word of introduction, the MIF is a computer-controlled, real-time interactive, man-machine interface simulation laboratory for SAFEGUARD command and control studies. A significant feature of the MIF design is flexibility, which is achieved by a combination of modules hardware design and software control. These features permit a broad spectrum of command and control studies in which the man-machine interface, operator functions, and tactical environment can be systematically controlled and varied to permit accomplishment of the evaluation mission. We shall describe the MIF in more detail later in the paper.

DEFINITIONS

Let us now define how we are using the terms <u>control</u>, <u>command</u>, and <u>manual intervention</u> in our evaluation program.

---

1. SENTINEL System Evaluation Agency
2. NIKE-X Engineering/Service Test Office

Control is defined as a collection of in-line functions required for an active defense. These functions may be assigned to man or to machine.

Command is considered to be a collection of rules, constraints, requirements, and alternatives imposed on control functions prior to and during the execution of an active defense.

Manual Intervention refers to man's exercising assigned command and control functions in any complex, highly automated man-machine system, where tasks are allocated between man and machine and where man may be in parallel or in series with the system. Man's job in such a system is to decide if criteria have been met for him to perform a permitted manual function and to carry it out if the criteria have been attained.

SIMULATOR FACILITY DESIGN CONSIDERATIONS

In the SAFEGUARD System, the planned role of the command and control (C/C) officer is to manage the system: (a) to insure that the system reacts to a threat only when directed by competent authority; (b) to increase the flexibility and/or adaptability of the system to assure that the automatic system provides the best possible service in response to the total strategic environment and tactical situation; and, (c) to direct the system response and organization so as to minimize performance degradation.

The C/C officer accomplishes assigned functions by implementing management decisions by selecting appropriate action options which initiate pre-programmed operating rules, modes, and responses. During the course of operations the officer may modify selected action options on the basis of system information feedback to him via system information displays.

To conduct command and control studies appropriate to our mission, we needed a simulation system which would permit us to emulate SAFEGUARD man-machine function allocations where some functions are assigned to the machine, some to man, and some can be performed by man or machine. This conceptualization of function allocation is illustrated in Figure 1.

Next, the system had to have the capability to permit us to accomplish five basic mission-related objectives, each of which leads to a large variety of studies:

1. Evaluate the command control system--to include:

a. At least three levels of tactical command and control--national, regional, and local, singularly or in interaction;

b. Operating rules, such as tactical SOPs; and,

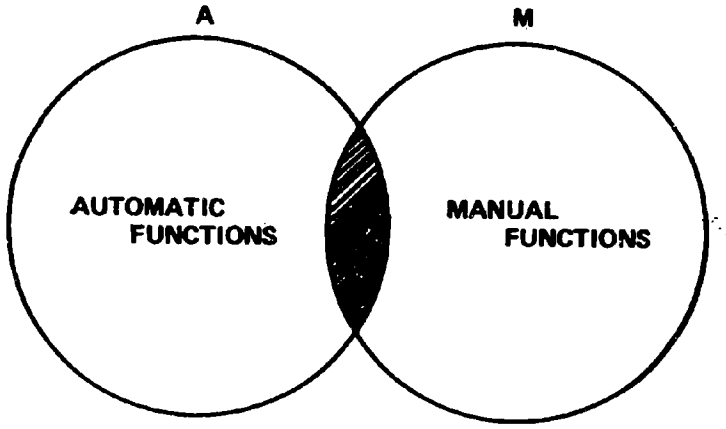
c. Maintenance command and control centers.

2. Evaluate and verify manual command and control functions--to include:

a. Verification of proper allocation of functions between man and machine;

b. Verification that manual functions have been properly allocated to level of command and control;

c. Verification of proper allocation of functions among operators



$F\text{-}AUM = \{$ALL C/C FUNCTIONS IN SAFEGUARD

$F_A = A \cap \overline{M}$ = AUTOMATIC FUNCTIONS

$F_S = M \cap \overline{A}$ = MAN IN SERIES

$F_P = A \cap M$ = MAN IN PARALLEL

FIGURE 1. MAN-MACHINE RELATIONSHIPS IN SAFEGUARD COMMAND AND CONTROL

within any given command and control center;

d. Verification of the feasibility of functions with respect to system performance requirements; and,

e. Examining the desirability of functions with respect to system performance requirements.

3. Evaluate design concept--to include such factors as:

a. Display formats, information adequacy, control efficiency, and feedback requirements;

b. Operations center configurations;

c. Imposed task loadings and operator performance; and,

d. Coordination among operators.

4. Manual Intervention skill analysis. To determine special skill requirements for officer personnel assigned to ABM C/C positions to provide information useful in the selection and training of C/C personnel.

5. Train test subjects. To provide ourselves with the capability to train test subjects in the skills required in C/C since our evaluation program will precede the training of SAFEGUARD C/C personnel.

TEST PROGRAM CONCEPT

To accomplish these objectives our test program provides for, and the simulator design permits three levels of simulation (See Figure 2).

The three levels of simulation represent a continuum of studies of increasing C/C complexity and increasing fidelity of situational simulation. The nature of the problem, represented by the "decision diamond" in Figure 2, will determine the level of simulation selected for a test.

Level I simulations will be single console studies in which the focus will be on the single command and control operator station. Required inputs from other operators and C/C centers will be simulated under scenario control. For example, Level I simulation will be appropriate to display studies, console layout evaluations, and early stages of test subject training.

Level II simulations will be multiple console command and control simulation in which the interaction among personnel in a single command and control center is a critical variable to be considered in the evaluation problem. In Level II studies all key interacting operator stations in a single C/C center will be provided for. Required stimuli from sources external to the represented center will be simulated under scenario control. Level II studies will be appropriate to evaluations of command and control procedures, center configurations, and operator task allocations.

Level III simulations will be multiple console command and control simulations in which live interaction between two or more C/C centers is a critical variable. In these studies the key interacting operator stations at two or more centers will be represented. Level III simulations will have applications similar to that of Level II. The variety of possible Level III studies is presently restricted by hardware limitations. Figure 2 also shows several of the products and applications of the three

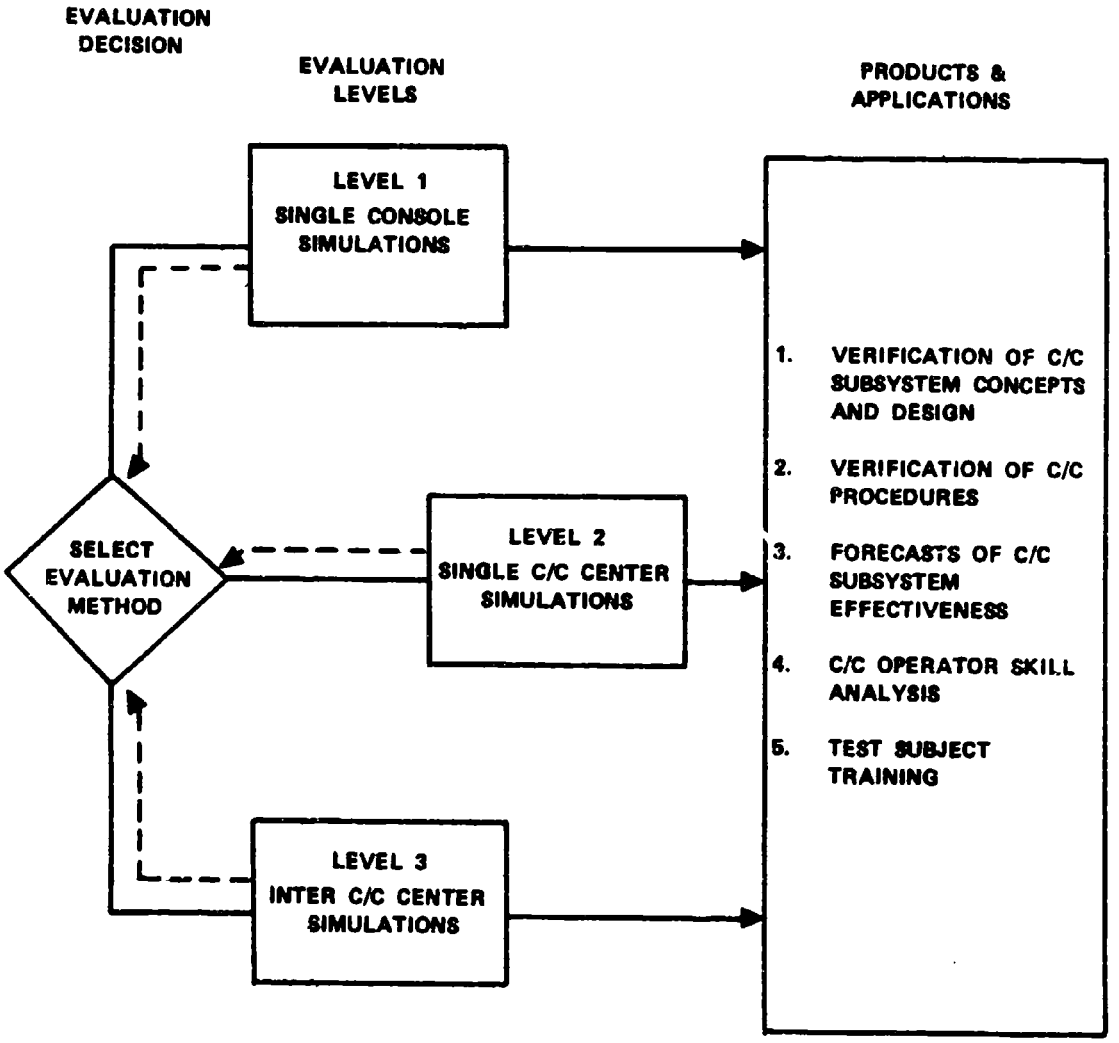


FIGURE 2. LEVELS OF EVALUATION AND THEIR APPLICATIONS

levels of simulation.

To drive the required simulations we are developing a set of software programs which we call Manual Intervention Driver's (MID). A MID is designed to drive the simulation of a C/C center to provide (a) all required operator console display and control functions; (b) critical stimuli for the operator response; (c) system feedback information to the operator; (d) threat representations; (e) system operation representations, and (f) a complete record of simulation events and operator responses to these events. The latter will permit recordings of response time, errors, and levels of response accuracy, Figure 3 illustrates the characteristics of several representative MIDs being developed. The figure shows type center being simulated, duty positions to be included, and simulation level. Note that all MIDs shown are Level II or III. A Level I simulation is provided by partitioning Level II or III MID software programs.

All MIF studies will contain the following elements: (a) a defined evaluation problem and associated test objectives; (b) an evaluation level which determines the complexity of the study and MIF configuration; (c) a scenario defining system and defense events, their sequences, permitted contingencies, and event stimuli; (d) a set of system operating rules; (e) appropriate test subject personnel; (f) an appropriate Manual Intervention Driver; (g) data collection plan; and, (h) a data analysis plan.

Our basic evaluation model will make use of baseline studies to provide basic C/C system performance estimates and to furnish control group data for comparative studies. A typical baseline study condition assumes a well-defined C/C center configuration, a set of standard operating rules, a normally operating C/C subsystem, no system degradation, and a reference threat. The effects of experimental variation in any of these factors will be assessed against the baseline system. Initially, in our program the baseline simulation will utilize the basic version of each MID program.

MIF DESCRIPTION

The MIF consists of the components shown in the block diagram in Figure 4: (a) a control-display subsystem consisting of four CRT consoles, eleven control consoles, tote board, and dynamic large screen display; (b) five VARIAN 620/i computers - a master and four slaves; (c) peripheral and maintenance equipment; and (d) a large computer (UNIVAC 1108) to "drive" the facility. An intercom system for inter-operator communication and simulation controller use is not shown.

The facility is capable of (a) real-time, interactive simulation by using the large computer for studies requiring operators to interact with the simulated SAFEGUARD system, or (b) real-time, non-interactive simulation by disconnecting the large computer, and playing "canned" exercises from the tape units. This non-interactive mode is intended for test subject training, critiques, and certain studies in which interactive simulation is not required.

Components of the MIF control-display subsystem are shown in Figure 5. The control-display subsystem configuration achieves flexibility through hardware modularity and software control. This system

BASIC PROGRAM	C/C CENTER	DUTY POSITIONS REPRESENTED (NUMERICALLY CODED) 001	002	003	004	005	006	007	008	SIMULATION LEVELS
MID 1	REGIONAL/ LOCAL		X	X			X	X		I, III
MID 2	LOCAL	X	X	X	X					I, II
MID 3	REGIONAL					X	X	X	X	I, II
MID										

FIGURE 3. MANUAL INTERVENTION DRIVER SUMMARY EXTRACT

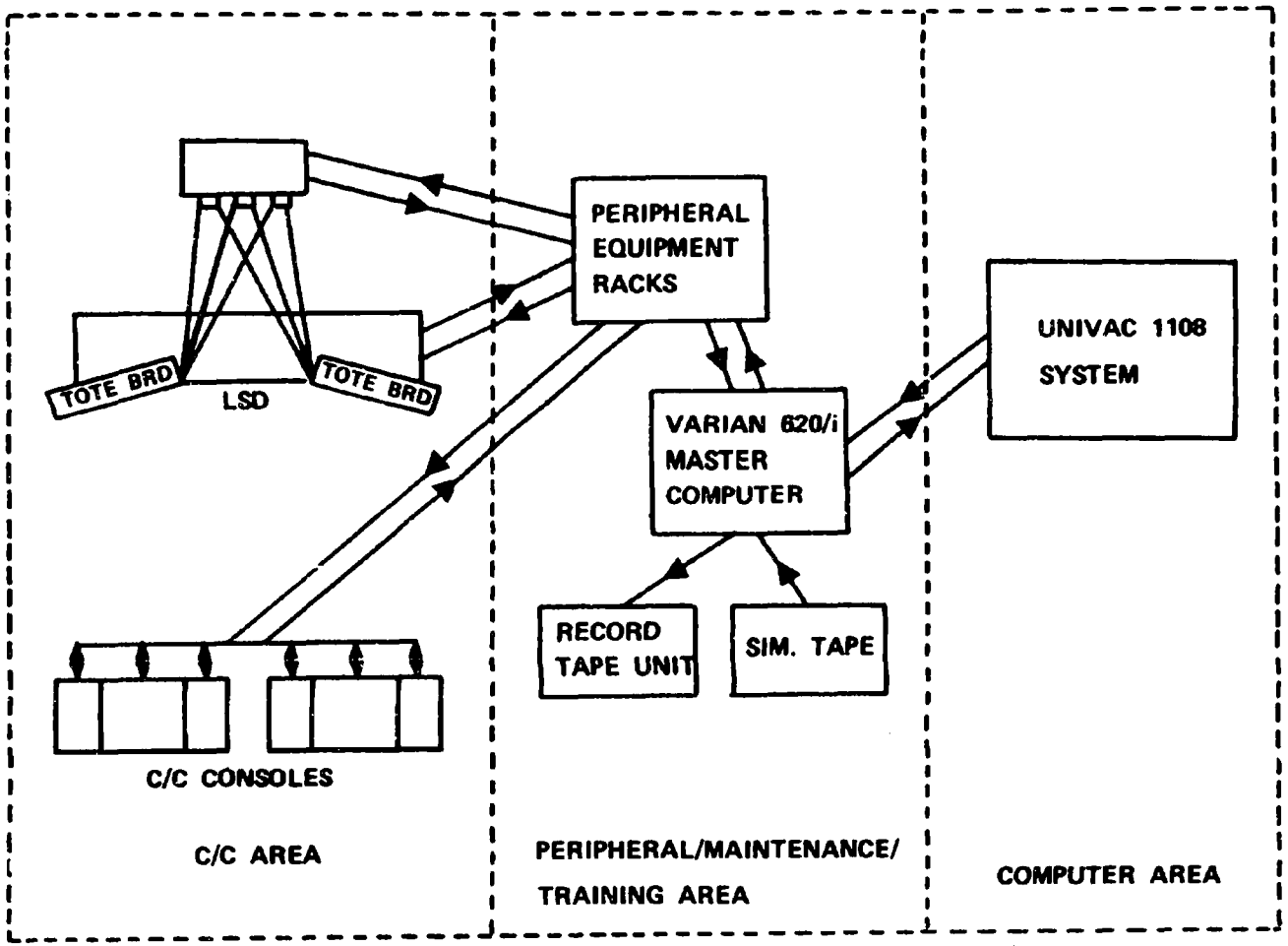


FIGURE 4. SAFSEA MANUAL INTERVENTION FACILITY

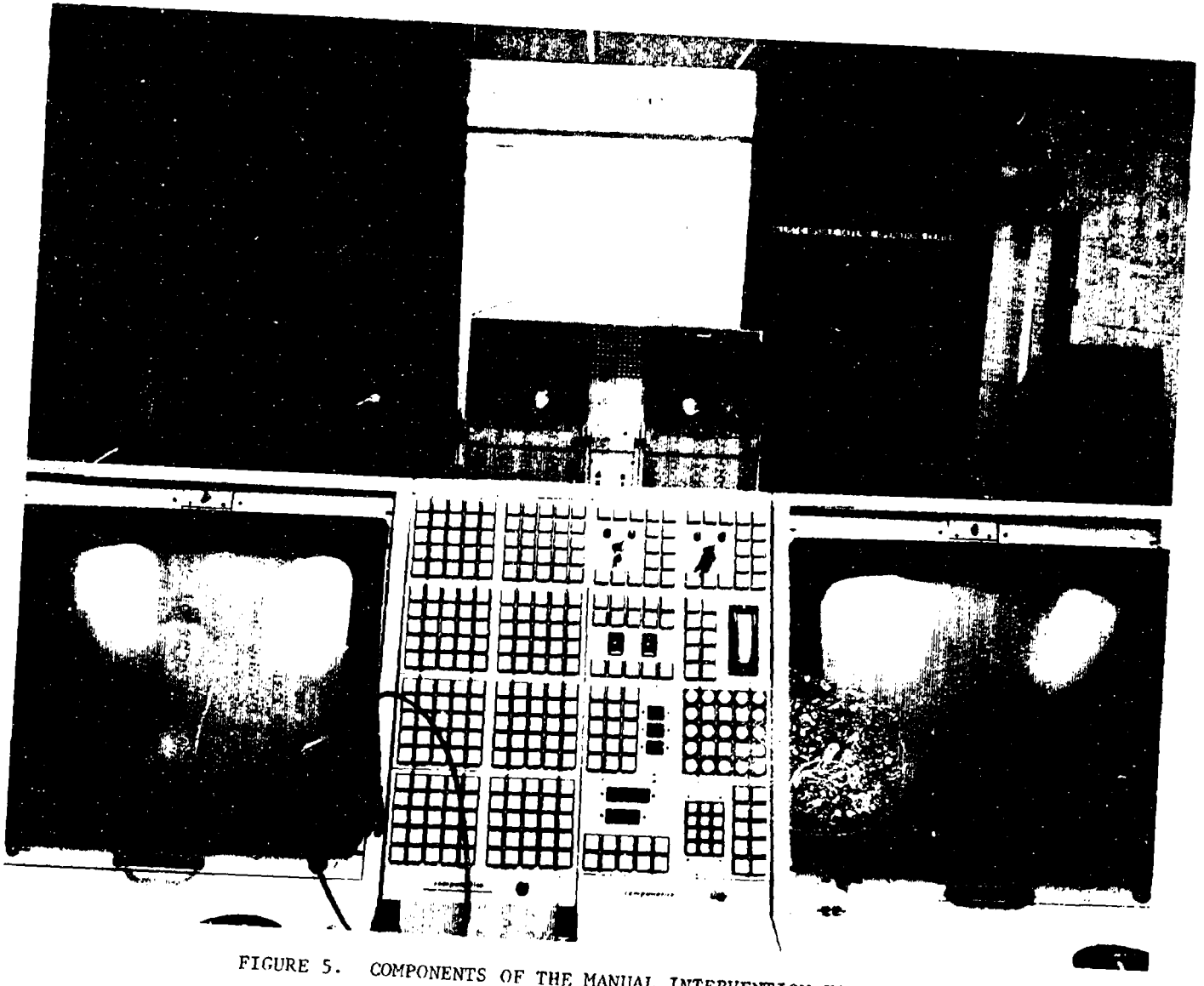


FIGURE 5. COMPONENTS OF THE MANUAL INTERVENTION FACILITY

consists of: (a) CRT consoles and control consoles which make up operator stations; (b) two tote boards containing indicator lights, back-lighted numeric indicators, and legend lights to display wall-type information found in C/C centers; (c) a large screen display system (not shown) utilizing a rear projection Nortronics Vigicon scribing projector system which has three color capability for the dynamic display of system status and tactical information in near real-time.

Four independent CRT consoles, each containing CRTs with 225 square inches of viewing area, are available for simulated operator stations. Two of the consoles are equipped with track ball input devices. All CRT consoles will be equipped with light pen input devices. This feature permits evaluation of the use of two types of input devices. All consoles--CRT and control--are equipped with casters to permit easy repositioning of console. Console mobility permits us to reposition consoles so that operation center configuration can be varied for evaluation studies.

CRT displays are software generated. We have the capability of generating four different CRT pictures simultaneously or four replications of the same CRT picture simultaneously. We also have the capability to program the system so that an operator can access any CRT display viewed by another operator.

Eleven independent control consoles will be available. Each console contains bays for eight 5 1/2 inch by 5 1/2 inch function modules. The control consoles are the same height (47.5 inches) as the CRT consoles and have the same mobility as the CRT console. The control consoles, their modularity, and software control add to the flexibility of control-display configuration.

Ten types of function modules will be available. These are shown in Figure 6. Each module can be utilized in any control console module bay. Unused bays are covered by blank magnetic plates. Each module is externally and internally reconfigurable. This means that push buttons and indicators can be selectively removed and covered by a plastic plate to permit us to vary push button and indicator configurations at operator consoles. All button and indicator functions are assigned and controlled by software. This feature permits us to evaluate various console control layouts. Figure 6 also shows the construction of the control consoles, their modularity, modular construction, and several of the module types available.

Operator stations are created by combining CRT consoles and the control consoles containing the module units. By combining operator consoles, the large screen display, and tote boards, as illustrated in Figure 7, we have a representation of a command and control center, which when driven by the appropriate Manual Intervention Driver, provides us with the capability to simulate a SAFEGUARD command and control center tactical environment in real-time. This capability provides our agency with a valuable tool which we are using to evaluate the SAFEGUARD command and control subsystem.

SUMMARY

In this presentation I have briefly described the SAFEGUARD System Evaluation Agency's Manual Intervention Facility designed for

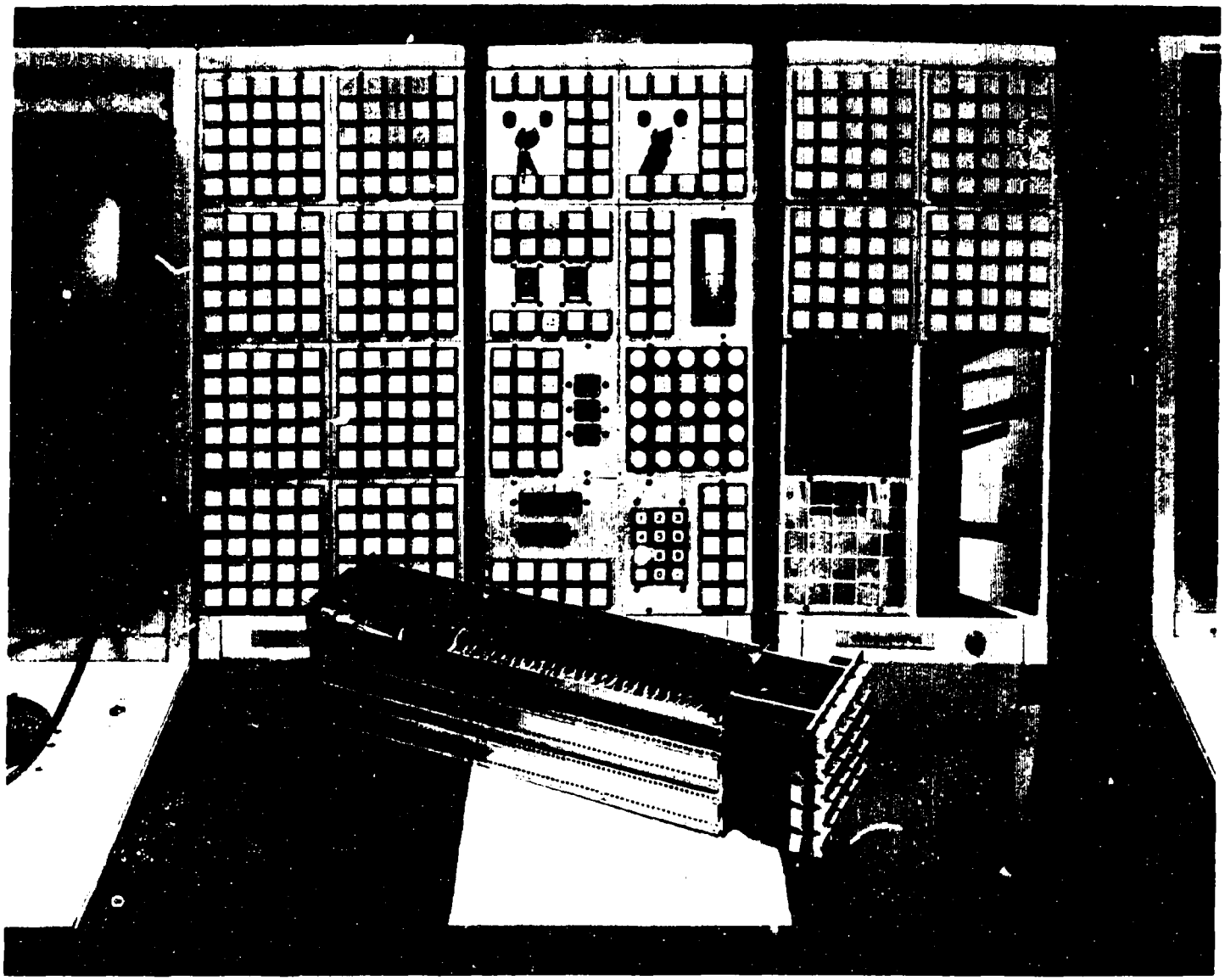


FIGURE 6. MIF CONTROL CONSOLE MODULARITY

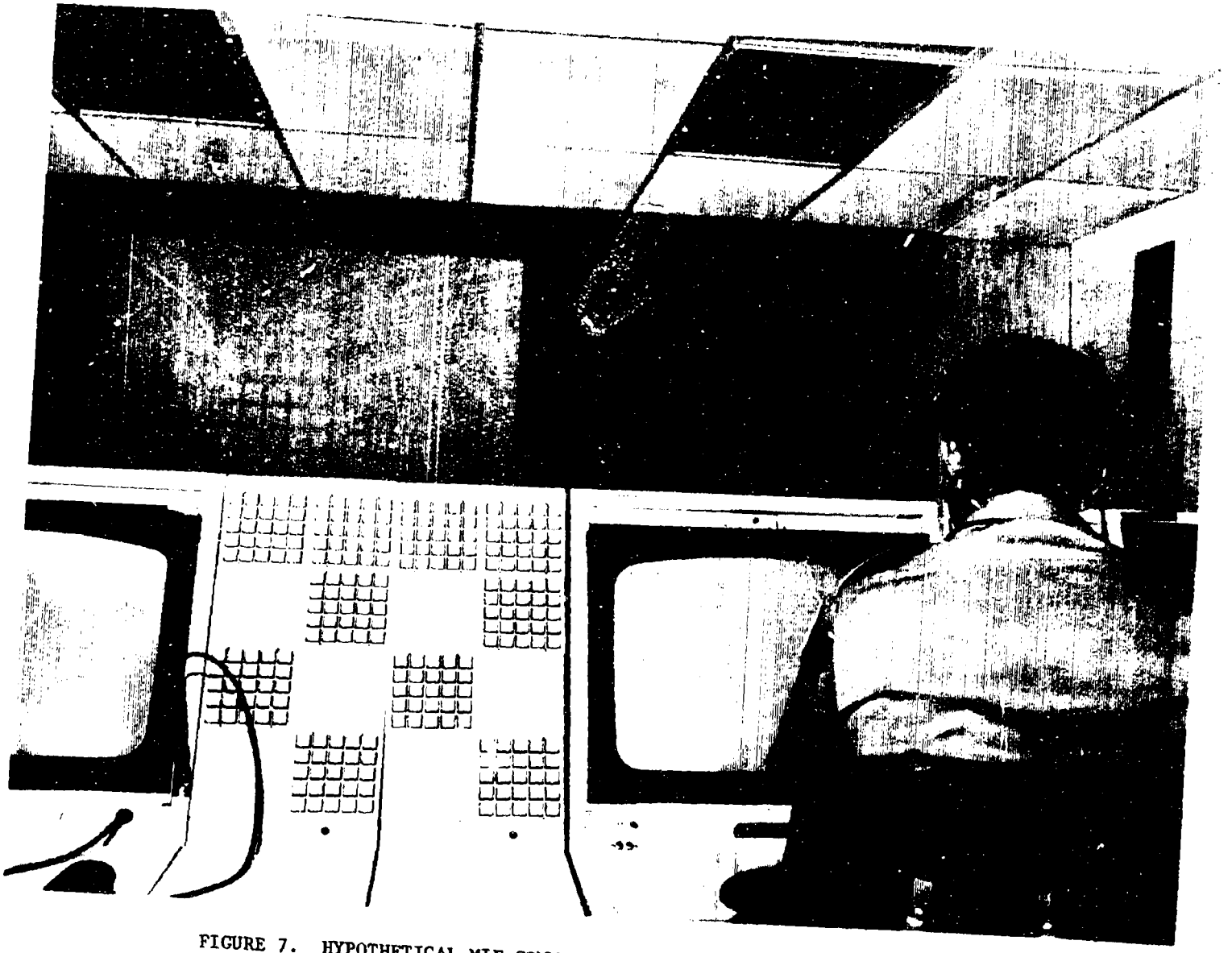


FIGURE 7. HYPOTHETICAL MIF COMMAND AND CONTROL CENTER CONFIGURATION

human factors evaluation studies of the command and control subsystem. I have presented some of rationale underlying its design capabilities, and I have presented an overview of our test program.

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5D. DINNER-SYMPOSIUM: MILITARY SOCIAL SCIENCE: CHALLENGE FOR THE FUTURE

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I had not planned on talking to you about human factors tonight. I would be foolish to attempt to do so to this audience; on this subject, it seemed better to take guidance from the admonition: "It is better to keep your mouth shut, and be thought a fool, than to open it and prove it."

What I would like to do for a few minutes here tonight is to explore the future with you, in a somewhat uncertain manner. For those of us who don't have in our possession a fortune teller's crystal ball, looking into the future necessarily shows us a rather dim and uncertain picture. Most of you as individuals, perhaps as a result of your background, training and experience will, I hope, be perceptive and sympathetic toward what I have to say.

A part of my responsibilities when I was involved in R&D matters in the Army was some long-range planning for the directions which research should take to help assure that the military hardware we needed would be the best science and technology could provide within the restraints of time and funding available. Parenthetically, we thought our planning was pretty good, but our developments always took longer and cost more than we anticipated; as I read the newspapers these days, I note that <u>that</u> situation hasn't changed. The broad outlines of how this kind of planning is approached are still pretty clear to me. The Army's general objectives are figuratively distilled out of a complex broth, whose ingredients are the pertinent portions of our national policy, doctrines, intelligence and technological studies or forecasts. The general objectives must be translated into less general, more quantified objectives or goals, such as operational capability objectives. Planning processes are started and as these proceed, technological barriers which stand in the way of achieving the objectives become apparent. From an analysis of these barriers, the research needs can be derived, and this helps set the directions of research programs, both applied and basic.

There was then, I think, a tendency to devote the major attention to research in the so-called "hard sciences," the resulting technology from which was envisioned as applicable to hardware which had to be developed.

This was true not only in military-related research areas

but in the country as a whole. The social and behavioral scientists were making nosies but not too many people were listening. Many of you probably recall the hearings conducted by Senator Harris about three and a half years ago on a bill to establish a National Foundation for Social Sciences. At that time, some of the testimony suggested that the advance in the physical sciences had gotten so far in front of the social sciences that we have to consider the possibility of a catastrophe as a consequence. It was also stated, Senator Harris was also told, that there is very real doubt in democracy's mind whether it really wants any more expert advice as far as the social sciences are concerned, "for this is peculiarly an area in which every single one of us thinks he is an expert and that if he is not enough of an expert, he would rather play it by hunch."

In a relatively few years, these attitudes have changed dramatically. There is now rather widespread recognition that our capability for generating and disseminating new technology has been greater than our capability for devising adequate organization to match achievements with aspirations. As we direct our attention to the demands of today's world and the needs of tomorrow's, a great majority of our problems are clearly of the sort to which the social sciences have and should increasingly turn their attention. Advancing technology has moved thousands upon thousands of people from hand tools to machine tools and from work benches to panels and buttons. And yet we really know very little of what this is doing to the meaning of work in human life. But at least I think there is now a realization that we should know what it is doing. Just a minor military example in passing. Admiral Rickover's views to the contrary, notwithstanding, I'm pretty sure that the human factors were given rather extensive attention in the design and construction of the nuclear subs. And yet the Navy is having a lot of trouble in holding crew members and in getting reenlistments. I'm sure that all the amenities have been provided -- but man is captive to the machine and he quits.

So what, you may ask, is all this about the social sciences? A few moments ago, I reviewed in a broad brush manner the steps in long range planning procedures for military hardware. Recall that one of the inputs forderiving the Army's general objectives was National Policies. Incrasingly, our national policies are including numerous social goals; you can all tick off several of these -- clean air, water quality, improving our environment in general; solving the problems of alcoholic and narcotic addition; reduction of interethnic and interracial conflict; reduction in crime; minimizing the alienation of much of American youth from society; solving the multiple problems of man living in urban settings; acceptable systems of mass transportation; efficient delivery of health services, etc.

The national defense policies are not a thing apart -- in isolation. They are influenced and affected by all of the other national policies -- just as, reciprocally, the other national policies are affected by our national defense policy. This is true on a broad national scale and it is true in the service club, mess hall and in an armored vehicle. Not too long ago, for example, the 7th Army experienced potentially serious racial problems arising from friction between our black soldiers and white soldiers. Such incidents could lead to a greatly reduced capability as a

combat-capable outfit -- and in a particularly important area, observed by our allies and our potential antagonists. Our social goals here have resulted in clear interaction with our defense goals.

This isn't a new situation in our history, or in the histories of other countries. About 2500 years ago, the Peloponnesian War went on for more than 25 years. The events leading to the outbreak of that war, the war itself and its aftermath are relevant to modern times, because they reflect the themes of domestic as well as international conflict and change. The confrontation was only in part a military contest. On a more important level, it was a clash in fundamental values and goals. The war was a situation which evolved from changing social values.

In our own country's history, we can identify numerous major interactions between our changing social values and their effects on the military. I'll take a non-Army example here.

During the first half of the 19th century, there was a growing participation of the rank and file of American society in the excitement and work of politics. Accompanying this was an increase of interest and activity in the welfare of all parts of the population. Doesn't this have a familiar sound today? American historians have characterized this as the "rise of the common man;" historians have noted that this interest in improving the lot of mankind embraced agitation on behalf of the Negro slave, workers, women, children, the poor, the insane, and the imprisoned, among others. Not too much thought or attention has been given to its impact on the country's military organizations. Here is one example:

As one reads Naval history from the end of the Revolution up to about the middle 1800's, a picture of the Navy develops as a kind of closed society -- one which you would think to be immune to influences from the American society exterior to it. Having been patterned on the British Navy, it began as something apart from a nation which had thrown off most of the vestiges of its colonial past. The monarchial organization and class outlook of the Navy were quite out of step with the democratic spirit of the country. Every warship was like a little kingdom that was ruled with a firm hand by a captain, assisted by junior officers who were analogous to nobles. The captain was the abolute ruler of this domain and life on board ship was usually lived far away from the sight and supervision of the authorities at home. Communications were pretty slow.

You may wonder, under these circumstances, how citizens generally could learn enough about the Navy to generate any concern. The shortage of sailors to man the ships provided the opening. Many aspects of naval life could easily be hidden from reform groups but recruiting methods could be studied quite easily. The flagrant abuses in enlistments and discharges which came to light gave impetus to a closer look at the Navy's organization and practices.

A whole host of reforms was gradually forced upon the Navy but I want to touch on only one of these, since in principle this long episode has some bearing on the main point I want to stress tonight. Flogging in the Navy was outlawed in 1850 after some years of effort on the part of humanitarian reformers directed to Congress. The majority

of Navy officers were sincerely convinced that discipline would be impossible onboard ship if flogging were abolished. In 1850, the Secretary of the Navy sent a circular to a number of officers asking their opinions on the wisdom of abolishing flogging. Of 84 who replied, only 7 felt that flogging could be abolished, and 2 of these were surgeons. No chaplains were quizzed. In the same year, a Senate Naval Appropriations Committee believed it was utterly impracticable to have an efficient Navy without flogging. It was their intention to publish a report to bring public opinion to the same conclusion. But the public opinion of the time wasn't so easily influenced. During the same year, Congress added an amendment to the Naval appropriation bill, approved by a very narrow margin in the Senate, which prohibited flogging in the Navy.

In today's idiom, discipline did not "go down the drain" -- the result was a much happier one. Flogging had been a keystone of discipline for so long that, when it was suddenly displaced, naval officers had to adjust to a serious new challenge. It called for the best qualities of leadership in the Navy. It was a proving ground where the inflexible or unimaginative officer showed up poorly. And it was also a testing ground for the men in the ranks; this was the time when the good, the industrious and the law-abiding must prove themselves anew.

This action, and other changes, laid the foundations for a career enlisted service. Opportunities were also held out for the talented and ambitious to rise to the commissioned ranks. These changes were the naval equivalent of the rise of the common man.

Thus, in the area of what we now would call perhaps "personnel management," significant changes were introduced in the Navy as a result of the slow but persistent pressures resulting from social reform movements within American society. It did bring in, and permit the Navy to retain, a higher-type enlisted person -- and this came about roughly at a time when the Navy needed better qualified and better motivated persons to cope with the increasingly technical nature of naval service. If some of you are interested, you might look for Herman Melville's novel, "White Jacket." He is far better known for "Moby Dick." This novel is a skillful piece of propaganda, drawn upon from his own service in the U.S. Navy in 1843-44, and has been credited with being more influential in "abolishing corporal punishment (flogging) in the Navy than anything else."

If we jump about 100 years, what do we find? We find the military services engaged in social-related efforts which were hardly dreamed possible when flogging was finally abolished. The services, and now I'll talk mostly about the Army, have been and are concerned with many things for the good of the common man. For those of you who are old enough, think back to the Army's creditable handling of the CCC.

The work camps of the CCC gave training and employment to 3,000,000 young men from the depression days of the 30's up until the early 40s. The work done was and still is of value, but of far greater significance was the saving of the spirits of millions of young people during those difficult times. The CCC didn't hurt the Army either; it gave experience in handling personnel to many regular officers, and reservists who were called into duty. The memories were apparently lasting ones; I read a few years ago where a CCC camp was holding a 30-year reunion -- both civilians and the military.

Now there is such a growing requirement for the military to assume responsibility for programs which seem to be strictly sociological in nature, that one magazine article asked the rhetorical question: "Is DoD becoming a sociological lion?" Today, military commanders are being asked among other things, to accept sub-standard recruits and draftees, assist in seeking outside employment for potential retirees, train near-discharge service men for civilian jobs and equip disadvantaged people for future government employment. The DoD supports these efforts but, understandably, some of our commanders concerned about doing their job well are raising some pertinent questions: -- Is DoD turning into a welfare society? Why should the military train people for civilian jobs? How can we expect people to re-enlist when they're greasing the skids to help these same people get jobs on the outside? Doesn't the OEO and HEW have these responsibilities and aren't they better equipped to deal with these social reform problems? These are good questions.

Secretary McNamara gave a major part of the answers to these when he initiated Project 100,000. He said in part: "Poverty in America affects our national security by its appalling waste of talent. In the technological revolution that is sweeping over the second half of our century, the prime natural resource becomes more and more the potential of the human brain. To the extent that this Nation loses the performance potential of these millions of human beings, to that extent this Nation's ultimate security is diminished." The DoD is not, of course, a social welfare institution. It's first responsibility is to provide the combat capability needed for national security -- but at the same time we have to be concerned with the broader aspects of national security -- all our national goals are significantly interdependent.

The military must provide a trained combat capability; beyond that, I think we have a responsibility to do what we can to produce good citizens. All in all, the Army has done a laudable job on these sociologically related programs; we usually bear the brunt of these tough assignments, but I think it is a complement to the Army that they are called on for the rough jobs, combat as well as non-combat.

The Army is not lacking in iniative in these matters, but for the most part, while we have responded well, we were told to do these things and have followed orders. I am convinced from my observations in a quite different environment during the last five years, that the social movements in which we are all caught up are going to be with us for a good long time. We must change our stance. I think it is no longer enough just to react to an existing situation.

Our experience in Indo-China has demonstrated rather conclusively, I believe, that having a combat capability in the usually accepted sense of the word is not enough. Counter-insurgency needs a lot more than that. From a combat viewpoint, I'm sure that our Special Forces can more than hold their own with the guerrillas. But I believe we were less than successful in what the British, in their inimitable way, call the Hearts and Minds program; capture the hearts and minds of the villagers; get and keep them on our side rather than the Communists (we call it civic action). There are numerous reasons why success eluded us, but that is another big subject.

The point I am making is that we

in the military have been involved in numerous programs related to social reform, and mostly because we were told to do so. We've learned a lot of lessons in Viet Nam but had to do it the hard way -- through bitter experience.

It is clear to me that there is going to be an increasing amount of sociological related programs in the military; civic action programs will continue to be important. I believe that it is time for the social scientists (and that includes behavioral scientists) to begin emulating their colleagues in the physical sciences and begin serious studies looking toward the longer range future. Start the groundwork for long range planning for basic and applied research of military interest (and relevance) in the social sciences to complement and parallel that being done in the physical sciences.

Getting into long range planning doesn't make the short range planning needs go away. A definite short range goal was announced last week -- an all volunteer Army in 1973. There is an immense amount of social science input needed there and I hope DoD doesn't overlook the need until it is too late.

Perhaps your first job is to convince those further up in the "chain of command" hierarchy, civilian and military, that you can do this and that it can be of value to the Army. I seem to recall that some of your colleagues have tried to set up some kind of a social science institute for the Army, but it apparently got bogged down somewhere on high. I have convinced myself that such a move is needed. Possibly, the planned Manpower Resources R&D Center will fulfill this need, at least in part.

What I am proposing to you, long range planning for research in the social sciences, in areas which will help achieve our national objectives, is a tough job. It would be for me -- but I'm not a trained social scientist. You here, most of whom are working in areas involving both the social sciences and the physical sciences and technology, seem to be ideally suited to start promoting the concept.

And that is the challenge I leave for you.

CHAPTER 6
BEHAVIORAL SCIENCE SUPPORT OF SYSTEM DEVELOPMENT: NIGHT OBSERVATION

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6A. VISION: MONOCULAR, BI-OCULAR, BINOCULAR

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INTRODUCTION

The terms, monocular, bi-ocular, binocular are frequently used to categorize the intended mode of utilization of an optical instrument. A spotting scope is usually monocular, the standard microscope has come to be bi-ocular, and the usual sports glass is binocular. In a sense, the term applied to the optic summarizes certain characteristics of the observer-optic-target system. The monocular system is arranged to utilize one of the observer's eyes, a single optical axis, and a point in space from which to view the target field. The bi-ocular is arranged to utilize both eyes of the observer, a bifurcated optical axis, and a point in space from which to view the target field. The binocular is arranged to utilize both eyes of the observer, two optical axes, and two points laterally displaced in space from which to view the target field. In practice the choice of an optic is made to take advantage of certain strengths and/or economies associated with the particular system. Ideally a system would be maximized for efficiency and effectiveness by fitting the component parts one to the other.

Given the desire to produce an optical system, the optic, in general, can be specified to a satisfactory degree and matched to the target requirements which in turn can be specified generally. The situation is different, however, with respect to the observer. There is a great deal of information in the optical literature with respect to the single eye, its refractive capability, its resolution limits, its modulation transfer function, etc., but very little with respect to the interaction of the observer's eyes as he executes the many tasks in which he must use his eyes. For example, consider the discomfort experienced following a period of viewing with a night vision device, the starlight scope. Difficulty originates from the extreme difference in adaptation level of the two eyes. One eye is light adapted, the other dark adapted. Closing the light adapted eye - a natural defense to excessive light - does not change the situation. The retinal state of adaptation continues and the observer sees a ball of light or fog between himself and his surround. This situation is reminiscent of a solution offered for the maintenance of vision in the presence of an atomic

blast. The observer was to be instructed to wear a patch over one eye in anticipation of the blast and to switch the patch after the blast to cover the exposed eye. Those situations involve the assumption that an observer can function monocularly at will. In fact, the observer is binocular and unable to ignore the unwanted stimulation.

Suppose we build a binocular, a hand held optic to be provided to selected personnel for individual observation. The fact that it is a dual optic does not assure that the individual will use it binocularly. If the binocular is out of collimation, an observer who habitually uses both eyes will probably be aware of the lack of alignment and complain, particularly if the loss of alignment has been abrupt. Yet an individual, who by our usual tests has binocular vision, all too often will use a misaligned instrument without complaint being totally unaware of the misalignment. It frequently can be demonstrated that such an individual is using only one eye, (half the optics provided) while suppressing vision in the other eye. The observer is monocular. Between these two extremes, when viewing a distant scene, a movie or a television program, the observer is bi-ocular, using either eye or both eyes with no loss of information. The mode of functioning is determined by a selective mechanism internal to the observer.

THE SELECTIVE MECHANISM

Suppression of vision in one eye in response to conflicting inputs to the two eyes is a normal response of the binocular visual system. It is an adjustment which is readily learned, consciously or unconsciously, in response to a specific situation. This is the ability which permits a jeweler to use his loop or a soldier to sight his rifle without closing or patching the unused eye. The eye is stimulated but the observer does not see. Suppression is not always confined to a single eye or the entire eye. The phenomenon of rivalry (1) occurs when suppression alternates from eye to eye and vision in the individual eye is lost momentarily either for the entire field of view or portions of the field. For example, the stadia reticle in the eyepiece of the military binocular induces suppression of the immediately adjacent areas in the other eye, and for some individuals, can induce suppression of the entire field of either eye. The stereoscopic impression of depth can also be considered a phenomenon of suppression since it is characterized by the inability to report certain local detail from the individual eye views. The phenomenon of single vision from disparate monocular views is usually termed "fusion," without specifying the underlying mechanism which is the subject of controversy.

BINOCULAR VISION

I have undertaken in Fig. 1 to represent the response to a definitive stimulus that can be expected from the visual system over its functional range. At the simplest level, the horizontal axis represents a bi-directional gradient of light adaptation for the preferred eye relative to the non-preferred eye. (See Figure 1) Plus indicates that the preferred eye is adapted to a higher light level than the non-preferred eye; minus indicates the converse. On the left of the figure the preferred eye would generally be dark adapted and on the right, light

two eyes becomes equal, as pictured in the center of the figure, and visual effectiveness is appropriate to the available light.

The situation is essentially parallel for figured stimulation in both eyes with the definitive contour in one. This is represented by the dotted lines. It is assumed that local suppression of contour will occur in the eye with the lesser relative contrast. Thus, the usual experience would be to see with the preferred eye when the contrast is greatest in the preferred eye, and to see with the non-preferred eye when the contrast is greatest in the non-preferred eye. The relation is asymmetrical and favors the preferred eye.

STEREOSCOPIC VISION

I would call special attention to the central portion of the figure titled "zone of stereopsis." For these stimulus conditions, the range of which is unique to the individual, the stimulation of the two eyes is sufficiently balanced both in contrast and adaptation level that both eyes will function rather than one or the other eye. It is within this range of conditions that the phenomena of stereoscopic vision and rivalry occur. With appropriate "disparate" images, fusion or selective suppression occurs and the stereoscopic impression of depth is seen. With markedly different images, rivalry occurs with its characteristic partial suppression, twinkle and other associated visual impressions.

. have called this the "zone of stereopsis" because the impression of depth from static stereoscopic stimuli is generally stable over such a range of illumination imbalance as depicted in the figure. The facts are quite different for the case of movement of the observer or objects within the field of view. In the center of this zone where the adaptation level of the two eyes is equal, the path of movement is as truly perceived as it can be, given the geometric relation of the object in motion to the background. (Specific configurations give particular distortions, (4) and only in rather limited circumstances is the true path perceived at all.) When one eye is relatively light adapted with respect to the other eye (left or right of center in the figure) moving stimuli are displaced in depth. This is the Pulfrich (5) effect which is usually demonstrated with an oscillating pendulum and a filter, such as half a sunglass, held before one eye, both eyes being open. The effect can also be seen when looking from a moving vehicle at right angles to the line of travel (6). The half-sunglass is held before either the leading or trailing eye and the surround is viewed with both eyes open. The effect with the sunglass over the trailing eye is that of looking with an increased base stereoscopic instrument. The depth distance between objects is increased and all objects appear closer and smaller. The effect is most pronounced in the middle distances from 30 to 150 feet when viewing with the unaided eye. The converse - the impression of looking with a decreased base stereoscopic instrument - occurs when looking with the sunglass over the leading eye. Thus, the view from a moving vehicle seen with a binocular observation device with unbalanced light transmission will be perceptually distorted. The phenomenon is usually demonstrated with an order of magnitude imbalance in the stimulation of the two eyes: however, a 10% difference of

illumination to one eye could produce a noticeable effect since the function is continuous.

Flicker or shuttering of the field of view, a method of achieving light transmission reduction, produces unique visual phenomena with or without movement. It is well established that seizures can be precipitated in persons with a history of epilepsy by synchronous flicker at an appropriate frequency. This is a matter of concern in the selection of helicopter pilots. It is also well established that brightness enhancement occurs with flicker of approximately nine cycles per second (7).

A less known consequent of flicker called the Dvorak (8,9) effect involves asynchronous stimulation of the two eyes. This, like Pulfrich, produces depth displacements of moving targets as a function of their direction and speed of motion. Independent shuttering of the two eye views in addition to reducing the overall illumination level opens the possibility of manipulating the timing relations between the two eyes. In the simplest instance, if the left eye is stimulated before the right eye, an object moving from left to right will be displaced away from the observer and an object moving from right to left will be displaced toward the observer; or vice-versa with completely symmetrical interaction of eye sequence and direction of motion (10). The entire matter is seemingly consistent with the geometry of stereoscopic vision and reminiscent of the procedures of air reconnaissance where two cameras are exposed in sequence to achieve an extended stereoscopic base in the line of flight of the airplane.

This simple relationship falls apart, however, when the duty cycle of each eye is manipulated in conjunction with the phase relationship between the eyes. At one extreme a relatively long, 80 msec., exposure of one eye, and a relatively short, 10 msec., exposure of the other eye, with a recycle time of 110 msec., results in the short exposure always initiating the perception without regard to eye sequence. The direction of target motion remains effective in determining the relative depth displacement toward or away from the observer; however, the timing relation between the two eyes (left-before-right or right-before-left) is no longer effective and the interaction of exposure duration and target motion is asymmetrical. Systematic laboratory research of these phenomena has only recently been initiated.

The potential payoff of the knowledge to be gained from such research was intimated some years ago in the observation that the visibility of low contrast targets was enhanced with an apparent movement, coincidence rangefinder under test for Frankford Arsenal by the Nortronics Division of Northrop Corporation. Apparently the flickering of the field of view permitted the observers to work both earlier and later into the twilight hours. Extensive followup was not supported and the understanding that was achieved did not identify the critical dimensions.

DESIGN CONSIDERATIONS

Returning to considerations of optical design, another characteristic of the visual system and of visual stimuli needs to be appreciated. For example, in designing a binocular instrument, the

question must be answered, "What shall be the axial alignment of the two optical systems?" This question arises from the fact that the accommodation drives the convergence of the eyes and conversely, but not to the same degree. In general, once fusion is achieved, an observer can encompass considerable variation in vergence distance without experiencing loss of clear vision. Yet, a change in accommodative distance is accompanied by a corresponding change in convergence distance. At the present time there is no single answer to this question just as there is no single answer to a number of other questions which stem from the fact that naturally occurring visual stimuli and the response of the visual system change along several dimensions simultaneously. For example, a change in the physical distance of a fixated object results in lateral displacement of the object in the field of view, a change in angular subtense, and a change in contrast or some other aspect of the illumination. Optical manipulations similarly effect the inter-relations of stimulus variables. Telescopic magnification changes the angular relation between frontal and depth extents from that existing in the natural environment. Lateral displacement in the single eye view of a stereoscopic ranging reticle neglects the stimulus to accommodation and the apparent size change associated with the depth displacement of a real object. The choice of a single line width to produce a stadia reticle for use at multiple distances ignores the change of angular subtense with distance which characterizes a real object. Each compromise has its perceptual consequence. Vehicles moving obliquely across the field of view are seen, through a binocular, to scuttle sidewise. The stereoscopic wandermark moves obliquely getting larger as it goes out. The stadia reticle, in addition to occluding increasingly larger portions of more distant targets, appears as a window through which the observer looks into the field of view. In some instances for some observers, the perceptual distortion is sufficient to preclude the observer using the optic as intended.

Because of this, one can legitimately ask, "Can we identify those compromises that optical instruments impose on visual functioning which are and are not acceptable?" Certainly, if this information was available beforehand optical design efforts could be more effective. Unfortunately, this information is, at present, a matter of accumulated experience. For example, in a recent developmental effort two unity power optics were offered for a headmounted viewing device; the one optically refined and expensive, the other generally inexpensive. These optics were evaluated each against the other and against the headmounted housing with no optics. The test used was truck driving, a series of standardized maneuvers for which there were accumulated Army population measures. The results ranked the optics in order; first, the headmount with no included optics; second, the headmount with the expensive optics; and third, the headmount with the inexpensive optics. The primary performance decrement was associated with the reduction in field of view and the mount which obstructed head movement. In no instance did the average performance with either optic fall outside the range of performance to be expected of 80% of the Army population. Stated another way, there was no statis-

tically significant difference in performance of the soldiers with the devices on the truck driving tasks. Presumably one could substitute the less expensive for the more expensive optic. In fact, the more expensive optic was adopted to assure maximum capability with the item.

RESEARCH REQUIREMENTS

Such testing can substitute for field experience with the system under development and offers a degree of objectivity often lacking in a field test. Yet it does not provide hard data for design guidance. Much as the measures taken and the items of equipment tested represent real variations within the design criteria and test situations used, they do not necessarily represent significant differences along critical dimensions of visual functioning. The whole exercise may, in fact, have been nothing more than a test of minor variations of essentially equivalent visual conditions. The determination of the truth or falsity of this last point will not be resolved by more and more elaborate field tests. Fundamental knowledge of the visual system in all its aspects is necessary to identify the stimulus dimensions critical to effective visual functioning, including their range and the change that will constitute a significant change within each dimension. Only when such information is available will it be possible to evaluate an optical design variation in terms of its significance for effective seeing.

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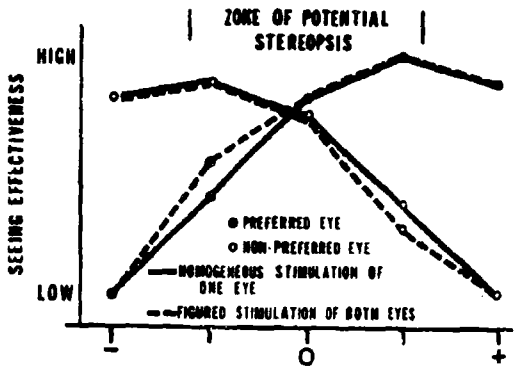

adapted. The solid line with filled circles traces those conditions in which the preferred eye is provided the definitive contour and the non-preferred eye is uniformly stimulated as from a sky backgorund. The solid line with open circles represents the converse. The dotted line traces conditions in which both eyes receive contoured stimulation but each eye a different figure as in the acuity tests of the Sight Screener, a stereoscope or a visual rivalry demonstration. The stimulation which will be seen for any combination of conditions is that which adapts the stimulated eye to the higher light level. Thus, on the left of the figure the stimulation or image presented to the non-preferred eye will dominate even though the observer may wish to see with the preferred eye. If the observer could consciously suppress the non-preferred eye, he would be prepared to see "in the dark" with the preferred eye.

The functions for both the preferred and non-preferred eye are shown in the figure; the function for the non-preferred eye is essentially a mirror image of the preferred eye function. This makes the figure somewhat confusing but it serves as a reminder that the visual system is always binocular and apparently responds otherwise only because of a unique combination of conditions.

In the middle of the figure, both eyes receive essentially the same level of stimulation and the definition of "preferred eye" is presented as that eye which provides the best capability under normal viewing conditions. Alternate definitions might be: that eye which is used the greater percent of time in a rivalry situation; or that eye towards which the "fused" detail is displaced in stereoscopic vision (2). On the right side of the figure, maximum effectiveness occurs for the preferred eye for some general level of stimulation of the non-preferred eye which is less than the stimulation level of the preferred eye (3). Finally, at the right of the figure is depicted the condition in which the preferred eye alone is stimulated and the non-preferred eye is covered with a black patch. This is the condition experienced by an observer with the Starlight scope. The filled circle portrays viewing with the scope and the open circle portrays the attempt to see immediately following a period of viewing with the night vision device. Since the stimulation provided by the more light adapted eye will dominate, visual effectiveness will be high with the device. On the other hand, the residual light adaptation will preclude seeing in the dark with the preferred eye as well as with the non-preferred eye when the device is initially laid aside. Given time, the adaptation state of the

6B. HARDWARE PARAMETERS RELATED TO OPERATOR TRAINING CAPABILITIES

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INTRODUCTION

In this paper I would like to describe some of the research we have conducted under HumRRO research project NIGHTSIGHTS. The broad objectives of this research are to identify critical human factors problems in the use of new night observation devices and to develop effective techniques of training men in the use of these devices. In working toward these objectives we have carried out a number of investigations and I would like to characterize our work with two examples.

First, I will outline our approach to the problem of the development of training programs for immediate application to the training of operators of specific devices, and present some of the results obtained in an experimental comparison of two techniques in training operators of the AN/TSS-7, a long range night observation device.

Second, I will describe our approach to the investigation of factors which limit operator effectiveness in target acquisition and to the development of training guidelines applicable to the requirements of devices which will be distributed in the future.

TRAINING THE AN/TSS-7 OPERATOR

The work described here is representative of our effort to develop training programs and Pictorial Training Aids for a selected set of high-priority night observation devices. Other devices for which training programs were or are being developed include the Airborne Search Light, the AN/ASQ-132 Iroquois Night Fighter and Night Tracker, the Ground Surveillance Radar and the AN/VAS-1 Far Infrared Target Indicator.

Problem:

The AN/TSS-7 Night Observation Device, Long Range is a versatile device which can be operated in a number of active and passive modes. The device is more complex than many night vision devices and presents more stringent training requirements. The objectives of the research were the

development of a suitable training program, an experimental evaluation of a Pictorial Guide to be used as a training aid, and an experimental comparison of traditional platform instruction with a videotaped instructional sequence.

Approach:

The development of the training program was carried out in two main steps. The first step was the development of a set of Training Objectives, that is, statements of capabilities which the trainee would have at the end of the training period. This step required us to analyze the application of the device, to analyze the operator's tasks, and to specify the skills and knowledges necessary for the operator to perform these tasks. The next step, using the results of these analyzes, was the development of the Lesson Plans and materials to implement training objectives. This step included the specification of the training program or sequence of materials, the development of appropriate written and performance tests, and the development of a Prototype Pictorial Guide to be used as a training aid.

To evaluate the developed training program and to determine the effectiveness of the use of videotaped instruction in comparison with standard platform instruction, a total of 37 enlisted men were given training in NODLR operation. The EM were divided into two groups; one group received standard platform instruction and the other, videotaped instruction. Within each group one-half of the EM were given the Pictorial Guide to be used as a training aid. The experimental conditions are summarized in Table I.

TABLE I

SUMMARY OF CONDITIONS IN EXPERIMENTAL COMPARISON OF INSTRUCTION APPROACHES

		TYPE OF INSTRUCTION	
		PLATFORM INSTRUCTION	VIDEOTAPE
TRAINING AID	PICTURE GUIDE	GROUP 2 N = 9	GROUP 4 N = 10
	NO PICTURE GUIDE	GROUP 1 N = 10	GROUP 3 N = 8

Except as indicated by the experimental variables, all the EM received the same training time, the same subject matter, and the same amount of practice with the NODLR. Written and work sample tests were administered at the end of each training sub-unit and at the end of the course.

Results:

The end of course scores on the written and work sample tests are plotted in Figure 1.

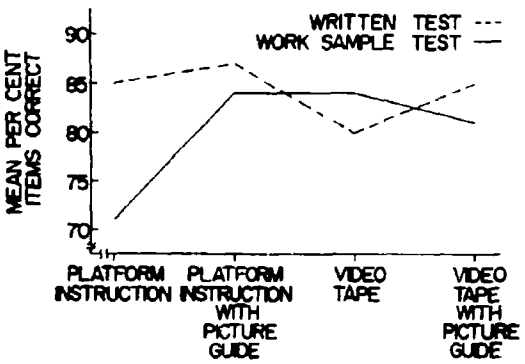

Figure 1. Mean End of Course Scores for Groups Trained With Different Techniques.

The main results of the experiment are:

(1) Specific knowledge, as tested by the written examination, did not vary significantly with the type of instruction or the use of the Pictorial Guide.

(2) Mean group skill level, as measured with the work sample test, was greater for the group trained with the videotape than for the group trained through platform instruction.

(3) The lower mean group skill level of the group given platform instruction reflects the low scores obtained by the subgroup which did not use the Pictorial Guide. The scores obtained by the subgroup which used the Pictorial Guide did not differ from those obtained by the groups trained with the use of the videotape.

The results show both the effectiveness of the Pictorial Guide as a training aid used with the platform instruction, and the effectiveness of videotape presentation. I should emphasize that a zoom type camera lens was used for recording the training material. One interpretation of the data is that the effectiveness of the videotape presentation is due in part to the use of this lens to record detailed information, similar to that included in the Pictorial Guide, for presentation to the EM.

TRAINING FOR FUTURE REQUIREMENTS

The limited data available from other sources as well as results we have obtained in working with night observation devices indicates that the utility of these devices is often operator limited. Further, this limitation is related to the operator's failure to note, or his inability to perceive and interpret the critical target information the device presents to him.

In the future, the perceptual and mental limitations of the operator will be the greatest hindrance to full exploitation of the potential of night observation devices. New devices will be much more sophisticated and complex, and should be employed in a widening range of situations. In order to

realize the potential utility of new devices it is necessary to systematically investigate the limitations of the operator and to develop training guidelines for techniques to reduce these limitations. The resulting information will provide needed input for device designers and personnel responsible for planning and doctrine, as well as a factual basis for solving training problems pertaining to specific devices and applications.

Problem:

An important characteristic of the observer is his capacity for processing visual information quickly and accurately. In many surveillance situations, an observer employing a night observation device may be expected to detect and identify a target which appears and moves across the visual display in a very short time. For example, the device may have an automatic scan feature or the operator and his device may be located in a moving vehicle. Under observation conditions such as these, the probability of target detection and identification may be very low. For our purpose we may simplistically attribute this performance limitation to two sources of interacting variables. The first, hardware and display characteristics, includes, for example, the field of view of the device, its sensitivity and resolution, type of viewing, target-ground contrast, location and size of target in the field of view, and its rate of motion. The second source of variables is the observer whose perceptual and mental characteristics limit his capacity to utilize information which the display may offer. The problem is first to isolate, identify, and relate these variables to the display variables, then to develop effective training techniques to increase the observer's proficiency in target acquisition.

Approach:

Since the first problem is to identify and isolate the most important variables, our present efforts are laboratory experiments. Here we can control the influence of hardware variables as well as extraneous variables which might affect performance. Through our choice of targets and observation conditions we can study the effects of display configurations and determine to some extent the physiological or sensory limitations of the observer's performance. The knowledge and understanding gained in these studies will provide the basis for the development of training techniques to improve the observer's performance, and for developing more cost effective programs for training men to operate specific devices.

Procedure:

The first series of experiments is designed primarily to determine the performance limits of untrained observers under a variety of simple observation conditions. The variables we are manipulating include type of target, location of the target in the visual field, and number of targets the observer must identify. Our general procedure is to determine the minimum brightness required for detection and identification of a target projected on a dimly illuminated field for a variable short time.

The following results were extracted from a pilot experiment on the effects of the number of different targets the observer had

to recognize. The targets were presented one at a time from sets of two or eight targets. The targets were flashed repeatedly at successively greater brightnesses and the task of the observer was to detect and then to identify each target at the lowest possible brightness level. The targets were silhouettes of geometric figures, random forms, and military targets. The observer viewed the screen with one eye and the conditions were chosen to roughly represent the task of observing a target of tank size at 1000 meters through an image intensification device on an overcast moonless night.

Results:

The results are unverified and are used simply to illustrate the performances of the subjects.

The trend of the responses of subject T, to two simple targets, a square and a triangle is shown in Figure 2. I would like to stress two features of the data: (see Fig. 2)

(1) The subject required considerably greater target brightness to identify the targets than to detect them.

(2) When the targets were exposed for a critical time of less than about 0.1 second, the target brightness required for detection and identification increased very rapidly as exposure time was decreased.

The trend of the responses of another subject, J, is shown in Figure 3. A set of 8 targets, including 3 military targets, was used to obtain these responses. (See Fig. 3)

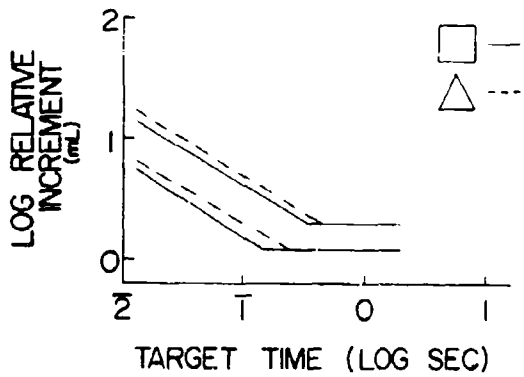

Figure 2. Mean Relative Log Brightness Thresholds for Target Detection and Identification of (Subject T)

The salient features of these data are :

(1) The subject required much greater target brightness to detect or to recognize the targets than subject T did.

(2) The critical time of approximately 1 second is very much longer than the critical time obtained for subject T.

These data probably suggest the upper limits of performance of untrained observers. The subjects were extremely well motivated and

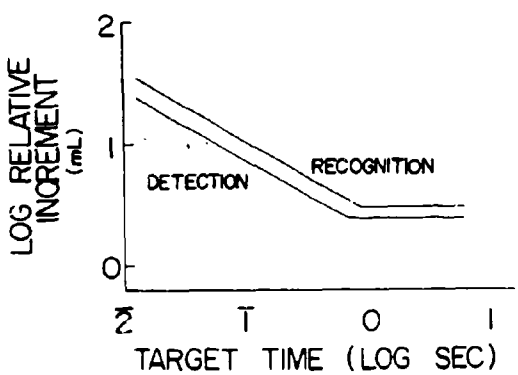

Figure 3. Mean Relative Log Brightness Thresholds for Target Detection and Identification of (Subject J)

better than average in intelligence, and the observation conditions were extremely simple. The differences in target brightness requirements for detection and identification and the long target presentation time that subject J required, clearly suggest, however, that target acquisition performance may be significantly improved by training. We plan, in the next series of experiments, to determine the effects of target movement on the observer's performance and to investigate techniques of training operators for efficient target acquisition under conditions of limited target exposure time.

CONCLUSION

In this overview of the activities of the Work Unit NIGHTSIGHTS, a primary objective has been to emphasize the variety of problems which may require solution in the process of developing training concepts and programs. The operator and his device are elements in a system, small or large, and have the vital function of gathering and processing information necessary to carry out the mission of the system. We cannot limit our concern to training men to perform specific operations with certain devices, but must consider all aspects of the behavior required of him. We must be more concerned than we have been in the past, with the operator as a processor of information, and with the factors which limit his behavior in this capacity. It must also be realized that these limitations are the concern not only of those involved in training, but also of everyone involved in the process of maximizing operator and system effectiveness.

6C. ENVIRONMENTAL FACTORS AFFECTING VISUAL PERCEPTION

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It is well known that extreme environmental exposure can be expected to impair human performance; e.g., muscles and joints stiffen in the cold, beyond some level of exertion men collapse in the heat, etc. The important question, of course, is what impairments occur at various degrees of exposure, and how much? The mission of the Army Research Institute of Environmental Medicine is to determine the nature and extent of impairment in military performance due to stresses produced by the natural environment (heat, cold, wind, hypoxia), and by the effects of work, both physical and psychological. Another aspect of this mission is to develop treatment and preventive techniques for such generated disabilities. The research I am about to describe was designed to provide some answers to the question of what happens to the soldier's performance under exposure to different naturally-occurring environmental hazards which he is apt to experience in the field, specifically with respect to his visual capability. This is an important area to examine, since it is estimated that 80-90% of the information we receive about the real world comes from the visual sense.

It has been known since the early 1900's (8) that reduction of atmospheric oxygen content produces a condition called anoxia, and more properly hypoxia, which results in impairment of visual capability. Although we know that these changes are rapid and significantly large, almost all of our information concerns only performance in the center of the visual field. Peripheral vision has been largely overlooked, even though common sense will tell us that the "corner of your eye" can be very important in many military tasks. I would now like to describe a series of studies which we conducted to examine the effects of hypoxia on peripheral visual sensitivity, and show you the major results.

We know that the color sense is a basic attribute of vision, and certainly must figure importantly in many military tasks. Since we know that color detection sensitivity is distributed spa-

tially in zones in the visual field, we raised the question of what happens to color sensitivity in the peripheral visual field under stress, in this case hypoxia. To answer this, we measured the outermost extent of these zones within which colors could be detected under different degrees of hypoxia exposure (5). Each subject was tested for red (611 mu), green (510 mu), and blue (494 mu) visual sensitivity during four-hour exposures to four different levels of hypoxia (0,13,000 15,000, 17,000 feet). These levels were induced by breathing oxygen-nitrogen mixtures equivalent to those elevations, and were given in different sessions one month apart. In each session, the subject was tested twice, at 1/2 hour and at 3-1/2 hours of exposure, for each eye, and at high and low target brightness. In addition, two groups of 12 subjects each were run, one group being given acetazolamide tablets, the other group being a control who were given equivalent-appearing placebo tablets. The drug acetazolamide was tested because it was previously shown to reduce the effects of mountain sickness in a field maneuver conducted by USARIEM using Army Special Forces troops at Mt. Evans, Colorado (1). The results of the present study are shown in Figures 1 and 2, which for brevity represent the color sensitivity zones averaged across red, blue, and green, for the various test conditions. Figure 1 shows the placebo group results, and indicates that the zone size in which color could be detected became smaller with increasing hypoxia. Sensitivity further deteriorated with continued exposure, and was worse for a dim target than for a bright one. The drug group performance is shown in Figure 2. One can see the same trends as in Figure 1, but also it is clear that the differences due to hypoxia are much smaller. This drug seems to have minimized the decrements which otherwise occurred among the group which did not use it. Thus, this study showed that peripheral sensitivity to color detection is systematically impaired with increasing hypoxia, and that acetazolamide may prove to be an effective medication both for mountain sickness and for reducing such visual decrements during mountain operations.

The above study involved mainly a sensory task; i.e., the detection of a color stimulus. However, most visual performance involves not only the detection of a stimulus but also a response to it in a meaningful way, which we refer to as perception - the interpretation or placement of meaning on visual events. We, therefore, raised the question next of what hypoxia might do to a perceptual task involving peripheral vision. To investigate this, we conducted a study in which subjects were required to make a very simple voluntary response, that of pressing a button whenever a stimulus was detected (7). The button both turned off the light and stopped a timer which was initiated when each light flashed. This was done while the subjects viewed a display of 48 stimulus lights evenly distributed throughout the visual field in a hemispheric arrangement which is shown in Figure 3. The 48 visual stimuli were arranged along 12 radial axes spaced at 30° intervals, with each axis containing four lights angularly displaced from the center (12°, 38°, 64°, 90°). Since the subject could not predict the location or time of onset of the stimuli, his response time (RT) was assumed to represent his unbiased percep-

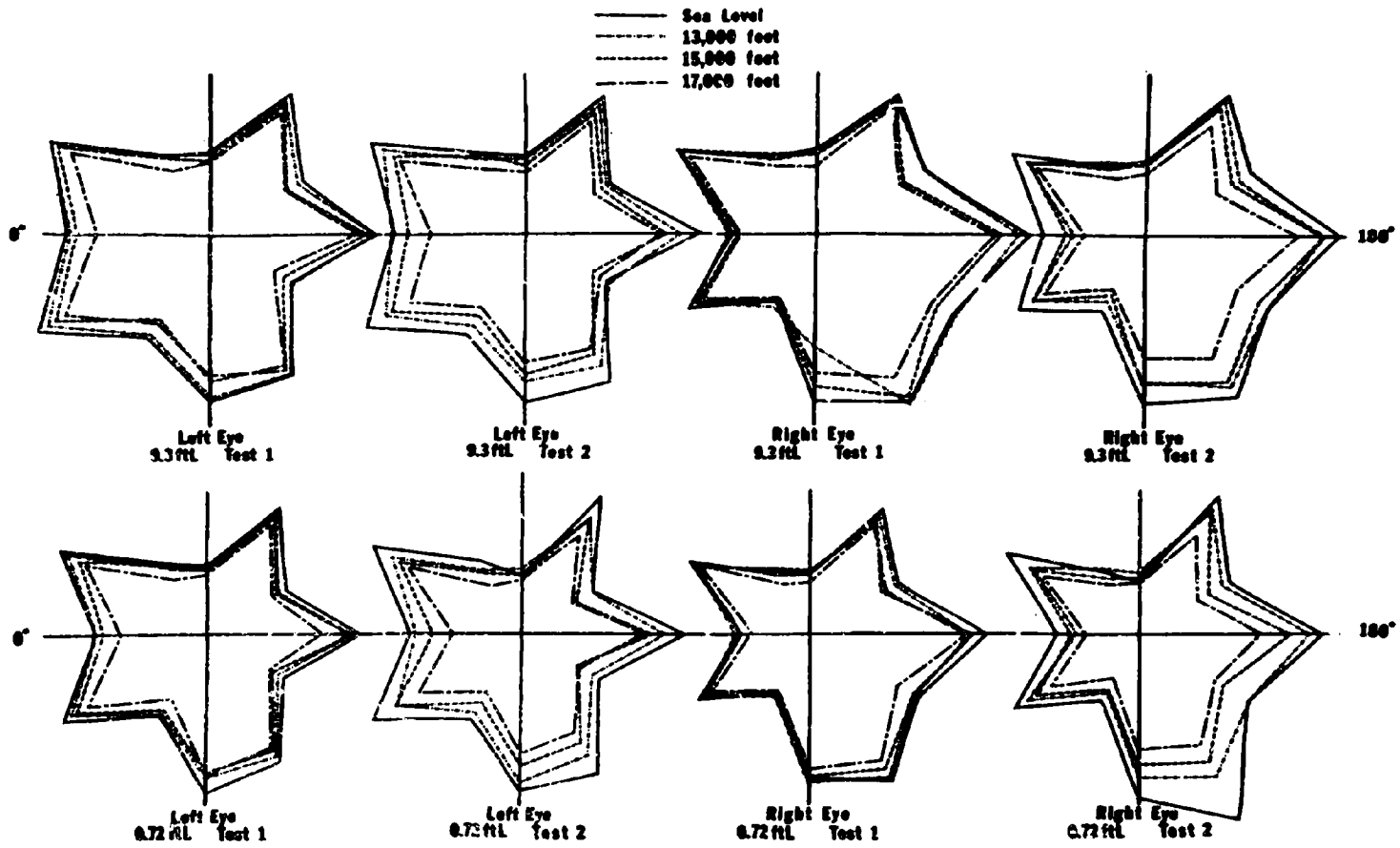

Figure 1. Average color detection zones for the placebo group.

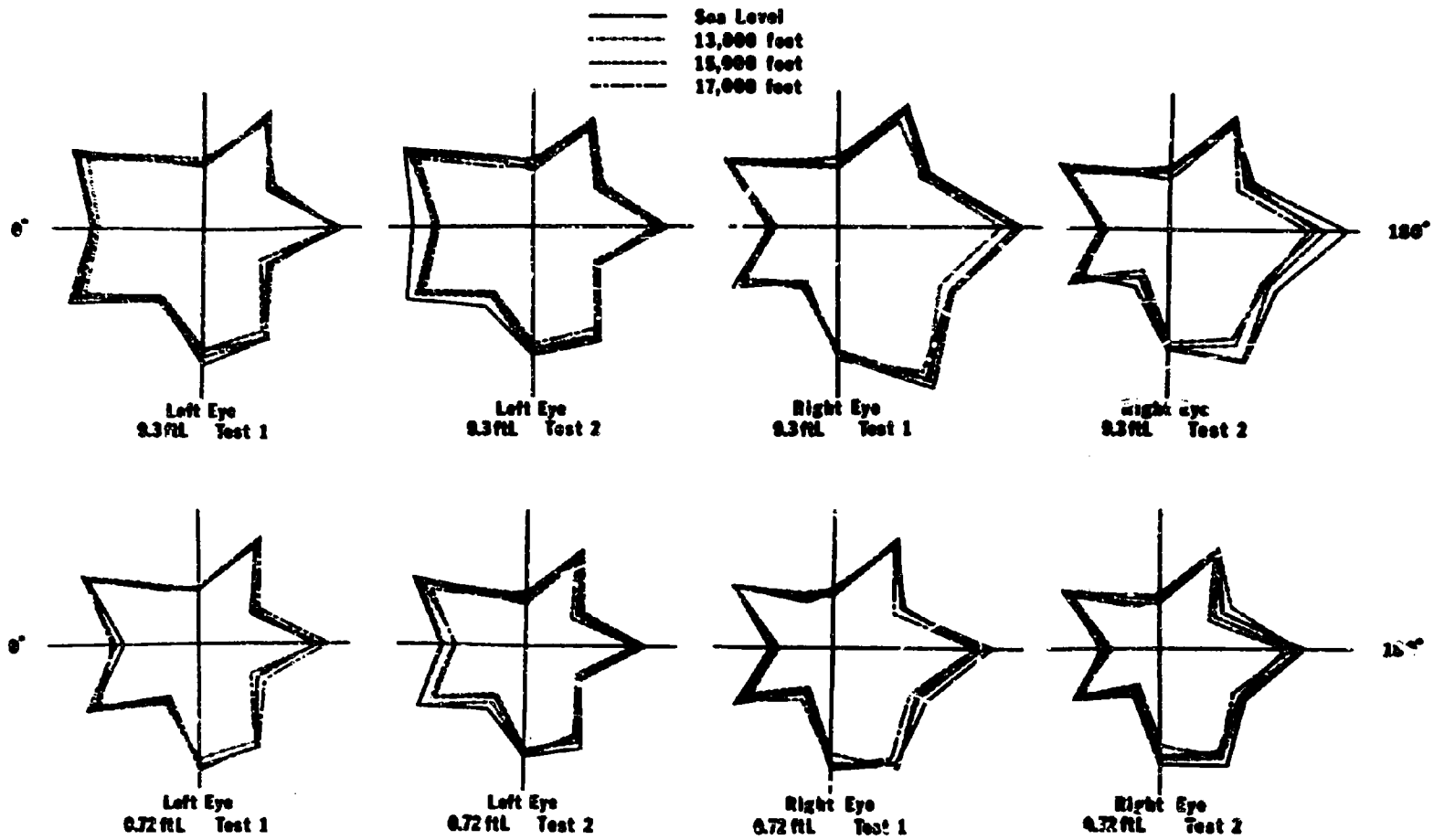

Figure 2. Average color detection zones for the acetazolamide group.

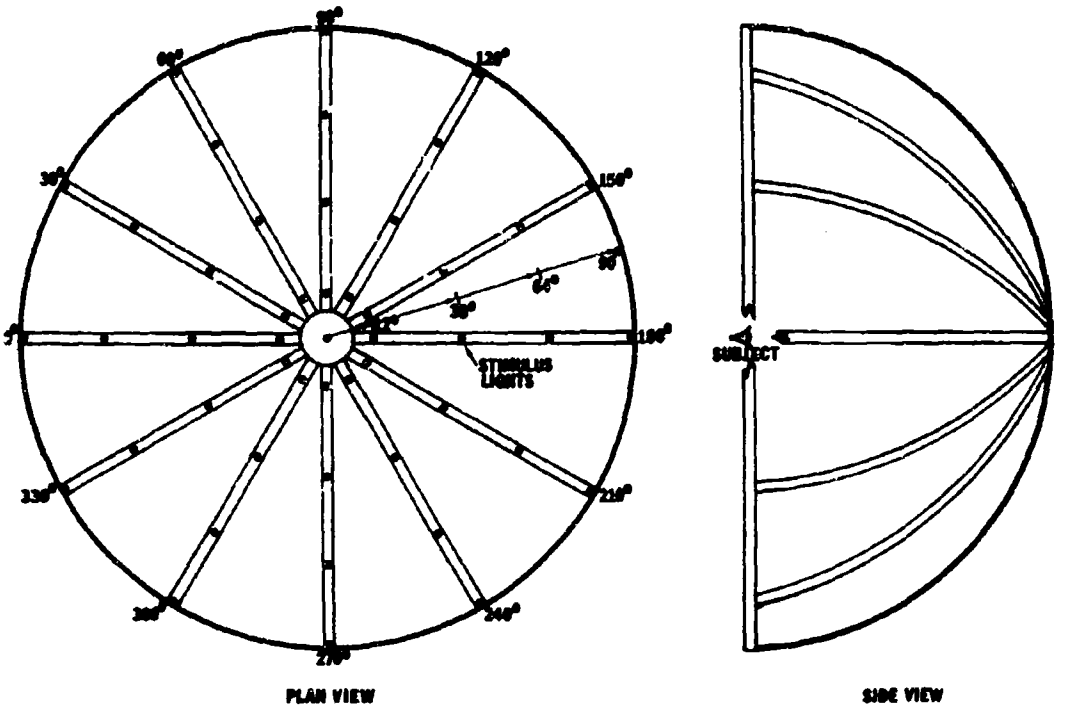

Figure 3. Schematic diagram of the stimulus configuration for the peripheral response time test.

tual capability as influenced by stimulus position. A previous study showed that RT's are much longer for stimuli in the upper and lower visual periphery compared to those along the horizontal axis; also, there is almost no improvement in RT beyond a practice period, so that for practical purposes they can be considered to be fixed values which do not continue to change during performance of the task (2). In the present study, 10 subjects were exposed individually to each of four elevations (0, 13,000, 15,000, 17,000 feet) simulated by breathing equivalent oxygen-nitrogen mixtures in a barogaseous chamber. Each session involved a 4-hour exposure in which the task was repeatedly performed four times. The sessions were spaced one week apart. The results are shown graphically in Figures 4, 5, and 6 giving the group mean RT's for degrees of hypoxia. Figure 4 shows that average RT increased as the stimuli became more peripheral, even at sea level. However, with increased elevation and therefore increased hypoxia, the RT's increased even more, than the sea level changes, and in direct relation to severity.

Figure 5 represents average RT's for each of the different radial axis in the visual field. It is clear that RT's were longest for the central areas of the upper and lower visual field. Again, hypoxia generally increased the RT's even more, with the greatest changes occurring in the upper and lower central areas.

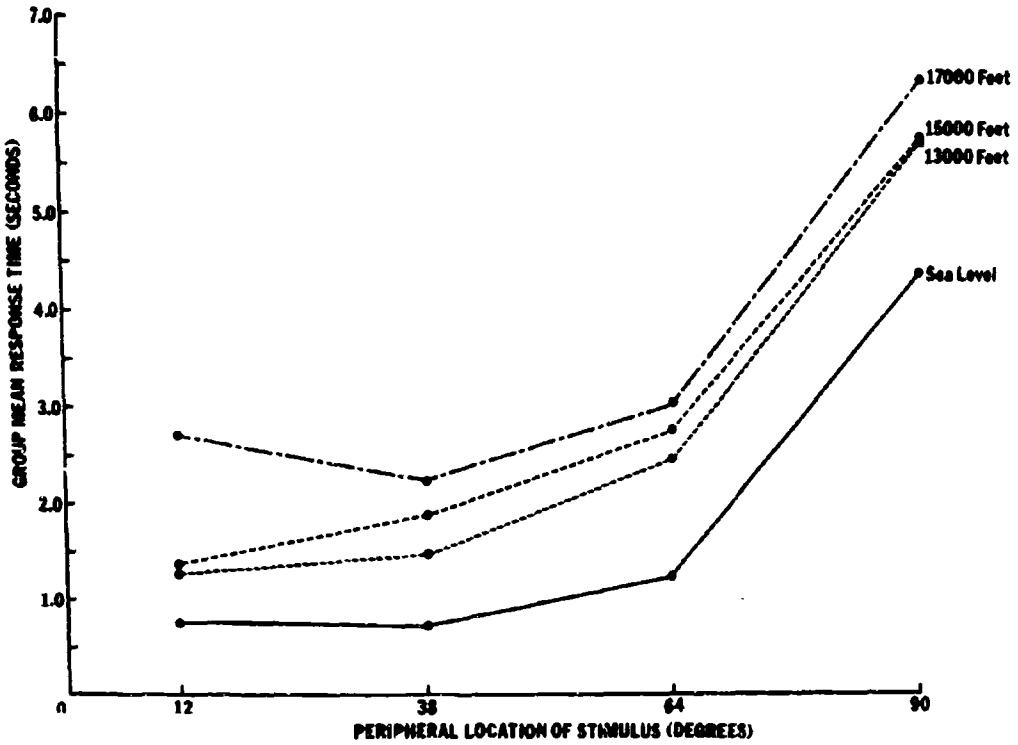

Figure 4. Group average response times for degrees of stimulus peripheralization.

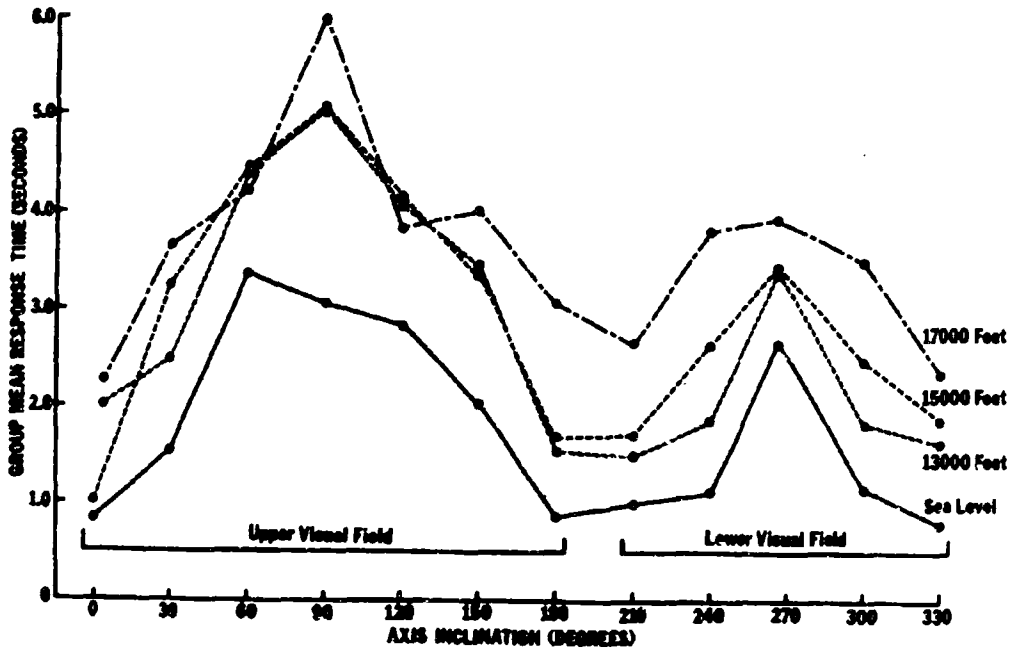

Figure 5. Group average response times for the various positions in the visual field.

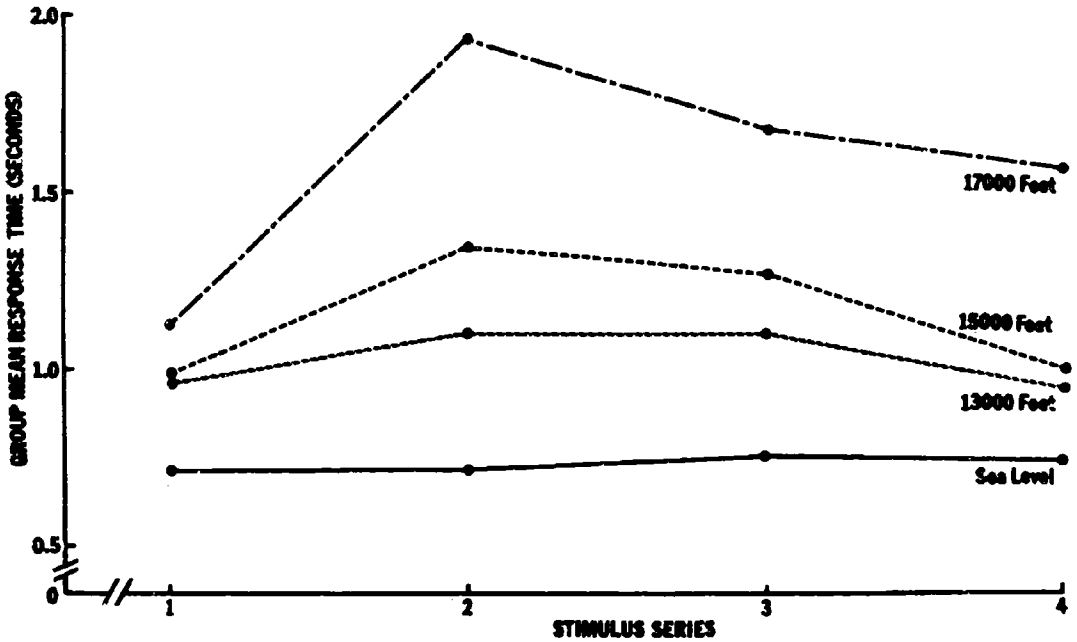

Figure 6. Group average response times as a function of continued hypoxic exposure.

Figure 6 represents the grand mean of all RT's for each of the 4 tests. Thus, this graph shows the trend of performance across 4 hours of hypoxic exposure. It is clear that the effect of hypoxia was in direct relation to severity, with an initial rapid rise within the first two hours, and only slight recovery. We can summarize these effects by saying that hypoxia rapidly affects response time to visual stimuli, with the greatest decrements occurring for the upper and lower central areas of the visual field, where performance is poorest even in the absence of stress. This suggests that target detection should be expected to be poorest in these areas, and the location of warning lights and emergency indicators should probably be elsewhere.

The above task is typical of the random monitoring situation, but many equipment operations require some centrally located task to be performed while peripheral signals must be detected at the same time. Since hypoxia affects routine random monitoring alone, one can ask what it might do to performance if more demands such as central monitoring are placed on the operator besides the situation used above. In order to answer this question, we conducted another study in which the exact experiment described above was repeated but with the addition of another light at the center of the visual field (6). This light also flashed on a similar random pattern and the subject now was required to operate two switches, one in each hand, one in response to a peripheral light and the other to the central light. Figures 7, 8, and 9 show the collateral values for this study in similar fashion to Figures 4, 5, and 6. The results shown in Figures 7, 8, and 9 are very similar to those of the previous study, except that the effects of hypoxia were not nearly as

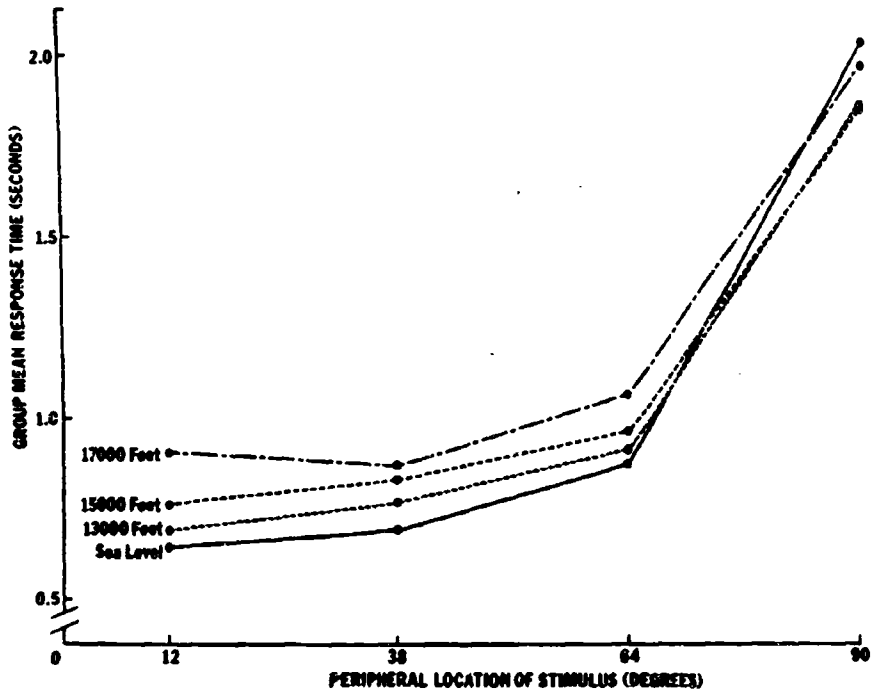

Figure 7. Group average response times for degrees of stimulus peripheralization during central monitoring.

pronounced, especially in regard to the overall effects of continued exposure, where the differences between both test points and levels of hypoxia are quite small. It should also be mentioned that RT values were generally shorter than in the previous study. Therefore, it seems that the central task functioned as an arousal device, which acted to maintain attention and alertness of the operator. Comparing these two studies, it looks as though hypoxia generates inattention or loss of alertness, which when present affects the peripheral more than the central visual field. However, these lapses can apparently be overcome by additional stimulation, so that the operator should be able to compensate for his perceptual losses if his arousal level is maintained.

On the basis of these studies, an additional question can be raised; namely, what happens to this kind of performance under more prolonged hypoxic exposure. In order to investigate this, we recently completed another study in which subjects performed both tasks under 48 hours exposure to a simulated altitude of 15,000 feet in our hypobaric altitude chamber. The subjects performed the task 5 times during the exposure period. Since the data are presently being analyzed, the outcome is unknown at this time but

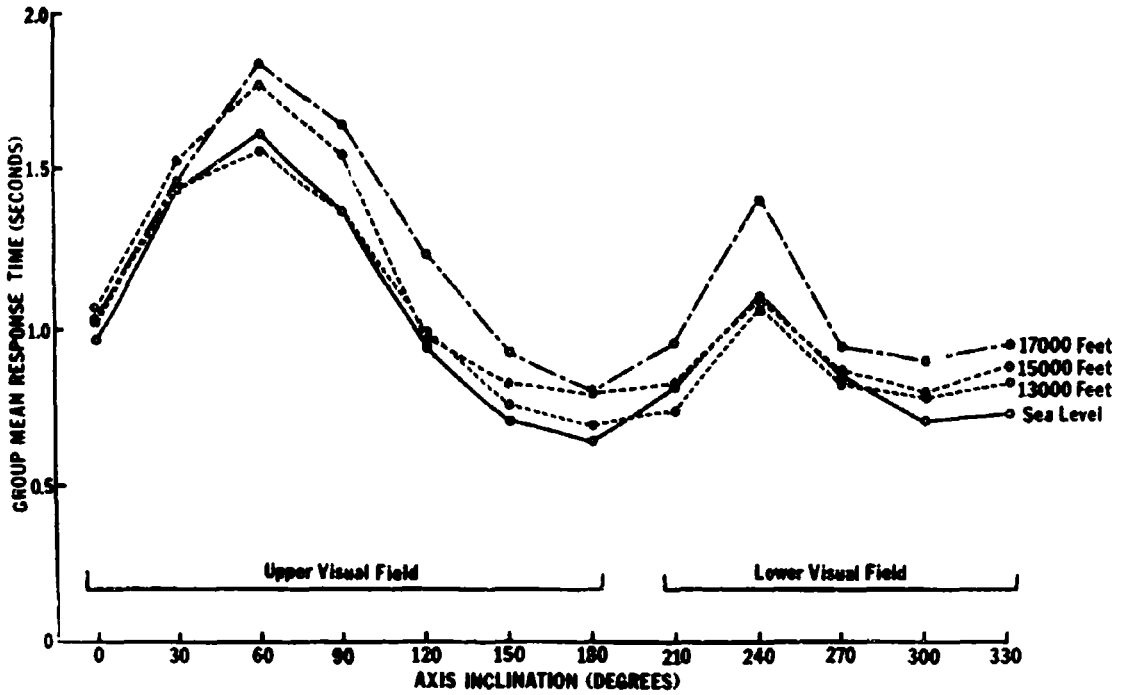

Figure 8. Group average response times for the various positions in the visual field during central monitoring.

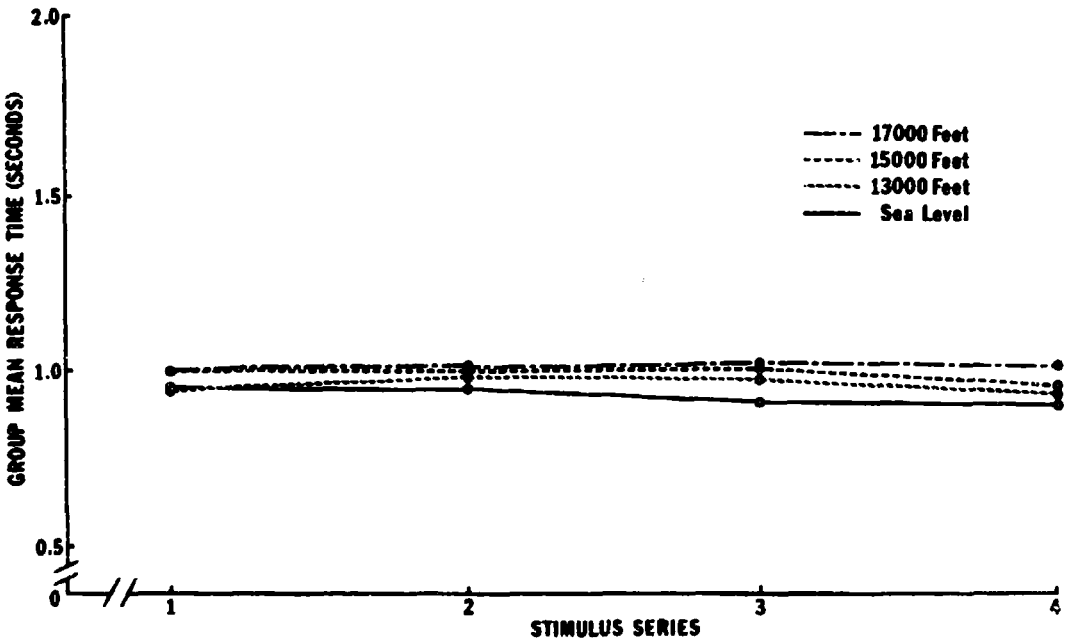

Figure 9. Group average response times as a function of continued hypoxic exposure during central monitoring.

will be available shortly.

The Army is also interested currently in night operations, in which the enhancement of visual effectiveness is crucial as evidenced by the need to develop a family of image intensification devices such as the Starlight Scope. It has long been known that hypoxia seriously degrades the light sensitivity of the eye, which in the normal state occurs under conditions of total darkness within 1/2 hour and represents a 100,000-fold increase in sensitivity. However, the effects of chronic hypoxic exposure upon the dark adaptation process have never been studied. Therefore, we repeatedly measured this continuing change in light detection threshold during the previous study involving 48 hours exposure to 15,000 feet altitude (at sea level, 1, 18, 24, and 42 hours). The results are shown in Figure 10. One can see an initial major increase in threshold (loss of sensitivity) at one hour, followed by a gradual recovery up to about 44 hours, where sensitivity apparently began to deteriorate again. Unfortunately, it was necessary to terminate the study at this point so that the subsequent trend is unknown and remains a question for future research. Nevertheless, it is significant that major losses of sensitivity occurred so rapidly, and never recovered to the original sensitivity levels seen at sea level, even though some recovery did take place.

Related to this are the effects of the familiar habit of cigarette smoking which generates a state of functional hypoxia in the user. In fact, Dr. Ross McFarland, Director, Harvard School of Public Health, states that the habitual smoker at sea level is actually living physiologically at an altitude of 5,000 feet. Smoking has several well-recognized effects upon the visual system, one of which is a loss in light detection sensitivity. Since smoking is common among troops, it becomes problematic as to what its effects may be upon night operations and also how much it reduces visual capability when combined with the hypoxia generated by altitude exposure. In order to investigate this, we are presently planning a study in collaboration with Walter Reed General Hospital of the combined effects of smoking versus non-smoking upon dark adaptation and peripheral vision during 48 hours of exposure at each of 3 altitude conditions (sea level, 10,000, 15,000 feet).

We have also done some work to determine the effects of other environmental variables besides hypoxia on visual performance. In this line, I would like to describe two other studies which we conducted to determine such effects due to low ambient temperature and wind exposure.

In one study, 12 subjects were exposed on different occasions to the 20 possible combinations of 5 ambient temperatures (70°, 20°, 0°, -20°, -40°F.) and 4 wind speeds (0, 10, 20, 30 mph) (3). The visual task consisted of setting the minimum visible gap between two vertical black lines seen against a white background at a viewing distance of 20 feet, a task definable as minimum visible visual acuity. The group average

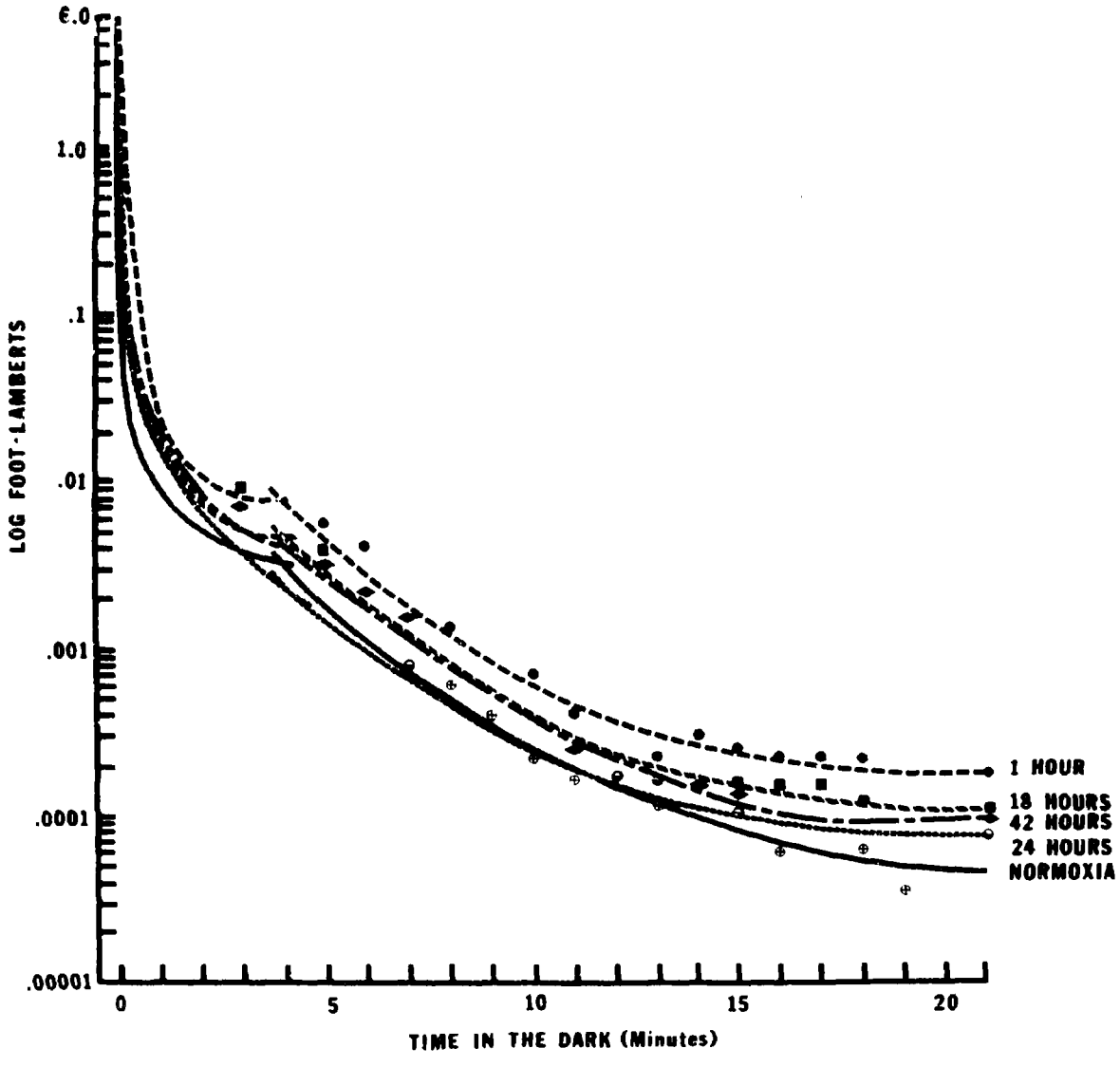

Figure 10. Average light detection thresholds during dark adaptation for various durations of hypoxic exposure.

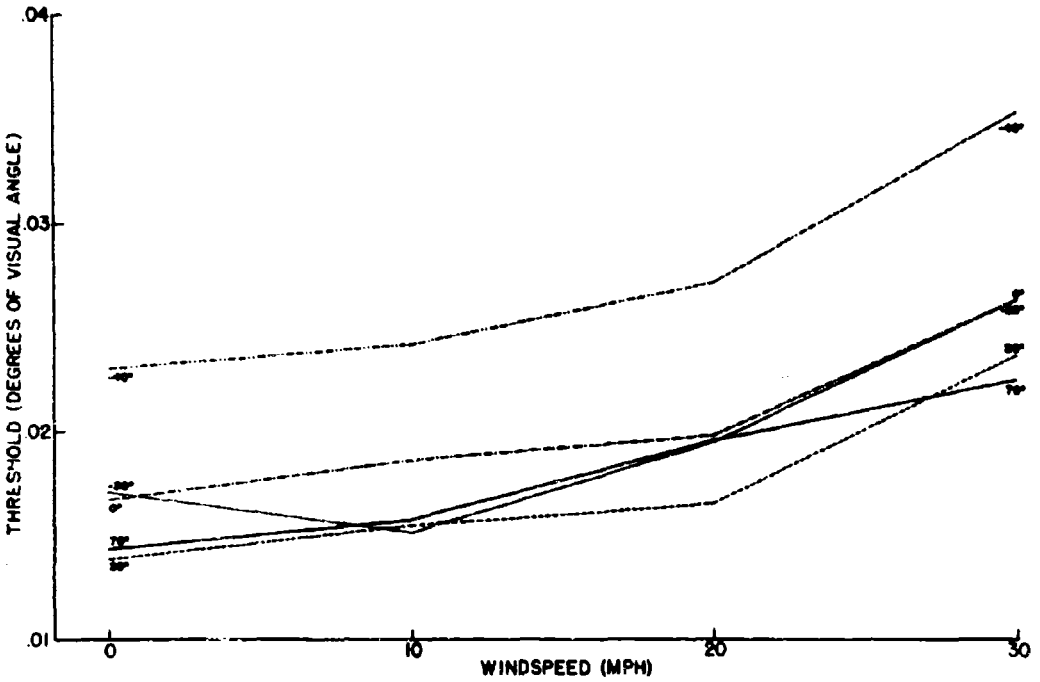

Figure 11. Group average visual acuity thresholds during exposure to various combinations of low ambient temperature and wind.

discernible threshold in visual angle units is shown in Figure 11. It can be seen that visual acuity deteriorated dramatically for temperature exposures lower than -20°F., and for windspeeds of 20 mph or higher, and for their combinations. These are important effects, because the exposure period involved was only one minute.

In another study, 480 subjects were exposed to the same temperature-wind-speed combinations and performed a binocular depth perception task at three viewing distances (20, 40, 60 feet) (4). The results are shown in Figures 12 and 13. In Figure 12, the group mean separation between the target rods (corresponding to error in depth judgment) is plotted for temperature exposure conditions for each viewing distance. One can see that errors increased markedly for temperatures lower than 0°, and that increased viewing distance resulted in major increases in error magnitudes, as one should expect. In Figure 13, similar effects are seen for exposure to windspeeds beyond 10 mph, which again increase in expected fashion for longer viewing distances. These results again are rather significant, because they, too, were produced by exposure periods of no longer than one minute.

These two studies show that other environmental factors are capable of markedly reducing the efficiency of the soldier's visual perception. I believe that the data for windspeed effects are particularly significant, since personnel riding in unscreened moving vehicles are very likely to be exposed to the windspeeds tested here, and such wind effects can

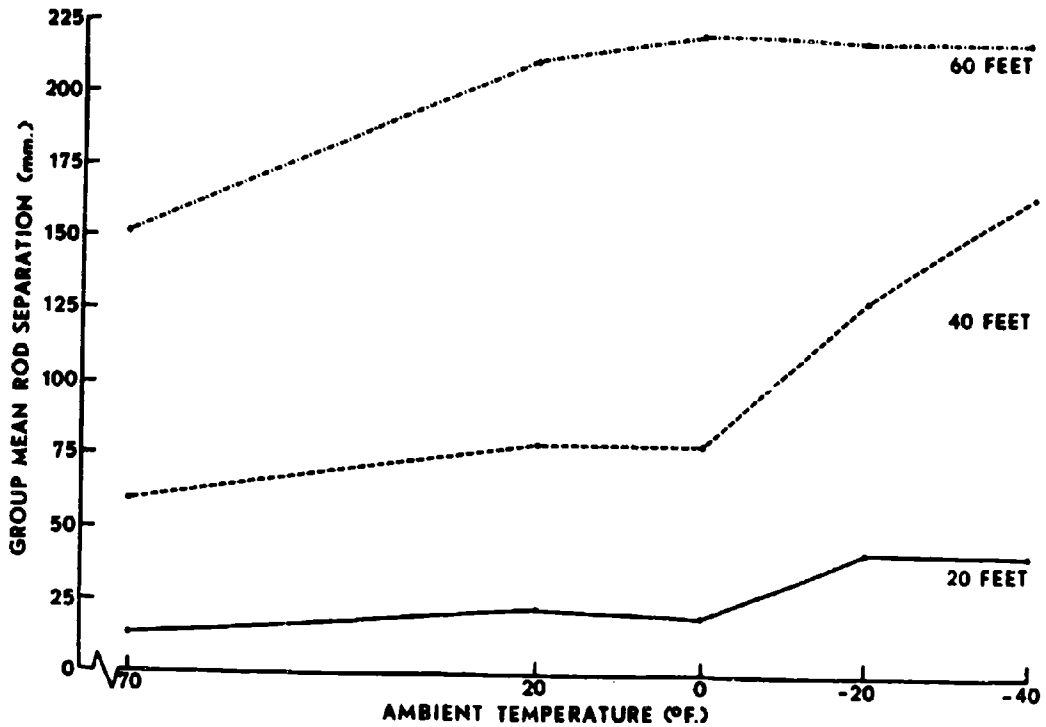

Figure 12. Group average depth judgment errors due to low ambient temperature exposure at three viewing distances.

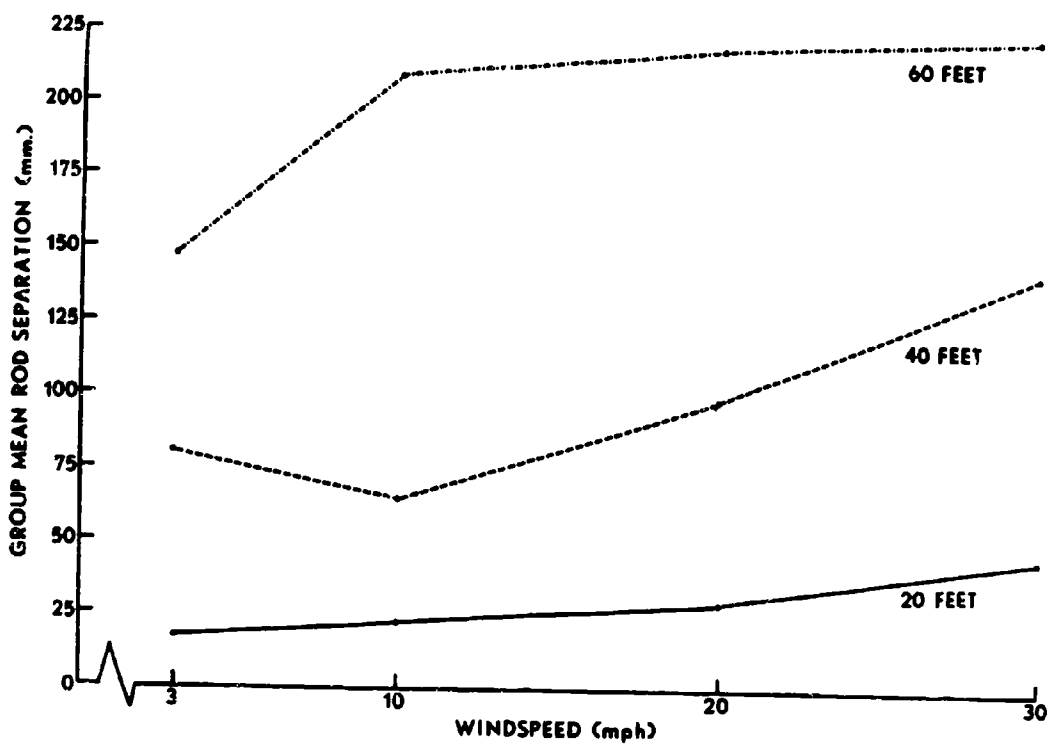

Figure 13. Group average depth judgment errors due to wind exposure at three viewing distances.

only be expected to increase at lowered ambient temperatures. Admittedly, these data have only determined that significant impairments will occur. The basic mechanisms affected and the means of prevention of such decrements remain to be determined.

In this paper, I have attempted to describe the general approach we are using at USARIEM to first determine whether the various classes of environmental exposure do in fact produce decrements of practical size in the various attributes of behavior involved in military performance, and if possible, the relative magnitudes of these decrements. From there, once we know impairments occur, we hope to identify the basic mechanisms involved in the failure, and to develop techniques for prevention and treatment of the disabilities. These studies have merely scratched the surface, and we plan to continue in these directions as well as in studies of the effects of heat exposure, and also fatigue.

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6D. BESRL FIELD EXPERIMENTATION FINDINGS ON PERFORMANCE EFFECTIVENESS WITH NIGHT OBSERVATION SYSTEMS

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INTRODUCTION

Human performance research information on night observation devices and sensors is required by many different military users. Training personnel want to know what kind of training is required and how long it will take. Operating personnel need to know how the devices should be used and how their effectiveness is influenced by environmental factors. Development personnel want answers on concepts, doctrine, and organization. Engineers seek to determine how the hardware can be improved. War gamers want to identify the key variables and their related parameters for inclusion in their models. And there is the military planner who wants a basis for his estimate of the potential tactical effectiveness of a system--will it increase present combat capabilities and to what extent? Should he buy or not buy? He needs all the information--and in consolidated form.

To provide information for these potential users, BESRL has established a field experimentation unit at Fort Ord, California. For the past two years, this unit has, with the support of the Combat Developments Command Experimentation Command (CDCEC), been conducting research with night observation devices. In order to make the research on these devices meaningful and realistic, it was necessary, first, to identify the critical factors affecting performance. Second, appropriate research technology had to be developed. Finally, relevant experiments had to be so designed that data could be extrapolated to cover a great variety of combat conditions, and also so that research findings could be generalized to other related systems.

RESEARCH PROCEDURE

The series of experiments conducted to date by the BESRL Field Unit have tested the performance of "players" using different devices under varying conditions and search requirements. Experimentation has been with passive night vision devices--specifically, the Starlight Scope (SS), the Miniscope (MINI), the Crew Served Weapon Sight (CSWS), and the Night Observation Device, Medium Range (NOD). These devices were selected because

of immediate promise of their large-scale deployment in combat and combat-ready zones.

The instrumentation system used, the MIDAS, is a new design developed through preliminary experimentation. MIDAS is an acronym for Multiple Input Data Acquisition System (the system was earlier called the Digital Electronic Data Acquisition System). Figure 1 shows a photograph of the system. The MIDAS, van-mounted to allow mobility, permits the collection of reliable data under field conditions and real-time monitoring and control of player personnel using devices or sensors. Data are recorded in a form permitting rapid analysis. The system is flexible and allows the recording of multiple data input of varying kinds. To date it has been used in conjunction with a Universal Device Platform (UDP) on which the night vision devices are mounted. The UDP contains encoders which measure the azimuth and elevation of the device with accuracy to within one-tenth of a degree. It also contains multiple buttons for player responses, which are recorded on the MIDAS. The azimuth and elevation of each device is recorded continuously at the rate of five times per second, providing a fine-grained permanent record of each player's search behavior. The MIDAS can handle simultaneous inputs of a very large number of players. So much for the instrumentation, but for those of you who have further interest, the unit is described in detail in a BESRL publication (Hyman, Sternberg, and Banks, 1970). (See Figure 1.)

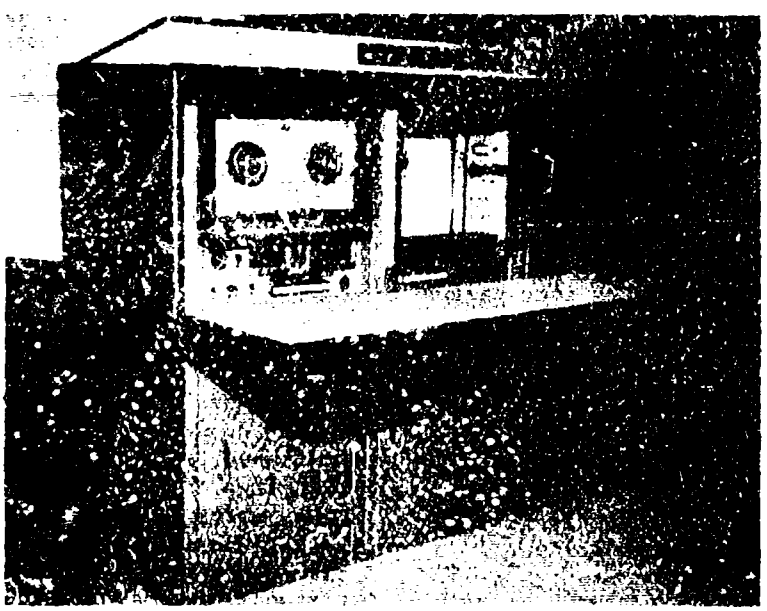

Figure 1. Photograph of Multiple Input Data Acquisition System (MIDAS)

The research is conducted at Hunter Liggett Military Reservation, part of the Fort Ord complex. Among the many terrain requirements, it was necessary that the terrain be of considerable size and suitable for a wide variety of experimentation. It had to be complex in order to provide a realistic search situation, and remote enough to be secure from outside light contamination. The terrain selected permitted use of a search area up to 75° wide and over 1500 meters deep. The land was flat to hilly, traversed by ravines and streams, with some large open grassy areas and some areas heavily cluttered with trees, brush, and rocks. The test area was surrounded by mountains and the nearest small town was 30 miles away. Skyglow and other light contamination was therefore eliminated.

The players were told that they were in a perimeter defense situation and were instructed to search the terrain continuously. Upon finding a target, they were to shoot it (simulated, of course) and continue searching. Search periods were of 30 minutes duration, followed by short administrative breaks. In general, the players were required to be on the devices for about six hours.

SELECTED FINDINGS

This presentation deals with a few selected findings which will be of interest to different users. More complete and detailed accounts are given in BESRL publications by Sternberg, Farrell, and Banks (1), Farrell, Banks, and Sternberg (2), Sternberg and Banks (3) and Hyman, Sternberg, and Banks (4).

Findings Are Related to Five Questions: 1) How effective is the man-device combination, and how can individual performance be improved? 2) How long can a soldier effectively use the devices? 3) How much time is required for training? 4) How are capabilities increased with Basis of Issue? 5) What are the effects of search area size on performance and on device deployment?

How Effective is the Man-Device Combination, and How Can Individual Performance be Improved?

To begin with, in all the experiments, the devices were far superior to the unaided eye. Performance was affected by a number of critical factors such as ambient light, distance, target mode, target type, and contrast. Table 1 gives the percent of targets detected in a 75° search area and how one of the critical factors--ambient light--affects performance. Notice that, with the exception of the NOD, performance on all devices shows a relative improvement of about 100% when illumination increases from starlight to full moon.

Although the players detected a substantial percentage of the targets, it is obvious that they also missed a large percentage. In order to improve the effectiveness of this man-device system, it was first necessary to determine why these targets were missed. Was it because the targets were too difficult--that is, beyond the intrinsic capabilities of the device? Or was it because of some failure on the part of the device operator? To answer this question, a technique was needed for determining which targets were perceivable within the capabilities of the devices when the operator's participation was at a minimum. The technique devised was to lay the device reticle on the center of

Table 1

PERCENT TARGET DETECTION
(Phase I Experiment)

DEVICE	AMBIENT LIGHT LEVEL		
	STARLIGHT	HALF MOON	FULL MOON
SS	24	36	52
MINI	20	30	45
CSWS	19	29	36
NOD	42	46	65

each target, so that no search was required, and then have the operator report whether or not he could see the target. Appropriate controls were used to keep everybody honest, and the measure was taken at the end of the evening's session so that the search test data were not contaminated. Thus, the obtained scores from the target seeability test provided a basis for determining what percentage of the targets each player could see with his own device under the environmental conditions for that night.

From the seeability test, it was found that some targets under some illumination conditions could not be seen with some devices--that is, the requirement simply exceeded the capabilities of the device. Table 2 shows the percentage of targets that could be seen with the various devices. As expected, there were considerable differences with the different devices, as well as under different ambient light conditions. With the exception of the NOD, target seeability was reduced dramatically as the light level decreased.

Table 2

PERCENT OF TARGETS WHICH COULD BE SEEN
(Phase I Experiment)

DEVICE	AMBIENT LIGHT LEVEL		
	STARLIGHT	HALF MOON	FULL MOON
SS	52	74	88
MINI	43	63	80
CSWS	56	82	87
NOD	83	82	91

For example, for the SS, the percent of seeable targets went from 88% under full moon to 52% under starlight.

Having determined the percentage of targets which were within the device capabilities, it was now possible to compute a new detection score based on the number of targets which were seeable, rather than the number of targets placed in the field. This new score, labeled the search efficiency index, was obtained by dividing the search detection score by the seeability score. It denoted the percentage of visible targets detected during search. Thus, the search efficiency score provided a basis for describing operator performance. If the player were performing perfectly, he would have been able to detect all the targets he was able to see. For example, if a player was able to see 52% of the targets and he actually found 52% of the targets, then he would have found all the targets available to him with his device. On the other hand, if he found, let us say, 26% of the targets, he would have found only one-half the targets available with his device. Table 3 shows the search efficiency scores. Notice that, on the average, only 50% of the targets that were within the capabilities of the device were actually detected during search. In other words, the operator was failing to find one-half the targets which were within the device capabilities.

Once operator behavior was identified as a major cause for failure to detect targets, two questions were raised: Specifically, what was the operator doing, or not doing, which accounted for this detection loss? How could his error be corrected? We started out by asking a simple-minded question: Was the player searching the area where the target was located? To answer this question, we examined the operator's search record to identify which targets he had missed, and then determined how many of these missed targets were ever in the device field of view. The results are shown in Table 4.

Notice that a relatively large percentage of the targets which were missed were never in the device field of view. In other

Table 3

SEARCH EFFICIENCY: PERCENT TARGETS FOUND OF TARGETS SEEABLE
(Phase I Experiment)

DEVICE	AMBIENT LIGHT LEVEL		
	STARLIGHT	HALF MOON	FULL MOON
SS	46	49	50
MINI	47	48	56
CSWS	34	35	41
NOD	51	56	71

words, those particular targets could have been as big as a house with a light in the window and the player still would have missed them because he simply never looked at that portion of the terrain at the appropriate time. The evidence is quite clear. The players were not searching the field comprehensively, particularly under the low illumination condition.

In this experiment, the players were to search in the manner in which the Army had instructed them--that is, after a hasty search they were to search the field with left to right, right to left sweeps until the entire terrain was covered. An interesting note: In debriefing sessions, the players indicated that they believed they had been searching the entire area.

This finding led to the second question: Were targets missed because the player was searching too rapidly the area in which the target was located? Based upon hit scores, the length of time a target should be in the device field of view in order to make a detection was established. The search records provided means of determining how many of the missed targets were in the device field of view for less than the specified time. The results showed that a large percent of the targets were missed because they were not in the device field of view for a sufficiently long period of time.

The results of these analyses clearly demonstrate that operator failure, which had previously been identified as a major problem, was attributable in large part to lack of comprehensive search and to search which was too rapid.

Once these deficiencies had been pinpointed, the question was whether anything could be done to correct them. To this end, three new search techniques were tested in a subsequent experiment. While there was no difference among the new techniques, each one was superior to the technique previously used. The one commonality of the three new techniques was that they produced comprehensive and timely search behavior.

How Long Can a Soldier Effectively Use the Device?

One of the critical operational problems with the devices is how long a soldier can continuously use them before his performance degrades. Two experiments provided data on this problem. In one experiment, players used the devices almost continuously for a six-hour

Table 4

PERCENT OF MISSED TARGETS WHICH WERE NEVER IN THE DEVICE FIELD OF VIEW
(Phase I Experiment)

DEVICE	AMBIENT LIGHT LEVEL		
	STARLIGHT	HALF MOON	FULL MOON
SS	25	20	10
MINI	28	22	18
CSWS	46	41	38
NOD	25	25	24

period. It was found that for all practical purposes, a soldier when properly motivated performs as well at the end as he did at the beginning. Figure 2 shows the effects of prolonged activity on performance under starlight illumination during the first, mid, and last part of the search test. Notice that level of performance did not change appreciably throughout the evening. Similar results were found for all ambient light levels. (See Figure 2.)

A second experiment was designed to test more specifically the effect of continuous military operations on the soldiers' effectiveness using the devices. The players were kept continuously active with a variety of military tasks and tests for almost 48 hours straight, with no scheduled sleep. After a full day's activity--approximately 14 hours--they were required to use the devices for the next six hours. They were then kept busy on military tasks for the next 24 hours and again tested on the night vision devices on the second night. There were two significant results: Performance on the second night showed no decrement. The players had more stamina than the experimenters.

A corollary question was whether prolonged use of the devices resulted in illness. In both experiments, and other BESRL experiments as well, only two out of approximately 750 subjects dropped out because of illness. Both had severe headaches with some nausea. An examination of their devices showed that each had an incorrect diopter setting--clear warning that if a soldier is to use a night vision device for an extended period, it is essential that he have the correct diopter adjustment.

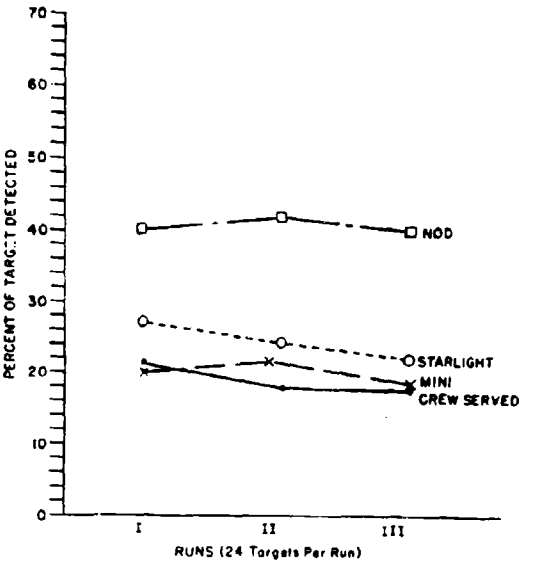

Figure 2. Effects of Prolonged Activity on the Percent of Targets Detected (Starlight Conditions)

One additional note, and this to researchers in this area: The data on prolonged activity indicate that the researcher does not have to worry about confounded data because of using subjects for lengthy periods of time.

How Much Time is Required for Training?

The amount of time required for training is only part of the problem. Of equal importance is how men are trained. Experimental subjects who claimed that they had used the devices in Vietnam indicated that they had received no training within CONUS and that they had received no formal training overseas. Their lack of knowledge and misinformation about the devices was enormous. Typically,

they did not know how to make the diopter adjustment or how to focus, and frequently confused the two operations. Some did not know how to change the battery or even the location of the on-off switch.

It was found that 90 minutes of individual instruction and practice is sufficient to bring the players to a stable level of performance. In the experiment the training period consisted of 15 minutes of device familiarization, which included how to focus and make the necessary diopter adjustments. A simple diopter adjustment procedure developed by BESRL proved to be very rapid and highly reliable. The next 15 minutes was spent in showing the players what targets looked like through the device. The final 60 minutes were spent in giving the players practice in comprehensively searching the area and locating practice targets.

How are Capabilities Increased with Basis of Issue?

Operationally, Basis of Issue (BIO) means more personnel and more devices and this means more money. Thus, one of the prime considerations is going to be whether the result is worth the cost. The answer, on the basis of present experimentation, is yes--up to a point.

In each experiment, multiple players used devices of the same kind; for example, on a particular night, three players used the Starlight Scope. Thus, what percentage of the targets were detected by one, two, or three players independently searching the same area could be empirically determined. Table 5 shows the BOI data from one experiment using a 75° search area. Notice that an increased BOI under starlight conditions resulted in a considerable relative percentage increase in going from one to two devices and a lesser increase in going from two to three devices, e.g., performance on the Starlight Scope increased by 12/17, (or 70%) in going from one to two devices, and by 9/29, (or 30%) in going from two to three devices. In other words, performance will show the largest relative improvement in going from one to two devices. Also, when performance for one operator is at a fairly high level, such as under the full-moon condition, the relative percentage increase with additional devices is appreciably less. Similar data have been obtained for smaller search area sizes; and while the percentage increases are smaller, they are still of sufficient practical significance to encourage the use of a second device.

What are the Effects of Search Area Size on Performance and on Device Deployment?

The search area obviously must be tactically determined. However, to the extent that the local commander has some degrees of freedom, information on the effects of search area size will be useful. An experiment was set up in which the same players using the same devices under the same environmental conditions were required to find the same targets using 25°, 35°, and 75° search areas. Two questions were asked: 1) How much does performance increase as the search area size is decreased? 2) When more than one device of a kind is used, what is the best way to deploy the devices--should overlapping or non-overlapping search sectors be used? Part of the results relating to the first question are shown in Table 6.

Table 5

PERCENT TARGET DETECTION WITH ONE, TWO, AND THREE DEVICE OPERATORS SEARCHING A 75° AREA
(Phase II Experiment)

DEVICE	AMBIENT LIGHT LEVEL					
	STARLIGHT			FULL MOON		
	NUMBER OF DEVICES			NUMBER OF DEVICES		
	ONE	TWO	THREE	ONE	TWO	THREE
SS	17	29	38	58	77	85
CSWS	26	38	50	47	69	81
NOD	40	59	68	66	86	89

Table 6

EFFECT OF SEARCH AREA SIZE ON PERCENT TARGET DETECTION
(Phase II Experiment)

DEVICE	SEARCH AREA	AMBIENT LIGHT LEVEL	
		STARLIGHT	FULL MOON
SS	75°	17	58
	35°	25	69
	25°	33	64
CSWS	75°	26	47
	35°	34	67
	25°	40	66
NOD	75°	40	66
	35°	54	69
	25°	56	69

Under starlight condition, there was considerable increase in performance as the search area size decreased; e.g., performance on the Starlight Scope almost doubled when the search area was reduced from 75° to 25°. On the other hand, under full moon conditions there was generally a very small increase. The operational implications are obvious: Under starlight conditions, the search area size should

Table 7

PERCENT TARGET DETECTION WITH THREE OPERATORS SEARCHING A 75° AREA HAVING OVERLAPPING VS NON-OVERLAPPING SECTORS (Phase II Experiment)

DEVICE	AMBIENT LIGHT LEVEL			
	STARLIGHT		FULL MOON	
	NON-OVERLAP	OVERLAP	NON-OVERLAP	OVERLAP
SS	33	38	64	85
CSWS	40	50	66	81
NOD	56	68	69	89

be decreased, if tactically feasible. If however, it is necessary to cover a larger area, then an increased BOI should be considered.

When the tactical situation dictates that a large search area must be covered and two or three men with devices can be used, what is the best way of deploying the devices--should search areas completely overlap or should the search area be divided into subsectors? Table 7 shows the results when three men searched a 75° area.

For each device, under each ambient light condition, performance resulting from overlapping the search sectors was superior to performance with the search area divided into non-overlapping sectors. This difference was particularly evident under the full-moon condition. As a matter of fact (although not shown in Table 7), under full-moon, the performance of only two men overlapping a 75° search area was superior to the total performance of three men, splitting the area into three 25° subsectors. The operational implications are that when more than one device is to be employed in a search sector, it is better not to fractionate the area, but rather to have all men search the same area.

CONCLUSIONS

The evidence is clear-cut: the night observation devices studied are effective and will add to the Army's combat capabilities, but their level of effectiveness is dependent upon how they are used. Performance is affected by critical factors such as ambient light, distance, and target characteristics. Device operators can be trained in 90 minutes and can use the devices almost continuously for at least six hours without degredation in performance. Effectiveness can be increased in a number of ways--by the use of improved search techniques, by better work methods and procedures, by deployment procedures, and by increased Basis of Issue. The military planner and the users can choose the alternatives which most efficiently meet their needs.

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CHAPTER 7
HUMAN FACTORS IN THE DESIGN, DEVELOPMENT AND TESTING OF COMMAND CONTROL SYSTEMS

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7A. BRIEF HISTORY AND PREVIEW OF HUMAN FACTORS ENGINEERING IN SAFEGUARD COMMAND AND CONTROL

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INTRODUCTION

The SAFEGUARD Anti-Ballistic Missile System is a large-scale, complex, military weapon system. It follows that the Command and Control Subsystem, that is, the equipment, procedures, and personnel responsible for the operation of SAFEGUARD, is a large-scale, complex subsystem. And, of course, the job of the human factors engineer in the design and evaluation of the Command and Control Subsystem and its interfaces with other subsystems, is large and complex. He must deal simultaneously with requirements for and details of information display, controls, communications, construction and placement of operating equipment, software capabilities and responses, training and of course, no topic can be discussed adequately these days without including man's environment. It is my purpose, in this talk, to discuss the human factors effort which has been undertaken by the Weapon System Contractor in the development of SAFEGUARD Command and Control.

GENERAL GUIDELINES FOR THE HUMAN FACTORS ENGINEER

There are several unofficial guidelines which have been and are being followed in SAFEGUARD. First of all, the human factors engineer should participate in the system design and development from the earliest possible moment. Second, he should coordinate his efforts with those of other contractor activities, the weapon system project manager, and the eventual user of the system. And, finally, he must continuously follow and evaluate the design and development of the system, being constantly aware of any system perturbations whether large or small, which may have impact in the human factors area. A small perturbation in this ABM system might result from a requirement for an additional pushbutton on a console. However, a much larger perturbation resulted when the President announced the change in our national policy from deployment of the SENTINEL to the SAFEGUARD System.

Early Participation

To discuss the first guideline, early participation, it will help to review some of the history and philosophy behind SAFEGUARD.

Following our development of the NIKE-AJAX and -HERCULES air defense systems, we were asked by the Army

to develop a ballistic missile defense system. This began as NIKE-ZEUS and later was changed to the NIKE-X System. This system has undergone changes in specific mission which resulted in the SENTINEL and now the SAFEGUARD System, but the basic NIKE-X philosophy concerning man's role in Command and Control remains essentially unchanged. Man is regarded primarily as a manager and controller, and not as an operator of the system. This differs from the approach in the early air-defense systems in which man performed many operating functions such as detection of targets, initiation of target tracking, and selection of targets to be engaged.

The specific division of functions between man and the machine stems from one of the first steps in the design process, namely, to examine the general functions required of the system, and arrive at a specific and detailed list of tasks which the system would have to perform. Each task was then classified as to whether the task:

a) could be automated;
b) could not be automated without unacceptable costs in terms of system performance, development time, or dollars; or
c) could not be automated at all either because of state-of-the-art limitations, unexpected system excursions, or legislated requirements set by the government.

As it turned out, a very large number of tasks could be automated, and we made the decision that any task that did not require man to be in the loop would be performed automatically. In many of these tasks, however, man is allowed to enter the loop in order to seek additional information and/or override the automatic system response. This then, is the basic Command and Control Philosophy - man manages and controls but, except for a small number of nonautomatic actions, he does not operate the system.

This difference between SAFEGUARD and other weapon systems is worth mentioning. The design process in most systems, whether the system is a rifle, a tank, a helicopter, or an air defense system, begins by asking "What must the man be able to do with the system?" He must be able to fire the rifle, control the tank, fly the helicopter, and operate the air defense system. The system has been built for man's use, and without man in the loop the system cannot operate. In SAFEGUARD and its predecessors, however, the design process began by asking, "What can the system do?" and man was thus assigned to the higher role of primarily managing and controlling the automatic system.

You may ask why the decision was made to automate all of those functions which could be automated. An intuitive though not completely correct answer would be that since the requirements for SAFEGUARD are quite complex and the response time must be very quick, man's capabilities cannot possibly match those of the automatic system. Obviously, there are many functions for which that statement is true, but in many cases we feel that man could, quite adequately, match or exceed the automatic system's responses. Of course, this would take a lot of men. Men who have to be trained, and fed. Facilities would be required for training, feeding, housing, recreation, medical care, as well as for offices and operating areas.

Personnel directly involved in Command and Control for the smallest SAFEGUARD deployment number in

the hundreds. This does not include a much larger number of support personnel. If we had asked, "What can man do in the system?" and assigned all of these tasks to man, many thousands of people would be required. Another reason, then, for assigning most of the functions to the automatic system is because the system can do them so much more economically while freeing man for the more important function of monitoring and controlling SAFEGUARD.

But to say that man is a manager and not an operator is not to say that he has it made. Assuming that our system functions perfectly, it would strain our credulity to believe that an attacking country would study our design threat documents and automatic system specifications and then build, fire, and target their missiles to conform exactly, without any excursions, to our specifications. In order to meet such excursions, and to deal with other perturbations which occur in the system, man has been provided with sophisticated display, communications, and control facilities and thus has available a large number of action options which allow him to query, intervene, and override the automatic system. Throughout the development of the system, the job of the human factors engineer has been intimately involved in the design of these displays, communications, and controls.

Coordination with Contractor and Government Personnel

The second general guideline was coordination with contractor and government personnel. Contractor personnel, in this sense, includes the large number of design and development groups of the weapon system contractor as well as the various subcontractors. Clearly it would be inefficient to include human factors specialists in each of these many organizations. But, equally clearly, the design of each component and subsystem must be satisfactory and consistent from a human factors standpoint. In order to meet these requirements each design organization verifies that certain basic human factors principles are satisfied, and these designs are then reviewed by a central group of human factors evaluation people. Some of the evaluation techniques and facilities will be discussed shortly. Following this review recommendations, if any, are made to the appropriate design organization.

The other major coordination arrangement is between our human factors evaluation people and the Army organizations which are directly involved in SAFEGUARD Command and Control. These include SAFEGUARD System Office in Washington, SAFEGUARD System Evaluation Agency at White Sands, SAFEGUARD Central Training Facility here at Fort Bliss, SAFEGUARD Communications Agency at Fort Huachuca, Army Air Defense Command (ARADCOM) at Colorado Springs, and Human Engineering Laboratories at Aberdeen Proving Ground. At our location in Whippany, New Jersey, we have permanent representatives from many of these agencies, and this naturally results in an excellent, coordinated working arrangement, and speeds the flow of information to all parties. Some examples of how this arrangement has worked are worth mentioning.

The eventual user of the SAFEGUARD System, ARADCOM, has organized a working group to discuss Man's Role in SAFEGUARD Command and Control, or MARSCCO. These meetings are held at appropriate Command and Control milestones and familiarize the contractor and all interested agencies as to the system's progress, usually

months before this material would otherwise be available. The meetings also provide an ideal forum for discussion of questions, problem areas, or anticipated changes in the design.

ARADCOM's Ballistic Missile Defense Test Unit at White Sands has two officers at Whippany working exclusively with our Command and Control people in our human factors evaluation area.

The human factors people at the SAFEGUARD Evaluation Agency at White Sands are constructing a facility which is intended, in part, to simulate the Command and Control Subsystem. We have a somewhat similar facility, which will be described later, and will be cooperating with SAFSEA in sharing our results and in avoiding unnecessary duplication of effort.

Continual Human Factors Evaluation

The third general guideline mentioned, that of staying on top of the system, encompasses the bulk of the continual human factors effort. In a talk such as this, rather than bore you with countless details, it is worthwhile to touch upon a few selected highlights of the SAFEGUARD human factors test and evaluation program.

The early system work, which was hinted at previously, began with a description of tasks which the system would have to perform. This, in turn, led to the formulation of action options to be made available to man in his role as a system manager. This was followed by detailed task analyses and studies of personnel requirements, conducted in-house and also by several government agencies and subcontractors. The physical plant, operator consoles, wall displays, and other command and control facilities were designed, mocked up, and run through several development iterations in order to match all of the established requirements. Where possible, dedicated human factors tests were run with the latest system equipment. For example, an extensive human factors test and evaluation program was conducted a few years ago at the operational NIKE-X MAR-I site at White Sands. As a result of the lessons learned from this effort, many human factors changes have since been incorporated.

The last few years have seen many significant changes in the system. For example, the standard NIKE-X console was a huge, massive piece of equipment. In order for the operator to see around it, he had to stand up or move a few feet to one side. The design of the SAFEGUARD CRT console, released within this past year, reveals a low, compact, easy-to-manage, L-shaped console. The first few consoles have been received at our Whippany location, and are currently undergoing design engineering testing prior to a large-scale human factors test and evaluation program which will encompass the entire Command and Control Subsystem. In preparation for this program, we are now completing development work on the SAFEGUARD Command and Control Test Facility at Whippany. This facility consists of a UNIVAC 1219 computer[1]

[1] The UNIVAC 1219 is an 18-bit, 32K core memory general-purpose computer, and has four tape units and a card processor for input-output. The programs require approximately 11,000 instructions and eight man-years of programming effort. Data analyses and output listings will use a line printer associated with a large, in-house computation center.

and equipment to interface the computer to on-line, operating SAFEGUARD consoles, wall displays, teletypewriters, and other command and control hardware which are also part of the facility. The computer programs which are being written for the 1219 simulate, insofar as the console operator can discern, the highly sophisticated SAFEGUARD software. In fact, the entire facility --displays, controls, physical environment, hardware, communications, procedures, and other elements--will, insofar as possible, duplicate those at a deployed SAFEGUARD site. What we have in this facility, therefore, is a real-time, on-line, dynamic interactive simulation of the man-machine interface.

Following training, scenario generation and other initiation procedures one or more console operators will perform several missions and tasks. Actions and responses of other SAFEGUARD personnel and equipment will be simulated under scenario or test plan control. Test conductors will observe the operators, and, as required, play the roles of SAFEGUARD System personnel. In this manner the test effort is directed toward the evaluation of the specific console operator positions. Worst-case tests will be designed to maximally stress the operators, within limits of realism. The console operators' actions and responses, as well as all significant system events, will be recorded by the computer in real time for later analysis. The test subjects will initially be Bell Labs technical personnel, followed, after equipment and test procedures have been verified, by ARADCOM personnel.

In addition to the Command and Control Test Facility, which serves primarily as a human factors laboratory, a large-scale software development facility, the Tactical Software Control Site (TSCS), is also being constructed. The TSCS will contain most of the SAFEGUARD Command and Control hardware and will have data processors that are functionally equivalent to the tactical SAFEGUARD data processors. All of the major software packages, including missile and radar packages which are far more complex than command and control software, will be developed here prior to being installed at the actual site. The human factors effort at the TSCS, which will not start until a year or more after testing on the Command and Control Test Facility has begun, will be a more limited effort than that at the test facility.

It might be worthwhile to ask, "Since a data processor which is functionally equivalent to the tactical one, and an equipment complement approaching the tactical complement exist at the TSCS, why have we established a test facility with simulated software and a limited equipment complement?" The answer is rather obvious, and probably applies to all large-scale systems. It became clear that changes in the design resulting from design inadequacies discovered in the human factors test program may be costly and time consuming, these costs and delays being increasing functions of time with steps in the function due to design freezes, delivery dates, and other factors. However, if these design flaws were left in the system catastrophic failures could result. Thus, in order to minimize costs and delays it is necessary to complete the bulk of our human factors test program at the earliest date possible. The Command Control Test Facility has been designed specifically to meet this requirement for early feedback in the command and control design evaluation program.

CONCLUSION

As the title of this paper suggests, I've presented some brief history and philosophy of SAFEGUARD Command and Control. In SAFEGUARD, as contrasted with other weapon systems, man is regarded primarily as a manager and controller and not as an operator of the system. The reason for this is to conserve manpower and associated expenses as well as because of limitations in man's ability to operate the system. I have also presented a review of the continuing human factors test and evaluation effort, and would again like to stress the importance of and the benefits from mutual cooperation between the contractor, subcontractors, and all interested government agencies. Finally I have described the SAFEGUARD Command and Control Test Facility which we have established principally for human factors test and evaluation. This facility will allow for inclusion of necessary design modifications at a date when they would be relatively less difficult to incorporate than if they were discovered at a later point in the program.

While this paper has specifically described SAFEGUARD Command and Control, many of the points which have been discussed are relevant for most large scale man-machine systems.

7B. HUMAN FACTORS TESTING OF UNATTENDED GROUND SENSORS

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The Human Engineering Laboratories (HEL) have been providing consultant support to several programs set up to field test unattended ground sensors (UGS). Our involvement in those programs provides the basis for this paper.

UGS represent a new class of items in the military inventory. As such, the parameters of human performance relevant to UGS have been ill defined. What tasks are required of the soldier, how well is he required to perform these tasks, and how well can he perform these tasks? This question summarizes the support HEL has been asked to provide through reviewing the literature and recommending test designs. This paper presents an overview of our current "answer." First, an overview of UGS systems is given. A systematic outline of human factors involved in UGS is provided. Finally, the type of testing ongoing and relevant literature is described.

UNATTENDED GROUND SENSOR SYSTEMS

UGS form one of the families of surveillance and target acquisition devices now available to the military. As an extension of the soldier's senses UGS may detect voices, footfalls, movement, or metallic objects. Sensors are usually integrated into a total battlefield surveillance and target acquisition plan where they supplement and complement other sources of battlefield information.

A simplified illustration of an UGS system is depicted in Figure 1. The three basic components of this system are the sensor, the monitor, and the command element. This UGS system model allows us to point out where human factors have the greatest impact on the system.

SENSOR. The sensor element in Figure 1 is an unattended environmental energy transducer. When stimulated by a change in an energy dimension it notifies a remote monitor site by radio link that a change in the environment has occurred. Several families of UGS have been developed, each designed to perform a specific detection function. These include acoustic, seismic, magnetic and infra-red sensing devices. Figure 2 shows a typical sensor and its accessories.

The choice and mix of sensors to be planted in the monitored environment depends on many factors including the terrain, composition of soil, vegetation, emplacement accuracy required and the overall tactical situation. Sensors may be hand emplaced by ground troops; or, in areas which preclude hand emplacement because of the terrain or the tactical situation, they may be delivered by air, artillery or mortar fire.

MONITOR. The monitor site receives information from one or more UGS. While some acoustic sensors provide the monitor an actual listening capability through the use of headsets, information from most other UGS is received in digital readout form and indicates only that the detection logic of the sensor was somehow satisfied. The incoming data is analyzed on a real time basis. The monitor knows the type of sensor being activated (seismic, magnetic, infra-red, etc.) and its approximate location within the environment. From the pattern of incoming signals the soldier monitor filters out true targets from continuous false activations (noise). In filtering, the monitor performs a three level perceptual classification task: detecting activity in the environment, recognizing or discriminating the source as man or vehicle, and identifying the source of activity as friendly or enemy. Through knowledge of the sensor deployment scheme and by analyzing sequential activations of sensors in a string, the monitor also attempts to determine direction and rates of enemy travel. The ability of the soldier monitor to perform these tasks is the key element in the entire UGS system.

COMMAND ELEMENT

The monitor of a sensor receiver unit is normally collocated or in direct communications with the intelligence or operations center. At the monitor site the incoming UGS information is interpreted and passed on to the command element for decision. The command element then further processes the sensor derived information (enemy activity or lack of it) in conjunction with current friendly activities and other collateral intelligence. The processed information received can then be used for immediate targeting or stored for longer range intelligence collection. Target acquisitions gained from UGS are normally short lived and, so, are usually followed by the delivery of timely and effective firepower upon the area in which the threat is detected. This firepower may come in the form of artillery or mortar barrages, air strikes, ground assaults or detonation of pre-positioned land mines.

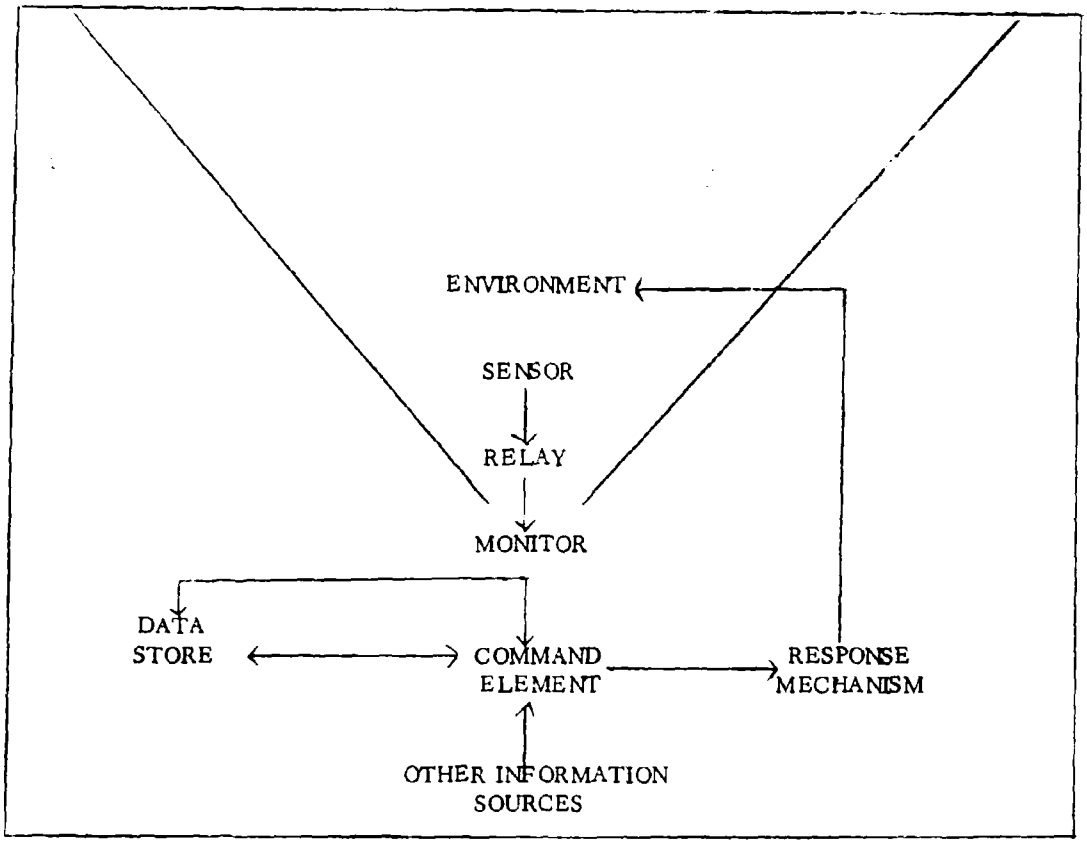

Figure 1. Unattended Ground Sensor System

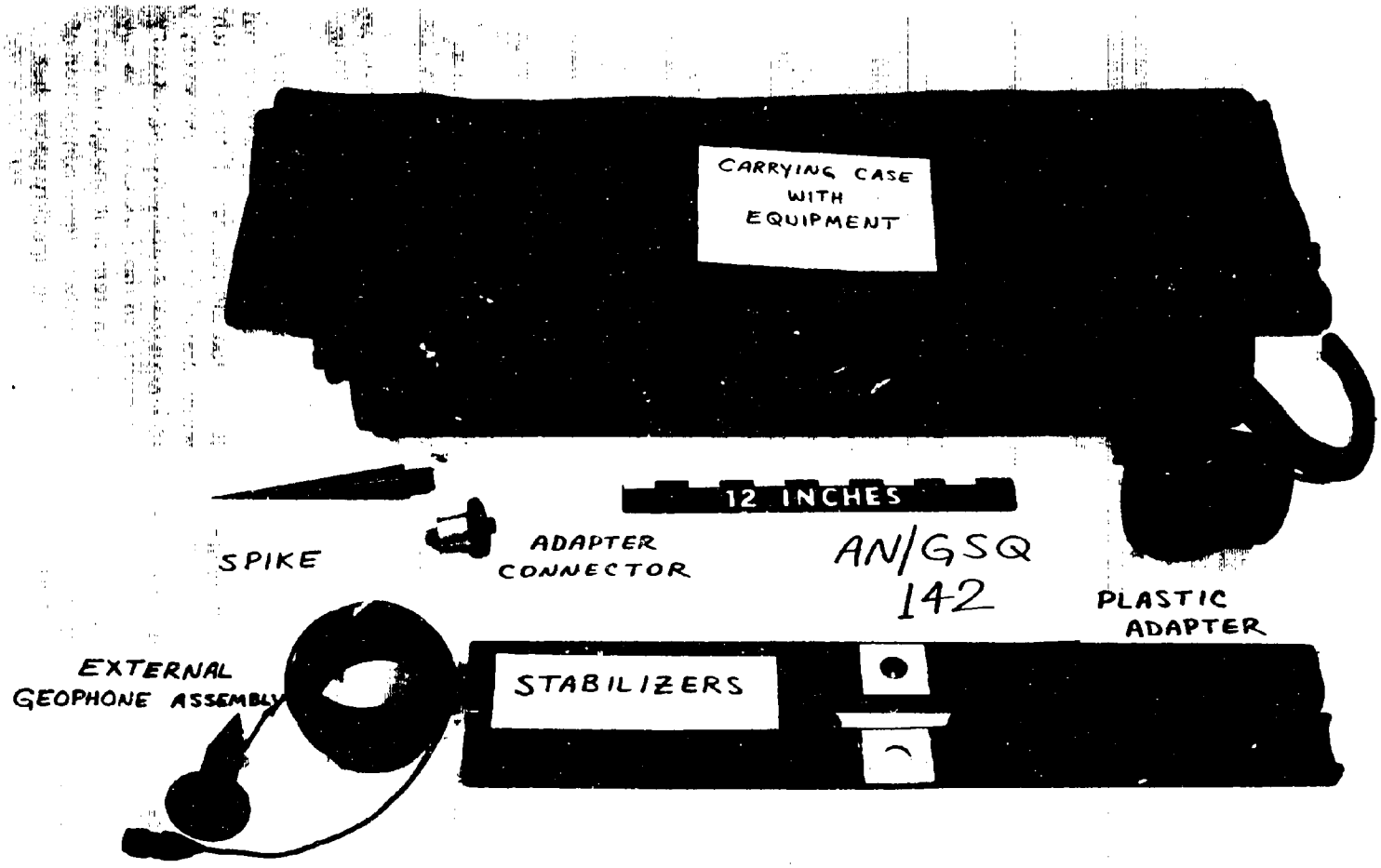

Figure 2. Typical Unattended Ground Sensor (UGS)

HUMAN FACTORS IN UGS SYSTEMS

The UGS system concept shown in Figure 1 contains some deceivingly simple human factors parameters. Table 1 outlines some of the tasks which man must perform in a hand emplaced UGS system. Most of these tasks are also common to systems which are to be emplaced by aircraft or by artillery/mortar fire. The outline contains two basic divisions: deployment schema and surveillance information analysis. In analyzing the important human factors parameters for each of these tasks, two facts become readily apparent:

1. Each of these apparently simple military tasks really involves quite complex human performance.

2. The literature provides little useful information on previous tests of these man-machine functions.

PORTABILITY

To exemplify the first of these points, Table 2 lists the separate tasks involved in porting an item in a tactical environment. The "simple" task of porting an UGS dictates many important implications for the design of that sensor. The individual soldier carries the sensor in addition to his rifle and the standard complement of combat clothing and equipment (steel helmet, canteen, first aid, ammunition, etc.) and while negotiating terrain obstacles and performing combat functions.

The surprising fact is that the literature contains relatively little useful information on how to design an item so that it is portable. The literature also provides little guidance on how to evaluate or test the portability of an item. For example, there are many references to physiological measures which were taken while a man ports an item. However, these are usually interpreted to indicate how hard a man is working but do not really tell how "portable" the item is!

CAMOUFLAGE

A second example which illustrates these points is the task of camouflaging an UGS. The literature discusses many visual perceptual variables (size, shape, color contrast, pattern of search, etc.) which play a part in the camouflage of small items. However, just knowing the variables involved provides little guidance on how to design an item so it can be easily camouflaged. For each newly developed item it seems the designer still must go through the same kind of camouflage analysis that the human factors tester does.

To empirically test the "camouflagability" of an item is a very complex task. It is usually accomplished by having a man camouflage an item(s) and then having other men try to locate them. This sounds straightforward enough. Typical measures of performance recorded are the time it takes to find items and the number of items which were missed in an area. However, it is known that search strategies vary according to the risk involved in not locating an item fast enough or not at all. Further, upon completion of such a test one quickly notes that

TABLE 1

HUMAN FACTORS TASK OUTLINE FOR ANALYSIS OF UGS SYSTEMS

Deployment Schema

1. Training/Documentation
2. Assembly and Checkout of UGS
3. Operability
4. Portability/Transportability
5. Land Navigation
6. Emplacement and Recovery
7. Camouflage

Surveillance Information Analysis

1. Acquisition (Monitor)
2. Command and Control

TABLE 2

TASKS INVOLVED IN PORTING

1. Preparing an item for carrying (disassembling, placing in carrying case, etc.)

2. Loading item on body (in addition to the normal complement of equipment).

3. Porting the item in tactical patrol posture.

4. Negotiating terrain obstacles while porting the item.

5. Performing combat functions while porting, e.g., firing rifle, running, fording streams, etc.

6. Removing of the item from the body.

7. Preparing the item for use at destination.

some people are more proficient at camouflaging than others. It is tempting to task the question: "Am I really testing the camouflagability of the item, or the ability of one man to hide something?" The best output of such tests is probably to specify to the equipment designer which features of his item are most difficult for soldiers to camouflage in a particular environment. In the absence of normative data on camouflage, test results provide only indications of camouflage quality.

SURVEILLANCE INFORMATION ANALYSIS

Table 3 lists some of the basic tasks which are involved in the monitoring and command and control functions of an UGS system. Some of these tasks also involve complex human performance. As might be expected, because of the newness of UGS, there is little relevant literature which indicates how well an operator/monitor can process information from multiple sensor readouts or similar types of multiple input.

HUMAN FACTORS TESTING OF UGS

The testing of UGS has been accomplished at a very fast pace and has been concerned mainly with questions of immediate and practical importance: "Is the UGS portable?" "Is it easily camouflaged?", etc. Thus, the human factors concern has been whether "the gadget will permit the using soldier to function with reasonable accuracy, safety and comfort in the item's intended environment," Elegance of testing was not required, only answers to specific questions.

To provide "answers," the system concept and task outlines described in the previous section were identified for the testers. Although admittedly simple, the development of this "systems" viewpoint was a necessity for establishing a framework for the human factors portion of the testing. No a priori criteria against which to test were available. These criteria had to be derived from an analysis of the expected system performance requirements.

TEST METHODOLOGY AND DATA COLLECTION. Since the requirement was for very fast reaction user evaluation testing, the use of instrumentation was deemphasized in the test programs. Human observers became the primary source of data in field observation settings. This was a fortuitous occurrence because the concern was not just with measuring performance on a task, but with making judgments of the adequacy of the task performance. All of the data collectors are personnel with SEA experience. They provide several advantages over "instrumented" data collection. Some of the more important characteristics of the human observer as data collector in this style of testing are:

1. Humans are easily reprogrammable for roles in different tests and can take advantage of contingencies.

2. Using standardized data collection forms, human observers can quickly produce "interpreted" data.

TABLE 3

UGS INFORMATION, ACQUISITION AND PROCESSING
TASK OUTLINE

1. Documentation

   a. Identify Sensor strings deployed

   b. Pinpoint sensor locations, by type, on a map

   c. Record the time it takes to traverse the terrain between sensors

   d. Distribute the documentation as required

2. Acquisition

   a. Monitor UGS readouts

   b. Record sensor activations

3. Processing

   a. Interpret sensor activations

   b. Correlate target information with other sources

   c. Determine significance of target threat

4. Decision

   a. Decide on action to be taken

      (1) Store Data

      (2) Call upon firepower

   b. Notification of fire direction center or maneuver elements to act

TABLE 4

SURVEILLANCE INFORMATION ANALYSIS

1. Monitoring/Information Processing

   a. What information must the operator receive or is the system designed for him to receive?

   b. What transformations of the information must the operator make?

   c. What informational output must (can) the operator make?

2. Command and Control

   a. How does sensor derived intelligence correlate with information from other sources?

   b. What response mechanisms are available?

   c. What decisions must be made?

3. Observers can monitor several channels of information which machines do not measure easily.

4. Observers can selectively filter relevant data from noise.

SAMPLE TESTS. Several static and dynamic human factors tests have been introduced into the programs. To test the design of UGS for ease of Assembly/Checkout and Operability, established human engineering standards and guides (i.e., MIL-STD-1472, HEL-S-7 and HEDGE) were consulted and comprehensive check-lists were formulated. Test personnel used these checklists to systematically evaluate each newly developed UGS in a static checkout session. Deficiencies were identified and recommendations for design improvements were fed back to the developing agencies.

One example of a dynamic test which was established is a portability test. A course of varying terrain conditions and obstacles is set up and test subjects are required to perform all the tasks listed in Table 2 while negotiating the course. A single data collector, an experienced infantry NCO, is equipped with standardized data collection forms and checklists and required to systematically assess whether the configuration of the ported item interferes with the subject's performance of the tasks while negotiating the course. The emphasis is on an experienced judgmental critique of the item's "portability." The test subjects are debriefed after the run. The data is summarized into simple descriptive statistics. Narrative descriptions of how an item interferes with the performance of specific tasks are included in test reports.

SURVEILLANCE INFORMATION ANALYSIS. Although the testing program has been predominantly oriented toward the evaluation of individual sensor items, stress has been given to the importance of "system evaluations." Table 4 lists some of the basic questions which are currently being addressed in the evaluation of the hub of operations -- the command and control center.

Two major tasks have been identified. We must first evaluate how well an operator/monitor can process information from multiple sensor readouts. Without reliable monitor processing, the sensor system cannot function. We must also evaluate alternative means of integrating the sensor derived information into the overall battlefield surveillance system. The crux of this matter is of course, how well does the commander use the sensor data?

SUMMARY

In summary, this paper has attempted to point out the human factors involved in unattended ground sensor systems. The apparently simple military tasks involved actually include "complex" human behavior about which there is little previous design information or test guidance. The human factors task analytic effort required to support an UGS field testing program was portrayed by a discussion of testing support provided.

7C. HUMAN FACTORS ENGINEERING FOR TACFIRE

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INTRODUCTION

This paper provides an overview of the contractor's human factors engineering effort during the development of the Army's TACFIRE command and-control system. A brief description of the system is included and the history of the TACFIRE technical development phase is summarized. System analysis and design efforts are discussed with emphasis on the contribution of human factors engineering personnel. Equipment and facilities design contributions are specified, an outline of the Training Aids and Devices Study is provided, and human factors engineering participation in system test and evaluation and to safety is described. The paper concludes with remarks about the personnel/equipment data (PED) file and engineering change documentation.

DESCRIPTION OF TACFIRE

TACFIRE is a computer-based command-and-control system for the Field Artillery. Digital computers are situated at Division Artillery and Battalion Fire Direction Centers. The computers are controlled from Artillery Control Consoles, which are CRT typewriters containing two CRTs - one to display received messages and one to edit or compose messages to be sent. In addition to the Artillery Control Console, the Fire Direction Centers are equipped with Electronic Line Printers and Digital

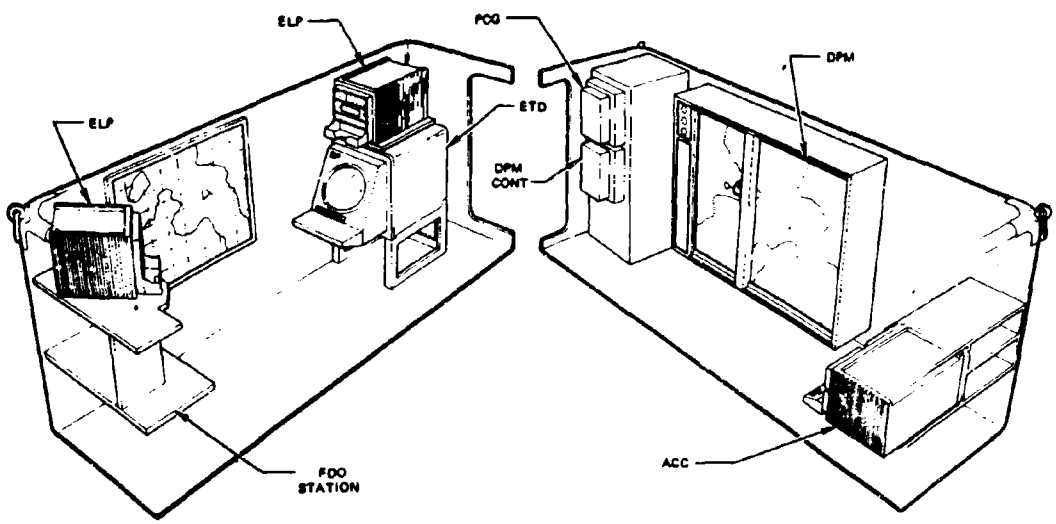

Figure 1. DivArty FDC Display Shelter

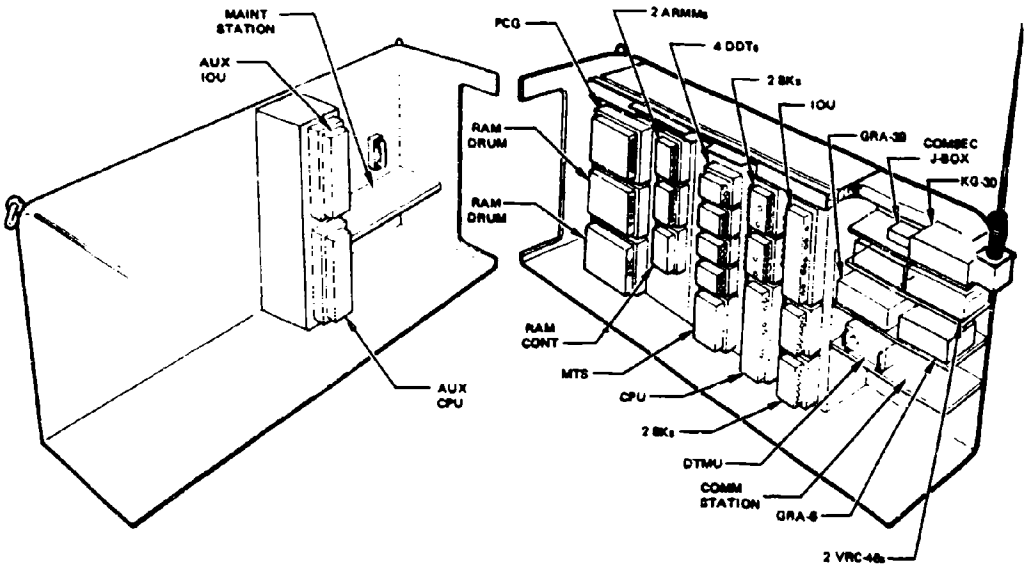

Figure 2. DivArty FDC Computer Shelter

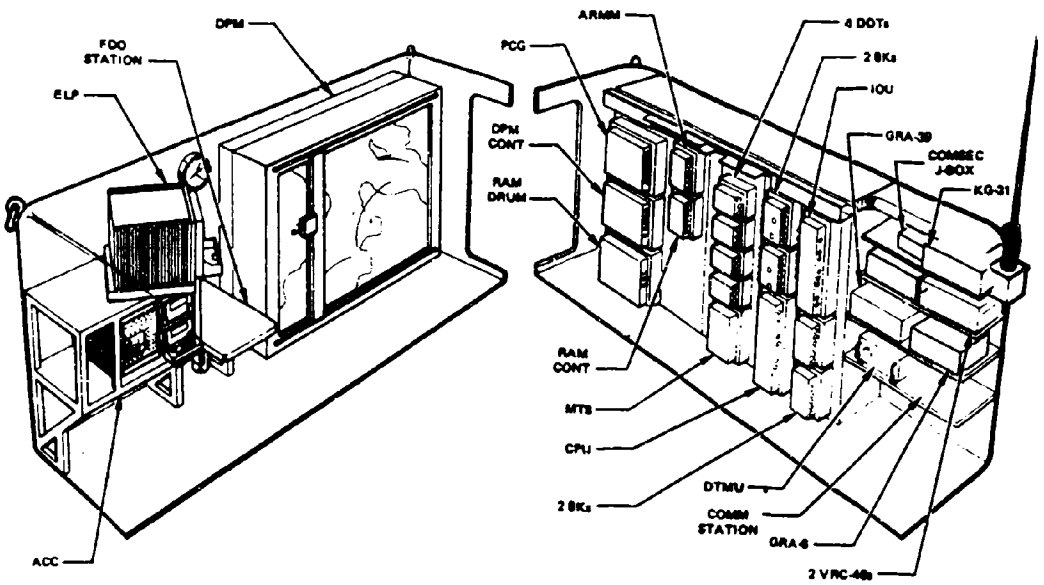

Figure 3. Battalion FDC Shelter

Figure 4. TACFIRE Displays

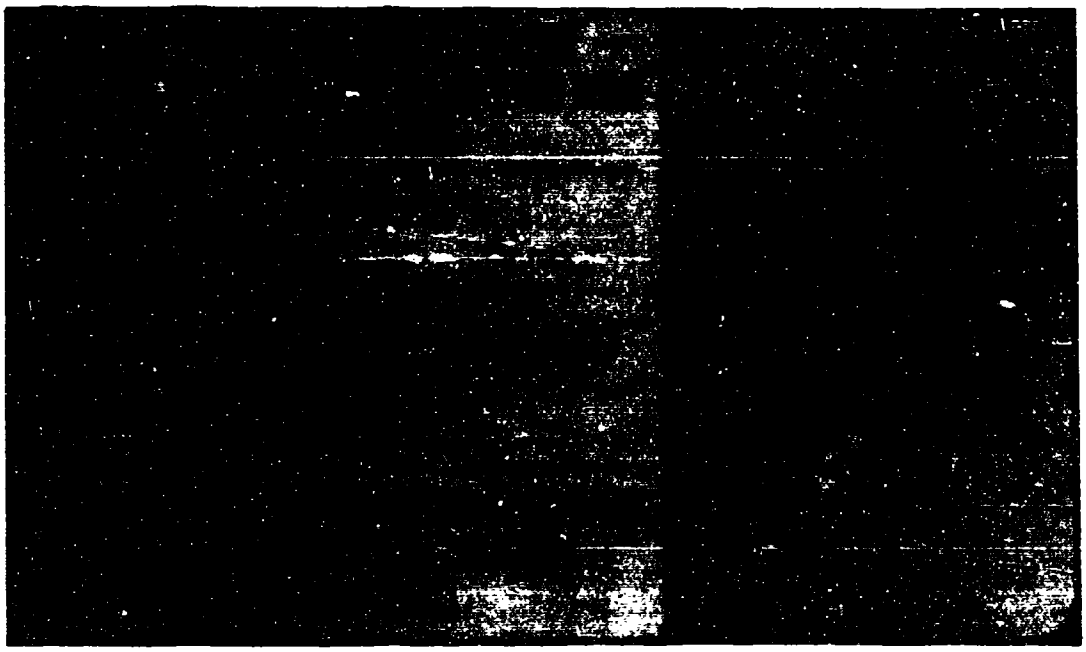

Figure 5. Fixed Format Message Entry Device

Plotter Maps. At Division Artillery, a situation display referred to as the Electronic Tactical Display, is also available. The computer is provided with a 32K word core memory, a 400K word drum memory (200K words at Battalion) and a 600K word tape memory (300K words at Battalion). Digital Data Terminals are the links between the computer and the communication (radio or wire) nets. The TACFIRE FDCs are shown in Figures 1, 2, and 3.

The Variable Format Message Entry Device is a remote input/output device which consists of a Digital Data Terminal, Electronic Line Printer and Keyboard, and one CRT (used for both receiving and composing messages) as used in the Artillery Control Console. This assembly, which can be jeep-mounted, initially will be supplied to the Fire Support Element and the Honest John Rocket Batteries. The Fixed Format Message Entry Device (FFMED) is a battery-operated hand-held switch panel remote input-only device supplied to ground and airborne forward observers. Firing batteries will be supplied with a remote output-only device, called the Battery Display Unit, consisting of a Digital Data Terminal and an Electronic Line Printer. The TACFIRE display devices are shown in Figure 4 and an FFMED is shown in Figure 5. TACFIRE employs existing Army wire and radio communications for digital data transmission, as well as GFE air conditioners, generators, shelters, and vehicles.

Computer programs furnished with the TACFIRE system support the mission of Division Artillery as well as the mission of the Fire Support Element, which will be a part of the Army's Tactical Operations System (TOS). (See Figure 6.) The following are the Division Artillery functions:

- o Fire Missions
- o Artillery Target Intelligence
- o Non-Nuclear Fire Planning
- o Meteorological Data Distribution
- o Artillery Survey

The above five functions are supported by two data base programs:

- o Ammunition and Fire Unit Data
- o Geometry and Display Data

The two data base programs also support the following Fire Support Element functions, which will eventually be part of TOS with backup functions retained in TACFIRE:

- o Preliminary Target Analysis
- o Chemical Target Analysis
- o Nuclear Target Analysis
- o Nuclear Fire Planning
- o Fallout Prediction

The programs listed above are controlled by three major programs:

- o Battalion major program
- o DivArty major program
- o FSE major program

Both DivArty and FSE major programs operate in the DivArty computer. The major programs, in turn, are controlled by the Operating System which operates in both DivArty and Battalion Computers.

The DivArty/Bn Operating System controls two special-purpose programs in addition to the programs previously mentioned:

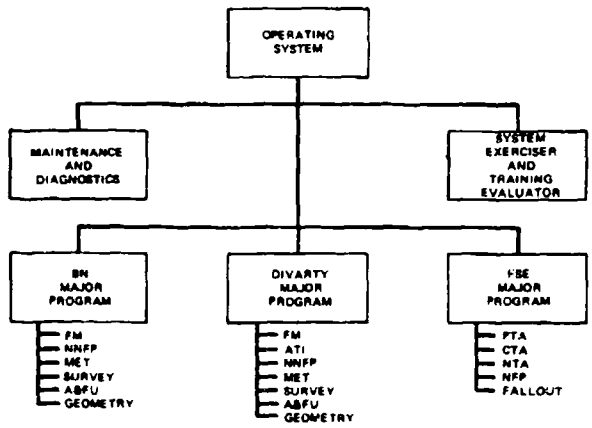

Figure 6. TACFIRE Computer Program Organization

- o Maintenance and Diagnostics
- o System Exerciser and Training Evaluator

The hardware/software system described above is an outline of the Engineering Test/Service Test configuration of the system; a somewhat abbreviated system configuration, called the Training Support System will also be delivered. Another system configuration, called the Programming Support System, which contains additional hardware and software, will also be delivered. It is anticipated that some functional changes will be required as a result of the test program.

HISTORY OF TECHNICAL DEVELOPMENT

TACFIRE was developed within the framework of the overall Army ADP development project, Automatic Data Systems within the Army in the Field (ADSAF). This overall project, initially known as the Tactical Automatic Data Processing Systems (ADPS) project, and later as the Command Control Information Systems (CCIS-70) project, started in 1956. A research and development project was formally established in 1957, and technical development was assigned to the Signal Corps which, in turn, assigned design and test responsibility to the U.S. Army Electronic Proving Ground (USAEPG) at Fort Huachuca, Arizona. In 1958, USAEPG contracted with what was then the Ramo-Wooldridge Corporation to provide technical assistance. In 1959, a time-phased implementation plan for Army ADP was proposed, and formally approved in 1960. That plan provided for the development of TACFIRE plans through cooperation between the U.S. Army Field Artillery School (USAFAS) and USAEPG.

Subsequently, the development of TACFIRE hardware and software plans was continued until the Army was ready, in 1966, to select a contractor for the production of the system.

When Litton Systems started the TACFIRE proposal, the results of approximately five years of work on hardware and software design concepts, as developed by the Army and its industry supporters – primarily Bunker-Ramo, were available.

Human factors engineering participated in the contract definition phase by contributing switch catalogs and some computer program specifications. In addition, a sample Task and Skill Analysis (TASA) was prepared, as well as proposed manning charts, position descriptions, and training requirements. Some material on training aids was also written as well as a proposed Human Factors Plan.

When the Total Procurement Package contract was awarded in 1967, a revision of the Human Factors Plan was the first CDRL item that was submitted by human factors engineering, and grouped our effort into three domains:

- o System Analysis
- o Equipment and Facilities Design
- o Test and Evaluation

SYSTEM ANALYSIS

The Human Factors Plan included the compilation of the Task and Skill Analysis (TASA) and New Equipment Training Requirements Study under this heading. The CDRL items for which human factors personnel were responsible, when work on the development contract started, is shown in Table 1.

Table . TACFIRE Human Factors Engineering CDRL Items

Item	Title
GG34	Human Factors and Safety Research and Development Acceptance Test
L051	System Safety Engineering Plan
M052	Task and Skill Analysis (TASA) and New Equipment Training Requirements Study
M053	Training Aids and Devices Study (TADS)
N083	Human Factors Plan

Human Factors was assigned to System Engineering in the TACFIRE Program Office. Accordingly, the TASA effort was used as a primary vehicle for system analysis and design, as illustrated in Figure 7.

It can be seen that we started the TASA effort with a great many things already decided by the Government during its work with Bunker-Ramo, and by its acceptance of the hardware and software designs in our proposal. Although the framework existed, all the detail design still had to be developed.

Much of this detail design was accomplished using the TASA compilation as a design tool. The framework consisted of the proposed hardware and software specifications, and the Government's Technical Data Package. In addition, the Government had furnished mission flow diagrams and response times to our System Effectiveness group. It was required, then, to design the tasks in such a way that they followed the Government flow charts, using the proposed hardware and software, and meeting or improving upon the required response times. This meant that the TASA compilers were actually system

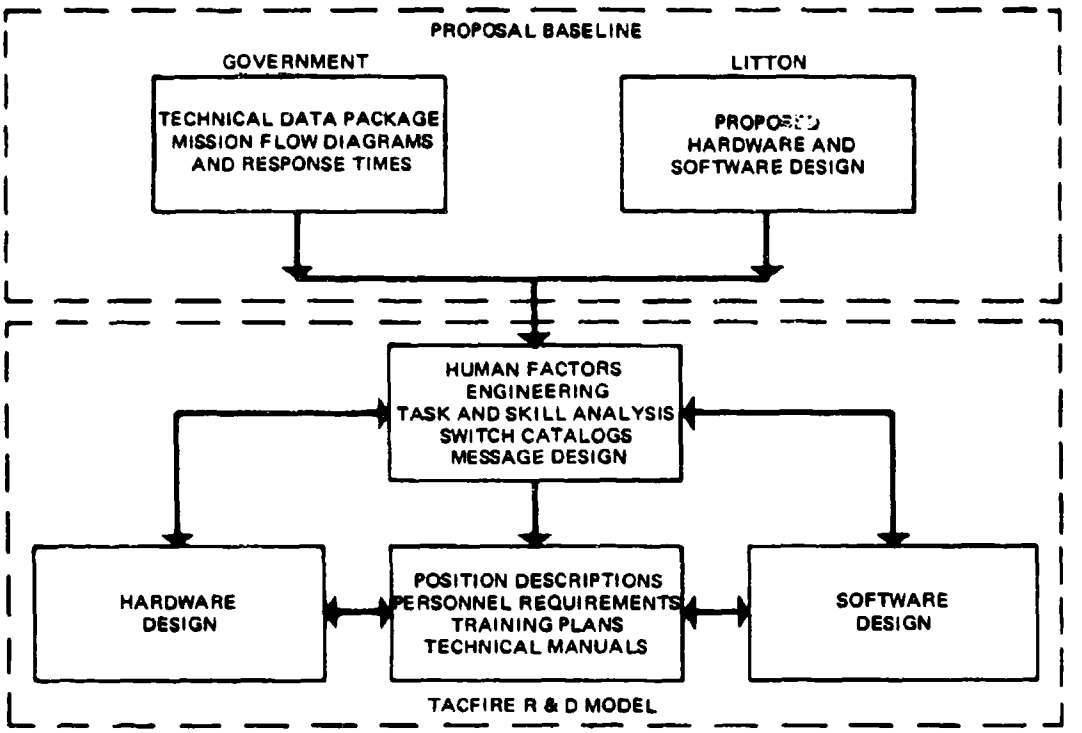

Figure 7. Human Factors Engineering and System Design

designers who worked with hardware and software designers, as well as system effectiveness engineering to meet the requirements and the proposed specifications. In addition to this internal coordination, we also worked very closely with local Government representatives, the TACFIRE Development Group.

Out of this effort, which consumed approximately three times as much manpower as human engineering on equipment and facilities design and test and evaluation put together, came not only the TASA document, but the following items.

New switch catalogs were developed for the Artillery Control Console and the Electronic Tactical Display, and new features were provided for the Keyboard and the Display Editor. In the case of the Artillery Control Console, the aim was simplification by reduction of the number of switches; for the Electronic Tactical Display, the aim was greater flexibility for the operator. In both cases, the improvements were implemented via software changes. For the Keyboard and the Display Editor, hardware changes were proposed and implemented to improve operability.

In the domain of programming, the content and format of over 300 TACFIRE messages were reviewed, modified, and standardized. Requirements were developed for the Artillery Control Console Support Program, as well as other functions of the Operating System such as initialization and message processing. The baseline for degraded mode operation, which is primarily a software function, was developed as a by-product of the TASA.

Another aspect was consideration of the distribution of work among the crew of four which is the physical limit of the equipped shelter. At Battalion, virtually the entire load must be carried by the Fire Direction Officer and the Console Operator, with some assistance from the Map and Radio/Telephone Operators. At DivArty, four men are available to carry the load in the Display Shelter: the Fire Direction Officer, the Console Operator, an Intelligence Officer or NCO and the Map Operator. These considerations, in turn, influenced man/machine interface design and equipment arrangement in the shelter, as described in the following paragraphs.

In addition to task and skill analyses of the operator and maintenance functions, the TASA contained a system description volume and a Personnel and Training volume. The latter volume contained personnel information that was derived from work on the TASA volumes proper: position

descriptions, manning and MOS tables, and training requirements. In addition, the last volume contained an organization and manning plan for a TACFIRE programming facility.

EQUIPMENT AND FACILITIES DESIGN

A human factors engineering design specifications document was published internally. The document was based on the appropriate Government specifications (MIL-STD-803A-1, HEL-STD-S-3-65, HEL-STD-S-4-65, SCL-1280D and SCL-1787B) and covered visual and auditory displays, controls, labeling, workspace design, maintainability and hazards and safety. The development of all hardware end items was monitored for conformance with the specifications. Human factors personnel attended all design review meetings, using a checklist developed for this purpose, and were also represented on the Engineering Configuration Control Board. Most of the equipment panels were laid out by human factors engineering, and the remainder of the layout received detailed human engineering review before engineering release. Special efforts were devoted to the following areas:

- o Illuminated pushbuttons
- o Audible alarm
- o Electronic Line Printer characters
- o Digital Plotter Map characters
- o Shelter layout and lighting
- o Operator chair configuration
- o Equipment cabling
- o Setup/Teardown procedures
- o Mockup design and fabrication

Several options were available for character formation on the line printer and the plotter map. Human factors engineering selected what appeared to be the most legible choices and assisted in the preparation of the appropriate specifications. In the case of the audible alarm, specifications could not be met with existing components Human factors engineering selected the best available alarm and prepared justifications for the specification waiver.

Four special studies were performed by human factors engineering in the domain of equipment and facilities design. The first was a layout study (conducted in conjunction with the on-site military personnel), which determined the optimum equipment arrangement in the shelter in terms of work space, work flow, weight distribution, heat dissipation, maintenance access and setup/teardown requirements. The work flow analysis influenced the positioning of the Console Operator, the Fire Direction Officer, and the Radio/Telephone Operator (in the Battalion shelter) as well as the configuration of the control console and the line printer. The layout study and succeeding studies were performed with full-scale shelter and equipment mockups. For the setup/teardown study a shelter mounted on an Army two and one-half ton truck was used as well as weighted mockups and cables.

After completion of the layout study, a shelter lighting study was conducted to determine the type and location of ceiling fixtures as well as supplementary plotter map illumination. In addition, the lighting study produced specifications for a lamp required for out-of-shelter control console illumination and for the illuminated pushbuttons for control panels mentioned previously. The study was conducted by fabricating and installing several types of fixtures and measuring control panel and display illumination. An informal report on the procedures and results of the study was published internally. To expedite setup and teardown operations a cabling study was undertaken to determine methods of cable routing, bundling, identification and connector keying. This study was also published internally and resulted in specifications for cable and connector placement and keying.

Following the cable study, a handling study was performed using weighted equipment mockups and a wooden rack structure within the shelter mockups, complete with dummy cables and connectors. This study determined the optimum procedure for emptying shelters and of setting up the equipment out-of-shelter in such a manner that it would be cabled and operational within 30 minutes (60 minutes for DivArty) after the power to the equipment was turned off prior to teardown. The truck-mounted shelter was also used in this study.

Last, but not least, human factors engineering was responsible for development and maintenance of mockups. This was a major effort since the mockups were in constant demand for design reviews and for exhibit to Government visitors. It should also be mentioned that human factors engineering was responsible for design of the operator chair.

TRAINING AIDS AND DEVICES STUDY (TADS)

It was the purpose of the TADS to determine whether training could best be conducted using trainers, operational equipment, or modified operational equipment. The study concluded that individual operator training could best be conducted with operational equipment in an out-of-shelter arrangement in a classroom. It was shown that by supplementing the equipment with additional simplified control consoles and with additional computer programs, the TACFIRE computer could be used for computer-assisted (programmed) instruction (see Figures 8 and 9).

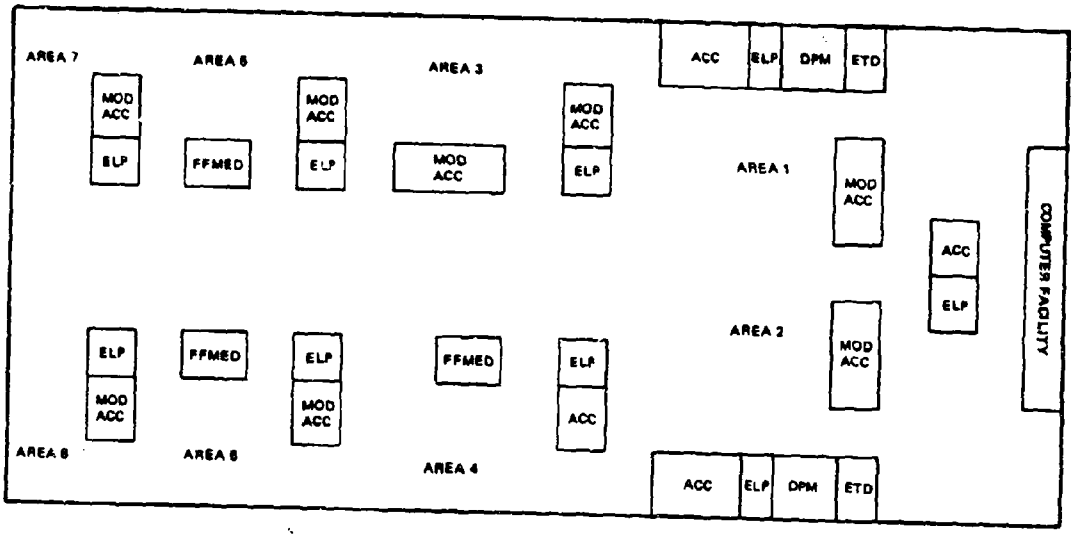

Figure 8. COT Classroom Layout

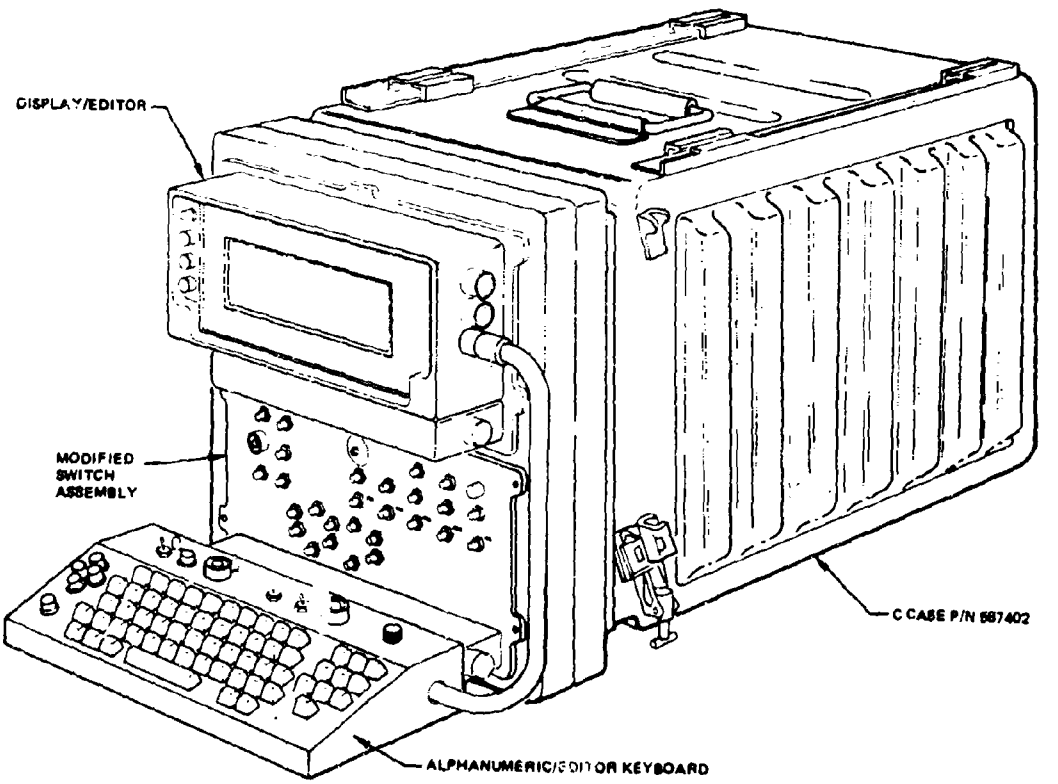

Figure 9. Modified Artillery Control Console

In the case of maintenance training, it was proposed that with the aid of a fault insertion console and minor modifications of operational equipment, it would be possible to insert and remove faults via remote control. The study showed that appropriate versions of this training setup could be used to provide:

- o Subsystem and degraded mode training to operators
- o Organizational maintenance training to organizational maintenance personnel
- o GS maintenance training support to maintenance personnel

The TADS also described the use of the tactical in-shelter equipment configuration for system training, and discussed static mockups and part-task trainers. Familiarization aids, including training films, were also described.

An extensive appendix provided design data on the hardware and software implementation of the Classroom Operator Trainer and its Programming Support Facility, and a discussion of fault insertion techniques for the Classroom Operator/Maintenance Trainer. The method proposed was remote insertion of faults via binary signals to circuit card pins within CEIs. This method obviates the need for insertion of faulty circuit cards, which wears out card connectors and is difficult to control. A schematic of the remote fault insertion method is shown in Figure 10.

TEST AND EVALUATION

In this area, human factors engineering prepared the Human Factors and Safety Research and Development Acceptance Test Plan, which was a deliverable CDRL item. This plan covered the following topics:

- o Personnel Safety and Physical Constraints
- o Legibility and Illumination
- o Working Space and Chair Static Load
- o Noise and Mobility

Step-by-step procedures were developed for inspections, demonstrations, and tests. A checklist was devised by listing the applicable and binding paragraphs from MIL-STD-803A-1 and MIL-STD-454A. This checklist was used with each Contract End Item (CEI), thus ensuring the maintenance of uniform panel design and layout. In addition to conforming to the checklist, some end item specifications contained unique specifications for legibility, brightness, contrast, temperature or noise; special tests were prepared for these devices.

The use of instrumentation in the Human Factors Laboratory to determine the brightness and contrast ratio of panel controls and indicators and cathode ray displays is illustrated in Figure 11. With the use of this equipment, optimum designs for legibility and visibility were determined for each display device.

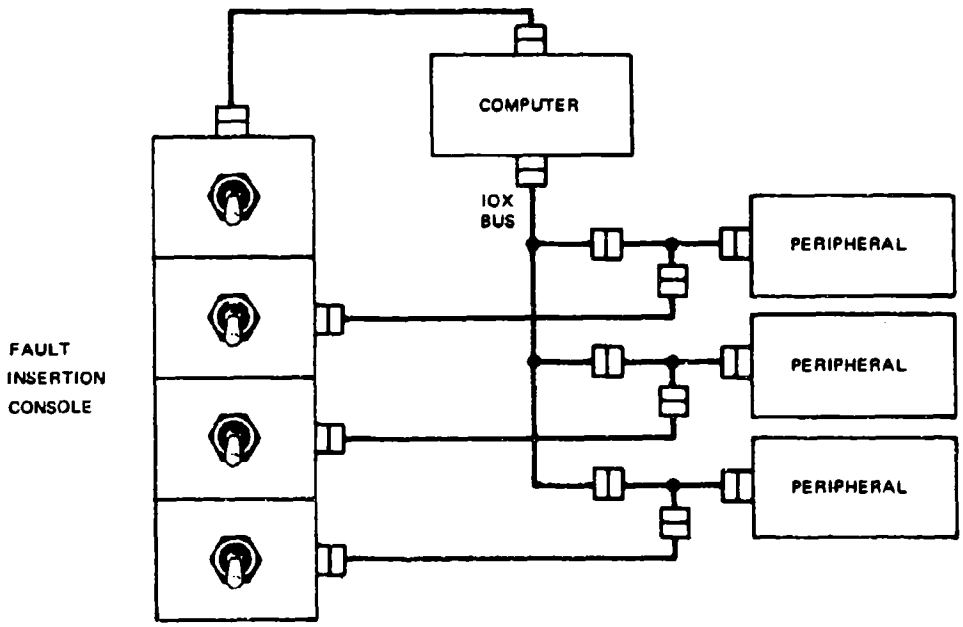

Figure 10. Remote Fault Insertion for Training

Figure 11. Brightness and Contrast Ratio Light Measuring Equipment

SAFETY

A Safety Plan for TACFIRE was submitted as a separate CDRL document. MIL-STD-454A provided many of the system safety requirements concerning access to high-voltage, interlocks, and high temperature. MIL-STD-803A-1, paragraph 13, provided design guidance for most other areas of personnel safety. In addition, human factors engineering was responsible for equipment safety and other items such as adequate circuit breakers and electrical ground paths. Lightning protection was made a system requirement and ensured by the test plan. The use of safety decals to warn maintenance personnel of the presence of unsafe temperature and high voltage on a typical internally-mounted power supply is illustrated in Figure 12.

RECORD KEEPING AND ENGINEERING CHANGES

A Personnel-Equipment Data file was maintained from the start of the program and every effort was made to make it complete. As a result, there is a comprehensive body of memoranda, letters, sketches, drawings, and engineering change requests on file showing the scope of the human factors effort on TACFIRE.

In conclusion it should be mentioned that many hardware and software engineering change requests were generated by human factors engineering personnel. In the case of software changes, human factors personnel not only generated the requests, but, after approval, prepared the change proposals to the Government, and the change orders or specification changes.

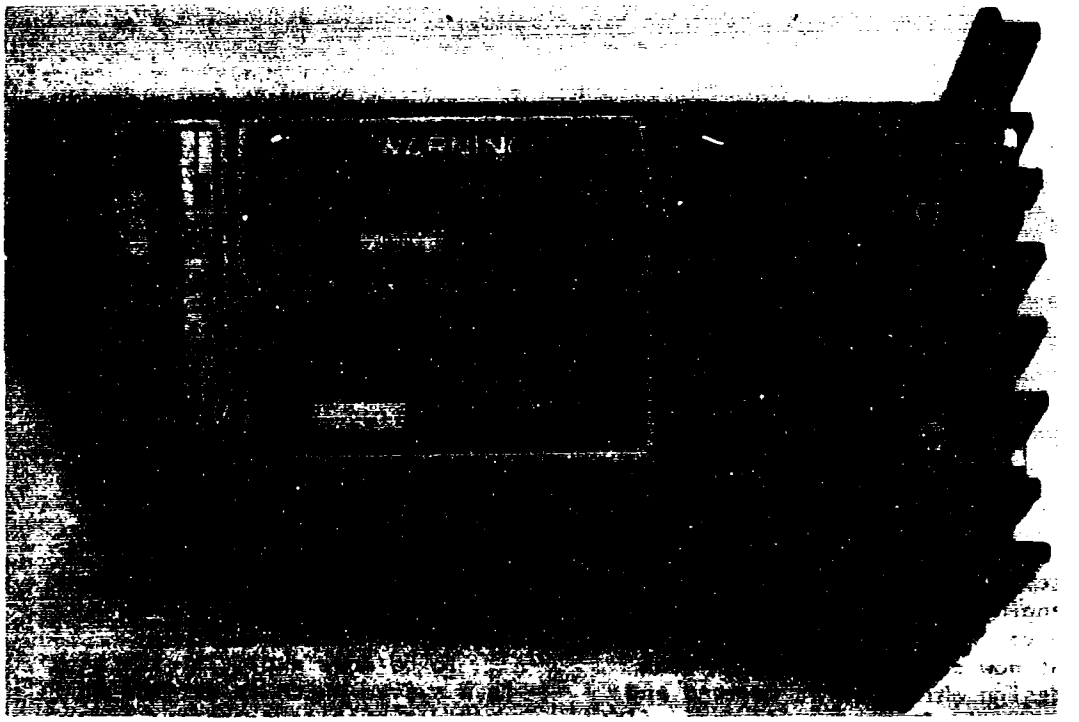

Figure 12. Typical TACFIRE Safety Decals

7D. THE EFFECTS OF TANK DESIGN ON COMMAND AND CONTROL

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In our efforts to take a systems approach to the human factors engineerings of combat vehicles, we have become more and more impressed at how certain aspects of tank design which affect command and control often have far more effect on tank combat performance than do design changes which affect the more acceptable criteria of hit probabilities, rates of fire, etc. As a result of these perhaps somewhat accidental impressions, I would like to discuss some of those tank design factors which affect command and control. But even more importantly, I will plea that we study more intensively the effects which command and control have upon tank effectiveness, and in future tank design consider these effects of command and control to the degree we consider ballistics, engine horsepower, or armor protection.

In effect, a tank system represents an excellent microcosm for the study of command and control. For here we have a relatively closed system, consisting of a complex machine and a crew of several people who must, essentially, perform their apparently independent roles as though this man-machine system were in fact only a single organism.

To be more explicit, the tank is a system which is defined as providing mobile protected firepower on the battlefield. In order to fulfill this role, it must, of course, have some degree of armor protection which is afforded by the skin within which the other components of the system must exist and function. In order to move, this system must have a power train and a driver (and notice that I said to move and not to possess the characteristic of mobility). In order to shoot, it must have a weapon, a gunner, and a loader--either man or mechanical (and again notice I said to shoot and not to possess the characteristic of firepower). These are the necessary, but not sufficient, characteristics required of a tank system. To be a truly effective weapon in combat, the tank system must be responsive to the commander. And it is in this aspect that vehicle design has such a critical effect on command and control.

Let us first look at the characteristic of mobility. For a long while, mobility was defined in terms of such factors as road speed, performance on slopes, trench crossing ability, etc. Thus, mobility characteristics were dependent solely upon the combined performance capabilities of the driver and the mechanical characteristics of the tank. More recently, we have attempted to define mobility as "movement of the tank in response to the will of the tank commander." Thus, mobility becomes dependent upon the degree of "communication" between commander and driver as well as the more usually accepted engineering characteristics.

In several studies which have been conducted by the Human Engineering Laboratories ("Human factors evaluation of tank driving from a turret position" and "An interim field comparison of the MBT-70 and M60A1E2 tanks") on tank mobility, we have begun to measure this mobility in terms of the movement of the vehicle in response to the will of the tank commander, and examine the effect which certain design characteristics can have upon mobility as thus defined. One good example of this can be shown by the effects of moving the driver from the tank hull into the turret. Let us look at a situation where we compare the mobility of a "driver-in-hull" tank with a "driver-in-turret" tank.

The tank is in a hull defilade firing position. The commander decides to move to a subsequent firing position as soon as the target currently engaged is destroyed. "Driver," says the commander, "on my command, move out as quickly as possible to a position just left of that big oak tree on the second rise of ground to our left front." In the hull position, the good driver has placed the tank in an optimum firing position to expose the minimum target to the enemy. Therefore, he is looking directly into a wall of earth in front of him and there is little communication (other than verbal) between him and the commander. The target is destroyed, and the commander says "move out." The driver backs out of position, tries to orient himself and find the next position he is to move to as well as select the best route to reach that position. The commander, who should be attending to other important problems, must provide considerable assistance to the driver in order for the tank to have mobility--that is, move as he wishes.

Now look at the driver in the turret position. He exposes the same minimum target area, but he is up in the turret where he has the same view as the commander; thus, when he receives the same verbal communication as the driver in the hull, he also receives additional information. He can see the second ridge line and the big oak tree. He immediately begins his route selection and when the order to move out is given, he can, using the mechanical capabilities of the tank, assure the system of a high degree of mobility by responding to the will of the tank commander more fully and yet with far less demand on the commander for further guidance and assistance.

Again, part of the mobility of a tank in combat requires it to move backwards--sometimes at maximum speed. Since the driver in the hull can see only a few degrees to the direct front of the vehicle, moving backwards requires not only his full efforts, but the complete attention of the commander and uninterrupted monopolization of the

intercom as well. On the other hand, in the turret position, the driver can traverse his station so that he can see to move backwards with minimum assistance of the commander, thus freeing the commander for the many other simultaneous tasks required to control a tank in combat.

Thus, independently of other factors associated with tank movement, we see that responsiveness of the tank to the will of the commander (i.e., mobility) can be significantly affected by those design characteristics which directly affect command and control. In fact, it is not inconceivable that these factors of command and control affect mobility in combat far more than doubling or tripling horsepower, or a new suspension system or transmission ever could.

Command and control implies adequate communication, however one might define adequate. So let's look at the communications sybsystem in the current main battle tank in order that we might gain some insight as to how better design future tanks for improved command and control. If we oversimplify the communication of the platoon leader's tank, we might derive something like this (Figure 1) as a schematic of the flow of information. Our poor tank commander must concern himself with a minimum of three separate channels of information flow: First, and most important, is his intercom which must function with first priority for him to have a viable tank system; second, he must communicate with the other tanks in his platoon in order that he can have an effective combat unit; and third, he must communicate with his company commander. Thus, the platoon leader must be effectively in control of three separate communication nets in order to maintain effective command and control over a tank platoon--an almost impossible task, made barely workable in the heat of a fire-fight because the loader serves as part of the communication chain between the company commander and the platoon commander.

And yet, how have we really considered this factor in the design of our future tanks? In some of our newer tanks, we have replaced the human loader with an automatic loader--but, we have not yet adequately considered replacing the function of the loader as a vital link in the command and control channel. Some soul-searching in this area is going on now with one recommended solution being to do away with the platoon nets and having only one company net. I think that we should investigate the effects of this proposal on command and control when we have three separate platoons (of five tanks each) engaged in three separate fire-fights, all trying to talk over one channel of communication. If you include the company commander and executive officer, this means that 17 different people, operating at three different levels of command, are all using one radio frequency with their very lives depending upon its effective use.

Now, let us turn to the more complex and critical area of firepower. First, we must realize that firepower involves far more than fast, accurate shooting at clearly visible panel targets. It involves not only firing at the target that is indicated by the individual tank commander; but, if we are truly concerned with effective firepower in combat, delivering fast, accurate fire at targets which are

assigned to individual tanks by the platoon commander. And this vital area is one which, while limited by, is not necessarily related to such factors as rates of fire and hit probabilities. We have considerable evidence to indicate that the effective firepower of a tank platoon in combat may be far more dependent upon the only partly understood factors of command and control, than upon the quite well-understood factors of round to round dispersion, tracking performance of the gunner, etc.

If we examine some of the major problems in fire effectiveness as indicated by field research, we may gain some insight as to how the design of current tanks affects command and control.

In Project ARNO, a study of "Night and day tactical fire effectiveness of tank units" (ORO T-371, 1958), we wanted to examine some of the factors affecting tactical fire effectiveness of the tank platoon. Essentially, Project ARNO was a free play, live fire exercise, in which we pitted a tank platoon (five tanks) against three stationary enemy targets. The three targets were metallic panels, in the open, equipped with gun-fire simulators to disclose their position (by firing a round every 15 seconds) to the tank platoon, and which, when hit by tank fire would stop firing and burst into flames.

The tank platoon was under the direct control of the platoon leader and each of the five tanks was supplied with five rounds of armor piercing ammunition. Fifteen different tank platoons were run through this course, some of them more than once. And yet, of all the runs made and all the rounds fired, there was only one single daytime run, and no instance at night, in which all three enemy targets received a hit. On the other hand, once a target had been hit, had stopped firing and begun to burn, it continued to receive hits (many targets receiving 10 or more hits) while the enemy targets still alive and firing were ignored. Clearly this is a problem of failure in command and control on the part of the platoon commander who has the responsibility of distributing the fire of his unit.

Other operational studies of factors involved in fire effectiveness have indicated that serious problems of command and control exist within the individual tank itself. Most studies of target detection, if they use realistic targets which take advantage of terrain in order to survive, have indicated that target detection is only one element in time to deliver a first round that is affected by command and control problems. Once the tank commander has acquired a target to fire on, he has a major problem in trying to assign that target to the gunner. We have found, for example, that the time required for the commander to put the gunner on the desired target is usually longer than the time required for the commander to detect the target in the first place. In fact, this acquisition time (defined as the time between detection by the commander to acquisition of the target by the gunner) is usually in the order of 15 to 18 seconds--the times often reported as total time to fire on a gunnery range.

Yet, fortunately, this is one area where, by the design of our tank equipment, we have made significant improvements in the command and control elements affecting times to fire. Both the

MBT-70 and the M60A1E2 now include a "target designate" system. It is the sole function of this target designate system to essentially increase the effectiveness of the command and control function by providing the commander with an effective means of quickly and accurately putting his gunner on the correct target.

The problem of obtaining a fast, accurate range to the target (a necessary element in effective fire) has always presented tank designers with a dilemma. Essentially, it has forced them to choose between disrupting command and control of the vehicle (by having the tank commander operate the rangefinder) or increasing the time to fire the first round (by increasing the number of tasks required of the gunner before trigger pull). And yet, unfortunately, the only hard numbers available to the designers upon which to base such a decision have been obtained from range firing data that is data obtained in situations where problems of command and control are minimal. In fact, we assume, in obtaining most of our input data, that the tank in combat behaves as an isolated entity--moving and shooting independently of other tanks in its own unit. And this in spite of the basic maxim of armored combat, that a single isolated tank on the battlefield is essentially a dead tank.

Why do we not obtain the data for tank design from investigations which consider the tank system as it is actually used in combat? Our philosophies of tank combat, our doctrine, even our training, emphasizes that the tank system must operate in conjunction with other tanks at a minimum, and optimumly with other combat elements as well. And yet we continue to ignore the interrelationships between tanks in combat--that is, the essence of command and control--when we design the tank. Essentially, ignoring the role of the tank commander as a commander, even though, as the speed and complexity of modern warfare increases, command and control becomes more and more important.

In recent years, our capabilities for the conduct of operational field studies have broadened to where we can now, if we so choose, begin to investigate factors of command and control in armored warfare. And I suggest we begin to emphasize our efforts in this area. In fact, I would dare to suggest that if we truly examine the role of the tank commander in combat, we might find that the day of the saber is not past (in fact, do we not still have crossed sabers on the armor insignia?). We might find that replacing the platoon leader's .50 caliber machinegun with a saber, even though theoretically reducing the number of rounds fired by the platoon in a given time interval, would actually increase the effectiveness of the firepower of the tank platoon in combat. Perhaps the effect of the saber would even be greater in tank warfare than its effects in the days of horse cavalry. For remember, when we equipped our officers in the cavalry with carbines, we had only an unorganized group of men potting randomly at marauding Indians. When we reduced the number of carbines by providing the officers with sabers, we increased the effective firepower of the unit by forcing our officers to command and control their unit, rather than getting overly involved themselves in potting Indians.

APPENDICES

1. ATTENDANCE ROSTER. 2. CURRENT WORK PROGRAMS. 3. BIBLIOGRAPHIES OF PUBLICATIONS SINCE LAST REPORT. 4. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL - OF HUMAN FACTORS RESEARCH AND DEVELOPMENT ACTIVITIES OF U.S. ARMY AGENCIES.

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APPENDIX 2
CURRENT WORK PROGRAMS

2A(1). U.S. ARMY MATERIEL COMMAND
ELECTRONICS COMMAND

Fort Monmouth, New Jersey 07703

A. Human Factors Engineering support to USAECOM and other AMC organizations.

1. The principal mission of the Human Factors Engineering Branch of the Product Assurance Directorate remains the day-to-day support given to the USAECOM laboratories and other AMC organizations such as:

a. Advisory and consulting HFE service to ECOM engineers and scientists.

b. Review and approval of 149 equipment QMR, SDR and Development Descriptions for suitability of HFE content.

c. Evaluation of contractors' proposals, including membership on Source Selection Evaluation Boards (SSEB).

d. Review of contractors' equipment design and specifications for HFE adequacy.

e. Visits to the contractors' plants to monitor HFE progress.

2. Some of the more significant tasks monitored during FY 70 were:

a. TACFIRE - HFE monitoring and testing of contractor (continuation from FY 69).

b. CEFIRM LEADER - HFE monitoring of contract (continuation from FY 69).

c. STAG - Evaluation of unsolicited proposals (continuation from FY 69).

d. NVSVS (AN/USC-20) - Review of revised development descriptions.

e. UTTAS - HFE support for avionics systems (continuation from FY 69).

f. UASS - HFE support and assistance (continuation from FY 69).

g. LORAN - Review of system specifications for expanded contract definition.

h. RATAC - Review of development description for sole source purchase.

i. MALLARD - Office of Prime Responsibility for the development of a Human Factors Engineering Plan for the MALLARD project.

j. SHORT RANGE RADAR - HFE for the development of Short Range Radar AN/PPS-9.

B. The following information is submitted on the current human factors engineering work program conducted by the Avionics Laboratory.

1. Task 1H1 63207 D 235 15 Instrumentation - Sub-task D235-15-03 Cockpit Panel Improvement: Investigator - E. Stern. This program is concerned with the improvement of instrumentation in rotary wing utility aircraft through experimental and analytical engineering and human factors studies and the application of up-to-date research results, currently available techniques, and state-of-the-art instrumentation. Experimental comparative evaluation of current industrial instrumentation developments (applicable to rotary wing aviation) will be accomplished through part-task and full dynamic simulation and actual flight evaluation. Instrumentation to be investigated will include: (1) Conventional dial/pointer instruments for flight control, navigation and engine status, (2) Vertical (moving tape and moving pointer) instruments for flight control, navigation and engine status, (3) Vertical Situation Indicators, (4) Horizontal Situation Indicators, and (5) Flight Directors. Information and data derived will be utilized to implement selected replacement of instrumentation for UH-1/UTTAS missions. This program further is supported by the following subtasks:

D235-15-05 Information Transfer Requirements

Investigators: A. Santanelli, USAECOM and J. Barnes, HEL

Determination of Information Transfer Requirements for the utility rotary wing aircraft (UH-1/UTTAS) through analysis of mission, functions, task, information transfer for task and task transition and time-based crew loading plus iterative experimental evaluation (through simulation). Current rotary wing cockpit display/control instrument arrays are evaluated through experimentation, analysis, and validation of data obtained from: (1) Time-based - Task Load Analysis, (2) Park Task, Fixed-base helicopter cockpit simulation, (3) Full helicopter system dynamic simulation, and (4) Flight experimentation. A report on the first phase of this work was published in March 1970.

D235-15-04 Crew Capability Under Stress

Investigator: A. Santanelli

Plan and direct a program to establish crew capability of Army's personnel resources under varying conditions and periods of stress in current rotary wing aircraft. Specific problems are: (1) Effects of Vibration, Noise, Rotor Flicker on Visual Perception, Utilization and Motor Response, (2) Effect of above factors as a function of exposure, repetition and age, and (3) Derivation of crew response characteristics and performance curves.

Work to be undertaken in conjunction with HEL involves the determination of Army crew performance (particularly as pertains to visual perception) as a function of the ambient spectra in the cockpits of rotary wing aircraft. This will be accomplished through a survey of existing work and such joint human factors engineering program involving the analytical and experimental talents and facilities of ECOM and HEL as may be necessary to supplement these findings. Data derived will provide inputs for design of future instrumentation displays to be used under severe vibration conditions.

2. Task 1H1 62202 A219-04 - Joint Army-Navy Aircraft Instrumentation Research program (JANAIR) - The following contracts are partially funded by the Army under the Joint Army-Navy Aircraft Instrumentation Research (JANAIR) program with technical guidance provided by the Avionics Laboratory:

Title	Investigator	Date Started
Geographic Orientation	Human Factors Research, Inc. Nonr 4218(00)	Jun 63

This subtask seeks to identify pilot's perceptual cues as used to maintain or reacquire geographic orientation and to relate these cues as used for determination of optimum display techniques and display symbol encodement. Particular emphasis is placed on determining the pilot's visual references in the flight requirement of low altitude and high relative speed over terrain. It is in this area where pilot geographic orientation is most vital and where disorientation is most severe.

Visual Requirements for Head-Up Displays	Sperry Gyroscope Co. Nonr N0014-66-60144	Apr 66

This is an experimental research subtask to define the visual requirements relating to the design of wide-field, virtual-image optical projection display systems and visual phenomena which may compromise the effectiveness of these displays. The phenomena to be investigated cover all the relevant aspects of binocular disparity, retinal rivalry, and monocular and binocular viewing of the display. Included are techniques for alleviating retinal rivalry, the effects of a real world background, and size of exit pupil and freedom for head movement.

This program is designed to contribute specific knowledge to be used in evaluating operational acceptability and design of wide-field head-up displays in future military aircraft in lieu of the current narrow-field, gun-sight type of display.

Formation Flight Display Study	Honeywell, Inc. ONR N0014-66-C0362	Jul 66

This research subtask required in this study is to investigate concepts and technology applicable to the display of aircraft formation flight information and to define the parameters of a suitable display system and technological requirements for tactical formation flight under all-visibility (i.e., flyable IFR) conditions.

Theory of Manual Control	Systems Technology Inc. Nonr C0072	Apr 66

There is a continuing need for a cockpit design methodology yielding optimum control-display designs from an engineering standpoint. A preliminary theory of manual control has been evolved which is believed to provide a basis for the required engineering approach. It is the intent of this subtask to refine the theory, and develop it for systematic application as a means of establishing display requirements, and for assessing the relative merits of various displays of flight and navigational information to pilots. The refined theory will be subsequently applied to a specific control problem to validate results.

Applications of System Identification Techniques to Manual Control Theory	Oceanics, Inc.	Apr 68

This subtask is designed to quantify and delineate further, mathematical descriptions of manual control through the application of the concept of state-variables to represent the human operator dynamics. This will be accomplished (by means of a computer simulation program) through the development of a cockpit display/control/man system identification procedure, using statistical information for random signals (operator, display, control) in the adaptation of existing estimation techniques based on imbedding methods and non-linear model of the human-operator.

This model will be further analyzed through computer experimentation and verified through further man-in-the-loop simulation.

Contact Analog Display Evaluation	US Navy Missile Center	Apr 66

This subtask is the determination and experimental evaluation of parameters and conditions for aircraft contact analog displays and minimal and optimal visual and perceptual characteristics of displayed elements. A contact analog display generator developed in previous work under this sub-task is being used in these experiments. A six-degree-of-freedom aircraft cockpit simulation was installed and completely checked out by early spring of '67 and is now in operation.

This facility is located at the Human Factors Engineering Laboratory at the Naval Missile Center, Point Mugu, California.

This research will provide a scientific foundation of data and knowledge for application in specifying display information requirements to meet particular Naval aircraft missions. The knowledge of basic optimum characteristics for multi-parameter aircraft displays, (Vertical Contact Analog Displays (VCAD), will allow the improvement of the pilot's discrimination on ability; and therefore, assist in the prevention of overloading his information processing capacity.

Virtually all future Army and Naval aircraft will employ electronically and optically generated displays to present flight control, navigational, or target information to flight crews. A detailed evaluation of experience and experiment with such Navy and Army aircraft displays is necessary to define the best symbology to ensure mission accomplishment and to minimize accident potential.

Aircraft Displays for Steep Approaches	Honeywell, Inc. N0014-68-C0191	Aug 67

This subtask will determine aircraft display characteristics, including status, command and emergency information, to permit all weather steep angle approaches with rotary wing and V/STOL aircraft. The approach angles studied will be greater than 14 degrees. The study will include data sensing rates and accuracies and, if necessary, data transformations. The influence of failures to all or any part of the system will be investigated to determine back-up or redundant display requirements. In addition, this study will examine the influence of (a) single versus formation flight, (b) ground and/or sea and self-contained landing systems, (c) tactical data and control systems; on display configurations and characteristics. The display system sought will enable manual as well as automatic control for IFR angle approaches to a landing at fixed as well as tactical sites.

The aircraft display system envisioned will reduce the sensitivity of tactical vertical envelopment of maneuvers to indigenous and enemy fire power (ground fire) and permit more expedient air operations through simultaneous approach/landing and take-off/departure of military aircraft from developed as well as undeveloped landing sites.

Cockpit Geometry Evaluation Study	The Boeing Co. N68-00289	Jan 68

This research on cockpit geometry is the first attempt to investigate and develop computerized methods to evaluate the geometryof an aircraft cockpit subsystem. In evaluating and developing crew stations, techniques such as analysis, simulation and testing of actual operations are used to determine the

degree to which system objectives can be successfully achieved. In performance thereof, problems are encountered in determining what to evaluate, how, when and the particular form the results should take. Accordingly, it would appear desirable to develop and implement computerized methods in an attempt to solve these problems. To do this, it will be necessary to determine what cockpit geometry factors require evaluation, how these are related to each other, and their relationship to an overall figure-of-merit for the crew station. Correspondingly, it will be necessary to develop methods that can be selected for single factor evaluations and for integrating individual factor results into a more encompassing combination value.

2A(2). U.S. ARMY MATERIEL COMMAND HUMAN ENGINEERING LABORATORIES

Aberdeen Proving Ground, Maryland 21005

A. CURRENT WORK PROGRAM

1. Systems Research

The work program of the Systems Research Laboratory falls into four broad, related categories:

a. Applied research of a general nature related to a class or classes of Army materiel.

b. Conduct research in support of concept feasibility and effectiveness analyses.

c. Direct systems support in the application of existing data and monitoring of industrial contractor's efforts for human factors engineering.

d. Human factors engineering data storage and retrieval, and preparation of human factors engineering standards and design guides.

The work is accomplished within three branches (Weapons; Aviation; and Missile, Communications & General Support).

a. WEAPONS BRANCH

This branch is responsible for the accomplishment of human factors engineering of Army weaponry falling in the following classes: infantry (such as small arms), antitank guided missiles, artillery (all but missiles), armor, combat vehicles, and fire control equipment. In order to accomplish this mission, the Weapons Branch performs the following functions: (1) conducts

applied research necessary to quantitatively describe man's performance associated with the tasks performed in the operation of weapon systems; (2) conducts parametric weapon design research during weapon systems feasibility or concept stages whereby the performance associated with particular weapon design parameters is described; (3) applies established human factors engineering data to weaponry during the RDT&E cycle and monitors industrial contractors; and (4) conducts comparative evaluations of weapon systems by field and laboratory experiments simulating the more important elements of the combat situation.

Title	Investigator	Date Started
Pistol Effectiveness Research	Nair, Lucas, Torre	1967

The objective of this task is to determine the effects of pistol design parameters on accuracy and rate of fire. The information will be used to predict pistol effectiveness as a function of such design parameters as weight, noise, center of gravity, sight radius, impulse, overturning moment, trigger-pull force and configuration. It is a three-part program. Part one is a non-firing program. The objective of part one is to identify the contributions of such design parameters as weight, trigger-pull force, sight radius, and center of gravity on aiming error while varying target exposure time. Part two is a firing program. The objective of part two is to determine the contribution of weapon design parameters associated with firing--such as impulse, overturning moment, noise--and the combination of these with previously mentioned parameters. The objective of part three is to investigate the behavior of a man/pistol combination when firing multiple rounds per trigger pull as a function of all of the primary previously mentioned design parameters and, in addition, the effect of a restoring moment which might be provided by a muzzle device.

In support of part one, a pistol has been designed and fabricated whose configuration, weight, center of gravity, sight radius and trigger-pull force can be varied. A light source is mounted on the pistol. It is projected onto a screen and, through the use of a movie camera, the light is photographed and deviations from the target before, during and after trigger pull are recorded.

In terms of part two, a range was set up which consisted of E-type silhouette pop-up targets which could be programmed for varying exposure times and which could electronically detect hits. The targets ranged from 10 to 30 meters from the firing point. In order to bracket the aiming errors associated

with the effect of impulse alone, 22 and 38 caliber conversion kits were fitted to a standard M1911A1 45 caliber pistol. No other design parameters were varied. Data from this experiment are presently being analyzed.

In terms of part three, attempts are being made to derive a mathematical model to predict the dispersion associated with serially firing two to three rounds per trigger pull. To this end there has been some experimentation whereby using fastex photography we have photographed the reactions of the man/pistol combination firing bursts of one, two and three rounds. This was done just for two impulse levels and two different cyclic rates.

Human Errors in Artillery Fire Horley 1969

The objective of this task is to obtain operational performance data on squad to battalion size field units engaged in different types of artillery missions. The data are collected in such a manner as to allow the human error to be isolated from the systems error and parceled into subsystems of artillery units such as survey, metro, forward observers, fire direction, and firing batteries. These data are used in assessing weapon design parameters and as baseline inputs to computer simulation research.

The first battalion size experiment was conducted at Fort Hood, Texas. The accuracy and precision for predicted fire was measured and the human error sources and magnitudes were established. Additional battalion experiments are being planned to investigate other types of artillery missions such as adjust fire, direct fire and hip shoots.

Aiming Behavior Research Kramer 1970

The objective of this work is to measure the accuracy and rate of fire of the M16A1 as a function of time, range (10-60 meters), target size, and the instructions to the firers.

The data that exist for firing against short range targets are incomplete. This experiment will fill some of the gaps. Additionally, it will investigate the interaction between target size and range, and effects of widely different instructions. Hypothetically, the only important parameter of target size is angular size.

In addition, the many experiments that have been run by various agencies over the past few years have sometimes produced different results which are not explained by the range setup. There is good reason to believe that instructions given the firer are as significant as the weapon he uses insofar as firing results are concerned.

The method will be to run a field experiment using several large groups of enlisted men. Each group will get a different set of instructions on how to shoot (e.g., aim, point, try to get a first round hit, try to get a hit as quickly as possible, etc.). Each man will be presented, one at a time, a large number of targets at ranges from 10-60 meters, although the targets will not be all the same size. For example, at 20 meters, the targets will appear as large as E-type silhouettes at 20, 40, and 60 meters. The time of occurrence of each shot and hit will be recorded.

Troop Posture — Horley, Garry — 1967

This task is designed to evaluate troop postures (standing to prone in and out of cover) of enemy forces under artillery fire as a function of time. These data will be used as inputs to artillery systems analyses to estimate the type and quantity of artillery ammunition required to defeat enemy targets. Since postures are a function of target complex, several different types of targets will be investigated. The first now being tested is an enemy artillery squad operating over a 24-hour cycle.

Tracer Experiment — Miles — Aug 69

The purpose of this task is to determine the increase in effectiveness, if any, of tracer ammunition over ball ammunition in the infantry ground-to-ground role.

The tendency of small arms development toward smaller calibers poses certain difficulties in the design of tracer ammunition. Given adequate time and money, these difficulties can be expected to be overcome. However, it is not clear whether the effectiveness of tracer is sufficient to justify that expense.

The HEL Tracer Program will consist of three phases: literature review, preliminary experiments, and major field test(s). Phase one has been completed and the report published. Phase two, a series of field tests with single shooters, is designed to establish what the major factors are which influence tracer effectiveness and how they operate. The first of eight planned experiments has been conducted. Phase three will be one or more field tests involving a reinforced infantry rifle squad.

General Human Factors Support
for Weapon Systems

This is a four-fold effort: (1) to provide assistance in the analysis of weapon system concepts from a human factors point of view; (2) to provide support in the preparation and analysis of testing procedures used in the evaluation of either proposed or existing weapon systems; (3) to provide assistance in the form of monitoring or consultation on existing systems, for example, participation in RPI's, evaluating inventions, and reviewing human factors proposed or accomplished work on the part of a contractor; and (4) to determine what research should be conducted to support future weapon systems falling within the class of infantry, artillery, combat vehicles, and fire control equipment.

During the past year there was a human factors' review of the Sheridan-Shillelagh firing accuracy; participation in the Quadripartite Committee for Unguided Antitank Weapons; participation in the ARDC Ad Hoc Committees for Combustible Cartridge Case Ammunition and for Caseless Ammunition; participation in the ARDC Committee for Gun Air Defense Systems; contributions to the Recoilless Rifle Applied Research Program; the Shillelagh Product Improvement Committee; the Shillelagh HAW Evaluation; the Reed Committee on Antitank Weapons; and continual participation in the Advanced LAW program.

Human Factors Engineering Support of MBT-70	Eckles	1966

The objective of this task is to insure the application of human factors engineering (HFE) principles in the detailed design of the 1970 Main Battle Tank.

Task efforts to date have included establishment of HFE programs for the MBT-70 Project Manager which are applicable in industrial contracts, informal evaluation of contractors' proposals, and participation in test and evaluation programs considering critical man/machine interfaces and interactions.

Operational Assessment of Man/Combat Vehicle/Environmental Interaction	Eckles Dickinson	1965

The objective of this task is to assess man/machine performance with respect to combat vehicles in an operational situation in order to evaluate the effects of equipment design characteristics on total system performance.

Field investigations under both controlled and free-play quasi-combat conditions will be conducted to assess the influence of various equipment design parameters on effectiveness of mission performance by the total man/machine system. This will require establishment of baseline data against which the effects of equipment design changes on total system performance can be evaluated. Data will be extrapolated to predictions bearing on potential combat performance of current and future combat vehicles.

Antitank Weapons Research	Gschwind Ellis	1965

A major area for improvement in unguided antitank weapons is their fire control, particularly their rangefinding capability. During the past year several stadiametric sights were evaluated through field study and plans were made to conduct more experiments.

b. MISSILE, COMMUNICATIONS & GENERAL SUPPORT BRANCH

This branch is responsible for human factors engineering of air defense missiles, artillery missiles, communications systems, general combat support vehicles, and combat engineer equipment. Work falls into three broad categories: applied research, design research, and systems support.

(1) Applied Research

Title	Investigator	Date Started
Investigation of Information Content of Air Defense Radar Symbols	Davis	Oct 67

The objective of this task is to capitalize on existing knowledge of symbology and extend the capabilities of information symbols to highly complex rapidly changing air defense situations to reduce the time required for decision making by reducing potential error or error contaminants of complex displays.

Three experiments have been accomplished to relate and evaluate the capabilities of various codes to synthesize a single code which will be further evaluated in an operational context using simulation equipment. This equipment will be operational during the current year and will also be utilized to investigate a wide variety of command-control interactive displays.

Mobile Communications	McCommons	Nov 70

The task objective is to investigate the ability to perform selected communication tasks in a 2 1/2-ton shelter while the vehicle is on the move. Typical tasks related to TACFIRE and MALLARD include typing, changing radio frequencies, calculating fire coordinates and plotting.

Human Information Processing	Symington	1970

The task objective is to quantify specific human performance parameters involved in information processing. Two subtasks currently under investigation are: 1) Eliminating subjective time uncertainty as a variable in psychological refractoriness, 2) The effects of signal location uncertainty and different search areas on response time.

(2) Design Research

Tactical Automatic Switch Systems Control Analysis	Phelps	Aug 68

The objective of this task is to investigate from a human factor's standpoint the impact of introducing automatic common user telephone switching on a limited basis on a field army manual switching communications system under conventional deployment.

Areas of concentration include:

(a) Subscriber information and education requirements

(b) Systems engineering

(c) System control

(d) Programmer task analysis

SAFEGUARD Command Control Analysis	Davis Symington	Jul 71

The objective of this task is to investigate methods and format of displaying dynamic target related information to Tactical Operation Center personnel to assure optimum integration of display devices and personnel.

Improved HAWK Battery Control Center (BCC)	Kurtz Emery MacLeod	1970

The objective of this task was to evaluate BCC crew performance in different tactical situations and system operating modes. The evaluation provided a measure of Improved HAWK Trainer crew performance. Problem areas were identified for future design modifications.

(3) Systems Support

Continued support is provided to on-going development projects. Major systems being supported are:

Engineer Equipment	Randall	Jul 65
Improved HAWK	Kurtz	1969
SAM-D	Davis	Oct 66
Tactical Switching	Phelps	Apr 67
Army Area Communications System	Krueger Keiser	Mar 70
Marginal Terrain Vehicle XM759	Kalen	1966
Twister Vehicle XM808	Kalen	1968
Truck Series	Kalen	1964
SAFEGUARD	Kurtz Erickson	1964
PERSHING	Emery	Jun 59
TACFIRE	Golden Erickson	Jul 67
MASSTER	Johnson Krueger	May 70

Human Engineering Evaluation of Strategic Communications Technical Control Facilities	Krueger	Jul 70

The objective of the evaluation is to determine the degree to which the design of semi-automatic technical control systems conforms to established HFE design principles and criteria. Two test bed semi-automatic technical control facilities are being evaluated. The first includes an Automatic Quality Monitoring and Reporting Subsystem (AQMRS) and the second is an Automatic Technical Control center including semi-automatic circuit switching capabilities.

The result of the evaluation will consist of recommendations for improvements in the design of future technical control systems and an identification of any display inadequacies and data processing procedures for semi-automatic technical control operations.

c. AVIATION BRANCH

This branch is responsible for human factors engineering in aircraft and aircraft-related materiel. Preponderance of the effort is devoted to V/STOL and VTOL systems.

The current work program of the Aviation Branch falls into three broad, related categories: AMC aviation project support, design research of specific aviation materiel, and human factors research in aviation materiel.

(1) AMC AVIATION PROJECT SUPPORT

Several major changes occurred in Aviation Branch workload during FY 70, primarily as a result of there being no new starts in aircraft procurement, and of special interest being shown in the human factors associated with aircraft survivability.

Although not apparent in the project structure presented below, direct support to project/systems managers is a continuing and consistent element of the workload. This manifests itself in the reviewing of QMDO's, program plans and the like, as well as the maintenance of expertise in a fast moving field such as contemporary aviation. Though of low visibility, these efforts are the very foundation of design competence in future developments.

Title	Investigator	Date Started
SEA NITEOPS Human Factors Engineering Support	Foster, DeBellis, Stowell, Pettit, Florip	1968

Technical support for the SEA NITEOPS Project Manager, included technical assistance and evaluation on the FIRTI, AIRBORNE SEARCHLIGHT, INFANT, FLIR (HAC), FLIR (AGC) and the AH-1G Installed Stabilized Night Sight (SNS).

Significant activity for PM-SN included the selection and modification of the KAISER FP-50 display for installation in the SNS equipped AH-1G COBRA, assistance in the conduct of the SNS/COBRA flight test activity preparation of the FP-50/SNS/COBRA flight test plan, conduct of a laboratory experiment on the effects of the FP-50 on dark adaptation and visual acuity and the publication of report on same (HEL-TN-2-70). A proposal was submitted to the PM-SN for the conduct of a study and flight experimentation for the preparation of a format specification for primary flight displays incorporating night vision devices.

(2) DESIGN INVESTIGATIONS OF SPECIFIC AVIATION MATERIEL

Human Factors Engineering Systems Analysis of Aircrew Armor	Corona	1970

Design investigations and experiments are being developed in the following areas: Dimensional suitability (physical measures to determine operator and vest compatibility, operator/vest compatibility with selected aircraft seat and cockpit configurations); Mission Interface (effects of body armor systematically related to operator performance of various flight tasks); Protection Need Matrix (vulnerability analysis); Aircraft Performance/Weight and Balance (effects of weight on CG using various armor configurations); Effects on Operator Performance (impact of the armor system on the performance of selected complex psychomotor tasks using multilimb coordination, perceptual-proprioceptive integration, serial reaction times and target acquisition), and validating the results against a new proposed anatomically configured aircrew body armor system.

CH-54, Crashworthy Armored Seat	Corona	1970

This effort provides human factors engineering monitoring of a USAAVSCOM contract with Sikorsky Aircraft and the Carborundum Company for Pilot and Co-Pilot Armored Crashworthy Seats in the CH-54.

This program is directed at integrating the existing aircrew station geometry with proposed seat configurations and the operator/clothing/equipment configurations. This will be achieved by providing crew station geometry constraint data, anthropometric considerations, the various clothing equipment configurations of the operator(s), and human factors engineering evaluation of the completed system.

Armament Systems	DeBellis	1970

An in-depth study of the maintenance, handling, mounting, and loading of the weapon along with developing procedures and techniques with design recommendations for interfacing the weapon to an AH-1G flexible turret (XM120 system).

Helmet Weight Program	Corona	1968

Analysis of data gathered under conditions of symmetric and asymmetric helmet weight distributions continues. Draft reports of the three experiments completed to date are approximately 25% completed. Apparatus used in these experiments is undergoing modification (30% completed) to allow more precise measurement of a wider variety of psychomotor tasks.

Evaluation of Solar Reflecting Paint on AH-1G	Pettit	Mar 70

An analysis of temperature measurement problems associated with the comparison of regular and solar reflecting paints (SRP) on the AH-1G COBRA was made. At the request of AVSCOM, prepared a detailed plan of test and instrumentation requirements to permit a valid comparison and allow the effectiveness of SRP to be properly evaluated. AVSCOM made funds available to purchase necessary instrumentation and to implement the test. This effort is currently underway and the results will be presented in a Technical Memorandum.

(3) HUMAN FACTORS RESEARCH IN AVIATION MATERIEL

Aircraft Survivability Human Factors Program	Cassatt, Waugh Barnes, Bauer	May 70

This program is under the direction of OACSFOR. The objective is to investigate the human factors aspects of aircraft survivability. The result of the program will be improved Army aircraft survivability characteristics, and more accurate analytic models of Army aircraft survivability.

The program consists of the following phases:

(a) CONUS interviews detailing mission scenarios and soliciting judgments and experience of Army aviators recently returned from Viet Nam.

(b) Operations research data collection in Viet Nam, including intelligence data and detailed debriefings of aircrew members recently completing missions under hostile circumstances.

(c) Analysis and exchange of information and literature in cooperation with the Army Materiel Systems Analysis Agency (AMSAA).

To date, CONUS interview data has been collected, plans for Viet Nam data collection continue, analyses of Battle Damage Assessment Reporting Program (BDARP) and TWX data continue.

Evaluation of Pilot Incapacitation in Combat (EPIC)	Cassatt, Doss	May 70

A program of research in support of the Vulnerability Laboratory, Ballistics Research Laboratory, was initiated in March 1970. The long range purpose of this program is to define those tasks in controlling the flight of helicopters, which cannot be performed in the event the pilot becomes incapacitated by bullet wounds. Current objectives are:

1. Determine the most feasible method of achieving a short-term incapacitation of individual limbs, and selectively immobilizing segments of limbs.

2. Conduct preliminary verification and validation of selected incapacitation techniques on a 1-CA-1 Flight Simulator/Trainer.

3. Conduct an in-flight evaluation with the Whirlymite Helicopter Trainer, to determine performance degradation as a function of selected modes of pilot incapacitation.

Aircrew Station Display and Information Processing	Barnes	Jul 67

During FY 70 regular participation in the Joint Army Navy Aircraft Instrumentation Research and Search and Rescue Working Groups has been continued. The initial phase of the Human Engineering Laboratories - Electronic Command Support Plan has been completed and the Tactical Utility Helicopter Information Transfer Study Report has been published. The equipment used to gather the data for the study to determine the effects of presently available instrument lighting systems on new generation instruments has been re-built and the research will be completed in FY 70.

Aircrew Station Environment	Bauer, Jones	Jul 67

Objectives are to develop measurement techniques and to assess environmental variables including light, heat, noise, and vibration as they interact with design and affect performance in aircrew stations. Experiments will provide a basis for improved Army air vehicle design standards. Illustrative of on-going work are the following:

(1) Investigation of the effects of flash duration and illuminance on dark/light adaptation;

(2) Evaluations of prototype cathode ray tube flight displays in simulated night environments;

(3) Effects of vertical vibration on multilimb coordination and target acquisition. In addition to the above, the collection of baseline measures of thermal environments in aircrew station environments under conditions of ground run-up, hover, climb, and cruise continues.

Aircraft Handling Qualities and Control	Waugh	Jul 68

During FY 70 a contract was negotiated for a tracking system slated for inclusion in the flight test facility which will provide continuous measurement of the translatory motion of a hovering V/STOL aircraft. Delivery took place

late May 1970. Also a paper has been written for journal publication justifying and delineating the Human Engineering Laboratories' approach to handling qualities evaluation for purposes of evoking comment and dialogue from the aviation industry and other government aviation agencies. Data collection on pilot subject performing hovering flight routine as well as independent testing of their psychomotor skill capability and assessment of their profile of flying experience is expected to begin in FY 71.

Human Factors Concept and Standards Development for Aviation Materiel	Cassatt	Jul 67

This task is designed to advance the development of air vehicle concepts feasibility analysis pertaining to critical human performance parameters and to insure the timely application of valid design criteria.

Experiments were completed on optical coatings for aircraft instrument glasses and filters for airborne roster scan displays. Review of the Draft Engineering Design Handbook for Rotorcraft is being carried out on a continuing basis.

2. Basic Research

The Behavioral Research Laboratory conducts all of the basic research within the Human Engineering Laboratories (HEL). This program is designed to establish human capabilities and limitations under a wide variety of operational and environmental conditions.

Six research teams have responsibility for the following tasks:

Title	Investigator	Date Started
Neural Control of Sensory Input	Oatman	Jul 68

The objectives of this task are to measure responses from sensory pathways in order to identify the physiological mechanisms involved in attention, where attention to one sensory input modulates or filters another sensory input; to specify the regions of the central nervous system which mediate such sensory interactions; and to assess the stimulus parameters under which such sensory interactions may be modified.

Experiments have been completed which demonstrated that, when cats are attentive to a visual discrimination task, the amplitude of auditory evoked potentials are suppressed. Electrophysiological evidence of cross-sensory interaction in the central nervous system has been obtained. Experiments are under way to determine the parameters of auditory input which are affected by attention to visual inputs, including loudness and frequency.

Vision - Depth Perception	McCain	Jul 69

Conventional depth perception tests use dark objects against lighter backgrounds. In the real world, however, people view colored objects to perceive real or apparent depth. This task investigates how colored objects are perceived in depth, how color, per se, affects apparent distance, and how to develop a means of measuring this variable.

Current efforts are focused on further definition of the color-luminance interaction, and investigation of the role of chromatic aberration in perceived depth.

Human Sensory Processes in Military Operational Environments	Monty, Karsh	Mar 68

This task's purpose is to investigate visual and cutaneous sensitivity to (a) examine selected properties of the sensors and (b) develop measures to indicate impairment or loss of sensory function. Of particular interest are similarities between visual and cutaneous systems and how fundamental perceptual processes common to both systems are altered by stresses associated with operational environments.

Relation of Hearing Change to Acoustic Input	Price	Jul 66

The objective of this task is to establish the relationship between acoustic input, immediate hearing loss, and recovery from such losses in the peripheral and central nervous systems. Research will be conducted to establish relationships between continuous, intermittent, and impulsive acoustic inputs and hearing changes.

The effect of spacing stimulation on the traumatic properties of stimuli have been published. Work in progress includes investigation of the effect of impulsive stimuli of various intensities and a study of the locus of changes in sensitivity within the central nervous system.

Physiological Aspects of Emotions of Military Personnel	Carriero	Jul 68

The purpose of this research is to determine to what extent changes in physiological activity such as heart rate, blood pressure, muscle activity, etc., can be used to measure attitudes, to predict attitude change, and actual acceptance-rejection behavior. Experiments will be conducted to determine the relationship between human performance and physiological activation.

Sources of potential emotionally arousing material have been identified and contacted. Equipment calibration and data reduction techniques are presently being explored.

Keeping Track of Sequential Information in Military Operations	Monty	Jul 66

The objective is to examine and isolate those variables affecting man's capacity to keep track mentally of a series of events occurring sequentially; to describe the memory and perceptual processes employed by individuals performing such tasks; to investigate the time required to perform complex mental tasks; to develop a general theory of keeping track performance.

Recent experiments have investigated problems associated with order of report required, methods of encoding in memory, the effects of multiple incremental manipulations and information rate, and problems associated with incremental processes. Principles for the design of displays have been deduced and submitted for publication.

Endocrine Response to Stress	Hudgens	Jul 68

The objective is to determine potential environmental effects and to gain an understanding of the central nervous system mechanisms which control the stress response and affect performance.

Experiments have shown that emotional reactivity in a stressful situation can be lessened by enriching the organism's past experience through added sensory input. Social interaction can enhance or modify these effects. A study is in progress to determine whether or not this beneficial effect can be transferred via brain RNA extracts from one organism to another.

Auditory Threshold Changes as a Function of Weapon Noise Exposure	Hodge	Jul 66

The objectives are (a) develop a predictive model of weapon noise effects on performance of combat-relevant skills; (b) improve existing damage risk criteria; (c) extend knowledge of variables involved in the acquisition and recovery of temporary hearing losses; and (d) improve methods for assessing human auditory capabilities.

A state-of-the-art review of the effects of noise and blast on man has been submitted for publication. Effects of exposure to single, large-amplitude impulses have been investigated, along with the protective value of ear plugs. Current emphasis is on determination of the feasibility of predicting the effects of hearing losses on performance of combat-relevant skills.

Parameters of Human Pattern Perception	Hodge (Monitor) Evans (Texas Christian Univ)	Sep 67

The objective is to conduct methodological, empirical, and theoretical investigations of human pattern perception emphasizing understanding human performance using patterns representative of the real world. Ultimate goal is the development of a computer-based model of human pattern perception behavior.

The completed methodological phase developed computer programs for generating controlled populations of patterns having features comparable to those in the real world. Empirical experiments are emphasizing the strategies by which man selects features from objects and patterns and uses them as a basis for classifying patterns into families. Multivariate and process models of pattern perception are being developed. Certain portions of a process model have been simulated via computer.

Performance, Recovery and Man-Machine Effectiveness	Hodge (Monitor) Dudek (Texas Tech Univ)	Sep 68

The objectives of this task are to determine man's ability to perform for long periods of time and his ability to recover from such performance. Environmental, task and organizational variables affecting several different conceptualized man-machine systems are being investigated. Means of sustaining performance and speeding recovery will be investigated.

Investigations of body orientation and tracking under conditions of vertical vibration have been completed, as have work-rest cycle studies. An environmental chamber is being used for investigations of temperature and humidity effects on performance. Nutritional and pre-conditioning variables' effects on vigilance performance have been studied.

3. ENGINEERING RESEARCH LABORATORY

The Engineering Research Laboratory is composed of four branches: Design Engineering, Electronic Development, Acoustical Research and the Experimental Shop. A photographic support service is also part of this laboratory. The primary purpose of this laboratory is to provide general and specialized support for the Behavioral and Systems Research Laboratories. The Engineering Research Laboratory also performs experimental engineering investigations and applied engineering research, as required, to carry on its mission. Examples of this work and support are as follows:

a. Mock-up of Sheridan Laser Range Finder and auxiliary equipment.

b. Pop-up targets, gas operated, radio controlled.

c. Instrumentation - analysis of mobile communication.

d. Remote controlled firing devices for Tracer Experiments.

e. Light flash projector - Aircrew Station Environment Investigation.

f. Helicopter instrumentation - Temperature and Display Research.

g. Installation of Command-Control Display Simulator.

The Acoustical Research Branch's principal areas of endeavor, at this time, are: criteria for evaluating helicopter noise detection and signature; improving voice communications and ear protection for vehicles in field operations; research on attenuating materials for use in AMC equipment; continuing consultation in the area of "effects of noise upon man", to the Systems Research Laboratory, and outside agencies upon request, improved noise measurement techniques are continuously being developed and the HEL Noise Standard, "Maximum Noise Level for AMC Equipment", is being continuously updated. This document is included in the contractural specification for almost all equipment purchased by AMC. Other phases of noise phenomena being investigated to include detection and identification of low level sounds in extremely quite noise environments.

Title	Investigator	Date Started
OH-58A Helicopter	Lince Young	Jun 70

The objective of this task is to obtain internal and external noise level measurements to be used to generate base line data to evaluate Army helicopter noise problems and how they effect human performance.

Internal measurement data including the firing of weapons will be used (a) to establish if personnel could suffer hearing damage, (b) the percentage of intelligibility obtained in the communications system.

The purpose of the external measurements is to determine the sound pressure levels produced by the helicopter in various flight conditions. The data collected will be used to plot equal sound pressure level contours by octave bands at the earth's surface for each flight condition. The sound contours will be used to make predictions of the aural detectability of the helicopter by personnel on the ground.

Communication System Intelligibility Criteria	Garinther Young	Jun 70

The objective of this task is (1) to determine the phonetically balanced (PB) score necessary to provide a tank crew with communications which are adequate to effectively perform their mission, (2) to determine the noise level to which a tank crew is exposed during a typical "24 hour battlefield day"; (3) to determine the hearing hazard incurred by this noise and the degree of hearing protection required to minimize this hazard.

The commonly accepted PB scores of 70% required and 80% desired for a communications system have been used by this laboratory over the past years. However, in some systems in which a limited number of standard phrases are used by trained personnel, the system would have a lower communications requirement than one with a more precise dialogue exchange.

This task will consist of a psychoacoustical determination of how much the intelligibility of a given system can be degraded and still maintain adequate effectiveness.

Attenuating Materials Investigation . Holland Jun 70

The objective of this task is to determine the articulation index (AI) from noise data generated inside an S-141/G Communications Shelter, with varying amounts of acoustical materials applied to all surfaces except the floor. The AI measured in octave bands is highly correlated with speech intelligibility as evaluated by speech perception tests.

An investigation of acoustical materials with a high coefficient of sound absorption and a surface sufficient to withstand usage requirements will be conducted for available materials. A thorough literature review will be made, and any pertinent data will be analyzed to determine if it contains any appropriate information, compatible for use with this task requirement.

2A(3). U.S. ARMY MATERIEL COMMAND MISSILE COMMAND

Redstone Arsenal, Alabama 35809

CURRENT WORK PROGRAM

1. Advanced Research Projects

Human factors consulting services are furnished to several advanced research projects in the areas of program evaluation, contract monitoring and technical support.

2. Army Forward Area Air Defense System (AFAADS)

Human Factors Engineering (HFE) support was furnished to two efforts being conducted under the AFAADS program--IRDA and AMTOC. The objective of the first task is to develop and build an infrared target signature data acquisition system using a precision tracking mount. The human factors role in this task is to design the workspace in the recording and instrumentation van for the remote control of the mount and to determine the functions required by the remote operator to successfully execute the tracking mission to include TV tracking. Remote facility layout, console design, control and display design and activity analysis have been completed. HFE support to the test program will be furnished as required. HFE efforts on the Advanced Sensors Tracking Mount Program are continued. HFE support was also furnished, during the current reporting period, to preparation of test plans for target detection, recognition and identification.

3. CHAPARRAL

Human Factors Engineering support of CHAPARRAL system development during the reporting period has been a minimum sustaining effort in the general areas of contract monitoring, system evaluation and product improvement design. A review and analysis of visual problems associated with canopy icing and deicing was completed and human factors planning for proposed target acquisition aid tests was undertaken.

4. Concept Formulation Programs

Human Factors Engineering inputs are furnished, on an "as required" basis, to programs in early phases of their life cycles. During the current reporting period, HFE efforts in this area included evaluation of concepts, identification of potential human factors problem areas and formulation of relevant research requirements for systems enumerated by the Army Missile Plan. HFE support to concept formulation is a continuing effort.

5. DOD Standardization Program
Project MISC-0600

This effort is a follow-up to DOD Standardization Program Project MISC-0422 which consolidated all Army, Navy, and Air Force human engineering design requirements into a single, fully coordinated military standard in February 1968. The objectives of this program were to incorporate into MIL-STD-1472 current requirements not contained in the military standards which MIL-STD-1472 superseded and to improve scope and presentation format. Pursuant to these objectives, tri-service inputs were processed through the departmental custodians (Army Missile Command, Naval Air System Command and Air Force Systems Command Aeronautical Systems Division) to the preparing activity (Army Missile Command). Other government and industry group inputs were submitted directly to the preparing activity. Formal coordination was completed with the convening of a Tri-Service/Industry working group, 15-16 April 1970, to resolve all essential comments. MIL-STD-1472A, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities," was subsequently submitted through standardization channels for publication, distribution and use. This project was initiated during FY 69 and was completed during FY 70.

6. DOD Standardization Program
Project MISC-A-601

The objective of this program was to consolidate general requirements for color and marking of Army materiel in a limited-coordination military standard. The purpose was twofold--to place in a military standard color and marking requirements contained in regulatory documents not readily available to contractors, and to consolidate into a single document color and marking requirements contained in numerous specifications and standards for different classes of material. This standard will, therefore, serve the dual purposes of stating requirements and serving as a convenient index for color and marking of Army materiel. This project was initiated during FY 69 and was completed during FY 70.

7. Design Evaluation, General

Human Factors Engineering evaluations are performed, as short term efforts, in support of numerous programs on an "as required" basis. Typical HFE design evaluations conducted during this reporting period included critical HFE areas for M-22 and QH-50, acoustic effects of HERCULES equipment, and TOW-COBRA tracking requirements. Program and HFE requirements support were furnished to MARS, LCSS, Met RDT&E Rocket System, BATS, PERSHING, and SAM-D.

8. DRAGON Maintenance Set

Human Factors Engineering support in the areas of subsystem evaluation, contract monitoring and design assistance is performed as a continuing effort for the DRAGON Maintenance Set. Tasks during the current reporting period included analyses of operating procedures, selection of appropriate anthropometric data for use in design, consideration of adverse temperature operation effects on personnel, consideration of size and weight of manually lifted and handled items, and establishment of requirements for general human engineering design.

9. Electro-Optical Missile Guidance Studies

Flight tests were completed at the Missile Command during the third quarter of FY 70 to define the capability of human operators to detect and identify tank type targets from the air by direct vision and lock a tracking gate in a helmet-mounted video display onto the target in preparation for missile launch. A formal report of findings was issued in the fourth quarter of FY 70. Experimentation performed on this program was a contractor effort (North American

Rockwell). Planned follow-up phase includes studies of methods to improve human performance under the conditions of the flight tests, and a simulation experiment on the indirect fire target acquisition problem with emphasis on simulated target designation as a potential operator acquisition aid.

10. FAAR

During the current reporting period, environmental requirements for a crewmember riding in the moving shelter have been developed. Testing of this mode and normal operation environment was initiated. An evaluation of the FAAR PPI was performed with particular emphasis on target size, screen brightness, IFF discrimination and target ambiguity check. Other areas of HFE analysis/evaluation included antenna alignment procedures, improved seating design, size and weight of items to be manually lifted and handled, and emplacement and march order test procedure preparation. The FAAR HFE effort is continuing.

11. Human Engineering Requirements and Criteria

As "Preparing Activity," MICOM maintains the following human engineering requirements and criteria documents: Mil-H-46855, "Human Engineering Requirements for Military Systems, Equipment and Facilities;" MIL-STD-1472, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities;" MIL-STD-XXXX, "Standard General Requirements for Color and Marking of Army Materiel;" the eight human engineering data items of the Army Authorized Data List; and the "Human Engineering Design Data Digest"--a graphical, tabular, and pictorial portrayal of human engineering design requirements.

12. SAFEGUARD

Human Factors Engineering consulting services are furnished to the SAFEGUARD System Command in the areas of system evaluation, contract monitoring, and design assistance.

13. SHILLELAGH

An investigation was conducted to evaluate Infantry SHILLELAGH concepts from the standpoints of safety and human factors. General relevant areas studied included launch induced environment, equipment weight/configuration, reaction time, and gunner performance. A detailed report of findings was prepared and published.

14. VRT

The objective of this effort was to determine the feasibility of building inexpensive flying models of jet aircraft using momentum compression ramjet engines and to analyze how these models can be used to realistically simulate tactical situations where personnel can be trained to identify friendly and foe jet aircraft. Approach included analytic determination of scale size of aircraft to accommodate momentum compression ramjet engine, optimum physical and flight characteristics, configuration changes required to optimize performance and effect on recognition features, concept for training, advantages and disadvantages of the concept and logistic costs. This effort (performed under contract by Brown Engineering Company) was initiated and completed during FY 70, including preparation and distribution of final report.

2A(4). U.S. ARMY MATERIEL COMMAND
MUNITIONS COMMAND

Dover, New Jersey 07801

EDGEWOOD ARSENAL

Current Work Program

The program of the Human Factors Group encompasses planning and conducting basic and applied research to produce human factors data for systems and components, planning and incorporating human factors considerations in chemical materiel designed and developed by the Edgewood Arsenal Development Laboratories and their contractors; incorporating human factors considerations in the safety and reliability evaluations and production inspections conducted by the Quality Assurance Directorate; reviewing operator manuals and other such documents to insure ease of reading and understanding, insure completeness of instructions for operation and maintenance, and to assure maximum effectiveness of man-machine combinations with chemical materiel in all operational environments.

Title	Investigator	Date Started
Multishot Portable Flame Weapon, XM191	Karr	Sep 68
Marking and Detection System	Karr	Oct 68
Disperser and Riot Control Agent, XM30	Houff	Aug 68

Disperser and Riot Control Agent, XM32	Houff	Aug 68
40mm, CS Cartridge, XM627	Houff	Sep 68
40mm, CS Cartridge, XM651E3	Houff	Sep 68
Portable RCA Disperser, XM33	Houff	Sep 68
Grenade, XM47E1 and XM48E1	DeLaney	Aug 66
Portable Flame Thrower M9E1-7	Houff	Apr 67
155mm, Binary Projectile	DeLaney	Feb 68
Service Unit, Flame Thrower Track Vehicle Mounted, XM45E1	Houff	May 67
Human Factors Evaluation of Foam Generators	Karr	Mar 69
Canister, Cluster, Tactical CS, XM15 and XM16	Houff	Jul 66
Shelter System XM51 (CB Pressurized Pod)	Jackson	Apr 68
Multi-purpose Military Mask Program, formerly (Aircrewman's Mask Module)	Jackson	Sep 67
Collective Protection Equipment M577 Command and Post Carrier	Houff	Feb 65
XM235 Detector Kit	DeLaney	Apr 67
XM181 Detector Kit	DeLaney	Apr 67
Auto Atropine Injector	Houff	May 69
Collective Protection for Vehicles, Van, Shelters	Jackson	Jul 68

XM14 Collective Protection Equipment, Command Post Vehicles M291A2	Houff	Feb 65
Liquid Agent Detector (LAD)	Jackson	Nov 65
Non CB Stress Effects of the Protective Ensemble	Jackson	May 69
Visual and Optical Consideration of Field and Protective Masks	Houff	Jan 69
Effect of the Protective Ensemble on Vigilance Performance	Jackson	Mar 69

PICATINNY ARSENAL

HUMAN ENGINEERING SUPPORT GROUP

Title	Investigator	Date Started
Missile System Warhead Development	DeTogni	1961

This series of projects provides human factors support for the design and development of the warhead sections for missile systems. Specific attention is given to total system compatibility, multiple warhead capabilities, test and handling equipment and operational and procedural manual development.

Specific projects receiving human factors support are:

a. Lance
b. Sprint
c. Spartan

Nuclear Demolition Development	Kostakis	1960

This series of projects provides human factors support for the continual design and development of various types of nuclear projectiles and demolition devices. Emphasis is placed upon portability requirements, environmental effects on handling and tactical employment procedures.

Specific projects receiving human factors support are:

AFS
1. XM17
2. XM94

human factors evaluation of the complete system will be undertaken during the development test phase which is expected to be reached during the first quarter of FY 1971.

7.62MM Standard Rifle Mount (Cartridge 7.62MM Tactical Packaging)	Kelly	May 68

Purpose of the program is to develop an optimal ammunition feeding system for the Mini-gun. A survey and analysis of systems currently in use was conducted to obtain information to assist in optimizing the parameters involved in the packaging, storing, handling, loading, and feeding of ammunition. A report with tentative conclusions and recommendations is being published.

5.56MM and 7.62MM Cartridge Ammunition Fixture	Kelly	May 68

Purpose of the program is to investigate the dynamics of the human system component as it affects the testing of small caliber ammunition. By reproducing the bodily reaction of an average gunner with programmed recoil buffers in a simulation test fixture, variation in the testing of ammunition resulting from individual differences in gunners could be controlled and reduced to minimal levels. Subsequent to the literature survey and review of prior work, a contract was placed and construction of the test fixture was undertaken. The program has been delayed by technical and funding problems but preliminary results and information are expected to be available during the first quarter of FY 1971.

Small Arms Applied Research (Fire Control)	Hanna	1969

Effort has been directed toward establishing a data base to define the weapon-man-sight dynamic interface for small arms weapons. Objectives are: determine human factors parameters affecting fire control system design; identify known areas where a small effort in human factors analysis or testing can significantly contribute to increasing the effectiveness of developmental or production items applicable to small arms fire control; establish technical limits of the program to be used as a framework for planning future effort.

Laser Target Designation System (LTDS)	Gallun	Jan 69

The objective of this task was to monitor the contractor's human factors efforts in the modification of the Seeker - Detection units and control panels to

Conventional Systems Development	Kostakis DeTo Carloc Bucklin Rayner	1960

This series of projects provide human factors support for the continuing design and development of mortar systems, landmines, hand grenades, rockets, etc., Laboratory and field studies are designed to evaluate specific engineering designs and particular operational procedures.

Specific projects receiving human factors support are:

a. M33A1 Hand Grenade (Product Improvement)
b. XM63 Anti-Disturbance Module
c. XM432 and XM433 Fuzes for 2.75" Rockets
d. 81mm Mortar Fuzes
e. Helicopter Sensor Dispensing System

SPECIAL PROJECTS GROUP

Visual Detection Center Activities	Bucklin Weasner Rayner Carlock	1966

These activities include human factors support for the establishment of design parameters for illuminating and target marking systems including flares, smokes and chemiluminescent materials. An extensive literature search and a continuing series of field studies has been and will be conducted to isolate the effect of illumination, color, visual acuity, burning time, terrain features, movement and other variables upon the effectiveness of specific line items.

Personnel of this group also conduct laboratory and field studies aimed at developing camouflage techniques for surface emplaced munitions and sensors. The principles of imitation, blending, decision jamming and noise introduction are being studied in relation to tactical practice and human detection capability. In addition, an effort is being made to develop a detection ability scale.

Specific projects receiving human factors support are:

a. XM56 AV Mine System
b. M127A1 Illuminating Signal (Safety Improvement)
c. XM125 Hand-Held Signals
d. BASS III

Portability Center Activities	Carlock Kostakis Weasner	1962

This project evaluates present and projected carrying devices and techniques for Picatinny Arsenal developed weapon systems. Effects of load-carrying upon fine motor performance and decision making ability are also studied.

Specific projects receiving human factors support are:

a. Components of BASS III
b. AFS Components

Behavioral and Psychological Effects Studies	Bucklin Weasner	1970

Attempts are being made to develop techniques for measuring lethal and non-lethal weapons system effectiveness through the use of behavioral and psychological effects.

Specific projects receiving human factors support are:

a. Barrier Counterbarrier Project
b. Disperse

Staff Service and Consultation	Staff	1966

Personnel of the Human Factors Section provide consultation services for Arsenal management in the areas of training, motivation, staff development and engineering and scientific personnel problems.

FRANKFORD ARSENAL

CURRENT WORK PROGRAM

Title	Individual	Date Started
Tracer Visibility Research Program	Kelly	Jan 65

This is a study of the characteristics of a tracer bullet for optimum visibility in daylight. Factors considered are: tracer candlepower intensity; amount of natural illumination; color and reflectance of background terrain; color of trace; velocity of bullet; and position of the observer. Correlation will be established between observed visibility and tracer intensity. Effort on this program is dependent on the availability of funding for FY 1971.

Target Acquisition	Kelly	Jan 66

Effort on this project is dependent on the availability of funding for FY 1971 and succeeding years. The program involves target detection, recognition, and identification with the aid of optical devices. Areas of concern for FY 1971 and following include: practical uppper limits of magnification; optimum combinations of magnification and field of view for stated visual tasks; relative merits of fixed and variable magnification; and the most effective search techniques for a given magnification and field of view.

Human Factors Study of Fuze Setting Problems	Gallun	1962

A continuing program in which general concepts such as safety, ease and accuracy of setting, visual factors, and specific problems are investigated for the purpose of validating existing information and generating new data concerning the human factor variables involved in fuze setting.

MBT 70	Kelly	Jun 60

Purpose of this program is to provide human factors engineering support for the fire control aspects of the Main Battle Tank. The Branch is primarily concerned with coordinating the efforts of Frankford Arsenal with other agencies involved in the program. Currently under investigation is the compatibility of fire control equipment with the personal and protective gear of combat vehicle crew members such as helmets and gas masks.

Special Products Devices	McGuigan	Jul 66

This is a continuing program for which funding is provided for human factors work for a variety of devices concerned with guerrilla and counter-guerrilla warfare and ancillary areas. Much of the work is of a classified nature and is conducted in the general areas of ammunition, improvised munitions, flares, and specialized devices concerned with unconventional warfare.

Advanced Flare and Dispensing System for Army Fixed and Rotary Winged Aircraft	Staff	Apr 67

Object of the study was to review and coordinate the data pertaining to human factors which would affect the feasibility of new target illumination and identification concepts. The study was completed and a final report has been published.

Forward Looking Infrared (FLIR) Target Acquisition and Fire Control Sub-system	Gallun	Dec 66

Branch effort on this program included a human factors analysis of control and display parameters to fulfill part of AVSCOM's requirements prior to issuance of an Allied Equipment Safety Flight Release for the UH-1M FLIR System. Future effort on the program will consist of Branch review of the human factors aspects of contractor proposals for an Advanced FLIR System.

Moving Target Radar (Fire Control)	Gallun	1967

Branch effort on this program included recommendations for the integration of an indicator (CRT), a tracking hand control, and associated control panels into a UH-1 helicopter. Human factors effort on the program was terminated when the Moving Target Radar system was redirected for installation into the AH-1 helicopter configuration. Branch involvement on the latter program will be dependent on the availability of funding for FY 1971.

Multi-Weapon Fire Control System (MWFCS)	Gallun	Jan 67

Branch role consists of monitoring the contractor's human factors efforts in repackaging the MWFCS for installation to the AH-1G helicopter. A task analysis of the pilot's and copilot's gunnery roles is currently in process. A

interface with the various sight systems involved in the UH-1 and AH-1G helicopters. A comprehensive in-house study of the contractor's panel drawings and Seeker - Detection unit mockup was performed and recommendations made. Branch effort on the program was terminated and future activity is dependent upon funding for FY 1971.

Psychological Barrier Effects	McGuigan	May 69

Branch responsibility involves coordination of the behavioral and social aspects of ongoing barrier effects, programs, and concept generation for controllable barriers. Future effort on the program will depend on the availability of funding for FY 1971.

Human Factors ATE (Automatic Test Equipment for Internal Combustion Engine Powered Material - Organizational)	Gallun	Feb 69

Branch effort on this program includes the preparation of the human factors engineering requirements for the Engineering Description of the ATE, evaluation of the human factors portion of contractor proposals and monitoring of contractor human factors efforts during the development and testing phases of the program.

Small Caliber Ammunition Plant Modernization Program	McGuigan Hanna	1970

Branch responsibility on this program is to assure contractor delivery of optimally human factors engineered equipment and facilities to the government. Prime areas of investigation include a complete task and systems analysis as well as specific items such as maintenance, safety, workspace, environmental conditions, and others. Evaluation of technical risks and program costs prior to system development will be stressed.

Consultation and Advisory Services	Staff

Human factors engineering services are provided for research, development, and production engineering activities on an on-call basis. These services include such representative areas as participation in feasibility and concept evaluations, evaluation of components and/or equipment, provision of human factors engineering data to design engineers, participation on committees for

consideration of human factors in product improvement contracts, and membership on ad hoc groups for investigation of specific problems.

Monitoring Services Staff

This function provides for the supervision, together with the technical supervision of the contract, of the human factors engineering portions of Frankford Arsenal Research and Development contracts. Services include the evaluation of progress and final reports, visits to contractor installations as required, and participation in other phases of procurement such as preaward meetings of contracts by personal contact with project engineers and evaluation of quarterly progress reports.

2A(5). U.S. ARMY MATERIEL COMMAND NATICK LABORATORIES

Natick, Massachusetts 07160

CURRENT WORK PROGRAM

1. Man/Environment Compatibility Engineering Research

Within the Army Human Factors Engineering program, the purpose of this task is to conduct human factors engineering research in order to define and apply scientific principles of human physical and psychological characteristics to the design of clothing, equipment, and food. Anthropometric data are collected on U. S. and foreign military populations and analyzed in order to define the characteristics of body size for use in the design, sizing, and tariffing of military clothing and personal equipment. Psychological studies and performance measurements contribute to the development of military materiel that will increase the soldier's efficiency and effect compatibility among the soldier, his equipment and his environment.

Title	Investigator	Date Started
Human factors research and compatibility studies of environmental, clothing, and personal equipment effects in cold and tropic environments	J. Lockhart H. Kiess J. McGinnis	1969

Human engineering studies are conducted to determine the sensory, perceptual, psychomotor, and psychological effects of cold and tropic environmental exposure for protected and unprotected individuals, and relate these effects to military task performance in extreme environments and to soldier personal equipment-performance compatibility.

Human factors research in support of material research and development to include clothing, personal equipment, aerial delivery, and food service systems	J. McGinnis H. Kiess J. Hearns	1969

Research is conducted on human factors and problems of applied experimental psychology to secure data and determine sound human engineering principles for use in developing Army material to effect compatibility among the soldier, his environment and his operational tasks. In addition, human engineering research, evaluations, assistance, guidance, and compatibility studies are furnished as needed in support of all types of equipment under development by NLABS. Clothing, armor, and personal equipment are included, along with airdrop equipment, tentage and air-supported shelters, containers for food and other items, food service equipment, field service equipment, and certain types of general equipment.

Conduct human engineering and applied research studies of the headgear, including helmet acoustics, weight, encumbrance, and other factors affecting performance.	T. Nichols	1959

Human engineering research is conducted to obtain guidance information for improvement of protective headgear, particularly for combat vehicle crewmen and aviators.

Design criteria for fitting and sizing clothing and personal equipment. (Clothing and Personal Life Support Equipment Laboratory).	R. M. White	1946

Anthropometric surveys are conducted to provide body-sized data on U. S. and foreign military populations. The resulting anthropometric data are processed, analyzed, synthesized, and evaluated as a basis for the development and improvement of size systems and tariffs for military clothing and individual equipment. Anthropometric data are utilized in the effective human engineering of military equipment and materiel. New anthropometric surveys of the U. S. Armed Forces were carried out in 1965-67 at the request of the Defense Supply Agency. A new anthropometric survey of U. S. Army aviators was conducted in 1970 to provide up-to-date body size information on aircrewmen, applicable to both human factors engineering and the design of life-support equipment. Anthropometric research is conducted to provide sizing and design criteria for helmets, body armor, and handwear.

Studies to determine attitudes and preferences of soldiers toward QM food items.	H. L. Meiselman D. W. Bloomquist H. L. Jacobs L. M. Bartoshuk	1964

Studies are conducted to determine the soldier's attitude and preference toward QM material, particularly food items. Current emphasis is placed on both a program of taste panel evaluation of food items under development and/or procurement and food preference surveys of Army personnel.

Conduct validation studies of acceptance data and development of new measuring devices.	L. M. Bartoshuk H. L. Meiselman H. L. Jacobs H. R. Moskowitz	1966

This task is a long-term applied research program evaluating food acceptance techniques, sampling procedures, and subject population.

2. Basic Research in Human Capabilities

The supporting research program is directly related to the long-range problems of the Food Acceptance Laboratory, and also designed for inter-disciplinary collaboration with common problems of other NLABS laboratories, including Nutrition, Food Chemistry, the Experimental Kitchen and Food Irradiation in the Food Laboratory, and Analytical Chemistry, Insecticides and Rodenticides, and Entomology in the Pioneering Research Laboratory.

Title	Investigator	Date Started
Investigate mechanisms of taste flavor, and food discrimination as a basis for food acceptance.	L. M. Bartoshuk H. R. Moskowitz H. L. Meiselman	1969

Studies are conducted in the basic mechanisms of the chemical senses to understand sensory acuity, and the perception of complex mixtures and flavors in man in direct support of NLABS in-house exploratory development work units in Food Acceptance Methodology and appetite control in the DoD Food RDTE program.

Studies of the regulatory mechanisms in hunger and appetite, including food and water intake, as a basis for food acceptance.	H. L. Jacobs P. L. Gentile C. L. Nixon	1969

Research on appetite regulation is conducted on man under controlled laboratory conditions, and on animals where humans cannot be used and data and explanations derived from the comparisons are used in direct support of NLABS in-house exploratory development work units in Food Acceptance Methodology and Appetite Control in the DoD Food RDTE program.

3. In-House Laboratory Independent Research

Title	Investigator	Date Started
Development of a technique for establishing performance decrement to ultimately protect the individual against impulsive noise.	T. L. Nichols	1968

An experimental technique is being developed to differentiate between normal hearing, and abnormal hearing produced by exposure to intense noise. The technique is based on averaged evoked potentials (EEG), obtained for pedestal plus increment stimulation, and shows promise for clinical and experimental applications.

2A(6). U.S. ARMY MATERIEL COMMAND NAVAL TRAINING DEVICE CENTER

Orlando, Florida 32813

CURRENT WORK PROGRAM

Six major work programs are now being carried out in the Human Factors Laboratory. Current projects in each of these areas are described below:

(1) Human Factors Guidelines for Design of Training Devices

Title	Investigator	Date Started
Design Factors in Environmental Simulation-Phase 3	Grumman Aircraft Engineering Corp.	FY68

The objectives of this project are to determine role of motion cuing in pilot performance in a flight simulator and to evaluate differential roles of motion cuing and simulator fidelity. Matched groups of pilots will be trained and tested on a flight simulator involving various levels of motion simulation. This phase will deal with transfer of training effects of the simulator and will include a wider range of pilots in terms of skill and experience than was used in the previous phases.

Human Factors in Training Equipment Design	Dunlap & Associates	FY68

This project is a three-year effort, the objectives of which are to identify and describe significant human factors problem areas in the design of training systems, develop a logical scheme for assigning priorities for human factors

design effort, and study techniques for translating psychological human factors research into design criteria applicable for training devices. Two selected training systems will be analyzed with regard to simulator fidelity, instructor workload, appropriateness of strategy for training, and the role of selected training factors. Data is also being collected on methods for translating existing psychological research into human factors design criteria for training devices and systems.

Perceptually Similar Visual Environment for Naval Training	Martin-Marietta	FY68

The objective of this project is to determine specific television parameters necessary to produce an accurate visual simulation environment commensurate with the resolution capability of the unaided human eye for use in air-to-ground search and detection tasks. Comparison tests will be conducted to measure resolution and target recognition thresholds of human subjects using a high resolution TV system and the unaided human eye. Comparisons of subjects' performance will be made to determine the effectiveness of the TV system image and how it must be augmented to approximate the functions of the human eye. Pilot studies will be undertaken to devise an acceptable approach to the measurement of TV simulation performance under dynamic conditions.

Visual, Aural and Kinesthetic Cues	Life Sciences	FY69

The objective of this project is to determine the effects of visual, aural and kinesthetic cues singly and in combination as an alerting mechanism in recognizing and effecting control responses in flight simulators. Multi-sensory cues in piloting performance will be analyzed, testable hypotheses with respect to effects of cues will be generated, and experimental designs for these tests will be developed. Experimentation will be conducted based on the results of the analysis and experimental designs.

Relative Effectiveness of Two- and Three-Dimensional Image Storage Media for Training Applications	Martin-Marietta	FY70

The objective of this project is to investigate the relationships between two-dimensional and three-dimensional image storage media and the cues that govern the perception of apparent depth on a two-dimensional dynamic display. The task will be accomplished in three steps, (1) acquisition of relevant imagery consisting of various military targets and terrains represented both two- and

three-dimensionally, (2) preparation of appropriate stimulus materials for use in a behavioral analysis, and (3) a behavioral study of the factors influencing the illusion of apparent depth which can be derived from a two-dimensional display.

Development Behavioral Sciences Program Language	Bolt Beranek & Newman	FY70

The objective of this project is to specify the design criteria and implementation plan for a behavioral sciences program language to be used in training effectiveness studies in a high-performance aircraft weapon system simulation. The broad spectrum of psychological studies that will be conducted in the simulator will be analyzed and a program language which will enable the psychologist-experimenter to communicate in a natural and efficient manner with the digital computer system he controls, will be designed.

Performance Measures for High-Performance Naval Aircraft Systems	Manned Systems Sciences	FY70

The objective of this project is to specify quantitative criterion and trainee performance measures to be used in experimental studies on a high-performance aircraft weapon system simulator used in an automated adaptive mode. A systematic study will be conducted to determine (1) what criterion measures should be used in the light of the training goals to be achieved and of the operational missions to be performed by the system, and (2) what trainee measures are to be taken through all stages of the learning process so that automated adaptive techniques may be used in the training program. A preliminary study of the reliability and validity of the selected measures will also be carried out.

Automated Auxiliary Naval Air Weapon System Trainer	LTV Aerospace Corp.	FY70

The objective of this project is to specify the design criteria for a series of auxiliary training devices for use as adjuncts to training in a Naval high-performance aircraft weapon system simulator in order to optimize training return for a minimum expenditure of simulator training time. A systematic study will be made to identify those portions of the total job performed by the weapon system crew which can be trained by auxiliary devices prior to or in conjunction with system simulator training; to identify functions of the auxiliary devices which may be effectively automated; and to delineate design criteria for these auxiliary devices.

Automated Operator Instruction in Team Tactics	Undetermined	FY70

The objective of this project is to determine by means of analysis the extent to which tasks performed by operators in the team tactical training situation are generalizable across specific operational systems, and to determine the applicability of adaptive automated instruction technology to the development of consoles for training operators at various echelons present in team tactical training devices. Results of the analysis will provide definition of training goals and criterion measures, delineation of operators' skills and knowledge and commonalities which occur in the various training systems, identification of applicable advanced training technologies, and definition of the instructors' role in monitoring and evaluating performance.

Wide Angle Cinematic Techniques	Anacapa Sciences	FY70

The objective of this project is to derive a detailed technical plan for applying wide angle cinematic simulation techniques to the operational problem of training Navy pilots in the specialized visual skills involved in low altitude navigation and target acquisition. A comprehensive analysis will be made of the training objectives that could be met by the application of cinematic techniques to all phases of low altitude flight training. A parallel analysis will be made of the training tasks which are amenable to cinematic training. The feasibility of utilizing cinematic techniques to achieve specific training objectives will then be assessed on a cost/effectivenss basis by a matrix comparison of potential training objectives arrayed according to priority considerations with potential training tasks arrayed according to costs. A complete set of supporting materials and training procedures will be developed and demonstrated for at least one selected training task.

(2) Methods for Analyses of Military Systems and Training Situations

Title	Investigator	Date Started
NATOPS - Technical Manual Analysis and Evaluation	Biotechnology, Inc.	FY69

The objective of this study is to analyze and evaluate the effectiveness of technical manuals used by avionics personnel engaged in maintenance leading to a definition of problems and recommendations for remedial action. Examination and evaluation of current technical manuals will be conducted together with analysis of information requirements, use conditions, and appropriate means of presentation.

Parameters, Basic Submarine Attack Simulation	General Dynamics Corp.	FY69

The objective of this task is to determine the training requirements for training submarine officers in basic tactical and fire control skills. The behavioral skills which can best be taught by the use of trainers will be identified. The analysis will result in more effective and efficient individual and team training for beginning submarine officers. A human factors investigation and determination of the skills and knowledge involved in the solution of submarine fire control problems will be made. This task analysis will yield information which will be used as a basis for determining desired training devices. In addition, provisional military characteristics and engineering design data for recommended training devices will be provided as a product of the human factors analysis.

Feasibility of Undersea Salvage Simulation	Dunlap & Associates	FY69

The objectives of this task are to analyze and define training situations for personnel operating the large object salvage system, to specify training problems on an individual operator and crew basis, and to recommend solutions to the problems. All the tasks involved in the operation of the large object salvage system will be analyzed, present and future problems in training personnel to perform these tasks will be described and solutions to the problems will be delineated, including the use and design characteristics of the training devices and simulators.

Advanced Submarine Casualty Control Simulation	General Dynamics Corp.	FY69

The objectives of this task are to define decision-making and procedural techniques for effective emergency ship control for submarine casualty situations, and to derive training system characteristics for use in casualty control training for the various classes of nuclear powered attack submarines and fleet ballistic missile submarines. An extensive task analysis of emergency ship control procedures and problems will be conducted. Based on this analysis, recommendations regarding the technical feasibility of providing interchangeable control display devices specific to given classes of nuclear submarines for use in a general purpose, selectively adaptable, multi-class submarine casualty control trainer will be made.

Land Combat Training	Litton Systems	FY69

The objective of this project is to analyze Marine land combat training and to recommend appropriate training devices and their usage. Through the use of techniques such as survey, observation, questionnaire, and training situation analyses, data will be collected with respect to land combat tactics and training in order to define training device concepts.

Generalized Military Operator and Maintenance Training	Undetermined	FY70

The objective of this project is to identify by means of analysis of task and equipment commonalities, areas of military training which can be supported by generalized training devices primarily in the area of maintenance training but with secondary emphasis on operator training. Based upon analysis of tasks and hardware requirements design characteristics of generalized trainers will be derived. This task should result in improved methodology for the identification of training areas which can feasibly be supported by generalized training devices and for determining effective device design.

(3) The Evaluation of the Use and Effectiveness of Training Devices

Title	Investigator	Date Started
Experimental Training-Simulation System for Navy Training	Singer-General Precision, Inc.	FY69

The objective of this project is to identify the resources and methods basic to the development of an experimental training-simulation system applicable to a broad range of Naval training situations. The purpose of this system is to investigate the feasibility of specific training techniques and hardware configurations to meet training objectives, and to perform experimentation on the human factors aspects of training systems. It will also provide means for evaluating alternate design solutions from a cost effectiveness standpoint, and provide a test bed for the development of methods for use in field evaluations of existing and planned training systems. Initially, the study identified problem areas requiring experimental definition in current and future training systems, and defined them in terms of facility performance requirements. In addition, the study is directed at developing functional specifications for hardware to permit the simulation of training concepts which are to be investigated, and to provide for the efficient collection of experimental data.

Quantification of Naval Training Tasks	American Institutes for Research	FY69

The objective of this project is to develop quantitative indices of the characteristics of the instructor's and trainee's tasks so that the effectiveness of a given amount and type of training of military personnel on a given task can be predicted. The results of this research will lead to greater accuracy in establishing the human performance requirements in a training system utilizing training devices, greater accuracy in human factors design recommendations, improved instructor station design, and improved prediction of the effectiveness of a given amount and type of training on a given task. A set of indices will be developed in terms of which trainee and instructor tasks can be described quantitatively and systematically. Experiments will be conducted to establish how the rate and degree of learning is affected by tasks which contain various amounts of the task characteristics.

Training Effectiveness Evaluation of Naval Training Devices	Bunker-Ramo Corp.	FY69

The objectives of this study include the development of an evaluation methodology which can be applied selectively by instructional personnel. One performance goal is to indicate design principles which will make trainers more effective teaching devices; another is to devise methods to determine the amount of trainer time which can be substituted for training time on the operational equipment. The accomplishment of these goals will provide more efficient trainers and training methods, thus producing better trained men at less cost. Field evaluations of training devices will be conducted to determine if the trainers meet the user's needs, and to provide guidance for improvement in the use of trainers in particular training situations. The characteristics of the trainers which are most effective in securing improvement in performance will be analyzed.

Training Device Acceptability	Undetermined	FY70

The objective of this project is to identify the factors which lead to acceptance of training devices by their users and to determine the extent to which those factors are present in training devices which are designated as "effective" or "ineffective." A survey of users of a variety of training devices will be made to determine their attitudes toward the training devices. An analysis will be made to determine the relationships among acceptance of training devices, judged effectiveness, design, and utilization.

Training System Use and Effectiveness Evaluation	Dunlap & Associates	FY66

The objective of this project is to develop evaluative criteria for evaluation of training device cost/effectiveness and preparation of evaluation guide handbook. The project is organized into three phases: (1) a comprehensive review of existing training devices and relevant materials, (2) a field evaluation during which evaluation of training devices at actual field settings is conducted, and (3) handbook preparation. Recommendations will provide inputs to training device requirements and to technical development plans.

Advanced Generalized Sonar Maintenance Trainer	Human Factors Research, Inc.	FY69

The objective of this project is to investigate the potential for generalized training in maintenance, calibration, and fault-finding for advanced sonar equipment. Development of knowledge of functional units rather than specific equipment items will be emphasized, and commonality of maintenance activities, state-of-the-art circuitry, and latest processing techniques will be demonstrated. General maintenance requirements common to certain sonar equipment will be determined and detailed specifications for the development of an advanced sonar unit as an adjunct to the Generalized Sonar Maintenance Trainer will be prepared.

Training Device Employment Materials	Dunlap & Associates	FY70

The objective of this project is to analyze materials associated with training devices to determine answers to such questions as: (a) which devices have materials such as a syllabus, course outline, lesson plans and problem scripts; (b) apparent thoroughness of the above; (c) evidence of tie-in to the trainer; (d) similarities and differences among similar "types" of trainers, especially the same trainers in different locations; (e) adequacy of the materials for effective training; and (f) the function of such variables as type, location and age of trainers on the characteristics and use of the materials. The materials will be collected, catalogued, and analyzed to determine their characteristics and how they are used. Data will be cross-tabulated according to various combinations of variables.

Naval Pilot Training Systems Design	North American Rockwell Corp.	FY70

The objective of this project is to obtain information which will support the Naval Air Training Command undergraduate pilot training program as an integrated system, with particular emphasis on the following: (a) requirements for training devices, training aids and training aircraft; (b) application of state-of-the-art educational technology to equipment and techniques employed in the syllabus; and (c) establishment of the role and criteria for the use of simplified trainers which will increase validity while increasing cost effectiveness. Training equipments and materials associated with their employment will be evaluated to determine their effectiveness in teaching pilot skills. Empirically-based measures of training effectiveness will be obtained.

Training Effectiveness Evaluation Aircraft Carrier Landing Trainer	Ryan	FY69

The objective of this project is to assess and evaluate the training effectiveness of the Aircraft Carrier Landing Trainer, with particular emphasis on the costs involved in this kind of training. One goal is to determine if training using the trainer will substitute for field landing practice and improve the pilot's initial performance during actual carrier landings. Matched groups of pilot trainees will be trained, one in the conventional manner and the others receiving varying amounts of training on the trainer. The performance of all groups will be compared to evaluate the transfer of training effects.

Training Effectiveness Evaluation of Naval Training Devices	Micheli	FY69

The objectives of this project are to establish the training effectiveness of certain major training devices, determine the degree and rate of learning when using the trainer, establish the cost benefits of using the trainer, and establish guidelines for effective utilization of the trainer. There will be four levels of evaluation, namely (a) descriptive analysis, (b) non-comparative measurement, (c) comparative measurement, and (d) transfer of training test. All of these will be examined in field settings of on-going training taking place in training devices.

(4) Machine Controlled Adaptive Training

Title	Investigator	Date Started
Adaptive Training in Naval Training Devices	Lauber	FY69

This project is concerned with the investigation of techniques and parameters involved in adaptive training of human controllers of man-machine systems. Training functions to be studied include motor skills, perceptual processes, cognitive processes, etc., as these relate to performance in a variety of tasks. Adaptive training is an appealing method for the training of human operators, however, there are a number of problems that must first be resolved. These problems include the adaptive logic, adaptive variables, error criterion levels, number and magnitude of adaptive steps (task difficulty levels), and measurement variables and data analysis and comparison techniques.

Computer Based Naval Maintenance Training	Rankin	FY68

This is an in-house laboratory investigation of ways to improve trainee machine interface in a computer based training situation. Findings can be employed in the design of training devices and in establishing their patters of use. An excellent course of instruction has been prepared. Three experimental, trainee-feedback treatment conditions have been developed for the first experimental effort.

Adaptive Training Student/ Computer Interface	Florida State University	FY69

The objective of this project is to investigate the utility of various training strategies in adaptive training to the individual trainee's needs. Suitable tasks will be selected and course materials structured to explore the relationship of the training strategies to training objectives. Additionally, methods of student-computer interaction will be investigated.

Automated Naval Weapon System Training	Logicon, Inc.	FY69

The objective of this effort is to determine the feasibility of and design guides for relegating to computer control, routine instructor-operator functions in weapons system trainers, and through better definition of what the instructor's role should be, to ultimately automate all instructor functions not requiring human judgment or intervention. The end result of such effort will provide for an upgrading of the instructor's efficiency in his primary role and will impact on the training effectiveness of weapons system trainers. Design guides for automation have been developed and are being implemented and evaluated in the NTDC TRADEC simulation system.

Effective Time Constant in Design of Naval Training Devices	Life Sciences, Inc.	FY69

The objective of this project is to compare three methods of adapting the difficulty level of the training task as a function of the trainee's measured performance in an aircraft control task. The goal is to provide design criteria for individualizing training for military vehicular control tasks. The experimental plan is to train subjects under adaptive training conditions in which the task difficulty is varied as a function of their skill acquisition and to transfer the subjects, after training, to a common criterion task which will simulate the control of a high-speed jet aircraft. The parameters for adaptively varying the level of difficulty of the training task are the Effective Time Constant (a combined measure of system response and human reaction time), turbulence, and system quickening.

(5) Learning, Retention, and Transfer

Title	Investigator	Date Started
Feedback and Cuing in Sonar Training Tasks	University of Hull	FY68

The objective of this project is to develop and evaluate methods of training personnel in the discrimination of complex auditory signals for purposes of application to sonar training. Human subjects will be tested for their ability to discriminate different types of auditory signals, including experimental conditions involving the selective addition or removal of selected components of the signals.

Maximizing Transfer of Training in Military Tasks	Honeywell, Inc.	FY68

The objective of this study is to identify the tasks, methods, and conditions which affect the relationships among learning, retention, and transfer. The results should serve as a basis on which to make decisions concerning the design of training methods and training devices. A series of experiments will be conducted that will establish parametric relations among measures of learning, retention, and transfer. The tasks to be used shall be varied systematically in terms of levels of difficulty and complexity. Selected tasks shall provide the complexity and difficulty of operational training tasks.

A System for Classifying Military Training Tasks	Blaiwes	FY68

The objective of this project is to produce a workable system for defining operational tasks in behavioral terms. The purpose of the system are twofold: (1) to facilitate the translation and implementation of research data in the design and use of military training systems, and (2) to identify areas of training research with high potential payoff in terms of training efficiency. A taxonomic system for tasks will be developed and military tasks will be analyzed using this taxonomy in order to evaluate its utility.

Sub-task Practice in Naval Training Devices	Micheli	FY69

A complex skill for which training is desired can be analyzed into subtasks which differ in difficulty. It is a reasonable hypothesis that differential treatment of specified components of a complex skill will yield differential amounts of transfer to the total task. The implications of such results could very well be that a systematic rearrangement of sub-task practice or differential amounts of practice on specified sub-tasks of a complex skill produce greater transfer to complex skills than does a "natural" arrangement. The purpose of this project is to explore, experimentally, the conditions under which differential treatment of specified sub-tasks of a complex skill may result in more efficient transfer to the final task. This project seeks to find better ways to train helicopter pilots. Tests will be made using a complex perceptual motor task representing the actual helicopter flight task.

Motivation in Training	Thomas	FY69

The objective of this study is to evaluate the usefulness of employing competition as a means of motivating trainees by determining the relationship between levels of task difficulty and differential incentive methods. Research review will be conducted. Experimentation will be conducted to ascertain the usefulness of employing competition between trainees as a technique for improving trainee performance and skills.

(6) Physiological Factors in Training

Title	Investigator	Date Started
Visual Skills in Navy Aircraft Targeting and Low Level Flights	Jordan	FY68

The objective of this program is to investigate the utility of eye movement patterns in training situations by determining the relationship of eye movements to performance and the extent to which eye movement patterns can be trained. The goal is to determine the appropriate training techniques for improving eye movement patterns which have the greatest positive transfer to visually loaded operational tasks such as targeting and low level flight for Naval aircraft missions. The effect of visual training on the performance of complex visual motor tasks is being investigated in a two-phase design. The first stage involves the development of effective training techniques and the second is concerned with the applicability of these methods to enhancing the job performance of the trainee.

Levels of Alertness and Military Proficiency	Jordan	FY68

The objective of this program is to train operators to increase their level of self awareness of their body condition, and thus be able to adjust the level of work to better fit their capacity to work at any given time. This has particular relevance for military tasks involving extended duty cycles. Trainees will be provided with accurate quantitative data on the state of their bodies, e.g., fatigue, level of alertness, etc., so that they may take appropriate action to improve their level of performance.

2B. U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND OFFICE OF THE SURGEON GENERAL

Washington, D.C. 20314

SELECTED ASPECTS OF CURRENT WORK PROGRAM

1. Although the US Army Medical Research and Development Command does not have a primary "human factors" mission as such, virtually all of the Medical Research and Development program bears directly on problems of human effectiveness and, hence, in the broadest sense, may be thought of as human-factors-related. Fiscal support for this research program is provided by the Life Sciences Division of the US Army Research Office.

2. AR 705-5 gives the Surgeon General sole responsibility for conducting research and development within the area of "psychophysiological aspects of sensation, perception, and motor coordination." The major part of this work is conducted at the Psychology Division, US Army Research Laboratory, Fort Knox, Ky. Selected aspects of this research program are as follows:

WORK UNIT	INVESTIGATORS	DATE STARTED	CURRENT STATUS
a. Psychophysiology of Vision	Behar, I., Ph. D. Lewis, G. W., CPT, MSC Schjelderup, J. Dryer, F. N., Ph. D. Harker, G. S., Ph. D.	July 63	Continuing

To develop knowledge concerning the mechanisms of binocular and stereoscopic visual function in the soldier as it relates to military visual tasks. This involves a study of neurophysiological processes involved in military visual task, the problem of visual resolution and visual suppression in the presence of double vision induced by instrument misalignment and disorders of ocular muscle balance.

b. Biomechanical Aspects of Performance	Lloyd, A. J., CPT, MSC Herbert, M. J., Ph. D. Caldwell, L. S., Ph. D. Harker, G. S., Ph. D. Schjelderup, J. Leibrecht, B.C., CPT, MSC Baron, M. L., CPT, MSC McClaskey, E. B.	Jun 56	Continuing

This research is concerned with factors that affect a soldier's ability to perform useful work and complex tasks to provide a basis for determining performance efficiency over extended periods. Areas considered are: skill degradation due to extended performance and overload stress; basis abilities in common complex tasks and their differential rates of acquisition and fatigue; acquisition of control over single motor units; and assessment of electromyography as an index of effort in extended performance.

c. Auditory Perception and Psychophysics	Cronholm, J.N., Ph. D. Mosko, J.D., Ph. D. Schjelderup, J.	Jan 55	Continuing

To identify and assess those factors which enhance or degrade the soldier's ability to attend, perceive, and respond to simple and complex auditory signals in the presence of various masking sounds. To assess and improve the predictive value of certain models of the processess involved in the communication of auditory information and to use these models to predict auditory performance in military tasks.

d. Traumatic Origins of Hearing Loss	Patterson, J.H., CPT, MSC Luz, G.A., CPT, MSC Mosko, J.D., Ph. D. Schjelderup, J.	Jan 55	Continuing

To provide information that may allow a more precise screening of noise-susceptible individuals at the time of their induction; to evaluate devices and techniques for the protection of Army personnel during normal military operations. Information in this area will also contribute to the development of better hearing protective devices for the soldier.

e. Psychophysics of Visual Perception	Harker, G.S., Ph. D. Behar, I., Ph. D. Dyer, F.N., Ph. D. Schjelderup, J.	Mar 56	Continuing

To define the visual mechanisms underlying target detection and identification under conditions including those in which visual capability is severely reduced. To study individual difference in visual skills and selection criteria for superior visual (especially night vision) performance. To study vision in monkeys as an experimental model most closely applicable to man for assessing potentially hazardous conditions. Research in this area will be of inestimable value in the enhancement of the soldier's inherent visual capability during night military operations and may provide a sound basis for developing selection criteria in those soldiers with superior night vision performance.

f. Physical Decrement and Enhancement	Caldwell, L.S., Ph. D. Schjelderup, J. Shiflett, S.C., CPT, MSC	July 68	Continuing

Study alterations in the work limits of the skeletal muscle system due to fatigue, stress, social facilitation, learning and practice in static and dynamic tasks and develop reliable tests to assess the degree of performance impairment due to muscle damage, neuromuscular disorders, etc. and to measure response to treatment. Knowledge in this area will permit a more accurate assessment of the soldier's ability to perform effectively in combat and in the development and applications of special skills in various work situations.

3. The mission of the US Army Aeromedical Research Laboratory is to conduct studies on current and anticipated medical research problems of fundamental or immediate nature relevant to Army aviation and airborne operations. To provide consultative service to other elements of the Army as appropriate. Maintains liaison with Army, Navy, Air Force, Federal Aviation Administration and other federal and civilian institutions, both domestic and foreign which are concerned with, or have an interest in aviation. Current USAARL work program includes the following programs of human factors interest:

a. Direct Field Research Support to Immediate Army Aeromedical Problems	Knapp, S.C., LTC, MC Jordon, J.E., MAJ, MC	July 62	Continuing

The purpose of research in this area is to provide medical information applicable to immediate field aeromedical problems found in Army Aviation. Studies on airborne fire suppression systems, litter design requirements, toxicants in Army aircraft cockpits and other pertinent areas are continuing.

b. Applied Medical Research	Littell, D.C., LTC, MC Blackstone, E.H., CPT, MC Schane, W.P., LTC, MC Kasvinsky, P., CPT, MSC	June 64	Continuing

The purpose of this work unit is to investigate variables which affect the health of the Army aviator. This unit includes studies on medical, physiological and human factors in long range, large scale aerial troop deployments; biochemical measures of stress and/or fatigue; effect of stress and/or fatigue on visual-motor performance; interactions of helicopter down wash and man.

c. Research on Visual Problems Medically Significant to Army Aviation	Bailey, R.W., COL, MSC Crosley, J.K., MAJ, MSC McLean, W., CPT, MSC	May 64	Continuing

The purpose of this work unit is to provide information about the visual sensory modality which has medical importance for U.S. Army Aviation. Studies in this area include: visual effects of painted rotor blades; illuminated warning, caution and advisory systems; visual distortions of helmet visors, canopies, and doors, florine coated ophthalmic lenses; multifocal ophthalmic lenses.

d. Research on Psychoacoustical Problems Medically Significant to Army Aviation	Camp, R.T., Jr.	July 1969	Continuing

The purpose of this unit is to provide information about sound which has medical import to U.S. Army Aviation. Research in this area has a twofold purpose. The first is to identify generators or sources, and to provide a physical description of the critical sound stimuli found in Army aviation. The second purpose is to study the effects of these sounds on the human receivers.

e. Research Psychology Applied to Medically Significant Problem in Army Aviation	Hofmann, M., CPT, MSC Martin, A.S., CPT, MSC	Feb 65	Continuing

The purpose of this unit is to provide information about the human factor in the aircraft man-machine system, with special emphasis on the performance of this human factor and the variables that influence it. Studies in this area include: aviator attitudes; the effects of INH and pilot performance; user information about instrument panels; time prediction and motion; photic flicker in helicopters; and, the effect of fatigue on visual search activity.

f. Research of Bio-engineering Problems Medically Significant to Army Aviation	Knapp, S.C., LTC, MC Landfield, B.S., CPT, MC Schrunk, D.G., CPT, MC	Dec 66	Continuing

The purpose of this work unit is to provide data derived from bio-engineering research which is medically pertinent to Army aviation. Studies in this area include; crash injury economics; physiological responses to impact acceleration; operational requirements and human responses to parachuting at high altitudes, and escape systems in rotary wing craft.

g. Color Vision	Bailey, R.W., COL, MSC	May 64	Continuing

The purpose of this study is to investigate the just noticeable difference in hue as a function of wavelength when presented with constant luminosity stimuli generated by a tri-stimulus colorimeter.

h. Operational Measures of Inflight Performance	Hofmann, M., CPT, MSC	July 69	Continuing

The purpose of this work is to develop and construct an in-flight monitoring system capable of quantifying both pilot and total system performance. This system will then be used to evaluate the effects of certain variables upon pilot performance.

i. Safety Design in Training Helicopters	Schrunk, D.G., CPT, MC	May 69	Continuing

The purpose of this work unit is to investigate the need for a training helicopter designed for a safety standpoint, and to evaluate present and proposed safety design concepts in light helicopters.

4. Other USAMRDC research programs of especial human factors interest are accomplished at the U.S. Army Research Institute of Environmental Medicine, Natick, Mass. The research program of USARIEM is an integrated multidisciplinary approach to the problem the Army faces in conducting operations in the heat, cold, high humidity, wind and at high altitude with soldiers working over a wide range of expended effort. Results of the research have an impact on item, equipment, and vehicle development; on training and indoctrination procedures, and on health and safety of the individual soldier. The disciplines typically involved in solving the military problems include biophysics, biochemistry, physiology, psychology and clinical medicine.

a. Medical Problems in Military Arctic Operations	Doolittle, W.H., LTC Sumner, D.S., LTC	July 65	Continuing

Objective - To identify and quantitate detrimental local and systemic physiologic changes induced by chold in experimental animals and military personnel and to generate and evaluate effective methods of treatment of prevention of these changes.

b. Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment	Goldman, R.F., Ph. D. Breckenridge, J.R., Mr.	July 70	New

Objective - Develop mathematical equations and computer programs to synthesize available information on military task requirements with the interaction between the man and his clothing, equipment, and environment, to predict mission performance capability and identify areas where additional information is necessary.

c. Biomedical Impact of Clothing and Equipment Design Including the Selection of Crew Compartment Environments	Breckenridge, J.R., Mr. Goldman, R.F., Ph. D.	Jan 64	Continuing

Objective - Investigate heat and moisture exchange in the Man-Clothing-Environment system to provide a basis for improving thermal protection and recommending environments for crew compartments in military vehicles, and for increasing soldier effectiveness

d. Biological Processes that Limit Heavy Physical Work	Therriault, D.G. Ph. D. Burlington, R.F., Ph. D. Vogel, J.A., Ph. D.	July 70	New

Objective - The soldier's ability to carry out his mission is often limited by his capacity to do sustained heavy physical work. The objective of this research is to identify and charcterize those biological processes that affect his ability to perform heavy work, thus providing a rational basis for improving the soldier's performance.

e. Interaction of Environmental Extremes with Extended Operations or Unusual Activity Rest Cycle	Francesconi, R.P., Ph. D. Shershow, J.C., CPT Cahoon, R.L., Ph. D.	July 70	New

Objective - The requirement for transporting troops abruptly to desert, jungle, arctic, or mountain areas requires that these troops adjust simultaneously to not only the adverse climate but also altered activity-rest cycles or periods of sustained sleep loss. Such troops will be expected to function efficiently upon arrival with little time for adaptation to environmental and combat conditions. Such combined stressors can be expected to limit combat effectiveness. This research will characterize these human limitations at biochemical, physiological, and behavioral, levels. Further, we shall study various methods of attenuating the effects of these limitations on military personnel.

f. Prevention and Treatment of Disabilities Associated with Military Operations in the Cold	Newman, W.R., Ph. D. Goldman, R.F., Ph. D.	July 70	New

Objective - Measure and describe: the effects of localized and generalized cold exposure in inducing damage or reduced efficiency, the biological defense which minimize, delay and repair the damage from the cellular level through the intact organism (soldier, animal, or model) and his military performance.

g. Prevention and Treatment of Disabilities Associated with Military Operations in the Heat	Fine, B.J., Ph. D. Witherspoon, J.M., CPT	July 70	New

Objective - The objectives are the identification, prediction and prevention of heat-induced disabilities which critically impair the performance of military missions and the development of methods of treatment of casualities due to such conditions as dehydration, heat stroke and heat exhaustion collapse.

h. Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevation	Robinson, S.M., Ph. D. Kobrick, J.L., Ph. D.	July 70	New

Objective - Exposure of soldiers to high terrestrial elevation results frequently in reduced efficiency as well as disabilities which are incompatible with the successful completion of military operations. The purpose of this unit is to investigate methods of prevention and treatment of these performance decrements and disabilities.

i. Biological Processes That Limit Military Performance Under Environmental Stress	Cymerman, A., Ph. D. Robinson, S.M., Ph. D.	July 70	New

Objective - Exposure of military personnel to extremes of environment imposes limitations on the ability to perform mental and physical tasks. Determination of the biological processes which are involved in these limitations will provide a better rationale for the maintenance and/or improvement of the soldier's performance.

j. Development of Measures to Assess the Impact of Environment Stresses on Critical Military Performance	Cahoon, R.L., Ph. D. Dusek, E.R., Ph. D.	July 70	New

Objective - Severely debilitating effects of heat, cold, and high terrestrial elevation are identifiable by end points of exhaustion, cold injury, or collapse. However, such exposure can have less dramatic but highly significant effects on the soldier's efficiency and on unit mission performance. It is the objective of this research to develop sensitive and appropriate measures of these effects.

k. Development of Cold Injury Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss	Klein, A.W., CPT Casey, F.B., CPT	July 70	New

Objective - [illegible] ors involved in frostbite and other non-freezing injuries, as we[illegible] body heat loss in both animals and man, to provide a rati[illegible] r treatment and prevention of those cold

injuries sustained by the military.

l. Development and Charc-terization of Models of Heat Injuries and Disabilities and other Heat Responses	Alpert, A., Ph. D. Breckenridge, J.R., Mr.	July 70	New

Objective - Develop characterize models, i.e., experimental equivalents or analogues, of heat stress and heat induced injuries and abilities in the soldier.

m. Development and Charac-terization of Models to Study Acute Mountain Sickness and High Alti-tude Pulmonary Edema	Gerben, M.J., Ph. D. Dusek, E.R., Ph. D.	July 70	New

Objective - The scope and effectiveness of military operations at high terrestrial elevations are limited by symptoms and functional deficits associated with acute mountain sickness (AMS) and high altitude pulmonary edema (HAPE). The purpose of this work unit is to develop models, i.e., predictive procedures, for identifying and characterizing those aspects of AMS and HAPE relevant to the success of military operations.

n. Disease Suscept-ibility of Soldiers in Harsh Environment	Previte, J.J., Ph. D. Casey, F.B., CPT Whitten, B.K., Ph. D.	July 70	New

Objective - Disease causes more combat noneffectiveness than do battle injuries. There is an Army requirement to study factors which influence disease susceptibility and to provide prophylactic and/or therapeutic measures (Institue of Land Combat/Adance Materials Concept Agency material data sheet, S/MD-14, dtd May 1969). Fatigue, exposure to temperature extremes or altitude increase susceptibility to disease and diminish the efficacy of therapeutic regimens. The objective of this research is to predict the extent to which environmental extremes and fatigue influence disease susceptibility and combat effectiveness, to determine which responses are critical in causing altered susceptibility; to establish prophylactic and/or therapeutic regimens which minimize the stressexacerbated symptoms.

o. Historical Analysis Development and Dis-tribution of Military Environmental Medical Information	Goldman, R.F., Ph. D. Evans, W.O., LTC	July 70	New

Objective - Research in military environmental medicine frequently proceeds in isolation where application of the results to a specific military problem and dissemination of this information to military users are often limited. Further, since essentially similar environmental problems reoccur only to be forgotten in the intervals between the acute need for such knowledge, better techniques are necessary to retain it. This work unit will address retention of knowledge on the effects of heat, cold work, and high terrestrial elevations on military performance, evaluate present techniques for its dissemination to the military, and conduct research on improving the communication between the military man with an environmental problem and the scientist with relevant information.

p. Effects of Multiple Environmental Stresses on Military Personnel	Vogel, J.A., Ph. D. Whitten, B.K., Ph. D. Gleser, M.A., CPT	July 70	New

Objective - Natural occurring stresses are often experienced in combinations, e.g., cold plus altitude, heat plus confinement, etc. but are almost exclusively investigated as separate entities. Information does not presently exist as to whether many of these stresses combine in an additive or synergistic (greater than additive) fashion. This must be known in order to predict resulting disabilities and reduction of military performance efficiency. The objectives of this work unit are (1) to examine multiple stresses important in military operations for their relative effect on mental and physical performance as compared to that by each stress alone; (2) to identify the occurrence of additive and potentiative responses; (3) to explore mechanisms of any synergistic effects and, thereby, susgest ameliorative measure.

q. Development of a Non-Sedating Analgesic	Evans, W.O., LTC Hansen, J.E., COL Vogel, J.A., Ph. D.	July 70	New

Objective - A formal requirement has been established by the Combat Developments Command for an analgesic compound which will provide adequate relief from pain without producing sleep, mental confusion, or a depression of vital bodily function. The objective of this research is to help in the development of such compound.

r. Factors Limiting Exercise at Sea Level and High Altitude in Peruvian Natives	Hartley, L.H., LTC Hogan, R.P., MAJ	July 70	New

Objective - High altitude environments which are potential theaters of war as known to lead to decreased physical performance and disease. These effects vary in duration from days to years, however, potential opponents might be fully acclimatized. Several altitude populations have the ability to perform at high elevations almost at sea level efficency, and one such populations is Andean in Peru. It is proposed to study the mechanism of disability which results from high altitude exposure, and the measn by which natural acclimatization occures in an effort to determine ways of speeding acclimatization and normalizing performance at altitude.

2C. U.S. ARMY BEHAVIOR AND SYSTEMS RESEARCH LABORATORY

Arlington, Virginia 22209

MISSION AND SCOPE

The Behavior and Systems Research Laboratory, an activity under the jurisdiction of the Chief of Research and Development, in accordance with AR 70-8 and CSR 10-56, undertakes research in behavioral science and operations research in support of the broad areas of personnel management, human performance experimentation, and manned systems research. The research is conducted in and for the Department of the Army to meet objectives of Army-wide scope and significance and is directed toward optimal employment of Army personnel in a variety of military settings.

The research effort is RDT&E-funded and is carried out principally under six Project-level DD 1634's, with additional RDT&E funding provided for In-House Laboratory Independent Research, for Basic Research, and for special DOD assignments. The program is organized around four Research Areas:

Personnel Management Research--Selection includes research on selection and classification and evaluation of behavior involving demands upon individuals, teams and systems, on the development of military selection and classification systems for other cultures. The research has implications for manpower planning (e.g., impact of EM with low general aptitude on training and operations), early identification of individual assets (including officer and combat potential) for maximum job performance; also, adjustment, motivation and operating relationships with fellow team members, particularly leadership relationships within the group, team or system.

Personnel Management Research--Manpower Management seeks direct solutions to problems involving development and implementation of mathematical manpower models to assist in manpower processing, planning and policy formulation, and quantitative models and computer aided

simulation studies relating to human behavior and/or personnel utilization. Use is made of operations research to evaluate systems performance where the human element is critical.

Human Performance Experimentation involves study of behavioral functions common to many systems in order to discover general principles which, when applied operationally, will enhance individual and team performance within these systems. Typical outputs are work methods, basis of issue, work-rest cycles, supervisory techniques, information input and response output procedures. Those means of improving performance determined to be successful in the laboratory setting are evaluated with field research in an operational setting.

Manned Systems Research has as its principal objective the enhancement of human performance in relation to total systems effectiveness. It involves experimentation with various configurations of systems components considering interactions with trade-offs, with the goal not only of improving human performance but of providing the means of evaluating systems effectiveness as a function of systems factors.

ORGANIZATION

The Director has responsibility for the planning and conduct of the scientific program, which is carried out by an in-house staff of 64 scientists with in-house and contract support. The scientists are professionally trained psychologists, statisticians and mathematicians. A Deputy Director assists the Director in a staff capacity in each of the BESRL broad areas--military selection research, manned systems research, and human performance experimentation. Line authority for execution of the program extends from the Director to five Divisions, one of which lends statistical and computer support to the other four in addition to carrying out its research responsibilities.

A. CURRENT WORK PROGRAM

Work Unit	Investigators	Date Started
Enlisted Manpower	Fuchs, E. F. Bayroff, A. G. (Monitor) Seeley, L. C. Ross, R. M. Hahn, C. (American Institutes for Research)	Jul 68

This work unit includes (1) Development of the Armed Services Vocational Aptitude Battery (ASVAB) used by all services in a joint recruiting program in high schools. Current effort involves new forms of the ASVAB. (2) Investigation of disguised aptitude tests to detect deliberate test failure. (3) Study of the feasibility of short limited range tests for go no-go screening and programmed testing (e.g., branching tests) including the use of testing machines.

Work Unit	Investigators	Date Started
Differential Classification	Fuchs, E. F. Maier, M. H. Williamson, R. L. Frankfeldt, E.	Jul 68

A new Army Classification Battery (ACB) has been developed, which includes measures of general mental ability (e.g., arithmetic reasoning), specialized academic knowledge (e.g., science), specialized nonacademic knowledge (e.g., automotive information), and vocational interests. Usefulness of the ACB was studied in over 100 training courses. Questions that need to be answered are impact of different kinds of score scales to use (standardizing individual tests vs standardizing aptitude areas) and the impact of the new ACB on men at the extreme of the input population (New Standards men and college graduates). The entire process of classifying, training, and utilizing the men will be studied in selected MOS to determine the consistency of requirements and performance among the various steps in the process. Analysis of the interaction between job environment and classification tests will continue.

Unit Performance	Fuchs, E. F. Bolin, S. F. (Monitor) Kristiansen, D. M. Houston, T. J. Dunlap, J. W., Jr. (Dunlap and Assoc.)	Oct 65

To study the impact of enlisted screening standards on unit performance. Find out how low enlisted mental standards may be set while maintaining acceptable levels of unit performance in terms of what balance of mental ability levels is needed for units to be effective. Current research points to a new approach focusing on the interaction of manpower quality and leadership. Rifle squads with differing percentages of low ability men were compared. Squad performance was related to squad leader ability as expected; moreover, relative squad performance was unexpectedly resistant to manpower turnover and varying field conditions over time. In FY 1970, mechanized rifle squads and motor maintenance sections in STRAF units were studied. The consequences of disciplinary problems on manpower availability may be illustrated. Longitudinal field analysis of battalions in intensive readiness training will be planned.

Primary Officer Leadership	Helme, W. H. Castelnovo, A. E.	Aug 70

Measures of information and orientation will be standardized and integrated into the cadet training programs. Evaluation methods will be developed for summer camp and other cadet and junior officer training situations, including techniques such as videotape recordings of performance. The dimensions of leadership which can be evaluated in the school setting will be determined to serve as a basis for the development of measures of leadership aptitude.

Work Unit	Investigators	Date Started
Officer Career	Helme, W. H. Willemin, L. P. (Monitor) Sait, E. M. Smith, K. (Utah State U.)	Aug 70

(1) Develop measures of differential potential for effective performance in field command and technical leadership, for application in officer selection, classification, and guidance, (2) improve techniques for performance evaluation, for use in early and mid-career personnel management decisions, and (3) measure factors related to career orientation and motivation, for use in continuing career management and guidance.

Officer Systems	Helme, W. H. Medland, F. F. Orleans, I. D. Yates, Louise D.	Oct 68

Career decision points and major aspects of officer leader development in different branches have been identified. Analysis of critical factors in promotion to colonel has been initiated. Ratings from first tour to early field grade have been collected. Members of a large sample of officer input of 1965-66, whose first tour performance in Vietnam and Europe was evaluated under the Cadet Leaders Work Unit, will be followed up to higher levels of leadership responsibility. Investigations will be conducted to determine reliability, usefulness, and feasibility of rating techniques and personnel records analysis for given personnel decisions. Techniques to be explored include peer ratings, group vs. individual ratings, ratings from descriptive content, and intra-individual ratings of differential potential.

SIMPO II	Johnson, C. D. Olson, Pauline T. Burke, Laverne K.	Jul 69

Develops new approaches and techniques for use in computerized models of manpower/personnel systems which may be used by management in evaluation of alternative policies. (2) Determines the effectiveness and efficiency of these approaches. (3) Applies the new approaches and techniques to models developed in SIMPO I to extend their usefulness as OR tools. (4) Develops new SIMPO II models capable of solving additional kinds of manpower/personnel management problems.

Work Unit	Investigators	Date Started
Enlisted Career Systems Research	Johnson, C. D. Haynam, K. W.	Aug 70

Data on the relationship among experimental aptitude measures and performance criteria will be combined with data from operational programs, and used in a combination of basic entity simulation models. The simulations required to meet the objectives of this work unit emphasize personnel actions and decisions that are determined by aptitude, achievement, or experiential characteristics of individuals. Effort will begin with the detailed definition of policies to be evaluated. The effect of such changes as an all volunteer Army, crossing career field lines, or the use of alternative reassignment approaches (e.g., batch vs. cascading approaches, etc.) on average predicted performance will be studied.

Monitor Performance	Hyman, A. Kaplan, M. Cohen, S. L. Dean, R. F. House, Joyce	Jul 62

A survey of over 1500 different Army jobs identified over 100 monitoring type duty positions requiring high operator vigilance for effective system operation. In a second major class of monitoring jobs which is becoming important, the operator is required to discriminate important from very similar but unimportant signals in an active signal environment, thus involving vigilance and judgment. Current effort is to identify and analyze variables which affect the ability of an operator to attend to a display and react appropriately when required. Variables analyzed include the physical parameters of the signals displayed, the work environment, the type of reactions required and the characteristics of the operator himself. Other efforts include the analysis of variables affecting the intelligibility of audio signals and speech, the enhancement of the ability of voice communication operators and analysts to recognize, extract, and report the essential elements of information from speech materials, and the study of operations and information processing techniques utilized by each type of operator across a variety of equipment.

Night Operations	Hyman, A. Sternberg J. J. (Monitor) Banks, J. H. Farrell, J. P. (Manned Systems Sciences)	Jul 67

This work deals with such questions as who should use which night operations devices, how, under what conditions, and what should be the basis of issue and mix. A BESRL field experimentation unit has been established at Ft Ord, California and data collection has been completed on several phases of a multi-phase research effort in support of SEA NITEOPS. Research will be conducted on new search techniques and work methods and procedures and on new devices and sensors as they become available.

Work Unit	Investigators	Date Started
Controller Performance	Hyman, A. Rupe, J. C. de Haan, H.	Jul 68

Controller performance critical to combat operations in the area of air defense was selected as the focus of this research. Current systems were analyzed and critical controller tasks were compared with those projected for the SAFEGUARD and SAM-D systems. The increased speed and volume of incoming targets require automation of the new defense systems' response to most attacks. Controllers must exercise unique human abilities and judgment to recognize special situations requiring that they intervene to change normally programmed responses. Such factors as display-control configurations, operating procedures, controller characteristics, work overloads resulting from improper allocation of controller functions, deficiencies in system communications and coordination, and differences in controller aptitude for specific tasks will be considered. The major factors identified will then be tested in controlled laboratory studies and subsequently in field conditions. Current effort is continuing to (1) identify critical aspects of control behavior by task analysis of human performance at the man-machine interface in a variety of MOS's where controlled laboratory experimentation offers promise of achieving significant improvement in overall system performance and (2) study the effects of factors associated with the signal, the control task, the environment, and the individual simultaneously in various combinations in a laboratory situation where scientific controls can best be maintained.

Response Systems in Human Performance	Kaplan, M. (Monitor) (American University)	Jul 68

Internal human response systems, which are generally regarded as involuntary and detectable only with instruments, have rarely been used to accomplish useful work in military performance situations. Exploring the possibility of such deliberate use is the major focus of this effort. Work is currently in two main problem areas: (1) Relations between internal responding and overt human performance. (2) Comparison of perceptual functioning in internal and overt response systems as they relate both to known motivating and instruction stimuli and to display signals typically employed in military man-machine systems.

Work Unit	Investigators	Date Started
Command Systems	Zeidner, J.(Monitor) Strub, M. H. Nawrocki, L. M. Robbins, J. (Bunker-Ramo Corp)	Aug 70

Basic human factors problems were identified and organized around five critical information processing operations: screening incoming data, transforming raw data for input into storage--retrieval devices, input, assimilation of displayed information, and decision making. An experimental facility was developed in which various aspects of tactical functions (operations, intelligence) could be simulated. Results delineate human performance capabilities and limitations and have implications for increasing the efficiency of the information assimilation-decision process and improved work methods. Objective systems performance measures will be developed. Research to be continued will investigate (1) the effects on performance factors such as: amount, coding, specificity, and alphanumeric and graphic formats; (2) man-computer generated probability data decision alternatives, and consequences; (3) problems inherent in preparing and storing information (screen, transform, input) for subsequent use; and (4) backup systems, integration of all the components within the systems, and interfacing of several systems.

Advanced Surveillance Systems	Zeidner, J. Birnbaum, A. H. (Monitor) Cockrell, J. (Systems Dev Corp.) Lepkowski, R. (Systems Dev Corp.) Fried, C. (Systems Dev Corp.) Jeffrey, T. E. (Monitor) Thomas, J. (Goodyear) Narva, M. A. (Monitor) (HRB-Singer)	Aug 70

The need to handle large volumes of imagery of various types (photo, infra-red and radar) in new tactical interpretation facilities demands a critical evaluation of the tasks and duties of the interpreter, his displays, and the total information system. Research should lead to improvements in screening, interpretation, target location, plotting and mensuration. Current plans include the following: Advanced image interpretation facilities will be conceptualized and mocked-up for evaluation. An effort will be initiated to evaluate interpreter proficiency requirements and to develop techniques for proficiency development or improvement. Work will be initiated on techniques for remotely-monitored battlefield surveillance systems. Quick-time infra-red and photo interpretation techniques will be developed and keys validated. Manual radar map coordinate location techniques will be validated.

Work Unit	Investigators	Date Started
Intelligence Systems	Zeidner, J. Andrews, R. (Monitor) Root, R. Samet, M. G. Nickerson, R. (Bolt, Beranek and Newman) Laymon, R. (Systems Dev Corp.)	Jul 68

This work unit will identify automated data handling techniques, computer aids and procedural and analytic techniques to increase the efficacy of the analyst in the system. Research will be on analytic procedures and computer aids for analysis and interpretation of intelligence information. Pattern analysis, correlational techniques, probability assessment, mobility modeling and deferred decision procedures will be evaluated. Task and system performance measures and criteria will be devised and development of a computerized data base for experimental simulation will be initiated.

Basic Characteristics of Image Interpretation Performance Measures	Zeidner, J. Martinek, H. (Monitor) Bigelow, G. F. Hilligoss, R. E. Herrington, B. (No. Amer. NARISCO) Hammer, J. (Raytheon) Connors, P. (Systems Tech. Assoc.) Good, L. (Bunker-Ramo Corp.)	Jul 69

Since the start of FY 65, more than 90 special rolls of film, varying in image size, quality, scale, and target density, have been developed into performance measures to meet specific research requirements. Present performance measures will be analyzed to determine image quality, scale, target density, target type, interpretation duties required, etc. Variables of greatest importance will be used to select performance measures to be administered to trained image interpreters.

In-House Laboratory Independent Research	Bayroff, A. G. Helme, W. H. Hyman, A. Johnson, C. D. Uhlaner, J. E.	Aug 70

(1) Study of programmed tests, to explore experimentally the promise of unconventional techniques. (2) Study of leadership styles and systems. (3) Evaluation of simulation experiments, to provide better experimental designs and to provide greater certainty in the interpretation. (4) Instrumentation for a night vision data acquisition system. (5) Theory of human performance and systems psychology.

2D. HUMAN RESOURCES RESEARCH OFFICE

Alexandria, Virginia 22314

CURRENT WORK PROGRAM*

The HumRRO Work Program is concerned with human factors research in training, motivation and leadership. Research aimed at solving practical military problems is carried on by seven research groups: Division No. 1 (System Operations) and Division No. 7 (Social Science) in Alexandria, Virginia; Division No. 2 at Fort Knox, Kentucky; Division No. 3 at Presidio of Monterey, California; Division No. 4 at Ft. Benning, Georgia; Division No. 5 at Fort Bliss, Texas; and Division No. 6 (Aviation) at Fort Rucker, Alabama. Divisions 2, 3, 4, 5, and 6 are co-located with Headquarters, CONARC, Human Research Units. In addition, a basic research program is being conducted by several research groups. Each research division provides Technical Advisory Service to assist the Army in planning implementation of research results and to meet other Army requests. Exploratory research aimed at identifying human factors problems likely to arise in future military operations are also conducted by the research divisions.

The Work Units and Work Unit objectives for Fiscal Year 1971, grouped by Research Areas, are given in the following list. This list also includes by number and title, Basic Research and Exploratory Research for Fiscal Year 1971.

*A copy of the approved Work Program for FY 1971 will be available when published, on request to the President, Human Resources Research Organization, 300 No. Washington Street, Alexandria, Virginia 22314

Research Area 1:
Individual Training and Performance

Work Unit	Experimenter(s)	Date Started
AIRSCOUT - Training Requirements and Concepts for Air Cavalry Training	Mr. William C. Osborn	Jul 70

Objective: To identify training requirements and to specify methods and concepts for training materials to support an aeroscout observer and aeroscout aviator training program.

FOLLOWTHRU - Characteristics of Men Tested in Work Unit UTILITY Who Remain in the Army	Dr. Robert Vineberg	Jul 70

Objective: To determine, through an analysis of HumRRO Work Unit UTILITY and Army records, (1) the performance characteristics of those men studied in UTILITY who have remained in the Army, and (2) the likelihood of men of lower mental ability increasing their effectiveness in the job.

MANPROBE - Human Information-Processing Requirements in Manned Aerial Reconnaissance and Surveillance Tasks	Dr. Francis H. Thomas	Jan 69

Objective: To identify and assess perceptual-cognitive functions associated with manned aerial reconnaissance and surveillance (R&S) tasks important to the success of operational R&S missions.

MARKSMAN - Combat Marksmanship	Dr. James Dees	Jul 70

Objective: To identify methods of improving marksmanship training.

MBT - Training Guidelines for the US/FRG Main Battle Tank	Mr. George G. Boycan	Jul 66

Objective: To outline the training methods and concepts for training materials that will be required by the personnel responsible for the development of programs for operator training and user maintenance training on the US/FRG Main Battle Tank.

NIGHTSIGHTS - Training Techniques for New Night Vision Devices	Dr. Harold P. Bishop	Jul 65

Objective: To identify critical human factors problems in the use of new night operations devices, and to develop effective techniques of training in the use of the devices.

Work Unit	Experimenter(s)	Date Started
SKYFIRE - Training Methods for Forward Area Air Defense Weapons	Dr. Albert L. Kubala	Jun 66

Objective: To determine man's capabilities to perform the operator skills required by forward area air defense weapons, and to identify effective training concepts for developing the required skills.

TYPETRAIN - Development of Improved Army Typing Training Program and Materials	Dr. Joseph S. Ward	Jul 70

Objective: To develop an improved Army typing training program, to develop manuals for training instructional personnel in the use of methods for presenting this program, and to develop training materials.

UTILITY - Study of Men in Lower Mental Categories: Job Performance and the Identification of Potentially Successful and Potentially Unsuccessful Men	Dr. Robert Vineberg Dr. Elaine N. Taylor	Nov 66

Objective: Using selected MOSs, to determine how men in Mental Category IV and men in other mental categories compare both in the performance of their jobs and in their overall suitability for military service; to identify characteristics of men in Category IV that are associated with successful performance on the job; and to determine what background and other non-intellectual measures might prove useful in screening, classifying, and assigning such men.

Research Area 2:
Unit Training and Performance

ENDURE - Tank Crew Performance During Periods of Extended Combat	Mr. John D. Engel Mr. William L. Warnick	Jul 65

Objective: To determine the endurance of troops using combat equipment with a 48-hour capability, and, as necessary, to establish ways of extending the endurance of troops so that the effectiveness of the equipment will not be limited by the user.

Work Unit	Experimenter(s)	Date Started
JOBGOAL - Improved on-the-Job Training for Logistics Personnel	Mr. Robert C. Trexler Mr. Patrick J. Butler Mr. Hugo F. Braden	Jul 70

Objective: To determine and develop means for improving on-the-job training (OJT) for enlisted logistics personnel.

Research Area 3:
Training for Leadership, Command and Control

CAMBCOM - Knowledges, Skills, and Thought Processes of the Battalion Commander and Primary Staff	Mr. Theodore R. Powers Mr. Arthur J. DeLuca	Mar 69

Objective: To identify the knowledges, skills, and thought processes of the battalion commander and primary staff officers of a combat arms maneuver battalion.

FORGE - Factors in Military Organizational Effectiveness	Dr. Joseph A. Olmstead Dr. Larry L. Lackey Mr. Harold E. Christensen Mr. Paul F. Ferguson	Jul 67

Objective: To identify and discover ways of controlling human factors that influence the effectiveness of military organizations.

INGROUP - Small-Group Instructional Methods for Military Training	Dr. Joseph A. Olmstead Dr. Larry L. Lackey Mr. Harold E. Christensen Mr. Paul F. Ferguson	Mar 69

Objective: To evaluate the effectiveness of small-group instructional techniques, and to identify ways to best exploit these techniques for military instruction.

MANICON - Determination of Performance Capabilities and Training Requirements for Manual Command and Control Functions of Automated Air Defense Systems	Dr. Harry L. Ammerman Dr. Robert D. Baldwin Mr. Robert J. Foskett	Jul 66

Objective: To identify and evaluate manual performance capabilities and training requirements for command and control functions of automated air defense weapon systems.

Work Unit	Experimenter(s)	Date Started
OC LEADER - Systems Engineering of Leadership Training for Officer Candidate Programs	Dr. James A. Caviness Mr. James A. Salter	Jul 70

Objective: To identify potentially productive approaches to the systems engineering of leadership training programs in the Infantry Officer Candidate School.

SKYGUARD - Curriculum and Instructional Improvements for the Air Defense Artillery Officer Advanced Course	Dr. Paul G. Whitmore	Jul 70

Objective: To provide the U.S. Army Air Defense School with the necessary information needed for systematic modification and optimization of the existing Officer Advanced Course and of similar career-type instructional programs.

Research Area 4: Language and Area Training

COPE - Development of a Method for Training Military Personnel for Interaction With Foreign Nationals	Dr. Alfred J. Kraemer	Jul 67

Objective: To design, produce, and evaluate a program of audio-visual instruction for effective working with personnel of other cultures.

DEBRIEF - Feasibility Study of a System for Debriefing MAAG Advisors	Mr. Samuel G. Taxis	Jul 67

Objective: To develop and evaluate techniques, instruments, and systematic procedures for debriefing U.S. military personnel who have served overseas with the Military Assistance Program, in order to (1) obtain information relevant to improving standards and methods of advisor training, and (2) develop and evaluate procedures for processing, packaging, and disseminating the information obtained.

EDGE - Studies of Effective Supervision of Foreign Civilian Employees of the Army	Dr. John W. McCrary	Apr 69

Objective: To identify sociocultural factors contributing to the productivity and morale of local national civilians employed by U.S. military units overseas. Implications that sociocultural factors have for management policies, training programs, and supervisory practices, will be examined.

Research Area 5:
Training Technology

Work Unit	Experimenter(s)	Date Started
IMPACT - Prototypes of Computerized Training for Army Personnel	Dr. Robert J. Seidel Dr. Felix F. Kopstein Dr. Harold G. Hunter Dr. Ronald J. Swallow Mr. Edward Kingsley Mr. Richard D. Rosenblatt Mrs. Judith G. Compton Mr. Leslie W. Willis	May 67

Objective: To develop (1) a prototype computer-administered instructional system with (2) accompanying prototype multiple-track (branching), individualized programs of instruction. To be selected for prototype development, each course must be (1) critical for the Army, and (2) representative of a particular kind of behavior.

LISTEN - Development of Automated Programs to Improve Listening Skills Required in Army Jobs	Dr. Thomas G. Sticht	Jul 70

Objective: To develop automated audio-visual programs for improving critical listening skills across a wide range of aptitude levels of men in Army jobs; and to evaluate the effects of training in critical listening as an adjunct to reading training in Army Preparatory Training.

MEDIA - Improving Media Implementation in Training Programs	Dr. Ronald W. Spangenberg	Jul 70

Objective: To develop methodology for improved media implementation to meet specified training objectives in Army training programs.

READNEED - Methodology for Evaluating Reading Requirements of Army Jobs	Dr. Thomas G. Sticht	Jul 70

Objective: To further develop and refine a methodology for determining reading tasks in Army jobs; to apply this methodology to several MOSs; and to determine reading skill levels sufficient for performing the job-related reading tasks.

SPECTRUM - Development of Efficient Training for Soldiers of All Aptitude Levels	Dr. Ernest K. Montague Dr. John E. Taylor Dr. Hilton M. Bialek Mr. Robert N. Hauke	Oct 66

Objective: To develop procedures for selecting and organizing training content and training methods for high-density combat and combat support MOSs in order to achieve more efficient training at all aptitude levels.

Work Unit	Experimenter(s)	Date Started
SYNTRAIN - Modernization of Synthetic Training in Army Aviation	Dr. Paul W. Caro, Jr. Mr. Eugene R. Hall Dr. Maurice M. Small Mr. Robert N. Isley Mr. Oran B. Jolley	Apr 68

Objective: To expedite the application of advances in training technology to the design and utilization of Army aviation synthetic training equipment, through surveys of training device design requirements and technology and by human factors and training research.

UPGRADE - Improving Aviation Maintenance Training Through Task and Instructional Analysis	Dr. Wallace W. Prophet Mr. D. Schley Ricketson Mr. James L. Wahlberg	Jul 66

Objective: To study the relationships among job requirements, training, and manpower considerations for aviation maintenance. Specifically, to develop techniques for gathering task data and procedures for translating the data into effective training programs; to develop techniques to assist in the definition of school and unit training responsibilities; and to study the effect of non-use of training on morale, retention in service, and proficiency of aviation maintenance personnel.

Research Area 6: Training Management

APSTRAT - Training Strategies and Incentives Appropriate to Different Aptitude Levels for Selected Army Training Courses	Mr. Kenneth Weingarten Mr. Mark F. Brennan Mrs. Jacklyn E. Hungerland	Mar 68

Objective: To develop and test, in an operational course, instructional systems appropriate for multi-aptitude populations.

CADRE - A Prototype Course in Training Techniques for ATC Instructor Cadre	Dr. John E. Taylor	Jul 70

Objective: To develop and evaluate an entirely new Methods of Instruction (MOI) Course for ATC instructor cadre.

ESPRIT - Development of Methods for Improving Soldier Adjustment to the Army	Mr. Eugene H. Drucker	Jul 70

Objective: To develop and evaluate an attitude/personality data program that will provide a continuing information base concerning areas of conflict between soldiers' motivational needs and Army goals to those agencies responsible for the selection, training, and career management of enlisted personnel. To also develop remedial information/training for lessening need-goal conflicts.

Work Unit	Experimenter(s)	Date Started
PREDICT - Predicting Aviator Success in Training and Operational Assignments	Mr. H. Alton Boyd, Jr. Mr. Peter R. Prunkl Mr. James L. Wahlberg	Mar 69

Objective: To develop operational systems for predicting performance of Army aviators during training and operational assignments by means of computerized multiple regression equations and probability tables. The initial system will be designed for use in secondary selection in the aviation training program.

STOCK - Development of Training Management Procedures for Different Ability Groups	Dr. A. James McKnight Dr. Harold Wagner	Sep 67

Objective: To develop practical techniques for the management of entry-MOS training programs in order that they may more effectively use individualized instruction for students at all aptitude levels.

Following is the list of Basic Research grouped by Research Area for Fiscal Year 1971:

Research Area 5:
Training Technology

BR 16 - Improving Ability to See Military Targets

Following is the list of Exploratory Research grouped by Research Area for Fiscal Year 1971:

Research Area 1:
Individual Training and Performance

ER 81 - Training USASA Operators

ER 82 - Low-Cost Simulation in Military Training

ER 83 - GED Program for the Army

ER 85 - Army Flight Skill Learning Curves

Research Area 2:
Unit Training and Performance

ER 86 - Performance of NCOs in the Army Training Center

Research Area 6:
Training Management

ER 80 - Methods and Media for Army Training

ER 84 - Retention of Army Flying Skills

APPENDIX 3
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APPENDIX 4
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ABBE, Earl C.; Chief, Computer Programming & Operations Sec. BA, 1961; MA, U. of Mass., Math, 1963. Mathematics. ACM. (202) 694-5450 (Autovon 22-45450) BESRL

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AMMERMAN, Harry L.; Senior Scientist. BS, Arizona St., Psychol., 1956; MS, 1958, PhD, 1960, Purdue U., Industrial Psychology. Curriculum Development. Vocational Training. Vocational Guidance. Job Analysis. Behavioral objectives. APA, WPA, MPA, SWPA, Certified, Texas, AERA, RMPA, Sigma Xi. Ft Bliss, Texas, (915) 568-4491. HumRRO

ANDREWS, Robert S.; Acting Program Director. BA, Boston C., 1950; MS, William and Mary C., Psychol, 1958. Information Processing, Intelligence Systems. Assoc. APA; HFS; Potomac Chapter (HFS). (202) 694-3858 (Autovon 22-43858) BESRL

BAILEY, Robert, COL, CO, USAARL, Ohio State University, 1958. Physiological Optics. USAARL/USAMRDC

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BALDWIN, Robert D.; Director, Division No. 5. BA, Wayne State U., Psychol.,1950; MA, 1952, PhD, 1954, U of Iowa, Psychology. Human factors engineering. Education and Training. APA, MPA, Certified, Texas. Ft Bliss, Texas. (915) 568-4491. HumRRO

FOR DESCRIPTION OF ENTRIES IN "BIOGRAPHICAL DIRECTORY," SEE NEXT PAGE

Description of entries in Biographical Directory:

Name, Rank; Current position. Academic degrees, awarding institution, major field, date. Current fields of professional specialization. Membership in professional and honorary associations. Location (if not at reporting facility's main address), Office phone number.

The following abbreviations have been used in identifying professional organizations:

Acad.	Academy
Am.	America(n)
Assoc.	Association
E	East(ern)
Engr.	Engineer(ing)(s)
Inst.	Institute
Internat.	International
Math.	Mathematic(s)(al)
N	North(ern)
Nat.	National
Psychol.	Psycholog(y)(ical)(ist)
Psychiat.	Psychiatr(y)(ist)(ic)
S	South(ern)
Sci.	Scien(ce)(tist)(tific)
Soc.	Society
Sociol.	Sociology
Stat.	Statistic(s)(al)
W	West(ern)

In addition professional organizations represented by three or more members are abbreviated as follows:

AAA	Am Anthropological Assoc
AAAS	Am Assoc for the Advancement of Sc
AAPSS	Am Acad of Political and Social Sc
AAS	Assoc for Asian Studies
AAUP	Am Assoc of University Professors
ACM	Assoc for Computing Machinery
AcSA	Acoustical Soc of Am
AERA	Am Education Research Assoc
AHS	Am Helicopter Soc
AMS	(Listed in) Am Men of Sc
AOA	Am Ordnance Assoc
APA	Am Psychol Assoc
APSA	Am Political Sc Assoc
ASocA	Am Sociol Assoc
AStatA	Am Stat Assoc
ASTD	Am Soc of Training Directors
AUSA	Assoc of the US Army
EPA	E Psychol Assoc
HFS	Human Factors Soc
IAAP	International Assoc for Applied Psychol
IEEE	Inst of Electronic and Electrical Engr
JAS	Japan Am Soc
MEI	Middle East Inst
MPA	Midwestern Psychol Assoc
NEPA	New England Psychol Assoc
NRC	Nat Research Council
NRC-HB	Nat Research Council Committee on Hearing
NRC-V	Nat Research Council Committee on Vision
NSPE	Nat Soc of Professional Engr
NSPI	Nat Soc for Programmed Instruction
ORSA	Operations Research Soc of Am
OSA	Optical Soc of Am
Psymet S	Psychometric Soc
Psynom S	Psychonomic Soc
RESA	Research Soc of Am
SAE	Soc of Automotive Engr
SGSR	Soc for General Systems Research
SEPA	Southeastern Psychol Assoc
SSPP	Southern Soc for Philosophy and Psychol
STWP	Soc of Technical Writers and Publishers
SWPA	Southwestern Psychol Assoc
USNI	US Naval Inst
WPA	Western Psychol Assoc
WWA	(Listed in) Who's Who in Am

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BARTHOLD, Stephen W., CPT, VC, Veterinary Officer, DVM University of California, 1969, Veterinary Medicine, USAMRDC

BARTOSHUK, Linda M., Research Psychologist, Psychology Group, Behavioral Sciences Division: Ph.D. 1965, Brown Univ, Sensory electrophysiology and psychophysics, physiological psychology; Member: AAAS, EPA, New York Academy of Sciences, Sigma Xi; APA USAMC/NATICK

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BRECKENRIDGE, John R., Research Physicist, B.S., University of Pennsylvania, 1946, Physics of Clothing. USAMRDC

BRENNAN, Mark F.; Research Associate. BS, USMA, Management Engineering, 1938. AUSA. Presidio of Monterey, Calif., (408) 242-8349. HumRRO

BROWN, Emma E.; Assistant for Reports. BA, U. of Colorado, Languages, English Language, Journalism; MA, U. of Colorado, Languages, Psychol. Measurement & Evaluation. APA, DCPA, Psi Chi, Phi Beta Kappa, Phi Sigma IOTA, Federal Editors Assoc. (202) 694-3705 (Autovon 22-43705) BESRL

BROWN, Frank L.; Senior Staff Technician. BS, Clarion (Pa) State C., Secondary Education, 1956. Military Training. Small unit operations. Specification of performances, knowledges, and skills. Ft Benning, Ga., (404) 545-1907. HumRRO

BROWN, George H.; Senior Staff Scientist. AB, 1947, PhD, 1952, New York U., Psychology. Language training. Technical training. Adult basic education. APA, EPA, NSPI. (703) 549-3611. HumRRO

BUCKLEY, Janet K.; Analyst Programmer. BA, U. of North Carolina, Math, 1948. (703) 549-3611. HumRRO

BUCKLIN, Bruce L., Engineering Psychologist. BA 1965, State Univ of New York at Fredonia; MA 1969, Farleigh Dickinson Univ; General Psychology. Member: Alpha Psi Omega. USAMC/MUCOM(PA)

BURGESS, George G.; Deputy Assistant Director for Utilization. BA, U. of Dubuque, General Science, 1945; AM, Washington U., Psychol., 1948; PhD, U. of Ill., 1957. Personnel Research, Human

Factors. APA, EPA, HFS-Potomac Chapter, AStatA, AMS. (202) 694-1297 (Autovon 22-41297) BESRL

BURKE, Laverne K.; Sr. Project Director. SB, U. of Chicago; MA, Ohio State U., Psychol, 1935. Operations Research. APA, EPA, DCPA, Psymet S, AStatA, ACM, Soc. for Indust. & Appl. Math.; Assoc. Member, ORSA; Pi Mu Epsilon. (202) 694-3947 (Autovon 22-43947) BESRL

BUTLER, Patrick J.; Research Scientist. BA, Piedmont C., Psychol., 1952; MA, U. of South Carolina, Psychology, 1957. Human factors. Military training. Computer simulation (GPSS). EIA, Psi Chi. (703) 549-3611. HumRRO

BYRNES, Peter J., SP5, Elect. Engr. Asst. BEE 1968, Manhattan College. Member: IEEE. USAMC/HEL

CADMUS, Lamont E., SP4, Elect. Engr. Asst. BSEE 1966, Univ of Notre Dame. Computer Electronics. Member: IEEE. USAMC/HEL

CAHOON, Richard L., Research Psychologist, Ph.D., Tufts University, 1966, Effects of hypoxia on physiological indices of behavior. USAMRDC

CALDWELL, Lee S., Research Psychologist, Ph.D., University of Kentucky, 1955, Biomechanics. AMRL/USAMRDC

CAMP, R.T., Jr., Director, Biophysics Division, B.A., University of Florida, 1955, Psychoacoustics. USAARL/USAMRDC

CARLOCK, Jack, Engineering Psychologist. BS 1960, MA 1961, Rutgers Univ, Visual Detection; Portability; Member: Human Factors Society; Mine Field Marking Committee. USAMC/MUCOM(PA)

CARO, Paul W.; Senior Staff Scientist. BA, Fla. State U., Psychol., 1955; MA, 1956, PhD, 1961, U. of Tennessee, Psychology. Training system analysis. Simulation. Simulator design. APA, SEPA, Ala PA, AAP, AHS, AMS, Who's Who in South and Southeast, Personalities of the South, License, Alabama, Sigma Xi. Ft Rucker, Ala., (205) 255-5002 (Autovon 558-5002). HumRRO

CARRIERO, Nicholas J., Research Psychologist. BS 1951, Canisius C; Ph.D. 1964, State Univ of New York at Buffalo. Physiological correlates of attitude change. Member: APA; EPA; Sigma Xi; AAAS. USAMC/HEL

CASEY, Francis B., CPT, MSC, Immunologist, Ph.D., University of New Mexico, 1970. Pathology, Immunology. USAMRDC

CASSATT, Robert K., Project Engineer; Harvard Univ. Member: Human Factors Society. USAMC/HEL

CASTELNOVO, Anthony E.; Task Leader. MA, Kent State U., Psychol., 1951; Leadership Evaluation & Leadership Development Processes. Certified--Virginia. (202) 694-4072 (Autovon 22-44072) BESRL

CAVINESS, James A.; Senior Scientist. BA, Portland State C., Psychol., 1960; MA, 1962, PhD, 1964, Cornell U., Exp. Psychol.. Selection and training. APA, WPA, OPA, PPA, Theta Delta Phi. Ft Benning, Ga., (404) 545-1907. HumRRO

CAYLOR, John S.; Senior Scientist. AB, Western Reserve U., Economics, 1942; MA, Western Reserve U., Industrial Psychol., 1950; PhD, U. of Michigan, Psychol., 1956. Human learning. Training. Criterion development. Perfor-

mance measurement. Reading and listening. WPA. Presidio of Monterey, Calif., (408) 242-8349. HumRRO

CLEARY, Fred K., LTC, AUS (Ret); Technician. AA, Columbus C., Secondary Education, 1968. Military training. Small unit operations. Specification of performances, knowledges, and skills. AUSA, AOPA. Ft Benning, Ga., (404) 545-1907. HumRRO

CLEGG, Thomas J., PFC, Biological Sciences Assistant, Behavioral Sciences Division: BA, 1969, Erskine College; zoology. USAMC/NATICK

CHAIKIN, Gerald, General Engineer (Human Factors): BSME, Purdue Univ, 1956; Integration of Human Factors Engineering into Weapon System Programs; Member: Human Factors Society; Registered Professional Engineer (Alabama). USAMC/MICOM

CHEEVER, Herbert A., Mechanical Engineering Asst. SP5. BS 1965, Mech Engr. Univ of Massachusetts. USAMC/HEL

CHIPSER, S. John, Electrical Engineer: BSEE, Lehigh Univ, 1964; Integration of Human Factors Engineering into Weapon System Development Programs; Member: Institute of Electrical and Electronic Engineers, Human Factors Society. USAMC/MICOM

CHRISTENSEN, Harold E.; Research Scientist. BS, U. of Utah, History, 1957; MS, U. of Utah, Psychol., 1960. Learning and Measurement. APA, NSPI. Ft Benning, Ga., (404) 545-1907. HumRRO

COGAN, Eugene A.; Director for Research Design and Reporting. AB, 1947, MA, 1949, PhD, 1951, UCLA, Psychology. Social psychology. Design of experiments and analysis of data. Application of systems analysis and operations research to human factors and social problems. APA, AAAS, WORC, AMSC, Sigma Xi, Psi Chi. (703) 549-3611. HumRRO

COHEN, Stanley L.; Research Psychol. BA, Geo. Washington U., Psychol, 1963; MA, Geo. Washington U., Psychol, 1966; PhD, Geo. Washington U., Psychol, Sep 1970. APA, AAUP, Psi Chi, Sigma Xi. (202) 694-3730 (Autovon 22-43730) BESRL

COMF[illegible], Judith G.; Behavioral Scientist. AB, C., of William and Mary, Psychology, 1963; MA, U. of Delaware, Psychology, 1966. Computer administered instruction. Individual differences. Learning. RESA, AERA, ADIS, Sigma Xi, Psi Chi. (703) 549-3611. HumRRO

CORLEY, Winon E.; Technician. Flight training systems analysis. Ft Rucker, Ala., (205) 255-5002 (Autovon 558-5002). HumRRO

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CORY, Bertha H.; Chief, Statistical Systems & Computer Br. AB, U. of Rochester; MA, U. of Rochester, Psychol., 1941. Methodology, Computer Applications, Interest & Aptitude Measurement. APA, EPA, Md. PA, DCPA (Pres. 1965), Psymet S, ACM, ACM Spec. Interest Gp. on Computer Sys. Installation Mgmt. (Sec-Treas); Certified Psychol.--Md.; Rsch Psychol. Panel of Interagency Bd of Examiners; Sigma Xi, Phi Beta Kappa. (202) 694-3754 (Autovon 22-43754) BESRL

COULSTON, Herbert V., Jr., E., Asst. Mech. Engineer, BS 1966, Lehigh Univ, Mech Eng; MBA, 1968, Univ of Pennsylvania, Indust. Mgmt. Mechanical Engineering Design. Member: Wharton MBA Club, Chi Phi, ASME. USAMC/HEL

CRAWFORD, Meredith P.; President. AB, Vanderbilt, Chemistry, 1931; MA, 1932, PhD, 1935, Columbia U., Psychology. Research Administration. Military psychology. Experimental psychology. APA, DCPA, MPA, EPA, AAAS, NRC, PS, AUSA, Fellow APA, Phi Beta Kappa, Sigma Xi. (703) 549-3611. HumRRO

CRONHOLM, James N., Psychophysiologist, Ph.D., University of Louisville, 1969, Mathematical Models. AMRL/USAMRDC

CROSLEY, John K., MSC, Optometrist, M.S., Indiana University, 1966, Physiological Optics. USAARL/USAMRDC

CRUSE, Charles S., Chief, Engineering Research Laboratory; Maryland Institute of Mechanical Arts. Member: US Naval Institute. USAMC/HEL

CRUTCHFIELD, John N., PFC. Electrical Engineer, Instrumentation Group, Behavioral Sciences Division: BS 1967, North Carolina State Univ; electrical engineering. Member: IEEE. USAMC/NATICK

CURRY, Lala J.; Senior Instructional Programmer. BS, Ohio State U., Home Economics, 1948; MS, Cornell U., 1965. Instructional systems and materials. Computer-administered instruction. Consumer education. AHEA-DCAHEA, ASTD-DCASTD, Phi Kappa Phi, Pi Lambda Theta, Omicron Nu, Phi Upsilon Omicron. (703) 549-3611. HumRRO

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DAVIS, C. Jane, Research Psychological (Engineering). AB 1937, Catharine Spalding College, Dept of Psychology, Univ of Delaware, Information Displays. Member: Kappa Gamma Pi; Psi Chi. USAMC/HEL

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DEAN, Richard F.; Research Psychol. BS, U. of Md., Psychol., 1958; MS, U. of Md., Applied Experim Psychol., 1962. Sensory Processes, Man-Machine Systems Analysis. AStatA, HFS-Potomac Chapter, HFS, DCPA. (202) 694-3730 (Autovon 22-43730) BESRL

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DE HAAN, Henry J.; Research Psychol. AB, Washington U., Chemistry, 1942; MA, Washington U., Psychol., 1949; PhD, U. of Pittsburgh, 1960. Experim & Physiological Psychol., Human Performance. APA, EPA, AAAS, Internat. Primat. Soc., Animal Behavior Soc., NY Acad. Sci., AMS, Sigma Xi. (202) 694-43549 (Autovon 22-43549) BESRL

DeLANEY, Joseph P., Research Psychologist (Engr). BA 1960, Northwestern Univ; experimental psychology, engineering psychology. USAMC/MUCOM(EA)

DE LUCA, Arthur J.; Research Scientist. AB, Ohio U., Math, 1939; MEd, Toledo U., Administration-Supervision, 1964. Officer training and education. Phi Delta Kappa. Ft Benning, Ga., (404) 545-1907. HumRRO

DeTOGNI, Gino R., Research Engineer (Human Factors). BS 1951, Union College; MA 1969, Fairleigh Dickinson Univ; System Analysis. Member: Human Factors Society; AOA. USAMC/MUCOM(PA)

DICKINSON, Nonnie F., CWO-4, USA (Ret); Engineering Technician (Human Factors). USAMC/HEL

D'MELLO, Joseph C.; Senior Technician. BA, Howard U., Drama, 1963. Theatre: Acting and Directing. (703) 549-3611. HumRRO

DOOLITTLE, William H., LTC, MC, Director, USAMRLA, M.D., University of Vermont, 1960, Medical Effects of Cold Exposure. USAMRDC

DOSS, Norman William, Engineering Technician. USAMC/HEL

DRUCKER, Arthur J.; Assistant Director for Operations. BS, U. of Rochester, Education, 1942; MS, Purdue U., Industrial Psychology, 1947; PhD, Purdue U., Psychology, 1949; Human Factors Systems Research. APA, EPA, HFS, IAAP. (202) 694-3540 (Autovon 22-43540) BESRL

DRUCKER, Eugene H.; Research Scientist. BS, U. of Illinois, Psychology, 1956; MA, U. of Ky., Psychol., 1958. Attitude measurement, attitude change, leadership. APA, MPA, SEPA. Ft Knox, Ky., (502) 624-5646 (Autovon 726-3300, Ext. 5646). HumRRO

DUVA, James S. Psychologist. MA 1948, Fordham Univ; BA, Iona College, 1947. Specialization: Training Research and Human Factors. Professional Society Membership: APA; AAAS; Research Society of America; Senior Member, IEEE; Digital Equipment Users Society. USAMC/NAVTRADEVCEN

DULIN, Evelene H.; Technician. (703) 549-3611. HumRRO

DUSEK, E. Ralph, Director, Behavioral Sciences Laboratory, Ph.D., State University of Iowa, 1951, Environmental effects of human performance. USAMRDC

DYER, Fredetck N., Research psychologist, Ph.D., Michigan State University, 1968, Visual Perception, AMRL/USAMRDC

ECKLES, Andrew J., III, Research Psychologist (Engineering). BS 1950; MA 1952, Univ of Louisville. USAMC/HEL

ELLIS, Paul H., Industrial Designer. BS 1963, Philadelphia Museum College of Art; armored vehicles, small arms. USAMC/HEL

ENGEL, John D., Research Scientist. BS, City C. of New York, Psychol., 1964; MA, U. of Detroit, Psychol., 1966. Tng Systems Engineering. Test theory. Test Development. APA, KPA, ASTD, NCME. Ft Knox, Ky. (502) 624-8149 (Autovon 726-3300, Ext. 8149). HumRRO

EMERY, Mason C., GMMC, USN (Ret). Equipment specialist. USAMC/HEL

ERICKSON, John R., Supervisory Engineer (Human Factors); Chief, Missile, Communications/General Support Branch. BSME 1951, Case Institute of Technology. USAMC/HEL

EVANS, Wayne O., LTC, MSC, Director Military Stress Laboratory, Ph.D Duke University, 1960, Psychopharmacology and Human Performance. USAMRDC

FAIR, Paul A., Supervisory Research Engineer. Certificate, Pratt Institute 1926. Member: National Society of Professional Engineers, Susquehanna Chapter. USAMC/HEL

FARRELL, Francis M.; Assistant for Plans. BS, Fordham U., English Literature, 1940; MS, Fordham U., Educational Psychology, 1947. R&D Management. Mass. PA; Licensed Psychol NY State. (202) 694-3538 (Autovon 22-43538) BESRL

FARRELL, John P., Jr.; Research Psychologist, BA, Boston C., Psychol., 1961; MA, Catholic U. of Am., Experim Psychol., 1965; PhD, Catholic U. of Am., 1969. Human Performance. APA, HFS. (202) 694-3730 (Autovon 22-43730) BESRL

FERGUSON, Paul F., AUS. LTC (Ret); Technician. Military Training. AUSA, ROA. Ft Benning, Ga., (404) 545-1907. HumRRO

FINK, C. Dennis; Program Director. BA, U. of Maine, Psychol., 1950; MA, 1955, PhD, 1958, U. of Colorado, Psychology. Employee training and development. Job and systems analysis. Training systems and technology. Information requirements and analysis. APA, ASIA, ADI. (703) 549-3611. HumRRO

FINK, Donald, CPT, MC, Research Internist, M.D., University of Nebraska Medical School, 1969, Environmental Medicine. USAMRDC

FINE, Bernard J., Research Psychologist, Ph.D., Boston University, 1956, Biochemical-endocrine correlation of behavior under stress. USAMRDC

FISHER, Dennis F., Research Psychologist, BA 1964, San Jose State; MA 1970, Univ of Delaware. Perception, memory, learning, information processing. USAMC/HEL

FLEISHMAN, Joseph J., CPT, MSC, Research Psychologist, Ph.D., Yeshiva University, 1969, Development of performance indices sensitive to stress effects. USAMRDC

FLORIP, David J., SP5, Electrical Engineer Asst. BS 1961, Michigan Technological Univ, electrical engineering. Member: IEEE. USAMC/HEL

FOSKETT, Robert J.; Electronics Engineer. BEE, Ohio State, Electrical Engineering, 1962. Ft Bliss, Texas, (915) 568-4491. HumRRO

FOSTER, Murray Jr., Engineering Technician (Aviation), Johns Hopkins Univ. USAMC/HEL

FOX, Lynn C.; Research Associate. BA, Gettysburg C., Psychology, 1963. Presidio of Monterey, Calif. (408) 242-8349. HumRRO

FRANCESCONI, Ralph P., Chemist, Ph.d. Boston College, 1966, Environment biochemistry. USAMRDC

FRANKFELDT, Eli; Research Psychologist (PM&E). BS, CCNY, Mathematics, 1933; MS, CCNY, Psychology, 1938. Change Process, Optimization of Individual & Group Performance, Utilization of Social Indicators as a Criterion and/or Predictor of Performance. APA, EPA, WORC, SPSSI. (202) 694-4039 (Autovon 22-44039) BESRL

FREDERICKSON, Edward W.; Research Scientist. BA, Willamette U., Biology, 1955; MA, Baylor U., Psychology, 1961; PhD, Baylor U., Industrial Psychol., 1970. Research design. Evaluative research. Behavior modification. Ft Bliss, Texas (915) 568-4491. HumRRO

FROEHLICH, Dean K.; Senior Staff Scientist. AB, U. of Michigan, Psychol., 1953; PhD, U. of Illinois, Psychol., 1961. Research on bi-national work groups. APA, RAS, Sigma Xi. US Army Research Unit - Korea, APO San Francisco 96301. HumRRO

FUCHS, Edmund F.; Deputy Director for Selection Research & Chief, Military Selection Research Division. MA, Fordham U., Psychology, 1942. Testing Research Design, Personnel Management Research. Fellow, APA, AAAS; Member, MPA, DCPA, DA Civilian Appeals Review Board; Diplomate (Industrial) ABPP. (202) 694-3881 (Autovon 22-43881) BESRL

GARINTHER, Georges R., Research Engineering, BSEE 1957, Gannon College. Member: Acoustical Society of America; National Academy of Science-NRC Committee on Hearing. Bioacoustics and Biomechanics. USAMC/HEL

GALLUN, Louis, Mechanical Engineering Technician; Weapon systems and equipment. Member: Human Factors Society, National and Delaware Valley Chapter; OSA. USAMC/MUCOM(FA)

GANCHROW, Donald, Biological Psychologist, Behavioral Sciences Division: Ph.D. 1969 Duke Univ, biological psychology; taste electrophysiology and behavior. Member: AAAS, Sigma Xi. USAMC/NATICK

GARNEAU, Jean A.; Director of Systems Development, Work Unit IMPACT. Design and development of teleprocessing systems. (703) 549-3611. HumRRO

GARRY, Thomas A., Research Psycho logist (Engineering). BS 1952, Long Island Univ. USAMC/HEL

GEHRINGER, Edward E., Research Psychologist, MA 1959, George Washington Univ. USAMC/HEL

GENTILE, Robert L., Research Psychologist, Psychology Group, Behavioral Sciences Div. Ph.D. 1967, Cornell Univ; Experimental psychology. Member: Phi Kappa Phi; Sigma Xi. USAMC/NATICK

GERBEN, Martin J., Research Psychologist, Ph.D., University of Pittsburgh, 1966, Effects of hypoxia on animal and human performance. USAMRDC

GERJUOY, Herbert G.; Senior Staff Scientist. AB, U. of Southern Calif., Psychol., 1949; MA, 1952, PhD, 1953, State U. of Iowa, Psychology. Meta-languages and programming language design. APA, AAAS, MPA, EPA, Sigma Xi. Presidio of Monterey, Calif., (408) 242-8349. HumRRO

GIAMBER, Samuel A., CPT, MC, Research internist, M.D., University of Pennsylvania Medical School, 1966, Environmental medicine. USAMRDC

GIORDANO, Dominick J., Electronic Engineer (Instr.) BSEE 1961, Newark College of Engineering. USAMC/HEL

GOLDEN, Michael G., Engineering Technician. BS 1963, Philadelphia College of Art; industrial design; MA 1964, Stanford Univ; industrial design. USAMC/HEL

GOLDMAN, Ralph F., Director, Military Ergonomics Laboratory, Ph.D., Boston University, 1954, Environmental physiology. USAMRDC

GOLDSTEIN, Ira, Research Psychologist. BA, Boston College, 1951. Specialization: Computers and Psychological Experimentation. Professional Society Membership: Association for Computing Machinery; Digital Equipment Users Society (Installation Delegate). USAMC/NAVTRADEVCON

GORDON, Thomas P., Research Psychologist (Physio & Exp). BS 1962, Univ of Scranton; MS 1965, Univ of Delaware. Member: Psi Chi; Sigma Xi. USAMC/HEL

GRAFTON, Frances C.; Personnel Rsch Psychologist. BA, Mary Wash. College of U. of Va., Psychology. Psychometrics, Computers, Systems Analysis. Alpha Phi Sigma, Phi Sigma Iota. (202) 694-4469 (Autovon 22-44469) BESRL

GRAHAM, Warren R.; Senior Scientist. AB, U. of Calif., Psychol., 1948; MA, New York U., Industrial and Personnel Psychol., 1952; EdD, Columbia U., Measurements and Psychometrics, 1955. APA, AERA, NCME. (703) 549-3611. HumRRO

GRANDA, Thomas M.; Personnel Rsch Psychologist. BA, Wagner C., NY, Psychology, 1965; MA, Calif. State C. Long Beach, Psychology, 1967. Operations Research. Assoc. Member, APA, EPA. (202) 694-5400 (Autovon 22-45400) BESRL

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GREGORY, Ruth S.; Senior Technician IPMA, IPMA-ER, IPMA-W.Ch. STWP, STWP-W.Ch. (703) 549-3611. HumRRO

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U., Industrial Psychol., 1950; MS, North Carolina State C., Industrial Psychol., 1952; PhD, State U. of Iowa, Psychol., 1956. General Experimental Learning theory. Statistics. APA, MPA, KPA, PS, ASID, AERA, Sigma Xi. Ft Knox, Ky., (502) 624-3450 (Autovon 726-3300, Ext. 3450). HumRRO

HALL, Eugene R.; Senior Scientist. BA, U. of Michigan, Social Sciences, 1958; MA, Michigan State U., General Experimental Psychol., 1960. Training analysis. Training system design. Who's Who in the South and Southwest, Sigma Xi. Ft Rucker, Ala., (205) 255-5002 (Autovon 558-5002). HumRRO

HALPIN, Stanley M., Social Psychologist, Ph.D., Purdue University, 1970, Group Behavior Effects. USAMRDC

HAMLET, Murray P., CPT, MC, VC, Veterinary Officer, D.V.M., Washington State University, 1969, Veterinary Medicine. USAMRLA/USAMRDC

HANNA, Thomas D., Engineering Psychologist; MS 1962, Temple Univ; Vision, audition, systems analysis. Member: Aerospace Medical Assoc; Aerospace Industrial Life Science Assoc; Space Medicine Branch of ASMA; EPA; HFS; NY Acad of Sci; Phila Physiol Soc. USAMC/MUCOM (FA)

HANSEN, James E., COL, MC, Commanding Officer, M.D., Johns Hopkins University School of Medicine, 1949, Altitude Physiology. USAMRDC

HARDING, Francis D.; Senior Staff Scientist. BS, Boston U., Education, 1947; MA, U. of Illinois, Psychol., 1948; PhD, Purdue U., Psychol., 1953. Manpower. Technical education. Surveys. APA, AAAS, AIR, APGA. (703) 549-3611. HumRRO

HARKER, George S., Director, Experimental Psychology Division, Ph.D., University of Iowa, 1950, Vision. AMRL/USAMRDC

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HARRIS, Lyman K.; Chief, Developmental Engineering Shop. Developmental engineering. AOA, National Rifle Assoc. Ft Benning, Ga., (404) 545-1907. HumRRO

HART, Robert D., P7C, Biological Sciences Assistant, Behavioral Sciences Division; BA 1969, Taylor Univ; biolgogy; MS 1969, Ball State Univ., biology. USAMC/NATICK

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HAVERLAND, Edgar M.; Advisor for Program Development. AB, 1949, AM, 1954, PhD, 1954, U., of Illinois, Psychology. Measurement of human performance. Design of experiments. Statistical analysis. APA, MPA, DCPA, Psymet S, AMS, Phi Beta Kappa. (703) 549-3611. HumRRO

HAYNAM, Kenneth W.; Sr. Project Director. BA, The C. of Wooster, Math., 1960. Operations Research, Computer Science. AStatA, The Institute of Mgmt. Sciences; Assoc. Member, ORSA. (202) 694-4469 (Autovon 22-44469) BESRL

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HELME, William H.; Chief, Behavioral Evaluation Research Div. BA, Drew U., Economics, 1938; MA, Columbia U., Vocat Guid & Occup Psychol., 1947; PhD, New School for Social Research, Psychol, 1959. Personnel Meas & Eval., Social Psychol. APA, EPA. (202) 694-4050 (Autovon 22-44050) BESRL

HERBERT, Dorothy C.; Research Librarian. BA, U. of Louisville, Psychology, 1967; MSLS, Spalding C., Library Science, 1969. ALA, SLA, SELA, KLA, AAUW, ASA, Phi Kappa Phi. Ft Knox, Ky., (502) 624-2055 (Autovon 726-3300, Ext. 2055). HumRRO

HERBERT, Marvin J., Research Psychologist, Ph.D., University of Minnesota, 1953, Motor Skills, AMRL/USAMRDC

HEYL, Arnold A.; Director for Operations. AB, Mission House C., Math, 1940; MA, U. of Texas, Math, 1947. Data processing research operations. Education and training research management. Statistical analysis. (703) 549-3611. HumRRO

HIBBITS, Francis L.; Program Budget Manager. B., U. of Rhode Island, Biology, 1937. (703) 549-3611. HumRRO

HILLIGOSS, Richard E., Research Psychologist. BA, U. of Akron, Mathematics, 194; MA, Geo. Washington U., Psychometrics, 1960. Psychological Measurement. APA, SEPA, Psi Chi, Certification - Va. (202) 694-3780 (Autovon 22-43780) BESRL

HODGE, David C., Research Psychologist. BA 1953, Hardin-Simmons Univ, MA 1959, Texas Technological C; Ph.D. 1963, Univ of Rochester. Psychological acoustics, noise effects on hearing and performance, damage-risk criteria. Member: APA (Div. 3 & 21); EPA; Acoustical Society of America (& Wash., D.C. chapter); Psychonomic Society; Sigma Xi; AAAS; NRC Committee on Hearing, Bioacoustics and Biomechanics (& Subcommittee 7), USAMC/HEL

HOEHN, Arthur J.; Director, Division No. 7. BA, U. of Illinois, Education, 1940; MA, 1947, PhD, 1951, U. of Illinois, Educational Psychology. Training technology. Intercultural communication. APA, MPA, DCPA. (703) 549-3611. HumRRO

HOFMANN, Mark A., MSC, Director, Aviation Psychology Division, Ph.D., University of South Dakota, 1968, Human Factors. USAARL/USAMRDC

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HOUFF, Charles W., Training Specialist (Human Factors). BS 1968, Univ of Maryland; training, test evaluation, systems analysis. USAMC/MUCOM(EA)

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HUDGENS, Gerald A., Research Psychologist. BA 1960, Knox C; MA 1961, Univ of Denver; Ph.D. 1965, Purdue Univ; stress, psychobiology, early experience, aggression. Member: EPA. USAMC/HEL

HUIBREGTSE, William H., Research Physiologist, Ph.D., University of Arizona, 1966, Environmental Physiology. USAMRLA/USAMRDC

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SHERSHOW, John C., CPT, MC, Psychaitrist, M.D., University of California Medical School, 1965, Experimental psychiatry. USAMRDC

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TAYLOR, John E.; Senior Staff Scientist. BA, Penn. State, Psychol., 1949; MA, Bowling Green State U., Psychol, 1950; PhD. State U. of Iowa, Psychol., 1953. R & D in instructional technology. Design and evaluation of instructional systems. AERA, APA-MPA-WPA, Psynom S, AAAS, Sigma Xi. Presidio of Monterey, Calif., (408) 242-8349. HumRRO

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THOMAS, Francis H.; Senior Staff Scientist. AB, Howard C., Psychol., 1942; PhD, Cornell U., Psychol., 1953. Human vision. Perception. Information processing. Fellow, APA-Ala PA, HFS, AAPSS, NRC-V. Ft Rucker, Ala., (205) 255-4404 (Autovon 558-4404). HumRRO

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UHLANER, J(ulius) E.; Director, Behavior and Systems Research Laboratory. BS, CCNY, Mathematics, 1938; MS, Iowa St. U., Psychology, 1941; PhD, NYU, Psychology, 1947. Systems Psychology, Theory of Human Performance, Measurement of Behavior. Fellow, APA (President, Div Mil. Psychol), Iowa Acad of Sci, Washington Acad of Sci.; Member, EPA, DCPA, SEPA, WPA, HFS, HFS (Potomac Chapter), Psymet S., Psynom S., ORSA, NRC-Highway Research Board, NRC-Armed Forces Committee on Vision, Army Behavioral & Social Sciences R&D Committee. (202) 694-3411 (Autovon 22-43411) BESRL

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VINEBERG, Robert; Senior Staff Scientist. AB, New York U., Psychol., 1949; MA, 1950, PhD, 1952, New York U., Experimental Psychology. Cognitive processes and problem solving. Training. Learning. Psychological stress. Fellow APA, Psynom S, Sigma Xi. Presidio of Monterey, Calif., (408) 242-8349. HumRRO

VOGEL, James A., Research Psychologist, Ph.D., Rutgers University, 1961, Cardiovascular and Brain Physiology. USAMRDC

VORACEK, Donald F., Mechanical Engineer; BS 1958, North Dakota State Univ; Industrial Engineering and Management. Member: AOA; Human Factors Society. USAMC/WECOM

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WAGNER, Harold; Research Scientist. BBA, City C. of New York, Industrial Psychology, 1959; PhD, New York U., Psychology, 1968. APA, EPA, DCPA, Psi Chi, Sigma Xi. (703) 549-3611. HumRRO

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WHITMORE, Paul G.; Senior Scientist. BA, Millsaps C., Psychol., 1951; PhD, U. of Tennessee, Psychol., 1956. APA, SEPA, MPA, SWPA, AAAS. Ft Bliss, Texas, (915) 568-4491. HumRRO

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WITHERSPOON, John M., CPT, MC, Research Internist, M.D., Duke Medical School, 1967, Water Immersion Effects. USAMRDC

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ZEIDNER, Joseph; Deputy Director for Manned Systems Research and Chief, Support Systems Research Division. BS, CCNY, Psychology, 1949; MA, Fordham U., Experimental Psychology, 1951; PhD, Catholic U., Experimental Psychology, 1954. Information Processing, Decision Making, Human Factors. APA,(Div. Mil. Psychol, APA), DCPA, NRC-V. (202) 694-3759 (Autovon 22-43759) BESRL

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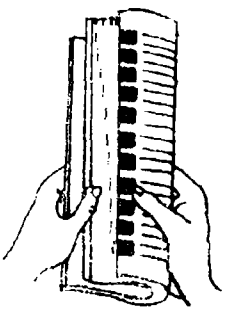

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