REPORT

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Eighth Annual

ARMY HUMAN FACTORS ENGINEERING CONFERENCE

16-19 OCTOBER 1962

UNITED STATES ARMY INFANTRY CENTER
AND
UNITED STATES ARMY INFANTRY SCHOOL
FORT BENNING, GEORGIA

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ARMY RESEARCH OFFICE
OFFICE OF THE CHIEF OF
RESEARCH AND DEVELOPMENT,
DEPARTMENT OF THE ARMY

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF RESEARCH AND DEVELOPMENT
ARMY RESEARCH OFFICE
WASHINGTON 25, D C.

CRD/J 12 November 1962

SUBJECT: Eighth Annual Army Human Factors Engineering Conference: Foreword and Transmittal

TO: See Distribution

1. This Report is the record of subject conference held at the U.S. Army Infantry Center, Fort Benning, Georgia, 16-19 October 1962. The continued annual sponsorship of these conferences and the publication of this Report by the Office of the Chief of Research and Development, Department of the Army, reconfirms the valuable contribution of the conference to the interchange of information among agencies and personnel concerned with the effectiveness of U.S. Army man-machine systems in the operational environment. A compendium of current Army human factors engineering work programs will be found in the appendices of this Report.

2. The conference successfully serves the vital functions of bringing together the diverse elements of the Army's human factors engineering activities and stimulating joint efforts on common problems. This year as in the past the scope of the conference has been widened to include a larger number of both military and civilian agencies and institutions interested in the various facets of the human factors program.

3. The Army's Human Factors Engineering Committee is to be commended for thoroughly planning and effectively conducting this successful conference. The Committee is encouraged to continue its diligent and critical search for more effective means to assure that Army materiel is fully compatible with the human capabilities and limitations of our soldiers. Comments regarding this conference may be directed to the Human Factors Research Division, Office, Chief of Research and Development, Department of the Army, Washington 25, D. C.

FOR THE CHIEF OF RESEARCH AND DEVELOPMENT:

C. W. Clark

C. W. CLARK
Major General, GS
Director of Army Research

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THE INFANTRYMAN - INVINCIBILITY ON THE BATTLEFIELD
REPORT OF THE
EIGHTH ANNUAL ARMY HUMAN FACTORS ENGINEERING CONFERENCE

16-19 October 1962
U. S. Army Infantry Center
Fort Benning, Georgia

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THE INFANTRYMAN - INVINCIBILITY ON THE BATTLEFIELD
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CHAPTER 1. INTRODUCTION

A. 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 Laboratory, 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. Army Regulation 70-8, "Research and Development, Human Factors Research," 1 July 1958.

Sponsorship and Planning of the Conference

The Annual U. S. Army Human Factors Engineering Conference is sponsored by the Chief of Research and Development, (OCRD) Department of the Army. Seven such Annual Conferences have previously been held and are reported in references a, b, c, d, e, f, and g.

In accordance with references, planning for the Conference, as well as follow-up of its suggestions and recommendations, is accomplished by a U. S. Army Human Factors Engineering Committee (AHFEC). The Committee has been composed of representatives of the Chief of Research and Development (Chairman), the U. S. Continental Army Command, and each of the U. S. Army Technical Services. In addition to the above representation directed by reference h, the Committee has been augmented since 1960 by regular participant observers (without vote), from the U. S. Army Personnel Research Office, a Class II activity under the jurisdiction of OCRD, the Human Resources Research Office (HumRRO), of The George Washington University, the U. S. Army Board for Aviation Accident Research (USABAAR) and the Army Participation Group at the U. S. Naval Training Device Center (USNTDC). The membership of AHFEC will be changed in the near future to reflect the recent reorganizational of the Army.

Purposes of the Conference are

a. To provide direct exchange of information on human factors engineering 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 Human Factors Engineering Committee to assure exploitation of all opportunities for improving man-machine compatibility in the design of U. S. Army materiel.

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 engineering research and development activities.

Following the invocation by Colonel Silas E. Decker, Post Chaplain, the Eighth Annual Conference was called to order in Theater Number 1, Fort Benning, Georgia, at 0900 hours, 17 October 1962, by the General Conference Chairman, Dr. Lynn E Baker, Scientific Advisor, Human Factors Research Division, Office of the Chief of Research and Development, Department of the Army. Registration of the conferees was accomplished 1500-2200 hours on 16 October at the Salerno Mess Billets where the majority of the conferees were quartered.

Major General Ben Harrell, Commanding General, U. S. Army Infantry Center and Commandant, U. S. Army Infantry School, welcomed the conferees and put the facilities of the Post at the disposal of the conference. The keynote address was delivered by Lieutenant General John P Daley, Commanding

General, U. S. Army Combat Developments Command. General Daley emphasized the urgent need for human factors engineering on the clothing and equipment of the combat Infantryman

The Conference Banquet was held at the Fort Benning Main Officers Open Mess at 1830 hours, 17 October. The After Dinner Address was given by Major General Harrell who stressed the Infantryman's role in the Army's over-all mission and gave a colorful summary of Fort Benning and its functions and facilities. Following General Harrell's remarks the conferees were entertained by the Infantry Chorus.

During the second day of the Conference, Fort Benning personnel put on a series of demonstrations to highlight the training, activities, weapons and equipment of the Infantry soldier. The field demonstrations included orientations on airborne, ranger, and leadership training, on river crossing techniques, on capabilities and limitations of ground mobility means, and on the display and firing of all weapons of the infantry battle group and brigade. These demonstrations were highly professional, sophisticated, and extremely well received by the conferees

Acknowledgements

This Conference extends to its hosts, the U. S. Army Infantry Center and the U. S. Army Infantry School and to Major General Ben Harrell, the Commanding General of our host agencies, our appreciation and congratulations for the outstanding manner in which the Conference was planned and conducted.

Specifically, the Conference wishes to record its appreciation to the following who toiled diligently for our comfort and convenience:

To Major George R. Henderson, G-3 Section, U. S. Army Infantry Center, for the excellent planning and the outstanding preparations for the Conference.

To Major Joseph Hall, G-3 Section, U. S. Army Infantry Center, who so effectively guided the execution of the plans during the Conference

To 1st Lieutenant Edward J. Shanahan, Jr , G-3 Section, U. S. Army Infantry Center who personally arranged the many administrative matters of the Conference and who was constantly in attendance as a gracious representative of our hosts.

To Major Paul Schultz, Office of the Provost Marshal, U. S. Army Infantry Center, who served in an exceptionally fine manner as our Senior Guide Officer.

To Master Sergeant John Kirkland, 72d Engineer Company, 1st Infantry Brigade, for his excellent and flawless service as our Chief Clerk.

Adjournment

The Conference adjourned at 1410 hours on 19 October 1962.

Forecast for 1963

The Annual Army Human Factors Engineering Conference now has a history of eight successful years. There are numerous indications that this series of eight conferences has contributed measurably to the maturation of the human factors engineering program within the Army. Under the recent reorganization of the Army, the Army's human factors engineering activities were conveniently and efficiently consolidated within the newly formed Army Materiel Command. Throughout the course of the past eight conferences, the scope of the conference has been steadily broadened to include research from other human factors groups not specifically engaged in human factors engineering. This procedure has promoted recognition of the interrelation of the varied human factors endeavors. Therefore, in view of past success and the existing propitious circumstances, the scope of the ninth conference, to be held in 1963, will be expanded to encompass the entire Army human factors program It is planned that the conference in 1963 will, in fact, be an Army Human Factors Research and Development Conference.

B. WELCOMING REMARKS TO THE EIGHTH ANNUAL ARMY HUMAN FACTORS ENGINEERING CONFERENCE by Major General Ben Harrell, Commanding General, U. S. Army Infantry Center and Commanding General, U. S. Army Infantry School, Ft Benning, Georgia

Dr. Baker . . . General Daley . . . and Delegates to the 8th Annual Army Human Factors Engineering Conference

It is a real pleasure for all of us at Fort Benning to have as our guests such a distinguished and important group of visitors And, I extend to each of you our very warmest welcome! Our entire Post and its facilities are at your disposal, and we sincerely hope that your visit will be enjoyable as well as professionally profitable. We rarely have the opportunity of meeting with a group that is so influential in developing the Infantryman's Weapons and Equipment.

The theme of this Conference - "The Infantryman, Invincibility on the Battlefield" - is especially meaningful to us at Fort Benning. In fact, it's the theme we live by 365 days of the year. We know that Infantry is the very core of our Army's combat strength. We know from past experience that the doughboy always carries the brunt of the Army's fighting and suffers the highest casualties. His job is the dirtiest, the hardest, and often the least recognized. Further, he must be prepared to fight anywhere in the world under any conditions of weather or terrain. He must be organized, equipped, and trained to play a major role in any kind of war, from guerrilla war to unrestricted nuclear warfare. It is precisely for these reasons that everyone at Fort Benning, considers your conference so important.

Following General Daley's address this morning you will hear a lot more about the modern-day Infantry from Colonel Short of the Infantry School. This morning I would like to spend the next few moments telling you about Fort Benning and some of its various functions and facilities.

Fort Benning is the hub of Infantry activity and the fountainhead of Infantry knowledge within the U. S. Army. It is the home of the Infantry Center, the Infantry School, and the 2d Infantry Division. The Infantry Center supports the Infantry School and the entire complex at Fort Benning. It furnishes all of the services for a military community of over 70,000 personnel, which includes soldiers and their families. In addition, it provides the maintenance and upkeep of all the facilities of the 183,000 acre reservation.

The famed 2d Infantry Division, commanded by Brigadier General Billingslea, is stationed here. This organization of 15,000 men is a highly trained, combat-ready division prepared now for any task that might confront us. It also renders valuable assistance to the Infantry School.

Also located at Fort Benning are the U. S. Army Infantry Board and the Combat Developments Agency The Infantry Board is responsible for evaluating and making recommendations on Infantry weapons, clothing and equipment, and other items under development. They are the ones who see how well you've done your work as design engineers The Infantry Combats Developments Agency, a subordinate element of General Daley's Combat Development Command, is also here The CDA, as we call it, is concerned with how the Infantry will be equipped and organized, and how it will fight in the future.

I'm sure you are aware that the Infantry Human Research Unit is located at Fort Benning. This Unit conducts psychological and sociological studies to gather data relative to training methods applying to the Infantry.

We have many other organizations here, such as the 1st Brigade, and the 151st Engineer Group, the Lawson Army Aviation Command, and Martin Army Hospital. But our most significant activity, to my mind, is the Infantry School.

It is here that we train the leaders and men of the Infantry. This is the largest military training institution of its kind in the world. In effect, it is a vast proving ground where Infantry Officers and Noncommissioned officers are made, trained and tested. Last year we had over 20 thousand resident students attending 16 different courses of instruction. Included in this number were over 472 Allied students from 49 different countries. These courses include branch training for Infantry officers, advanced courses for Infantry leaders, and specialist courses such as Ranger, Airborne, Communications, and Weapons training. Officer Candidate training for prospective second lieutenants of Infantry is one of the most important functions of the School. We also supported more than 275 thousand nonresident students from the Reserve Components and ROTC.

Our activities compare to those of a large university. The Infantry School employs the most modern teaching methods and techniques, and the facilities of Fort Benning are unmatched anywhere in the world for Combined Arms training. Our students from Allied nations come from as far away as Ethiopia and Indonesia, primarily to study our methods and to use them in their military schools.

In many ways our work here at Fort Benning is very similar to yours. Our primary concern is with men and their performance as members of Combat teams. Of course, we are concerned with equipment, particularly that used by the Infantry soldier, for his equipment and weapons must be the best available.

And since you are the people who can get us that good usable equipment, we are doubly happy to welcome you to Fort Benning. While you are here we are going to show you what Infantry does. We have arranged your schedule so you can see at least some of the various types of training conducted by the School. During these demonstrations I hope that you will notice the very high level of professional skill possessed by the Infantrymen who conduct them.

I hope you will leave Fort Benning with a clearer picture of the importance of the ground soldier and the vital role he always plays in any kind of war. I hope, too, that you will leave with renewed conviction of the importance of Human Factors Engineering as it applies to the Infantry soldier.

Again, welcome to Fort Benning, I hope your stay will be pleasant and profitable and that this Conference will be an outstanding success.

C. KEYNOTE ADDRESS by Lieutenant General John P. Daley, Commanding General, U. S. Army Combat Developments Command, Fort Belvoir, Virginia

General Harrell, Dr. Baker, Members of the Human Factors Engineering Conference.

It is particularly appropriate that we meet here at Fort Benning, the home of U. S. Infantrymen, and, indeed, the greatest Infantry Center of the Free World. It is peculiarly appropriate because the theme of this conference is the Combat Infantryman.

In words the theme of the conference is expressed as "Infantryman - Invincibility on the Battlefield." If you and I are to turn our attention, as we must, to help this man in his task, we must understand that task explicitly. Stated in Field Manual, 100-5, Field Service Regulations, this man's function is as follows

"78. Infantry Function

"a. The basic infantry function is to close with and destroy the enemy by fire and maneuver and shock action The essential characteristic of infantry close combat elements is the ability to fight on foot in all types of terrain and under all conditions of weather, coupled with the ability to move and fight with any means of mobility provided, either organic or attached."

To set this conference in perspective, I would like to look from the infantryman's task to yours. Your task as defined in Army Regulations is as follows.

"Human Factors Engineering—The application of scientific principles concerning human physical and psychological characteristics to the design of equipment, so as to increase speed and precision of operations, provide maximum maintenance efficiency, reduce fatigue and simplify operations."

Paraphrased then, the purpose of your task as related to infantry is simply.

Design equipment:
- to increase the speed and precision of infantry operations,
- to provide maximum maintenance efficiency for the infantry,
- to reduce the infantryman's fatigue,
- and to simplify infantry operations.

I propose this morning to explain to you briefly the Combat Developments Command and how we in Combat Developments attempt to provide the Infantryman the wherewithal to perform his functions. Secondly, I propose to point out to you some of the things which you can do to assist this man.

Many years ago, Cato, the Roman Senator, ended every speech with these words "Carthage must be destroyed." He demonstrated the value of repetition in or out of context. It is a lesson I have learned.

In every speech I make I keep driving home to every captive audience the fact that the mission of the Combat Developments Command can be summed up in these three questions

How should the Army be organized?
How should the Army be equipped?
How should the Army fight?

I have at each Army school a CD Agency and here at Fort Benning I have the Infantry Combat Developments Agency commanded by Colonel Eckland, whose task can be equally simply expressed How should the Infantry be organized? How should the Infantry be equipped? and How should the Infantry fight?

We in Combat Developments answer the question, How to organize units?, by producing Tables of Organization and Equipment. We answer the question on how to fight by producing Field Manuals. It is the third question that is of most interest to you conferees. How should the Army be equipped? We in the Combat Developments Command produce the Qualitative Materiel Requirements, QMR's which state in detail the equipment needed—in this case the equipment needed by Infantry. If you have never studied a Qualitative Materiel Requirement, I suggest you do so because in effect it is the contract between the Combat Developments Command and the Army Materiel Command for a piece of equipment, and a part of that contract is a statement of the human factors which must be considered in producing the equipment. This is the first opportunity for human factors engineering to influence equipment design. For example, here is the statement taken from a Typical QMR

<u>Extract from QMR for Lightweight, Self-Propelled 155mm Howitzer</u>

"10. (U) Human Engineering Characteristics. Human engineering is required to insure efficient operation of the weapon for extended periods of time without undue fatigue of the crew. Specifically

a. (Essential) Provisions for the crew to mount and dismount easily and safely are required. Seating, hand holds and foot braces are required for safety and comfort of personnel riding on the weapon while negotiating rough terrain. Provision should be made (seat belts) to enable personnel to operate individual weapons for defense while on the move.

b. (Essential) The driver compartment should provide maximum room for the driver to prevent fatigue from cramped quarters even while wearing arctic clothing.

An adjustable seat (with safety belt) is required Instruments and controls should be visible and accessible to the driver throughout the adjustment range of the seat.

c. (Essential) All dials, gauges, levers, control buttons, hand-wheels, etc., should be located to be easily read-operated by the individual required to control such items from his normal operating position.

d. * * * * * *.

e. * * * * * *."

The following are several examples of human factors engineering specifications taken from the Combat Developments Objective Guide. As you can see, one of these examples does not specify very much concerning the precise human engineering inputs which are required.

a. Reference CDOG Paragraph 238d(1) - Foxhole Digger (U)

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10. (U) Human Engineering Characteristics.

a. The device shall be of optimum simplicity in design and operation requiring the minimum human effort and intelligence in its operation.

b. The soldier should not require any external assistance in handling and using the device.

c. Environmental factors induced by the operation of the device should be within the requirements set forth in the performance and physical characteristics.

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b. Reference. CDOG Paragraph 237b(10) Heavy Assault Weapon System (U)

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3s. (U) Human Factors Engineering. Design in conformity with human factors engineering principles is required. More specific guidance on human factors engineering can be furnished after the system is better defined.

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c. Reference: CDOG Paragraph 237a(5) - Special Purpose Individual Weapon (U).

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16. (U) Hun [illegible] gineering. Human engineering is requ [illegible].

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We produce QMR's as a result of studies which are coordinated between the various Combat Developments agencies, for example, between the Infantry, the Ordnance, the Signal, and which in turn reflect lateral coordination with agencies of the Army Materiel Command, for example, with the Infantry Board or with the Munitions Command. By this coordination we attempt to insure that there is a proper statement of the requirement for human factors engineering. It is here that those of you connected with either the Combat Developments Command or the Army Materiel Command can first directly effect the adequacy of human engineering. You can make certain that an adequate statement of the required human factors engineering appears in the QMR.

When a Qualitative Materiel Requirement is approved by the Department of the Army and becomes an active project with the Army Materiel Command, then those of you working in the laboratories, arsenals, and other facilities of that command have a chance to directly affect the design of the equipment.

It is my hope that your visit here today and the demonstrations you will see tomorrow will make your Human Factors Engineering more realistic since you will have a better picture of the tasks facing the Infantry and the environment in which the Infantryman works.

I sometimes think that in our entrancement with Human Factors Engineering for major pieces of equipment, we have perhaps neglected our duty with respect to the simple, reliable, rugged, usually man-portable equipment that our Infantryman needs and deserves.

Several weeks ago at our Combat Developments Experimentation Center at Fort Ord, I asked an Infantryman who was charged with manning a small ground-search radar what he would change about the equipment if he could. The answer was quite frank: "General, it's got about six knobs on it. That's too many knobs to work from a fox hole. I think two would probably do." Quite frankly, gentlemen, this is a case of poor Human Factors Engineering. But with infantry equipment the task you face is really not [illegible]n that complex, because that radar is [illegible]tainly as complex a piece of equipment a[illegible] one would expect an Infantryman to have in the fore-front of the battle.

I suggest that we could afford some Human Factors Engineering, starting with the heel of the Infantryman's boot and stopping with the cap on his head. It is an unfortunate fact that we still send the Infantryman out to battle loaded with equipment which is too heavy, too bulky, not satisfactorily human engineered.

About a year ago in Mannheim, Germany, we loaded down a lieutenant with all the equipment he was supposed to carry. It was quite a sight. I happened to be the G-3 of USAREUR at the time. I took one look, turned to the G-1, General Lindeman, and said, "Obviously it is not an equipment problem. It is a personnel problem. We need bigger lieutenants." Unfortunately, gentlemen, the production of bigger lieutenants falls in the very long-range development cycle and we should do things to help today's [illegible]nfantry.

I would like you gentlemen to study the equipment that you will see the Infantry here at Fort Benning use in a battlefield environment. I urge you, individually and collectively, to consider whether or not there is any means for lightening the load that man carries. An ounce reduced here and a pound there can make a great deal of difference to the man who fights on foot. Ask yourself if all the wonders of modern technology cannot in some way reduce the load the Infantry carries. Ask yourself such simple questions as whether or not the Army's canteen is actually human engineered. Frankly, I doubt it.

The keynote to this conference is the Infantryman–Invincibility on the Battlefield. The challenge to you, gentlemen, is to assure that we have engineered that Infantryman's equipment for the Infantryman and have not tried to engineer the Infantryman for the equipment. In other words, your challenge is to insure that that Infantryman, when he goes into battle, has the support of every bit of engineering and scientific know-how that this country can produce. If you do your task, then in a small way you can share in the glory of the Invincible United States Infantry; the best human factors engineering for the finest infantry in the world--the U.S. Army Infantry.

D. INFANTRY DOCTRINE AND CONCEPTS by Colonel Walter D. Short, U. S. Army Infantry School, Fort Benning, Georgia

The Infantry welcomes the opportunity provided by this conference to put its views to you. General Decker, our former Army Chief of Staff, says concerning materiel design that, "It is the responsibility of the combat arms to establish requirements that embody the desired standards of simplicity and to demand that these standards be followed. Simplicity and directness are hallmarks of combat effectiveness—they are evidence of constructive imagination and thought, they indicate insight into the heart of the military problem." Therefore, we are also most interested in your views and the items on your agenda. I realize that the title of this talk should more appropriately have been "Infantry Psychological Patterns and the Ph   ·ena of its Conceptual Response" in the light of your scientific sophistication, but perhaps you will be able to find a few technical terms as we progress.

During the next 50 some minutes, I propose to discuss with you the missions of the Infantry, and to examine our organizational structures. Thereafter, we will see the general manner of the Infantryman's tactical operations that you may better visualize the environments in which he must operate. From this we will proceed to outline some of our equipment deficiencies, where perhaps you will be able to help us, and then we will examine the problems which we consider remain to be solved in regard to our organizations and their support.

As an instrument of war the infantryman has been declared obsolete many times since the decline of the Roman legion. In theory, over the years he has been replaced by many weapons developments from the armored knight to the first cannon, the tank, the airplane, the rocket and the nuclear weapon. But this is only in theory for the pages of modern history prove that this alledgedly obsolete footsoldier has played a critical part in every war. Even in the short span of time since the end of World War II we have seen this rifleman—or his Allied counterpart—fight in Korea, Malaya, Indo China, Greece, Laos and Viet Nam. And in each of these so-called "Small Wars" he has been the decisive element. But we are here to deal not with the past but with the Infantryman's role in the present and on the battlefield of the future. All of the Army's resources as well as many of those of the other Services exist to support the man on the ground. In the final analysis he is the most valuable asset in our Defense establishment. The Doughboy's ultimate job is still to close with the enemy by fire and maneuver in order to capture or destroy him---or to repel the enemy's assault by fire, close combat and counterattack.

To accomplish his mission our Infantryman must be capable of winning, in any area of the world under all environmental conditions as he fights a counterguerrilla operation, a limited war or an all-out nuclear war. He must be able to combat all types of enemy forces be they massed mechanized units or elusive guerrilla bands. He cannot be cast in a mold which allows him to fight only on the plains of Western Europe or the mountains and deserts of our CENTO friends—or only in the jungles of Southeast Asia. He must be able to fight anywhere. Moreover, he must be capable of quick deployment and be able to operate with austere logistical support and without a long and vulnerable administrative tail. Therefore our tables of organization and equipment must be designed with the specific idea of multicapability

As you all know, the Army is currently in the process of reorganizing its combat divisions under the ROAD concept. "Reorganization Objectives Army Divisions" is the translation of this acronym. The purpose is to give the divisions, and the division is the basic combined arms unit of the Army, a greater flexibility so as to achieve the multicapability we seek. There are four so-called type divisions Infantry, Airborne, Mechanized and Armored: the first three of which concern us most here at the Infantry School. I said "Type" because we will no longer expect to find a large number of identical units the size of a division, - some 15,000 humans. Rather, each division will be tailored to fit the characteristics of the theater of operations for which it is destined and the missions it is expected to accomplish. Each division is given a common division base. With minor modifications, such as increased maintenance support for mechanized divisions or an Air Equipment Support Company for an airborne division, this base is identical. It consists of a Division Headquarters, a Military Police Company and a Signal Battalion to exercise command and control. An Armored Cavalry Squadron exists to provide air and ground reconnaissance information to the commander. This organization is highly mobile and well armed so it can fight to get information. It has an air cavalry troop with helicopters and light aircraft.

The Engineer Battalion is invaluable in helping the combat elements to get forward. Its companies can demolish enemy obstacles, fix roads, build bridges or fight as infantry if necessary.

The primary fire support for the division is found in its artillery. The Division Artillary has howitzers and rockets capable of providing indirect fires of high explosives.

In addition to backing up the ground gaining elements with indirect fire support at ranges out to 39,000 meters, the division artillery provides the division with an organic tactical nuclear weapons delivery capability.

The Aviation Battalion exists to provide the division commander with a degree of air mobility—the newest dimension in Army operations. The 45 helicopters and light aircraft of this battalion will move a dismounted 175 man rifle company in a single lift. The battalion also has airborne radar, infra-red equipment and drones for target acquisition so the division commander can better employ the massive firepower of the new division.

The divisions administrative support elements—personnel, medical, supply, transportation and maintenance are found in the Support Command under the control of a single headquarters. The support command is a functional organization organized by activity rather than being compartmentalized by technical service, such as quartermaster, transportation corps, signal, and ordnance. This is a step forward as it provides the division commander with a single responsive operator and also lends itself to being readily fragmented to give balanced support to individual brigades as required.

Lastly, as part of the Common Division Base there are three Brigade Headquarters. The Brigade Headquarters is a command control facility with a capability of controlling and coordinating maneuver elements together with essential administrative support. The brigade headquarters, therefore, is a tactical control element and its capability of conducting military operations is bounded only by the type and number of maneuver elements, support elements, and other resources provided by the division to which it is subordinate. These resources would be provided in a mix appropriate to the mission to be accomplished.

To form a division we add to a common base, battalions of infantry, airborne infantry, mechanized infantry, light tanks, and tanks, in an appropriate mix. In the type infantry division there are 8 infantry and 2 tank battalions, in the airborne division there are 9 airborne infantry and 1 light tank battalion; in the type mechanized division, 7 mechanized infantry and 3 tank battalions. All three types of Infantry battalions have the same basic structure. Regardless of how they get there, when these various units get to the objective area they fight alike. We have a One Infantry concept.

Now that we have looked at the divisional organization we are ready to examine the infantry units of this combined arms team. Since man is the basic element of any organization let's begin by examining the fighting heart of our Service—the rifle squad. The squad leader and his men have in the two fire teams two modified M14 rifles of high cyclic rate of fire and two 40mm grenade launchers with a 400 meter range plus six rifles.

There are three rifle squads organic to all rifle platoons. We fight by fire and maneuver so to give these maneuver squads fire support, each rifle platoon is provided with a weapons squad. This is an 11-man organization armed with two M60 machineguns and two short range 90mm recoilless antitank rifles, the successor to the bazooka. The mechanized infantry rifle and weapons squads are each provided a personnel carrier. By combining the three rifle squads, a weapons squad and a control headquarters, the rifle platoon is formed.

To give rifle platoons additional fire support, a weapons platoon is provided. It is organized with a platoon headquarters, a section of three 81mm mortars, and an antitank section with two 106mm recoilless rifles. By combining the 3 rifle platoons, a weapons platoon and company headquarters, the rifle company is formed. The company headquarters is organized into a headquarters section, a ground surveillance section and in the mechanized infantry a maintenance section. The ground surveillance section contains two portable short range all weather radars, with line-of-sight ranges up to 6,000 meters. Commanded by an infantry captain, the rifle company is the maneuver element of the infantry battalion. From the rifle company we will proceed to the battalion.

To assist the battalion commander and provide support to the rifle companies, we have the headquarters and headquarters company of the battalion. The battalion ground surveillance section consists of two medium range radars, with line-of-sight ranges up to 18,200 meters. The communication platoon assists the battalion commander by providing radio, wire and message center service. An air control team is assigned to this platoon. The support platoon provides the battalion logistical support with its transportation, supply and mess sections. The maintenance platoon provides the necessary second echelon maintenance for vehicles within the battalion. The medical platoon provides treatment and is equipped with 6 front line ambulances to provide for evacuation of casualties. The battalion commander's reconnaissance element is the armored cavalry platoon. For fire support, the battalion mortar and Davy Crockett platoon has 4 mortar squads with 4.2 mortars having a range of 5,425 meters. It also has a nuclear capable light 2000 meter range Davy Crockett and two heavy 4000 meter range Davy Crockett weapons. The antitank platoon has three wire guided ENTAC missile launchers mounted on 4 ton trucks.

The headquarters and headquarters company, and the three rifle companies make up the Infantry, Airborne Infantry and Mechanized Infantry Battalions. You will recall that each type division contained one or more tank battalions. Our tank battalions are also organized with Headquarters Company and three fighting companies—in this case tank companies with 17 tanks. You know our mission and our new organization. Now let us see what is expected of our Infantry battalions in combat.

In a war against a major power employing regular forces the tactical employment of our infantry battalions, our basic tactical units, may be described under the general categories of offense and defense. As we discuss the tactical doctrine of the United States Infantry, it is well to remember that Soviet tactical doctrine also emphasises firepower and mobility. The Soviets apparently are prepared for tactical nuclear warfare. They are attempting to mechanize nearly everything that fights and at the same time they are stressing air mobility. This threat we must be able to counter if war were thrust upon us.

In the offense the battalion may be employed in a movement to contact, as the covering force, advance guard, flank guard, rear guard, or it may move as part of the main body. When contact is made the battalion may be all or part of the main attack of a brigade, the supporting attack or the brigade reserve. In the attack of an enemy position, the battalion may conduct a ground envelopment or an aerial envelopment. It may also participate in a penetration where we pierce a soft spot in the enemy lines, to seize a deep objective and divide the enemy forces. In conducting an envelopment or penetration the battalion may employ infiltration techniques.

The missions assigned to the battalion and the method of employment will vary with the mission and organization of the brigade to which attached. For example, a mechanized infantry battalion in an armored division will normally be employed to support the advance of tank elements, whereas in an infantry, airborne, or mechanized division, the tanks will normally be used to support the advance of infantry elements. However, all commanders must gear their actions to the mission of the higher headquarters, and not be reduced to thinking in terms of one particular type of operation or one form of mobility. In the defense, as in the offense, the battalion when operating attached to a brigade may receive additional combat power through the attachment of rifle, tank, or armored cavalry units.

The battalion may be employed in any one of three echelons of defense. It may be employed in the security echelon, in the forward defense echelon, or in the reserve echelon. At times the battalion may be employed as all or part of the covering force of a higher headquarters, or a rear area security force.

When the battalion conducts the area defense as part of a brigade, it organizes its defense oriented toward the retention of specific terrain. Forward positions are strongly organized and emphasis is placed on stopping the enemy forward of the battle area, with penetrations destroyed or ejected by counterattack and the control of the forward defense area regained.

Our tactics also envisage the conduct of a mobile defense by our corps and divisions. This is a more fluid form of defense wherein minimum forces are employed in the forward area and the retention of specific terrain is subordinate to the execution of counterattacks by strong mobile reserves. When the battalion participates in the mobile defense, the primary differences are that the forward battalions will often conduct delaying actions while a greater number of battalions will be involved in the counterattacks of the division reserve.

Although I began my discussion of tactical operations with what you might call the traditional type of war, the Infantry is well aware of the threat posed by communist inspired insurgency movements. We are leaving no stone unturned in our efforts to train our men to fight guerrillas. Of course, in counterinsurgency operations we recognize that counterguerrilla tactical operations are only one aspect of the problem. Concurrently, certain policies must be implemented at the governmental level of the country involved aimed at eliminating the causes for the growth of discontent with resultant communist exploitation. The small unit commander must be knowledgeable of the overall programs designed to accomplish these political/economic aims and the role of his unit in their implementation.

Even the rifle company commander is a strategist in this type war where the best strategy for one locale will differ from that of another not only because of the guerrilla strength and type terrain present but also due to the density of the civilian populations and their varying attitudes, political traditions, and economic environments. Adapting to the location situation is essential for a unit both prior to and during counterguerrilla operations.

Here is how we are teaching that an Infantry brigade might be involved in a specific counterguerrilla situation. Visualize, if you will, that a certain area is under effective control of the hostile guerrilla force; and that an adjacent area is under the effective control of neither combatant except for small areas occupied by troops or civil defense elements. In order to simplify this tactical example we will assume that the civilian population is sparse and is largely apathetic or friendly to our cause. The brigade commander places the majority of his combat power in the area where the guerrillas must be located and destroyed. In the adjacent area, the commander feels that the main effort will be directed to civic assistance and police operations including the security of installations, communities and lines of communication as well as population control.

Companies and larger units are assigned definite sectors of responsibility in the guerrilla dominated area, and a priority for clearance of sectors or subsectors is established. Now the guerrilla force must be located. First we would prefer that our clandestine intelligence effort be good enough to find the guerrillas—and we will certainly strive for such efficiency but we cannot realistically expect such results. So we must also employ continuous aerial surveillance, patrols, ambushes and hunter/killer teams. A high priority is given to locating the guerrillas outside sources of supply and shutting them off.

Within its sector, each company maintains a reaction force of a platoon at its combat base, the battalion two platoons and the brigade a battalion task force. These forces must have priority for use of all Army transport aircraft. When a guerrilla force is located, one or more of these reaction units is moved immediately to the area to finish off the enemy. When possible, an encirclement is effected, if time or forces are insufficient a pursuit is launched. The key is rapid violent reaction with adequate combat power to destroy the guerrilla element. This is a pre-eminently infantry effort wherein the entire, massive effects of the other arms and services can rarely be brought to bear.

This has been a brief and over-simplified visualization of counterguerrilla tactics. Once the local strategy is determined we find that while the tactical principles for conventional operations have a general validity, their application against an irregular enemy with little interest in the securing or retention of terrain differs markedly. But, we are sure that a rifle squad or platoon trained to defeat guerrillas will have no equal on any other battlefield.

Here are the primary areas which we believe will require increased emphasis in counterguerrilla operations:

(1) Training motivation of troops and tailoring of TOE units for the specific mission to be accomplished.

(2) Continuous and accurate intelligence.

(3) Detailed planning of small-scale decentralized tactical operations.

(4) Continuous orientation of the operation on the separation of the guerrilla forces from support and supplies, on the destruction of the enemy guerrilla force, and on the removal of the primary cause of the resistance movement.

(5) Gaining and maintaining a mobility differential over the enemy primarily through the use of airmobile and airborne forces.

(6) Provision of civic assistance to and effective control over the civilian population.

Having discussed our Infantry mission, organization and tactics, you are doubtless interested in our ability to do all these things, particularly from the standpoint of our equipment. When we examine the Infantryman's weapons, we find some good areas and some areas where we have failed to provide adequate means. First of all, we are generally satisfied with the M14 rifle, M60 machinegun, and the M79 grenade launcher. These are excellent weapons providing a good close-in firing capability.

Only in one area in the small caliber field do we have a serious deficiency. The caliber .50 machinegun does not meet the Infantryman's requirement for a mounted automatic weapon. What we need, of course, is a simple and somewhat larger caliber machinegun which is effective at long ranges against materiel, personnel and air targets. It is hoped that one of the 20mm systems now being tested may at least partially answer these requirements.

In the antitank field we find one of our most notable deficiencies. We have a good weapon - the LAW, effective at ranges up to 250 meters. It is packed in a telescoping tube which is both a packing case and a "throw-away" launcher. It is carried by the troops when required and we are satisfied with its capabilities.

The same cannot be said of our medium and heavy antitank weapons. The M57, 90mm recoilless rifle is our current platoon level weapon. Unfortunately, it needs too many people to carry it with the required ammunition, and its range is too short. We need a platoon weapon a soldier can carry with him wherever he goes and use it to kill a tank at ranges up to 1000 meters.

The current heavy antitank/assault weapon for the rifle company is the 106 mm recoilless rifle which is not hand-portable. The ENTAC, our current battalion-level weapon, is a wire guided missile. It offers improved accuracy over recoilless systems at the longer ranges, however, poor performance in the assault role, slow rate of fire, expensive gunner training, and potentially degraded performance in a battle environment make it undesirable. What we need at battalion level is a heavy antitank/assault weapon which can deliver accurate fire against a variety of targets at all ranges to 2000 meters and which does not exceed 200 pounds in weight. Our Infantry antitank weapons must be oriented towards the offense and this requires mobility.

When we examine the organic indirect fire support provided to the doughboy we find that the 81mm mortar in the rifle company and the 4.2 mortar at battalion are both excellent weapons. Additionally, development is proceeding on improved, lighter models with an increased range capability.

The Davy Crockett is, of course, a relatively new weapon for the doughboy. Although the Davy Crockett does add a nuclear dimension to the Infantryman's firepower, the weapon does have several disadvantages, including the signature effect, lack of crew portability, and limited range and yields.

When we look at the Infantryman's organic air defense weapons, we find that they are totally inadequate. At present he has only his ground weapons and the caliber .50 machinegun. The Redeye has been developed to provide an active air defense capability to the Infantryman, however, this weapon is still undergoing tests and may not be in the hands of combat units for sometime.

There is one other type weapon available for Infantry support which deserves mention. This is the armed helicopter which we find organic to the ROAD division. This weapon system includes the use of either machineguns, rockets, or antitank guided missiles mounted on utility helicopters. It is anticipated that the airborne weapon system will be particularly effective against tanks, APC's, personnel, bunkers, and other similar targets. However, it should be remembered these aerial weapons platforms are not a substitute for and do not duplicate the close support aircraft required from other sources.

In summary, the Infantryman has good small arms, an excellent close in antitank weapon and indirect fire weapons in the inventory or under development which meet present and future requirements. An effective large caliber machinegun, organic air defense weapons plus medium and long range antitank weapons are not now available. Our weapons development program needs emphasis in these areas, and for the Infantryman, we feel that the human factors engineering aspects play a key role.

Let us now consider the Infantryman's ability to move; first, by foot. With all of his equipment our soldier is loaded with over 90 pounds of clothing and equipment. He is not very mobile. Unfortunately all of his gear is essential in some phase of his combat operation and it or its equivalent must be available to the Infantryman. This is one area - lightening the load and still providing the needed items - where a real breakthrough in equipment and support techniques is needed. We are hoping you can assist us here.

When we speak of lightening the Infantryman's load, this inevitably brings us to the subject of ground vehicles. Certainly one way of lightening the doughboy's load, as well as allowing him to move rapidly on the battlefield is to provide him with a vehicle which will carry his crew served weapons, ammunition, and supplies wherever he must go including swamps, mountains, jungle, and other difficult areas. When you objectively examine our present and future ground vehicle inventory, you can see why we are far short of our goal. Our wheeled vehicles are little better than those we had ten or fifteen years ago. They are bigger, heavier, more difficult to maintain, cost more, and consume more gas. And their capabilities have not increased proportionately. We are still quite roadbound with our wheeled vehicles

Although our tracked vehicles have greater cross-country mobility, their logistical support is still dependent on wheeled vehicles. Even our tracked cross-country mobility is not all that it should be. The armored personnel carriers and tracked reconnaissance vehicles have been armored at the expense of reduced maneuverability and increased gasoline consumption. Protection should be considered only after the required mobility has been achieved.

In summary, we are far from satisfied with current or proposed ground vehicles. Their complexity and gasoline consumption places a heavy maintenance and supply burden on our combat forces, while their use is restricted in far too many potential battle areas. What we need is a simple, durable, lightweight economical vehicle—tracked, wheeled or zero ground pressure—which can move the Infantryman and his equipment to the final objective in any part of the world - truly multicapable.

In the field of air mobility we are somewhat better off. We are generally satisfied with the types of helicopters programmed to be available in the Infantry division; however, in numbers, there is room for improvement. Looking to the future we hope to see an increase in the lift capability particularly within the Infantry division to improve its potential for airmobile operations. In addition, we see a long range requirement for increased airborne fire support. In the overall picture we expect Army aviation to play an increasingly important role in future operations.

A thoughtful look at our Infantry communications equipment leads to some uncomfortable but inescapable conclusions. We are able to communicate with a man in orbit around the world; yet we have not equipped our leaders in rifle companies with the much less sophisticated radios they require to exercise effective control of their men. The rifle company commander, who must be ready to direct his unit in dismounted operations, no matter what the terrain, lacks a radio that can meet his needs with respect to range, reliability and size. Although the new family of radios, now in a drawn-out distribution phase, doubles the range and reduces the bulk in Infantry vehicular radio sets, this family constitutes no significant improvement in range or weight in the man portable models necessary for Infantry company operations. Perhaps single sideband equipment more contemporary to that widely employed by business and "ham" operators will answer the Army's needs. But at present, one cannot avoid the conclusion that current Infantry communications equipment, as well as some of that now scheduled for production falls significantly short of the state of the art.

Turning to the electronics field, in any Infantry surveillance device we require accuracy, durability, light weight, an IFF capability, simplicity of operation, and maximum possible immunity to ECM and weather extremes. In addition, our systems should overcome the limitations of line-of-sight surveillance and the power sources for surveillance equipment should be standardized and simplified. The short range radar currently organic to the rifle company is rated as having the ability to detect a walking man up to a range of 1500 meters and moving vehicles up to a range 6000 meters. However, this equipment is heavy, complex and quite fragile. Additional limitations are that it produces excessive operator fatigue and provides line-of-sight coverage only. The medium range radar organic to the battalion can detect to a range of 4400 meters and moving vehicles up to a range of 18200 meters. However, it also is heavy, complex and fragile. In summary, we have made just enough progress in the development and employment of Infantry surveillance equipment to whet our appetite with regard to its potential.

To review our position, we are generally enthusiastic about the multicapability envisaged under the ROAD organizational concept. However, we believe that, not only are we faced with certain deficiencies in our weapons and other hardware which must be overcome, but that certain problems still remain to be solved with regard to our organizational structures.

From our discussion to this point I am sure it is apparent to you that we accomplish our missions by fire and movement; and for this to be efficient and effective it must be controlled, and directed towards decisive points, which requires enemy information. Also, any unit, from squad to field army, requires enemy information. Also any unit, from squad to field army, requires administrative support to accomplish this objective and certainly Infantry units require a lot of combat support. Finally, all of these functions require trained individuals and units. Therefore, we operate on the premise that fire and movement are the basic elements of battle and that their application requires the other four—control, information, support and training. They are the basic ingredients which must determine our operational concepts. When their relationship changes so should our concepts which we express in organization and doctrine. A material increase in the effectiveness of anyone of them will not alter our concept when it is considered by itself. On the other hand, such a change should cause us to examine our current doctrine and organization with a view to developing new concepts which would then be reflected in modified organization and doctrine. Or in other words, have we related the use of these basic elements to each other in such a way as to best accomplish our objective?

Obviously, they should be in balance with each other, and no gaps should exist in any one of them. When they are out of balance and gaps do occur, our materiel development program should then be directed towards filling such gaps, and to bringing them back into balance. However, such programming should be done in conjunction with our examination of doctrine and organization; or else we will never develop really new concepts. With these points in view, we continually study the six so-called ingredients. Today the obvious conclusion is that firepower is greatly out-of-balance with control, mobility, and our means of acquiring enemy information.

At the present time, we are not able to control all of our available conventional firepower, much less the nuclear. We also lack the tactical mobility to exploit its effects, and, in the case of Infantry firepower, adequate means to move it. And everyone will agree that our surveillance and intelligence system is far from being able to provide us with adequate target acquitition. Yet, even with the devastating firepower represented by today's warheads and improved munitions, we still find one critical gap in the antitank weapons field.

In the ROAD division organization great strides have been made in capabilities in the field of administrative, logistics and combat support but little has been done to make it responsive to the user. This is because the user has too little means to ask for it; while too often the provider has no rapid way to deliver it. So again, the need to beef up mobility and control to bring them into balance with support capability, particularly administrative, becomes apparent.

Finally with respect to training we feel that our methods are sound but that we must continually look for ways to get maximum participation in realistic training oriented towards the battlefield rather than our garrison posts.

Therefore, we conclude that our major problems (where we believe Human factors engineers may be able to help us) are to increase our means of mobility, to make more effective our control—which in hardware is represented by communications, to seek better ways to get information about the enemy, to close the gap in antitank weapons, to make combat and administrative support more responsive, and, finally, to improve training We are working hard to find the answers and, tonight, General Harrell will describe for you some proposed solutions

Over the past hour we have taken a close look at the Infantryman his organization, weapons, equipment and doctrine. We have pointed to his needs for improved antitank means, air defense weapons, mobility, communications and electronic equipment. We have also looked at the doctrinal and organizational areas where problems exist which when solved will maximize the capabilities of the ROAD divisions.

However, I most emphatically do not wish to undermine your confidence in the current combat capability of the Infantryman. He is ready, willing and able to move quickly to any part of the world to fight any type of war at any time. He can be counted on to do his job as a part of the combined arms team of your Army living up to his proud tradition as a prime defender of this nation.

E. BANQUET ADDRESS by Major General Ben Harrell, Commanding General, The U. S. Army Infantry School, Fort Benning, Georgia

Dr. Baker, General Daley, distinguished members of the Eighth Annual Human Factors Engineering Conference. When General Beach asked me to appear before you tonight, I ecognized at once that your theme for the Conference—the Infantryman—and this group's dedication toward improving his effectiveness, created an opportunity to be heard that the Commandant of The Infantry School could scarcely pass up. With this in mind, I set about preparing my remarks

I am delighted to have the opportunity to discuss some of our Infantry problems with such a highly qualified audience. We at Fort Benning have a great deal in common with this group. You are concerned with the application of scientific principles concerning human physical and psychological characteristics to the design of equipment. You strive to increase speed and precision of operations, to provide maximum maintenance efficiency, to reduce fatigue, and to simplify requirements. Success in this area makes a great contribution to the combat effectiveness of the individual soldier. Our mission as professional soldiers of the combat arms is an extension of your task. We must shape the soldier and his weapons and equipment into combat units which will win on the battlefield. In the final analysis, we are both vitally interested in the performance of the individual soldier.

I realize, of course, that the combat effectiveness of our Army is reflected in the sum total of our country's resources for national security and in the way these resources are distributed and brought to bear on the task at hand. Schematically—we might indicate our military power this way. Obviously, our potential depends on our ability to produce more than that required to sustain our people. And, then, after reaching this production goal, there must be some personnel left to man our Armed Forces. We would hope that our production base and our Armed Forces would be in balance as to their capabilities and size. I don't necessarily mean that the entire effort of the Navy and the Air Force is in a supporting role, but no one would deny that the Army does require their support. Finally, I have divided the Army into the basic maneuver elements which are charged with seizing, holding, and controlling a piece of ground, and the elements, both combat and administrative, which support them. I have not intentionally omitted our respected friends, the Marines. They fall in the same category as does the Army.

I should like to think that all of these elements are in perfect balance—that we have distributed our resources in such a way that when each element is one hundred percent effective, then their sum, our total power, would also be one hundred percent effective. Certainly, we don't want some elements to have a greater effectiveness than required while others fall short. This is a problem for our masters in Washington. But I do believe that we must leave nothing undone to make our part, the frontline soldier, as effective as possible.

The experiences of World War II and Korea leave no doubt that our combat units were not nearly as effective as they should have been, particularly when we consider the high caliber of men and equipment found in them. As indicated—according to many experts—their combat effectiveness in World War II and in the Korean War probably did not exceed twenty percent of their full potential. The figure of twenty percent itself is not important—what is important is that our combat units have never been as effective as they can and should be. Also, I am certain that the effectiveness of our combat units was considerably less than that of the other elements behind them, both the administrative and combat support units of the army, as well as the other elements of national power shown on my chart. I am sure we will all agree that when these maneuver elements are in a position on the ground to control it and its people, we have realized the full results of our national power. Therefore, it seems ridiculous to spend billions of dollars in our factories and in the maintenance of our defense forces in order to support a twenty percent effective combat force.

In my opinion, the overriding reason we failed to realize our full combat potential was not due to the quality of our manpower, nor the lack of equipment, nor even the type of equipment but rather was due to our failure to control men and equipment properly.

Tonight, I should like to discuss control for a few minutes and suggest some aspects of it which merit further study and investigation by interested and qualified people such as yourselves. At the combat unit level—that is at the battalion and lower—effective control means to me that each individual is pulling his fair load. This results in our being able to place our firepower where we want it, when we want it, and to move quickly and decisively to exploit its effects. Effective control—especially control of combat units on the battlefield—is not something which occurs automatically simply because we have good equipment and good men. It is, rather, the product of superior leadership, workable communications, sound organization, and effective training.

All of these elements are highly important, but tonight I shall confine my remarks to the last two—namely, organization and training. By so doing, I don't deny for one minute that new and better equipment won't help tremendously in the matter of control. Exactly the opposite is true. This morning, Colonel Short discussed equipment with you in some detail. He pointed out areas of strength and weaknesses, and he cited the great progress we are making in mobility, especially air mobility. Increased mobility alone makes for much better control; for example, it improves our reconnaissance and surveillance capability, which in turn makes it easier to direct our efforts with more precision and intelligence. Moreover, greater air mobility will permit us to develop new operational concepts which will no longer require the combat soldier to do anything or carry anything on his back which can be done or carried for him by support units to his rear. We are also getting some fine new communication equipment. The new family of lightweight radios will help control immensely. In all of our weapons and equipment, we are striving, with your help, to get material specifically designed to meet the requirement of the soldier rather than trying to adopt our thinking and our men to match the equipment.

I don't have time tonight to talk about leadership and its great impact on control. Suffice it to say that we are doing our best to make improvements in this area. I am happy to say that, in my opinion, our army has never had better leaders. This is particularly true in our junior officer ranks and in our noncommissioned officer corps.

Therefore, recognizing these things, what steps should we take about our organization to improve control? For one thing, we should look for better ways of transmitting instructions and information to the soldier. As a corollary to this, we must search for easier ways to supervise him. What I am saying, in reality, is that we should study span of control and unity of command—the two organizational principles involved here—to see if they can't be improved.

Secondly, we can certainly reduce the number of tasks assigned to the combat unit and the combat soldier. Today, he is expected to be a jack of all trades when he obviously should be a master of only one. We should concentrate on homogeneous assignment and training. Our new and improved equipment—if it is designed properly and if we use it intelligently—can help in this respect. And, as I noted earlier—relieving the combat soldier and the combat unit of administrative and support chores, will place emphasis where emphasis belongs—fighting in combat and training in peace.

Finally, allow me to talk for a few minutes about training. I don't have to prove to this audience that a poorly trained unit performs ineffectively in combat, and that this adds immeasurably to the already difficult problem of control. Our greatest weaknesses in training do not lie in our training methods, in our training facilities, or in our training equipment. These are generally acceptable, although improvements can and should be made wherever possible. And there is no shortage of good officers and good noncommissioned officers who know their stuff and who are capable of conducting effective training. Our greatest weakness lies in team training.

Can we really have an effective system that can be efficiently operated with highly trained individuals who have never operated as a team. The answer is yes, in some areas. This is possible, for example, where the weapon is the airplane or the missile, in which the system itself is largely composed of mechanical elements requiring skilled technicians. Here the problem is one of marrying the individual up with the equipment. But I don't think you can ever transfer this type of training to the rifle squad, platoon and company. The individuals themselves are the actual instruments of power—soldiers seize objectives, defend critical terrain, and work together to provide their own fire and maneuver. They must be trained to fight together as a team. This, of course, is our primary responsibility.

However, it would be interesting to have your evaluation of how much more effective an Infantry Squad that has really trained as a team would be over a squad that has just been thrown together. Further, it would be interesting to know how much team training you feel is actually required for our combat units to achieve a really acceptable level of combat effectiveness, and once this level is reached, how much training you feel must be done to maintain it. You should recognize, too, that our team losses are high in combat, and such a study should include whether or not replacements should be assigned to and trained with the squad or team. In the Army we call such replacements, fillers.

I don't think we would be far off by comparing our combat unit to a football team. Certainly our squads should have the same opportunity to develop as a team as the Green Bay Packers do. I'm sure that Vince Lombardi wouldn't dream of taking a bunch of players who have never seen one another before and put them together on Sunday afternoon for the first time no matter how proficient they might be as individual runners, blockers, or tacklers. Also, I can't see Lombardi putting in a man who has never practiced with the team to replace someone who has been hurt.

My point here is to emphasize the importance of team training in any endeavor where the key ingredient is man. This applies to Infantry Squads and platoons with the same vigor that it applies to football teams. We of the Infantry are keenly aware of this requirement, but I should point out that it requires resources and effort, and should be considered when the overall distribution of national resources is made.

In summary, I am proposing that we give our organization and training some very careful thought and study—that we conduct research into these areas to determine whether they require more effort and resources We must make our end product—the ground combat unit—at least as effective as the tremendous and costly effort behind it. I know that the research and study I have suggested may not fit neatly under the heading of human factors engineering, but I cannot help but think that this highly qualified group could find ways to help solve these problems. I can assure you that we here in the Infantry School and those in General Daley's Combat Developments Agency here will welcome all the help we can get. Tomorrow you will see a number of demonstrations conducted by personnel of The Infantry School. In a very real sense, what you will see is the final extension of this country's power—the ground combat soldier in action. Ground combat is essentially a struggle between human beings—not machines—and in this environment, the Infantry always rules supreme. Anything that you can do to help the Infantry Soldier in his difficult, lonely, dirty, and dangerous job will be appreciated.

CHAPTER 2

DESIGN FOR THE INFANTRYMAN
CONFERENCE SESSION II-A

A. EVALUATING PROFICIENCY IN THE USE AND MAINTENANCE OF INFANTRY WEAPONS Thomas F. Nichols and Joseph S. Ward, U. S. Army Infantry Human Research Unit, Fort Benning, Georgia

B. INDIVIDUAL CBR PROTECTIVE CLOTHING UNDER SIMULATED COMBAT CONDITIONS. Edmund G. Cummings, U. S. Army Chemical R&D Laboratories, Army Chemical Center, Maryland

C. EXPERIMENTAL DESIGN FOR USER REVIEW OF CAMOUFLAGE FOR THE INDIVIDUAL COMBAT SOLDIER A. H. Humphreys and David L. Gee, U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia

D. HUMAN FACTORS AFFECTING RIFLE ACCURACY IN AUTO AND SEMI-AUTOMATIC FIRE (Abstract) James P. Torre, Jr., U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

E. OPERATIONAL ASPECTS OF INCAPACITATING AGENT BZ (Abstract). Richard S. Kneisel, U. S. Army Chemical Corps School, Fort McClellan, Alabama

F. MANAGEMENT OF THE U. S. ARMY HUMAN FACTORS ENGINEERING PROGRAM FOR THE PERSHING WEAPON SYSTEM John R. Erickson; U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

A. EVALUATING PROFICIENCY IN THE USE AND THE MAINTENANCE OF INFANTRY WEAPONS by Thomas F. Nichols and Joseph S. Ward, U. S. Army Infantry Human Research Unit, Fort Benning, Georgia

INTRODUCTION

The systems approach, including systems analysis and system engineering, is widely used as a useful modus operandi in the development of solutions to human engineering problems. For optimal design, a complete descriptive model of the system is essential. Such a model relates inputs, outputs, and system states in time. Design for the Infantryman, therefore, requires a special knowledge and understanding of the missions and the tasks assigned to Infantrymen during combat operations.

Since military systems are designed to accomplish missions, the nature of the mission determines the nature of the system. The Infantryman's basic combat mission is to take and to hold ground. This requires him to close with the enemy by means of fire and maneuver in order to destroy or capture him or to repel his assault by fire, close combat and counterattack. The nature of ground combat is essentially that of a duel between active, alert, and skilled opponents. Success demands continuously changing patterns of adjustment and readjustment from individuals and from units. Infantry combat is thus primarily a man function rather than a machine function. Consequently, most systems which include Infantrymen as human components are man-ascendant rather than machine-ascendant systems. What are the implications for human engineering design for the Infantryman? Since man is the heart of such systems, it is vitally important to ensure that the weapons and the equipment designed for use by Infantrymen enhance rather than hamper the application of human skills and knowledges to the successful accomplishment of ground combat missions.

Adequate description of a system must include those operations which are critical to the desired outputs of the system. For the Infantryman, it is necessary to know the specific performances required of him in the successful accomplishment of assigned missions. Task RIFLEMAN, a research effort conducted at the U. S. Army Infantry Human Research Unit here at Fort Benning, has developed and published a detailed job description in terms of the critical combat skills, knowledges, and performances required of the Light Weapons Infantryman (LWI) as a minimum but adequate preparation for ground combat. Although prepared primarily for use in the development of training, this comprehensive set of performances which define the behavior required of the Light Weapons Infantryman in combat is a prime source of descriptive information essential to successful human engineering design for the Infantryman.

Traditional human factors engineering strives to permit human beings to perform their functions most easily and reliably within the performance context of the particular system under study. The ultimate criterion performance context for systems involving Infantrymen is that of actual ground combat. Somehow or other, the ecology of Infantry combat must be kept in mind during the design of weapons and equipment for the Infantryman and must be represented with all possible fidelity during the evaluation of items designed for use by Infantrymen.

Task RIFLEMAN faced the problems involved in the simulation of ground combat conditions in the course of a recent assessment of the combat proficiency of graduates of the 16-week training program for the Light Weapons Infantryman. A realistic series of job samples was incorporated in a tactical exercise which provided for the scoring and the rating of individuals in terms of standards of performance based upon the actual situations and conditions which prevailed during the evaluation. This work, hopefully, may serve as a useful model for consideration by human engineers concerned with the evaluation of items designed for the Infantryman.

First, I shall describe the development of the combat job description and give you some idea of the scope of its content. Then I shall describe in detail the evaluation exercise used to assess proficiency on selected critical combat performances.

INFANTRYMAN COMBAT PERFORMANCES

Back in 1958 Task RIFLEMAN set out to develop a job description of the combat performance requirements to be met by the Light Weapons Infantryman should he engage in combat in 1962. This description of minimum requirements was a necessary prelude to the design of proficiency tests and th development of more effective training.

Such a job description had to be developed by experts whose knowledge, information, and body of experience constituted an assurance that they would be able to provide us with a meaningful one. We could use a single military expert for this if we could be assured that our choice was correct. To do this we would need to know (1) his degree of reliability which is the relative frequency of cases in which, when confronted with a number of alternative hypotheses, the expert ascribed a greater personal probability to the eventually correct alternative than to the others, and (2) his degree of accuracy which is the correlation between his personal probabilities and his correctness in the class of those hypotheses to which he ascribed this probability. Since all the relevant background data necessary for determining the choice of a single expert was not available, the decision was made to utilize a number of experts with each functioning as a check on the other. These experts acted as a single group, pooling their knowledge of a subject through a series of conferences and discussions, eliminating discrepancies in open debate, and attempting to find solutions satisfactory to all.

Each of the experts was an experienced military man who had taken part in aggressive actions against the enemy in World War II or the Korean Conflict and who was familiar with the training products of Basic Combat (BCT) and Advanced Individual Training (AIT). The members of this group studied and recorded their analysis of the combat duties of the LWI in a series of papers. This analysis was based on a conceptualization of the 1962 battlefield, the tactical utilization of the different weapons the LWI would operate, a study of current editions and drafts of relevant field manuals, training manuals, Army Subject Schedules, Army Training Programs, and relevant combat experiences. Groups of experts worked on different aspects of the combat job, formulating skills, knowledges, and performances for that job, and preparing papers which were reviewed by other members of the group. Differences were reconciled through solicited comments from other experts. Final papers produced on a given job were subjected to "murder boards" in which all members of the group made suggestions for changes. These papers were then revised to reflect consensus of the group and the other experts and submitted to the U. S. Army Infantry School (USAIS) for review and comment. Representatives of USAIS and Task RIFLEMAN reconciled their differences and the final statement of the skills, knowledges, and performances was produced. The end result was a set of skills, knowledges, and performances which comprised a detailed job description of the minimum requirements necessary for the LWI to perform effectively in combat.

Published in January 1961 by the U. S. Army Infantry Human Research Unit, Fort Benning, Georgia, as Research Memorandum Number 23, this job description is offered as a source of detailed information on what the Infantryman does in combat. Although directed specifically at 1962, the 41 subjects and the 102 performances described are considered to have continuing validity contingent upon the development and the issuance of new weapons.

EVALUATION OF COMBAT PERFORMANCES

In order to focus research efforts on those performances which were most directly related to combat and which were also most in need of improvement, two selective criteria were applied to the 102 performances specified in the job description. First, 13 RIFLEMAN staff members, who were combat veterans and who had participated in the development of the requirements for entry into combat, chose the 60 performances the thought to be more directly related to combat missions than the others. They then applied the same criterion to rank order these 60 performances.

Next, 50 members of a Strategic Army Corps (STRAC) division, all combat veterans familiar with the abilities of AIT graduates, arranged the 60 performances in order of need for improvement.

The 13 performances which rated highest on both combat relatedness and need for improvement were selected as the core elements of a combat proficiency test.

The next step was to devise an evaluation exercise which would incorporate the selected combat skills performances in a series of combat-like situations and provide objective measurements, ratings, and observations. This evaluation exercise was designed to simulate the first day of combat which might be experienced by an individual replacement at the end of 16 weeks of training. The vehicle for providing individual performance measures was a combat squad consisting of four trained actor squad members and an actor squad leader. Four AIT graduates completed the squad; two were assigned as riflemen and two as automatic riflemen.

Subjects (1) were received, oriented, and assigned at division, battle group, company, and platoon levels of command, (2) were taken on a 10-mile road march in battle gear, (3) ate field rations, and (4) conducted night security guard duty. The five actor members of the squad functioned as experienced squad members who, according to plan, moved the subjects through the exercise, issued and relayed orders, fired weapons, provided realistic combat cues by their actions, and assisted in safety control during live-firing situations.

Live-firing portions of the evaluation were scored individually in terms of hits, targets presented, targets fired at, and rounds expended. Each man was rated in various situations on such tactical considerations as use of cover and concealment, choice of firing position, skill in maintaining formation, and ability to receive and act upon verbal and signaled orders. Every man was followed closely by a military observer who noted individual errors of omission and commission which detracted from the man's effectiveness as a member of the squad.

In order to convey an idea of the nature and scope of the situations used, I shall briefly sketch the scenario of the exercise.

During the night, a simulated attack by enemy infiltrators provided a situation in which data on the proper choice of weapon and on the use of hand grenades were gathered.

The next morning, the squad leader gave the attack order, issued weapons and live ammunition, and moved the squad out toward the enemy. Sudden simulated machinegun fire from an enemy outpost, accompanied by a display of movable targets interrupted the forward movement and introduced a situation in which the subjects' immediate reaction to surprise fire was recorded. During subsequent maneuvers in response to leaders' orders, use of cover and concealment and choice of firing positions were rated by trained scorers and experienced military observers. Data on effectiveness of fire with rifle, automatic rifle, and hand grenades were also obtained.

Once the enemy outpost was "overcome," forward movement was continued. As the squad crossed the assault position, moving enemy personnel targets appeared and ran toward the forward edge of the enemy battle area (FEBA). Data on effectiveness in firing at moving targets with rifle and automatic rifle were obtained in this situation.

The squad moved forward in a squad line toward the enemy FEBA, represented by a display of silhouette targets and fleeting-glimpse indicators backed by scoring panels. A series of silhouette targets, representing an unexpected enemy defense in depth, appeared after the squad completed the assault of the enemy forward lines. The assault ended when the squad reached a hilltop. Data on effectiveness of various aspects of assault fire, fire distribution, and engagement of surprise targets with rifle and automatic rifle were gathered.

At the conclusion of the assault, the squad occupied 4 two-man foxholes on the objective. Each subject was paired with an "experienced" squad member who pointed out the limits of the subject's sector of responsibility. The expected counterattack began with simulated machinegun fire and a display of silhouette targets. A programmed presentation of single and multiple displays of killable silhouette targets at progressively decreasing ranges and for varying durations represented the progress of the enemy toward the squad. Some displays required shifts of fire from more distant to closer, more dangerous targets.

During this action, an enemy assault formation preparing to assault the squad's position was represented by a line of fleeting-glimpse indicators which extended across all sectors of fire and was backed by a scoring panel. The squad leader, in a separate fire order, designated the limits of this linear target prior to its presentation and gave the command to fire as the display began. This situation provided data on rate, distribution, and effectiveness of fire on suspected enemy locations with rifle and automatic rifle, and on understanding and compliance with the verbal fire order.

In addition, during this general defense action, enemy personnel approaching by rushes and bounds were represented by moving personnel-type targets which appeared at far, midrange, and near distances. The defense phase terminated with the presentation of a moving personnel-type target which arose from a concealed position and advanced for 5 seconds and then fell to a prone position 15 meters from the foxhole. These situations provided additional data on proficiency in firing at moving targets.

The silhouette target displays presented during the course of the simulated enemy counterattack provided a series of situations in which data were obtained on proficiency in engaging stationary single and multiply personnel-type targets, including "surprise" targets, under various conditions of distance and exposure time.

At the end of the defense phase, the squad leader ordered the squad to move to positions from which approaching enemy tanks could be engaged. A target tank traveling laterally back and forth represented the approaching tanks. The riflemen engaged the tank with inert antitank rifle grenades, while the automatic riflemen used inert 3.5-inch rockets. Data on proficiency in engaging moving tanks with the respective weapons were collected in this situation.

The moving tank situation concluded the exercise. Immediately afterward, each subject was interviewed regarding his pre-evaluation experiences, his reactions during the exercise, and his opinions regarding certain aspects of training. Also, the ability of each subject to disassemble, clean, and assemble both the M1 Rifle and the Browning Automatic Rifle was evaluated and scored through use of a checklist.

Because the exercise was designed and conducted primarily to gather data of significance for the development of improved training, the specific results of the evaluation are not relevant to this discussion. However, with an appropriate change of focus, data of direct relevance to design and evaluation of items for the Infantryman could have been collected. For example, observations made during the administration of the exercise to 51 men who had completed 16 weeks of individual training suggest that the provision of more adequate facilities for carrying hand grenades while crawling over rough ground would result in less loss of grenades en route to a suitable throwing position. Ammunition magazines were observed to have a distinct tendency to stick in ammunition pouches, with a resultant loss in volume of fire—often at critical moments. BAR firers were relatively ineffective on multiple targets and on near targets when firing from foxholes and using the bipod. A rather awkward body movement seemed to be necessary in order to engage such targets. Further investigation might reveal factors which could be corrected by an improved design.

A complete description of the exercise will soon be available in a forthcoming Technical Report. This document will provide an illustration of how the combat performance described in Research Memorandum No. 23 may be evaluated under combat-like conditions. The scope of such evaluations may be tailored to fit the particular human engineering problems of concern. In this way, the use of Infantry items by individuals performing in tactical situations under combat-like conditions may be observed and evaluated.

SUMMARY

Two products of Infantry training research have been described and offered as potentially useful in the human factors engineering of weapons and equipment for the Infantryman. Research Memorandum No. 23 provides a complete description of 102 combat performances required of men engaged in ground combat. The soon-to-be published Technical Report provides an illustrative example of how the combat performances can be incorporated in a series of tactical actions during which proficiency can be evaluated under simulated combat operational conditions.

Consideration of these two items by all those concerned with human factors engineering for the Infantryman is invited.

B. INDIVIDUAL CBR PROTECTIVE CLOTHING UNDER SIMULATED COMBAT CONDITIONS by Edmund G. Cummings, U. S. Army Chemical Research and Development Laboratories, Army Chemical Center, Maryland

I. Introduction

The primary objective of this experiment was to determine whether the M17 mask, E33 hood, and protective clothing could be worn and tolerated in the physiological and psychological sense for a continuous 24-hour period and for an additional 48 hours with interruptions only for food, water and egestion.

The second objective was to investigate problems that the soldier would encounter in sustaining himself while wearing the protective ensemble for extended periods of time.

The third objective was to investigate the usefulness of several experimental items, to develop concepts for future experimental items, and concepts for tactical operations while men are operating in a toxic atmosphere.

No attempt was made to estimate casualties that might result from leakage or faulty material.

During World War I, American forces were equipped mainly with the British Small Box Respirator (SBR) an extremely uncomfortable respiratory protective device to be worn during mustard gas attacks. The physiological limit of toleration of the SBR was from 6 to 8 hours at low-work rates, and heavy work forced removal of the SBR even in the presence of gas. Toward the end of the conflict, the response to the demands for a more comfortable mask resulted in the introduction of the American Tissot Mask.

Following World War I and up to the present time, continual effort has been directed toward producing a more comfortable mask. Breathing resistance has been lowered, head harnesses modified, and canister position changed. With a newer mask (presumably the American M3), wearing trials by 6 out of 12 resting men lasted for 48 hours.

The American M17 mask was developed for increased (a) comfort, (b) protection, (c) durability, (d) vision, and (e) voice transmission. Ease of breathing is shown by the M17's low-resistance capability, which enables men to exercise at exhausting rates, with only a slight decrease in normal performances

In the field trials, the American M17 mask has been worn for 72 hours, with intervals for food and water consumption. The American M17 mask, hood, and impregnated protective clothing have been worn under hot weather conditions for long periods of time, but the insulation of the underwear subjects men to a high-heat load while performing heavy exercise. The principal criticism by the investigator of these long-wearing trials is the frequent interruption for ingestion of food and water. The toleration point for unbroken wear of the protective ensemble in a CBR-contaminated area is not known.

II. Materials and Methods

A. Subjects

Twenty-three men from the Directorate of Medical Research Volunteer Program were selected to participate in a 72-hour field test. The men in this group were untrained for field operations and most of them normally worked at a desk. Only three of the subjects were accustomed to outside work at a fairly high rate of exercise. Most of the men were tobacco smokers and three of the group had head colds. Indications were that the performance of these men would not be as proficient as might be expected in a highly trained and organized combat group.

B. Test Program

The entire military activity was developed and supported by the U. S. Army Chemical Corps Board, Army Chemical Center, Maryland.

The test was conducted at a test site at the U. S. Army Chemical Center, Maryland. This field was a cleared area, approximately 1/4 sq mi, which was to be defended and held by a group of 17 men (including the Platoon Commander) known as the defenders. The field was bordered on three sides by a thickly wooded area, which was to be infiltrated by six men based approximately 1/4 mi away. These men were the aggressors. On the first afternoon, the defenders prepared their position by digging foxholes and sending out patrols. In the evening, the first attack by the aggressor forces occurred. A fifty per cent alert was maintained throughout the night.

On the second day, positions were further improved, and morning, afternoon and evening attacks took place.

The third day consisted of a prolonged attack in which smoke grenades were used. On the fourth morning, the aggressors attacked and withdrew.

C. Equipment

Each test subject was equipped with the M17 field protective mask, E33 field protective hood, steel combat helmet, CC-2 impregnated two-piece field uniform and field jacket, CC-2 impregnated long underwear, CC-2 impregnated gloves and socks, and field boots. The M1 rifle, canteen and cartridge belt were also standard equipment.

On the last day of the test armored vests were worn by three subjects, along with disposable protective outer garments The purpose of this experiment was to determine whether the mask and hood were compatible with the armored vest.

Eleven of the masks were modified with a special experimental drinking tube leading to a canteen (Figure 1).* The tube was designed to enable men to consume water or liquid food, such as soup and milk, without removing the mask and hood from the face. It consisted of two polyvinyl chloride plastic tubes, one inside the other.

At night, when the ambient temperature was cooler, the men wore field jackets. They slept in sleeping bags in and around foxholes.

D. Wearing Conditions

The test subjects were required to wear the protective clothing and mask ensemble continuously for the first 24 hours. They were instructed that if, for any reason, they were forced to unmask, or remove any part of the protective clothing, even for the briefest time, they were to consult the observers. The observers then would try to determine the reasons for their desire to unmask, and, if no physiological difficulties were noted, the observers would attempt to persuade the subject to return to the test.

Since this was a volunteer-type test, any man was free to remove himself whenever he felt that conditions became unbearable. The men were informed before the test of the importance of their cooperation. They were given instruction in wearing the mask and clothing and had 2 hours of preparatory mask wearing the day before the test began, but were untrained in so far as the individual protective equipment was concerned.

E. Feeding Methods

Three methods of supplying food were attempted during the field experiment. For the first 24 hours, the 11 men whose masks were equipped with drinking tubes were supplied with water and soups, the remainder of the men were without food or water. After the initial 24-hour period, the 12 men without drinking tubes were allowed to consume their first meal of assault rations by lifting the mask and hood for a brief instant, inserting food or water into the mouth and replacing the mask and hood until they had swallowed and were prepared for the next mouthful (Figure 2). The men with drinking tubes ate this meal in an experimental, protective field-feeding station.* The unit was fitted with a small gasoline-powered, collective protector, which supplied it with pressurized filtered air. This station, which accommodates three men, had openings on one side through which the head and hands could be placed. The subjects sat on a bench outside the station with head and hands thrust into the filtered atmosphere (Figure 3). The subjects unmasked inside the shelter and were given 15 minutes to eat their rations (Figure 4). Because of the higher internal pressure of purified air within the feeding station, there would be no toxic agent leakage into the structure. This feeding station was used by all men at subsequent meals.

In the feeding station C rations were supplied to the men and assault rations were supplied when they ate by the lifting of the mask and hood method.

F. Measurements

The resting pulse rates of the group were taken routinely in the morning between 0700 and 0800 hours and in the evening between 1700 and 1800 hours. These were radial pulses and were obtained after the men had been sitting quietly for 5 minutes while filling out the subjective questionnaire. The questionnaire was prepared by the Psychology and Human Factors Engineering Branch, these Laboratories, and sampled attitudes toward the protective ensemble. The same questionnaires were distributed in the morning and evening throughout the test period.

When a subject decided he needed medical or other attention or was about to withdraw from the test, his pulse and respiratory rates, as well as his oral temperature were recorded. Furthermore, he was asked the reason for his wish to withdraw and questioned about his previous activity, main discomfort, ease of breathing, and his desire for tobacco, water, and food. He was also asked if he would remove the mask if he were exposed to a toxic atmosphere. If the subject could not be persuaded to return to the test, he was removed without being seen by the remaining volunteers. Some nonparticipating volunteers, however, were utilized to assist in the feeding detail in the portable feeding station.

III. Results

A. Meteorological Conditions and Subjective Comfort

During this test period, the weather was temperate. Day temperatures rose from 54° to 74°F, while at night the temperature dropped to 53°F. During the seventeenth and eighteenth of October, the sun was direct with very little cloud cover. On the day of the nineteenth, clouds began to move over the test site and it started to rain at 2300 hours.

B. Wearing Time

Subject participation in the initial 24-hour interval of continuous mask wear is summarized in Table 1. Twenty-four men were scheduled to participate as test subjects, but one refused to wear the equipment. Of the 23 remaining, 3 had their masks off before 24

*The experimental drinking tube was made expressly for this test by the Respirator Branch, Protective Development Division, these Laboratories.

*Fabricated by the Air Filtration Branch, Protective Development Division, these Laboratories.

TABLE 1

Subject Participation during First 24-Hours of Continuous Ensemble Wear

Total participants	23
Pre 24 hour drop-outs	3
Remaining	20
Discounted for unreliability	3
Remaining	17
Involuntary mask removal (15 min)	1
Total 24 hour participation	16

TABLE 2

Unmasked Time, 72 Hour Field Test

	October 17	18	19	20
SUBTOTAL*				
Hrs.	0	9	0	0
Min.	40	53	53	3
Sec.	15	20	30	0
Freq.	2/22	6/16	9/16	1/16
TOTAL				
Hrs.	3	83	109	78
Min.	5	54	3	3
Sec.	40	18	30	0
Freq.	6/23	12/23	15/23	7/23

*Excludes those relieved from participation

hours had passed. Three were found sleeping with their masks removed on the third night of the test, thereby discounted, although there was no evidence that these men lifted the mask at any time during the first 24 hours of the test. One man, who engaged in a high level of activity, was removed briefly from the test, because of his elevated resting pulse (135 beats/min) and because he was found to have an oral temperature of 99.8° F. After sitting for 15 minutes, his temperature and pulse returned to normal, and he was reinstated in the test situation. This left 16 men who wore the mask continuously for the first 24 hours.

The unmasking occurred at the first meal, which was served from 1300 to 1530 hours on the second day (18 October). Some of the subjects were fed using the portable field-feeding station method and the remainder ate by temporarily lifting the hood and mask. Among those utilizing the feeding station, some of the subjects wore the mask slightly more and some wore it slightly less than 24 hours. The capacity of the portable station, which was built to accommodate only three men at any one time, accounted for the difference in wearing times among the subjects.

The amount of time spent by all participants, during the 72-hour trial, is shown in Table 2. The Table does not include the time spent unmasked for eating. During the 15-minute mealtime period taken in the protective shelter, facial skin abrasions were treated in the cases where this attention was required. The test subjects who ate by the lifting of the hood and mask method required more time to consume their meals, that is, 20 to 30 minutes.

The total unmasked time, shown in Table 2, also includes the wearing times of the personnel who dropped out of the test. The unmasked time for those who remained is given in the subtotal, which averages approximately 15 minutes per 24 hours for each of the 19 men.

The secondary period of complaints, in the men's desire to remove their masks, came after approximately 36 to 44 hours of wear. At this time, beard growth, ingrown hairs, and acne caused discomfort.

The increase in unmasked time on the morning of the eighteenth is attributed to one man who was forced to drop out of the test for 8 hours because of severe headache. He returned, however, after his headache had disappeared.

The characteristics and observations of subjects who withdrew from the test are given in Table 3. One subject, mentioned above, returned to the test after 8 hours when his headache had disappeared. Two of the other four withdrawals complained of feeling frightened or closed in during the night and mentioned feelings of impending death. One subject, Ru, had no real complaint nor any real reason for withdrawing from the test, but he had observed others leaving earlier and probably wished to do the same. Subjec Ju claimed to have a sore face but had expressed an unwillingness to participate in the test when first interviewed as a test subject. Pulse and breathing rates and oral temperatures of the four men were all fairly normal, even though the pulse readings were slightly elevated after 1/4 mi of walking. Mask removal occurred in three of the four cases during the night after the men had slept briefly. Sleep would account for the low oral temperatures measured on these men.

C. Liquid Consumption

There was concern among the observers about the ability of the men to regulate body heat adequately when deprived of the oportunity to ingest water because of restrictions on lifting the mask. Men without the drinking tube felt particularly thirsty after 15 hours of continuous wear. When these subjects were allowed to eat and drink after the 24-hour period, they consumed on the average slightly less than 1-1/2 canteen cups of water (approx 800 ml.).

TABLE 3

Characteristics of Subjects Withdrawing from Test

Subject	Participation Hours	H.R. b/min.	O.T. °F	Resp. R. b/min.	Complaint
Re	7	68	97.9	18	felt suffocated
Fr	9	92	97.8	--	vascular headache
Di	9	92	98.3	12	frightened
Ru	25	96	--	16	difficult breathing
Ju	17	80	97.8	--	sore face

The men who were provided with a drinking tube consumed approximately two canteens (2 pt) of soup and slightly less than 1 canteen of water during the first 24 hours.

D. Physiological State

In a field trial, the number of experimental differences increases so as to make biological measurements highly variable. The resting pulse rate was the most reliable index of physiological stress that was applicable to the test situation. The pulse rates of the subjects are shown in table 4. There was much variation in the rates, because there was no control over previous activity. Those in the aggressor group had consistently higher pulse rates than the defenders, presumably because this was the more active group. Two of the aggressors had resting pulse rates frequently over 100 beats/min.

TABLE 4

Resting Pulse Rates in Beats per Minute During 72 hour Test

	17 Oct PM	18 Oct AM	18 Oct PM	19 Oct AM	19 Oct PM	20 Oct AM
Mean	81	82	89	83	85	76
High	104	116	108	96	100	98
Low	56	60	68	68	68	52
No.	23	20	19	19	19	19

E. Egestive Activities

The frequencies and time spent by men during the test performing egestive functions are shown in Table 5. On the basis of these times, the skin exposure of men, performing these functions, can be calculated and from skin exposure and vapor concentration, casualty estimations can be made.

During urination, the surface of the penis is exposed. Assuming it to be cylindrical with average dimensions of 13.0 by 8.6 cm, the surface area would be 118 sq cm.

During defecation, the skin area exposed is irregular, but the regions generally involved would be the thigh, buttocks, and genitals. This area may be estimated to be 25% of the total skin surface area. On the average man 173 cm (5 ft 8 in) tall and weighing 67 kg (147 lb) the skin area exposed during defecation would be 25% of 1.77 sq m or 4,420 sq cm.

The most any man urinated during one day was four times, giving a repeated exposure of 118 cm of skin for a total of 4 minutes and 10 seconds. No man defecated more than twice a day; the one man who defecated twice would have had an exposure of 4,420 sq cm of skin area to toxic aerosol or vapor for 8 minutes.

F. Complaints Concerning Protective Ensemble

In general, the conditions produced by the mask and clothing after prolonged wear were not of a serious nature. The protective underwear has a tendency to irritate the skin of the crotch and armpits because of its roughness and because it has an acid reaction when damp. Only one man had a crotch irritation that bothered him enough to cause him to seek some form of treatment.

IV. Discussion

A. Criticism of Test Procedure

The main criticism of this field experiment was the lack of constant observation of each subject during the time of wearing the ensemble. It may have been possible that some of the men removed the mask, lifted it away from the face, placed a finger between the facepiece and face, or even removed the outlet valve in order to make breathing easier. An agent or irritant was needed in the area in a concentration that would be a positive deterrent to mask removal in the absence of continuous observation.

B. Factors Affecting Wearing of the Protective Ensemble

The continuous 24-hour wearing of the protective ensemble, indicates that it is possible for most troops to remain protected for this interval in combat situations. The length of the protection interval depends largely upon the ambient temperature at which the men are operating. The ambient temperature, during this test, did not rise above 74°F. As illustrated by the results of Project JACKPOT, an operational group would have to ingest water frequently, possibly every 2 to 3 hours, when operating at

TABLE 5

Skin Exposure during Urination and Defecation

	Avr. S. A. cm^2	Max. Exposure/day		Minimum Exposure/day		Avr. Exposure/day	
		min.	sec.	min.	sec.	min.	sec
U.	118	4	10	1	0	1	47
D.	4,420	8	0	4	0	4	24

high levels, at temperatures ± 90°F and high relative humidities. This is necessary to maintain high sweat rates for evaporative cooling. Also, in hot climates, the work rate would have to be reduced when men wear the two-layered ensemble to prevent their accumulating a high heat load.

Under cool and arctic conditions, the 24-hour protection interval could be maintained without difficulty, even without water ingestion, because heat stress would be minimized. Other problems, however, involved with cold protection, might become limiting.

In temperate and hot climates, the availability of a drinking tube would decrease the possible casualty expectation, because a mask would not have to be removed from the face to permit water ingestion; however, the drinking tube and availability of water did not prevent mask removal in this test, since three of the four men who withdrew had drinking tubes.

With suitable relief intervals, the protective ensemble can be worn for at least 3 days. After this period, the men who completed the test were suffering no severe effects from the ensemble. Physiologically, they were sound and the nature of the facial irritations, although annoying to these subjects, was not serious.

Psychologically, the volunteers were willing to remain masked for another day, as indicated by the questionnaires, and the majority felt they might remain masked indefinitely if their lives were in danger. The test does not include an assessment of the effectiveness of the protection after 3 days. Presumably, the mask filters would have required renewal at intervals if a toxic agent had been present. Also, the mask seal would have been less effective after 3 days because of beard growth. The addition of a pressurized hood would lessen peripheral leakage and decrease hazards of long-term wearing.

The group did appear to maintain higher motivation and combat capability if allowed to remove the mask after approximately 24 hours of continuous wear. It is quite feasible that the mask could be worn continuously for longer periods, however, relief periods of approximately 15 minutes, as utilized in the test, were important in alleviating the first peak of complaints. One might expect greater efficiency from troops engaged in prolonged wear of the protective ensemble if brief relief intervals were obtained in the field, possibly by means of the portable field-feeding station.

The reason the mask became intolerable after a period of wear was not primarily the breathing difficulty caused by airway resistance. The resistance of the M17 mask is low, although the addition of the tightly pressurized hood does produce noticeable expiratory resistance. The pressurized expiratory resistance during wear has not yet been measured.

The major complaints were those resulting from pressure and irritation on the head and face. Severe swelling of the scalp, from impeded lymph drainage, was probably the cause of the reported headache from mask wear. Only one man suffered from a severe headache, although the written questionnaires indicated that over half the men developed a headache at some time during the test.

In this field test, three of the four men who voluntarily withdrew can be considered as poorly motivated, since they gave no evidence of physiological strain at the time of withdrawal. Three of these subjects who withdrew the first day had masks equipped with drinking tubes, which indicated that the alleviation of thirst had little effect on prolonging mask tolerance.

From questioning the four men who withdrew, it was apparent that they did not wish to endure the discomforts of the test. It was also apparent that the effect of the dark hours upon mask wear may be a real problem to anxious individuals. Two withdrawals similarly described themselves as waking from sleep and becoming frightened at finding themselves with their faces covered. The descriptive phrase, "feeling I was going to die," was used by two men. The interpretation of this statement might depend upon the subject's acting ability. Quite probably, the isolation of the person at night during sleep results in increased anxiety about the problems that may be of minor concern during the daylight hours.

There is indication that an adaptive process occurs during the first day of protective ensemble wear. A basis for this has been described by Soloviev, that a series of physiological adjustments to the increased breathing resistance occur in the form of changes in breathing pattern and in cardiac output. In this field test, the resting pulse rate did not indicated adaptation in its pattern of change. Pulse rates dropped on the last day, but this may have been attributed to the cessation of military maneuvers. Adaption was indicated by (1) the cessation of withdrawals from the test after 24 hours, (2) the change in breathing patterns as recorded on questionnaires from short, shallow breaths to long, deep breaths, (3) an increase in the number of men who slept well after the first night, and (4) a decrease in the number of complaints after the first 24 hours.

C. Effectiveness of Methods of Eating and Drinking

1. Drinking Tube

The drinking tube utilized in the field program was attached to the mask and canteen. The tube seemed to be best suited to drinking water. Soups and milk, when sucked through the tube, had a tendency to spill into the facepiece, making the mask uncomfortably sticky. The drinking tube would be a valuable asset to troops wearing the hood and mask during hot weather, because it would lessen exposures resulting from lifting the hood and mask.

2. Lifting the Mask

Ingestion of food by the lifting of the mask and hood method is practical in the field only when aerosols or vapors are known to be at low concentrations. Even this method involves the risk of toxic exposure.

3. Portable Field-Feeding Station

The portable field-feeding station confers additional benefits by enabling the men to (1) change filter pads, (2) smoke, (3) obtain relief from mask wear, (4) obtain treatment for facial abrasions, and (5) shave. These units, or ones of similar utility, would extend the time men could efficiently operate in the field. The feeding station was highly praised by all subjects using it during the 72-hour wearing trial.

D. Physiological Condition

The resting pulse rates show that the men were not highly stressed. The type of stress expected from the equipment would result from heat storage, attributed to the layers of permeable clothing, and respiratory stress imposed by mask resistance. The new M17 mask imposes only a slight inspiratory resistance, but may impose a relatively high expiratory resistance when worn with the pressurized hood. The field test, however, did not show the men complaining of, or affected by, expiratory resistance. Heat stress, under the ambient weather conditions at the time of year the test was conducted, was not apparent nor was it expected. Also, the period of water deprivation for men without drinking tubes was not of a stressing condition, but it might have been a limiting factor in endurance at higher ambient temperatures or higher exercise levels. The men with drinking tubes consumed adequate liquids when masked. Those without tubes restored their water during the first and second meals.

E. Psychological Aspects

Besides physiological stress, there were indications that the anxious person may have become emotionally stressed from long-term mask wearing, especially during dark hours. This concept is exceedingly difficult to prove, however, from the practical point of view, this type of anxiety might be overcome by training the men to wear the mask so they can become familiar with its effects and develop confidence in its use.

F. Protective Clothing

In these tests, the protective clothing proved its intended worth since there was no evidence of obvious cuts or tears during the 3-day period of continuous wear. There were skin exposures, but these were attributed to the carelessness of the wearer. Observers reported that some of the subjects had skin exposed at the wrists and the back, where the shirt had been pulled out of the trousers during exercise or during sleep.

Because of the climatic conditions at the time of year the test was run, where the nighttime temperatures ranged from 53.5° to 67.7°F, the subjects were required to wear their field jackets in order to remain comfortable during the night.

G. Armored Vest

The armored vest might produce a high heat load when worn with the protective ensemble in hot climates. In this test, after one hour's wear, the clothing of the men was sweat soaked under the vest.

The E33 hood was worn with the lower apron covered by the vest. This greatly restricted head movement in all directions. Increased head movement was obtained when then protective hood was worn with its lower edge outside the vest.

H. Suggestions for Further Work

Tests to assess the reliability of the protective ensemble during prolonged wear would be important to determine casualty estimates. This reported test did not indicate how many men would be disabled because of mask leakage, meal preparation, mask removal during sleep, or innumerable other factors. The introduction of an irritant, such as CS, into a similar test plan would give valuable information about the protective barrier.

Additional problems could be encountered in climatic extremes. Project JACKPOT has provided information on hot-weather problems, cold-weather problems have not as yet been investigated.

Hazards of urinating and defecating in a toxic atmosphere are known, but practical solutions to this problem are lacking.

I. Military Significance of Data

1. Since the complaints about the discomfort of wearing the protective ensemble

were heaviest during the first 8 hours and particularly during the first night, it can be assumed that a tolerance to wearing the ensemble was developed. On the subsequent days, the men appeared to carry on their duties normally and in a much better psychological condition. The conclusion, then, would appear to be that training in the wearing of the protective ensemble is desirable It is expected that wearing the ensemble for long periods of time during exercises or maneuvers will confer three main benefits upon the troops so trained These are. (a) troops would become familiar with the equipment and develop confidence in it, (b) they would develop a tolerance for the discomfort associated with wearing the ensemble, and (c) they would learn to perform mission tasks more efficiently while wearing the protective ensemble.

2. This test was conducted during a mild season in a temperate zone. In hot, humid weather, the problem of heat would be significant. In this instance, there would be the problem of so pacing the task performance as to prevent heat exhaustion. This is normally done even without the protective ensemble. Activity in jungle and desert areas presents limitations, which the human body could not endure.

3. The requirement for water assumes a much higher priority than that for food. This is particularly true as the temperature rises. The concept of supplying water through the mask by the use of the drinking tube shows promise. The item would have to be engineered sufficiently to withstand hard field usage. The use of this item for liquid food, such as milk and soup, tends to present a sanitary problem inside the mask. For this type of use, the tube does not appear practical.

4. As a result of this test and chamber tests that have dealt with the problem of eating within chemical contaminated areas, at this time the most promising methods appear below in descending order of capability:

a. An uncontaminated shelter into which men are brought to be fed only after they have been decontaminated.

b. A shelter within which contamination is held to a minimum by air purification through a diffusion barrier or a collective protector unit.

c. A shelter within which contamination is prevented by positive internal pressure generated by tanked air or a collective protector unit.

d. A shelter into which men thrust their heads and arms, contamination being combated by positive internal pressure as in the experimental station tested.

e. Eating by temporarily lifting the hood and mask, holding the breath, taking a bite of food, returning the mask, then the hood, clearing the mask, and swallowing the food.

The methods listed above can be considered as those to be employed from rear areas to the actual line of contact. The last method is the most hazardous, primarily because of the possibilities for food contamination and for contamination of the inner side of the hood or the mask while lifting and replacing them. The hazard from vapor would be increased in proportion to the total amount of time that the hood and mask were off during eating. Also, the possibility for leakage through the seal of the mask to the face would increase with the number of times the hood and mask were lifted. Development of a one-bite package, opened readily in a manner that would preclude contamination, could reduce this hazard significantly. Also, the use of this method would be restricted to those troops who could not be relieved at least once during a 24-hour period to eat in a pressurized station similar to the one tested. The lifting of the hood and mask method would be utilized directly to the rear of the forward edge of the battle area and within walking distance of it. Further toward the rear, more sophisticated methods for eating in contaminated areas could be devised. The units used for this purpose, including the most elementary types, could also be used for a rest, shave, or examination of the eyes for miosis.

V. CONCLUSIONS

Sixteen of twenty-three subjects wore the M17 mask, E33 protective hood, and permeable, impregnated CBR protective clothing continuously for a 24-hour period, while engaged in a simulated combat situation. At mealtimes, after the first 24 hours, the men were allowed to remove the mask for intervals while in a protective field-feeding station, and the wearing trial continued for a total of 72 hours. Eleven masks were modified with an experimental drinking tube, which led to a canteen. The test was conducted duringt the month of October. The temperatures at the time of the field trial ranged from 53° to 74°F.

The following conclusions were reached:

1. The test indicated the feasibility and practicability of combat groups maintaining an unbroken protection interval of at least 24 hours in a contaminated atmosphere, without undue physiological strain caused by the present standard protective ensemble. This applies principally to temperate-climatic conditions.

2. Healthy men who attempted to escape from prolonged wearing of the M17 mask did so because they were poorly motivated or felt the mask restricted their breathing. During test situations, the most poorly motivated persons may remove the mask during the nighttime; some men may remove the mask unconsciously while asleep. Subjects who would remove the mask in gassed areas for reasons of comfort are usually ignorant of

the danger to which they would be subjected. Experiences reported in World War I indicated that, even in trained groups, casualties did occur because of this practice.

3. The drinking tube is a practical concept in mask usage, but its utility value appeared to be restricted to the ingestion of water. The tube should be protected so that it does not break off or catch onto any type of obstacle.

4. The portable field-feeding station was found to be practical and a morale booster, because it allowed the subjects (a) a brief respite from wearing the mask, (b) time to smoke, and (c) time for treatment of facial irritations.

5. Training in wearing the protective ensemble continuously for 24 hours is desirable for the purpose of enabling troops to become familiar with the capabilities of the equipment, to develop tolerance to its discomforts, and to learn to perform their missions efficiently while encumbered with the protective ensemble.

6. Prolonged mask wear produced minor irritations and abrasions on the skin of the face and neck. Severe headache, once a major deterrent to prolonged mask wear, is reduced by the new M17 mask design.

7. The reduced breathing resistance and improved design of the M17 mask appeared to be the most important factors contributing to the ease of prolonged wear.

8. Men slept less soundly than in their usual habit when wearing the mask and hood, and there was a tendency for leaks to develop during their sleep.

9. While the wearer slept, the pressurized hood collected condensed exhaled moisture, which soaked the chest and back when he arose.

Figure 2 Man in the Process of Eating by Lifting the Hood and Mask. The breath is held while the mask and hood are lifted and the man prepares to place food in his mouth The mask will then be lowered while the man chews and swallows the food

Figure 3. Outside View of Three Men Using Protective Field-Feeding Station. The heads and hands of the men are inserted through elasticized openings. Unmasking takes place inside the tent. The tent is supplied with filtered air under pressure, so that all leaks are directed outward. Pressure is indicated by the convex shape of the plastic window.

pressure, so that all leaks are directed outward. Pressure is

C. EXPERIMENTAL DESIGN FOR USER REVIEW OF CAMOUFLAGE FOR THE INDIVIDUAL COMBAT SOLDIER by A. H. Humphreys and David L. Gee. U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia

The experiments on which this paper is based are a part of the User Review of Camouflage for the Individual Combat Soldier in the Field. The experiments, using visual, infrared and radar detectors, were designed to provide reliable information on the detectability of various combat uniforms upon which QMRs for research and development of future uniforms and personal equipment may be based

The U. S. Army Infantry Board was assigned the responsibility for the conduct of the experiments, and the U. S. Army Corps of Engineers, Quartermaster Corps, Signal Corps, and Infantry School were responsible for technical guidance and material used in the experiments. The experiments were conducted at Lae Field and vicinity at Fort Benning, Georgia, during the month of May 1962.

Previous experiments in the camouflage of individuals have for the most part been confined to visual observation. This work in the past was highly subjective and the data obtained consequently were influenced by personal opinion and other factors. The experiments on which we are reporting utilized an experimental design through which personal opinions and prejudices should be overcome. Such an experimental design has not heretofore been attempted in this field of endeavor and thus is also an experiment within the User Review.

Six different uniform ensembles were employed in the various daytime experiments—British, USA OG 107 with soft hat and bandoleer, USA OG 107 with helmet and webbing, USA ERDL 1948 Camouflage pattern, Marine Corps Mitchell Camouflage pattern, and Khaki No. 1 (Figure 1). Two other uniforms were used only in the night experiments—OG 107 with an infrared pattern and OG 107 with 20% infrared reflectance. All subjects wore camouflage face paint on their hands and faces, and were instructed to place themselves in positions with a clear view to the O.P. Either helmet covers or foliage were used on helmets, and rifles were wrapped with burlap strips to reduce weapon shine.

Observers employed in the User Review were 21 enlisted men and one officer shown in Figure 2.

All of the experiments were conducted on or in the vicinity of Lae Field. A diagram is inclosed as Figure 3. The 12-day experiment used ranges from 500 to 1800 meters. Night experiments were conducted on ranges of 100 to 600 meters without moon, and on 100 to 1,000 meters with full moon. The far range experiment was conducted on three ranges diagonal to the line of sight from 2580 to 3248 meters. Each range as shown on the diagram had two range guards, two telephones for secure 2-way communication with the OP Controller, a loud speaker system, and two range panels (one on either side of the center sector).

The program was designed to be completely random is shown in a typical day (Figure 4). Ranges (distance in meters), postures (prone, standing, kneeling, walking laterally, walking forward) and uniforms were randomly presented and the distribution of men across the sectors was also random. One complete series in the 12-day experiment (six uniforms at six ranges for both morning and afternoon observation) required 6 days to complete. Thus, 12 days were required to complete the experiment and perform one replication.

The OP Controller controlled the entire experiment from a detailed plan, and each range guard had a plan for his range. The Field Controller also had a detailed plan for each day's operation and served as the manager and "trouble shooter" down range. The OP Controller or an assistant read over the field telephone the programs for each observation at each range prior to the observation, and the range guard at the appropriate range confirmed the random placement of subjects, postures, range and uniform, and also confirmed the readiness of his range to proceed

Each observer was placed at a small table enclosed by a booth The front panel of the booth was fitted with a standard window shade on a roller. The observer raised this shade during his observations and lowered it to obscure the range between observations All observers were cautioned not to discuss observations with anyone during the course of the experiments. The observer recorded his observations on a reaction sheet (Figure 5) which was provided, in duplicate, for each set of six observations. At the beginning of each set, the observer entered his name and mode of observation. He also entered the observation set and time which was provided by the OP Controller who was situated in a tower immediately behind the observers (Figure 6).

Upon a signal from the OP Controller the two range guards erected the range panels on either side of the center sector of the range in operation, e.g., Range A, 500 meters. The OP Controller then announced over the loud speaker system to the observers and subjects down range, the time and range. The observer entered this information on his reaction sheet. The OP Controller started the observation with the command, "Commence Observation." The observer marked the number of detections he made in each sector in the columns L, C and R. At the end of the prescribed two minutes observation time, the OP Controller commanded "Cease Observation." While the observers observed on range, the OP Controller or an assistant prepared for the next observation. At the end of each set of six observations the observers were given a short break away from the observation point while the subjects down range prepared for the next set. Each set of observations required approximately 30 minutes.

The reaction sheets for each set of observations were collected after each set of six observations and delivered to the data processing van where they were scored for total correct, omissions, and commissions. This information was then placed on master sheets. The experiment control personnel were thus able to monitor the progress of the experiment by using the master sheets and make any adjustments necessary in procedures of the experimental design. It also provided the opportunity to recognize and explain or make adjustments for any unusual trends in the information.

In addition to ability to follow the data within approximately one hour after any observation, a member of the experiment control team called the Experiment Controller monitored each observation from the Observation Point with 7x50 binoculars to ensure proper distribution and display of test subjects, recorded sun angle, cloud shadows, time of each observation, and any unusual phenomena during the observation (See Figure 7). When in his opinion circumstances warranted it, the Experiment Controller could instruct the OP Controller to re-run an individual observation at the end of a set.

Two other experiments were conducted—the Simulated Ambush Experiment then the Simulated Infiltration Experiment—employing variations of the same experimental design.

The Ambush Experiment (See diagram (Figure 8) also used random distribution of subjects, postures and uniforms, and also employed three sectors. However, the panels marking these sectors remained in place during the entire experiment. The questionnaire used in the 12 day experiment was also used in this experiment. The major differences between this and the 12-day experiment were that distances were shorter, the observers were required to record postures as well as numbers detected, and the observers were moved from range to range (325 to 125 to 50 meters) while the subjects remained along the assigned fringe of the woods. As in the case of the 12-day experiment, the subjects were instructed to take positions with a clear view to the observers (not screened by trees and bushes). Figure 9 is typical of the program used in the Ambush Experiment.

The Infiltration Experiment exployed four sectors with fixed panels to divide them (See Figure 10). A random distribution of subjects was designed, but subjects could appear in any two sectors and at any of the four ranges from the observers. The observers were situated as shown in the diagram and were required to record numbers detected and their postures. The observers stayed at the assigned position but the subjects could be at any range—75, 125, 175, and 225 meters. Figure 11 shows a part of the program used in the Infiltration Experiment. The reaction sheet employed was similar to that employed in the 12-day experiment except that provision was made for four sectors.

The curves included in this paper (Figures 12 thru 21) are immediate after-action results and show "percent detections as a function of range." These general trends are a strong indication that our method is valid and may be employed for meaningful experiments and tests of camouflage for individual soldiers. These curves place values on the observers' responses. Such values were not possible under previous methods which relied on a word description provided by the observer.

The data compiled during the User Review are being programmed into the RCA 301 computer at Fort Belvoir and we are hopeful that more refined data will be forthcoming soon. The final technical report on the Review is scheduled for publication early in 1963.

Figure 1. Uniforms, left to right: British; USA OG 107 with Soft Hat, without Webbing; USA OG 107 with Helmet and Webbing; USAERDL Camouflage Pattern, U.S. Marine Corps Mitchell Camouflage Pattern, and Khaki No. 1

Figure 2 Observers Employed During User Review

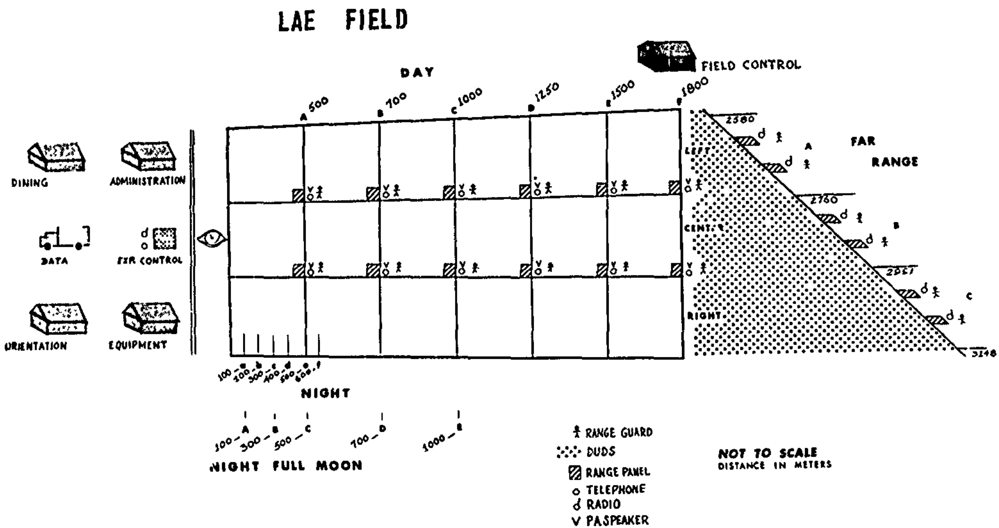


Figure 3. Diagram of Ranges for 12 Day Experiment, 12 Night Experiment, Full Moon Experiment, Far Range Experiment, White Tee Shirt Experiment, and Poncho Experiment

REVISED

DAY 12

Observation	Time	Range	Posture	Uniform	Sector L	Sector C	Sector R
1	0800	C	W_L	Beta	3	5	2
		A	W_L	Delta	4	3	3
		E	S	Zeta	3	0	7
		F	K	Gamma	4	3	3
		B	P	Epsilon	5	1	3
		D	W_F	Alpha	6	1	3
2	0840	F	S	Gamma	3	2	5
		C	P	Beta	1	7	2
		A	P	Delta	8	1	1
		E	W_L	Zeta	6	2	2
		D	K	Alpha	2	3	4
		B	S	Epsilon	0	2	8
3	0930	B	W_F	Epsilon	1	1	8
		D	W_L	Alpha	3	5	2
		F	W_L	Gamma	2	2	6
		A	S	Delta	4	2	4
		C	S	Beta	5	4	1
		E	W_F	Zeta	7	1	2
4	1030	C	K	Beta	2	4	4
		E	P	Zeta	2	2	6
		A	W_F	Delta	4	4	2
		B	K	Epsilon	5	3	2
		F	W_F	Gamma	7	1	2
		D	S	Alpha	1	3	6
5	1110	A	K	Delta	1	1	8
		E	K	Zeta	2	2	5
		C	W_F	Beta	0	3	7
		D	P	Alpha	4	4	2
		B	W_L	Epsilon	7	2	1
		F	P	Gamma	3	3	4

Figure 4. Typical experimental program for the morning of one day

USAEROL FORM 556
30 MAR 62

USER REVIEW CAMOUFLAGE OF INDIVIDUAL COMBAT SOLDIER
OBSERVER - RECORDER REACTION SHEET

NAME ______________________ DATE ____________

OBSERVATION SET ______________ TIME ____________

OBSERVATION MODE __________ (VISUAL, IR, RADAR, etc)

OBSV ORDER	RANGE	SECTORS			POSTURE	UNIFORM TYPE	CORRECT			INCORRECT							
							TOT. CORRECT			OMISSIONS			COMISSIONS				
		L	C	R			L	C	R	L	C	R	L	C	R	O	A
1																	
2																	
3																	
4																	
5																	
6																	

MODE
OBSERVER SYMBOL
EXPERIMENTAL SERIAL

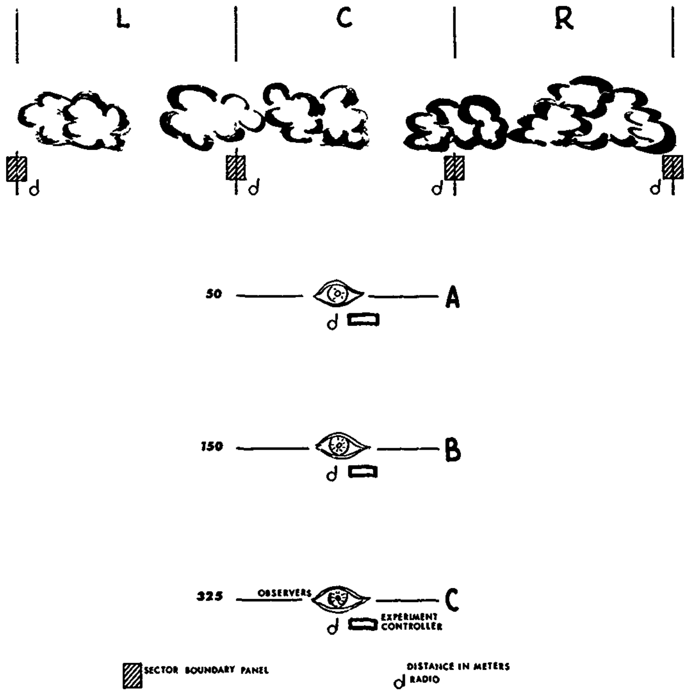
REMARKS

ARMY-FORT BELVOIR VA

Figure 5. Observer Record Sheet

Figure 6 View of Control Tower and Administration Tent

Figure 7. View of Lae Field From Behind Observers During 12 Day Experiment. Shows Experiment Control Verifying the Observation Conduct



SIMULATED AMBUSH EXPERIMENT

Figure 8

* - ERDL Pattern
Z - Marine Standard

Observation	Range	Uniform	Posture	Sectors 1	Sectors 2	Sectors 3
1	C	*	K	4	1	3
			M	0	4	2
			S	5	4	0
2	B	*	S	6	0	4
			K	5	3	0
			M	0	2	7
3	A	*	K	2	2	3
			S	0	5	6
			M	3	2	3
4	C	Z	K	5	0	6
			M	4	2	5
			S	2	3	2
5	B	Z	K	2	3	4
			S	0	7	5
			M	6	4	0
6	A	Z	S	5	0	4
			K	3	4	1
			M	2	3	3
7	C	*	K	3	1	4
			M	2	4	0
			S	0	4	5
8	B	*	S	4	0	6
			K	0	3	5
			M	7	2	0
9	A	*	K	3	2	2
			S	6	5	0
			M	3	2	3
10	C	Z	K	6	0	5
			M	5	2	4
			S	2	3	2
11	B	Z	K	4	3	2
			S	5	7	0
			M	0	4	6
12	A	Z	S	4	0	5
			K	1	4	3
			M	3	3	2

Figure 9. Typical experimental program for Simulated Ambush Experiment

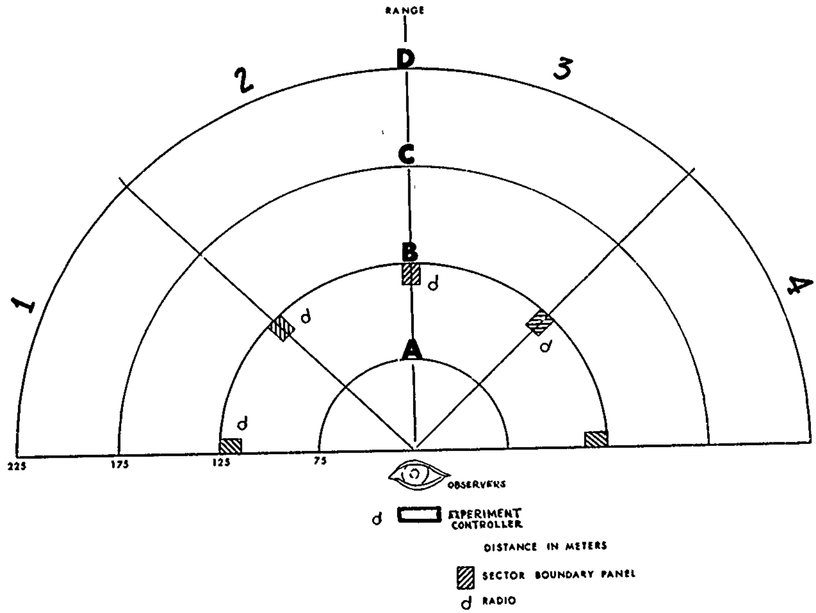


Figure 10. Simulated Infiltration Experiment

* ERDL Pattern
Z Marine Std

Set #1

Observation	Range	Uniform	Posture	Sector 1	Sector 2	Sector 3	Sector 4
1	B	ERDL*	W		2		
	C	ERDL*	S	1			
2	A	Z	K				3
	D	Z	S			5	
3	D	ERDL*	W			4	
	B	Z	K	3			
4	A	Z	S				2
	C	ERDL*	K		4		
5	D	ERDL*	K		6		
	A	ERDL*	S	2			
6	C	Z	W				5
	B	Z	S			3	
7	D	ERDL*	S				4
	A	Z	W		3		
8	C	Z	K	5			
	B	ERDL*	S			4	
9	C	ERDL*	W	4			
	A	ERDL*	K			3	
10	D	Z	K		4		
	B	Z	W				2
11	B	ERDL*	K			1	
	D	Z	W	5			
12	C	Z	S		3		
	A	ERDL*	W			1	

Figure 11. Typical experimental program for Simulated Infiltration Experiment

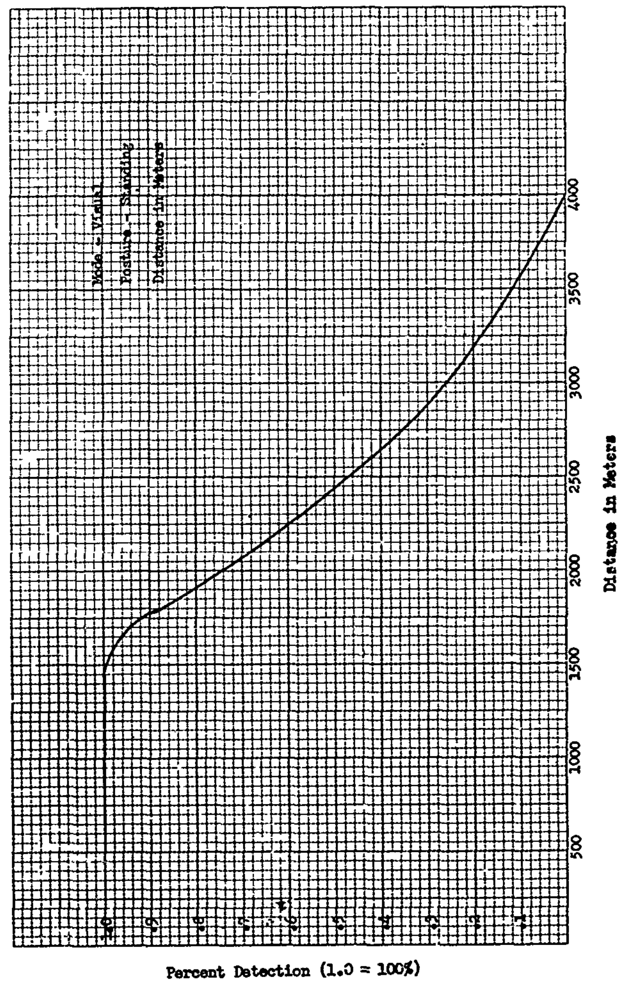


Figure 12. White Tee Shirts

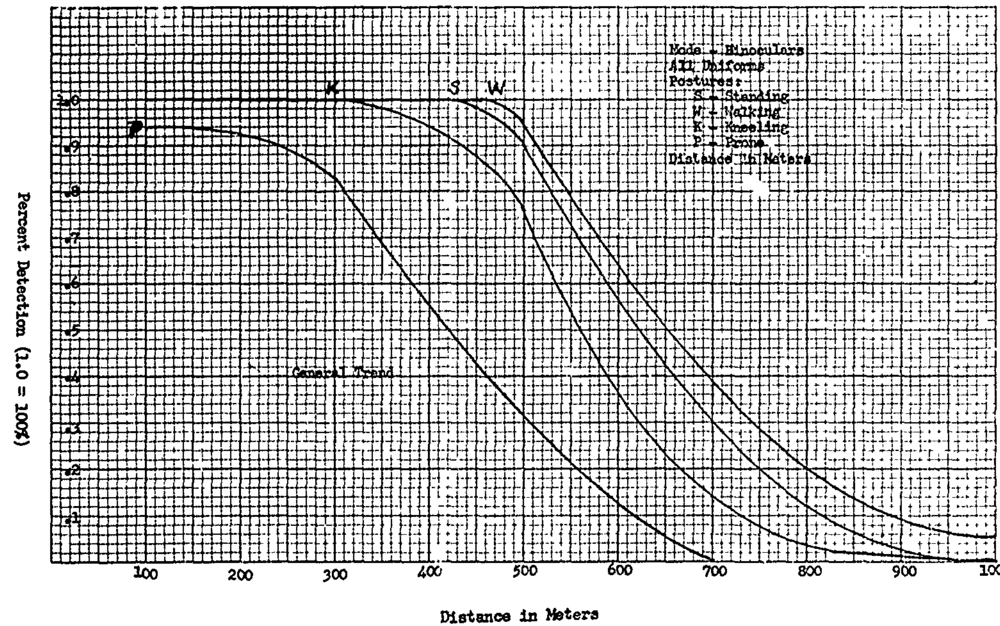
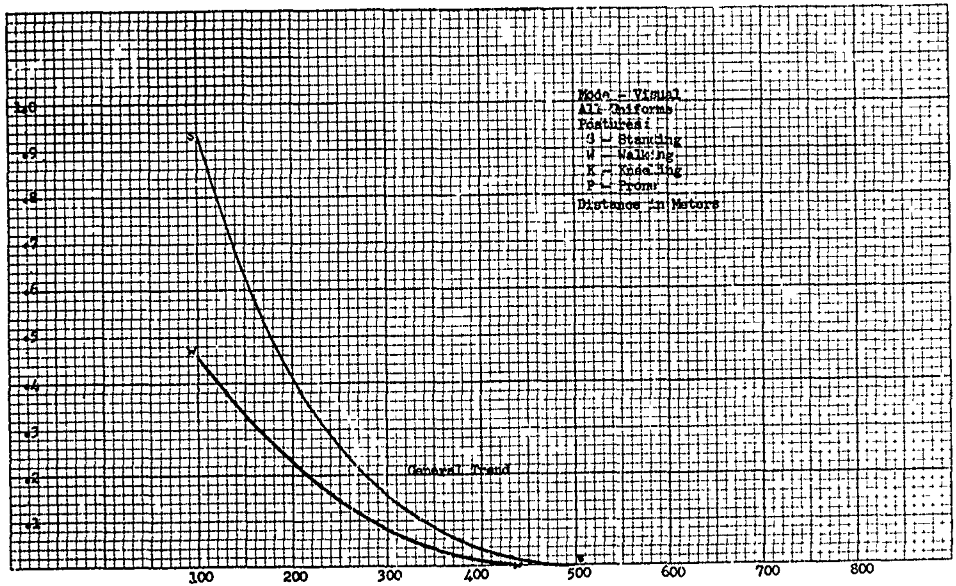


Figure 13. Full Moonlight Experiment



Percent Detection (1.0 = 100%)

Distance in Meters

Figure 14. Full Moonlight Experiment

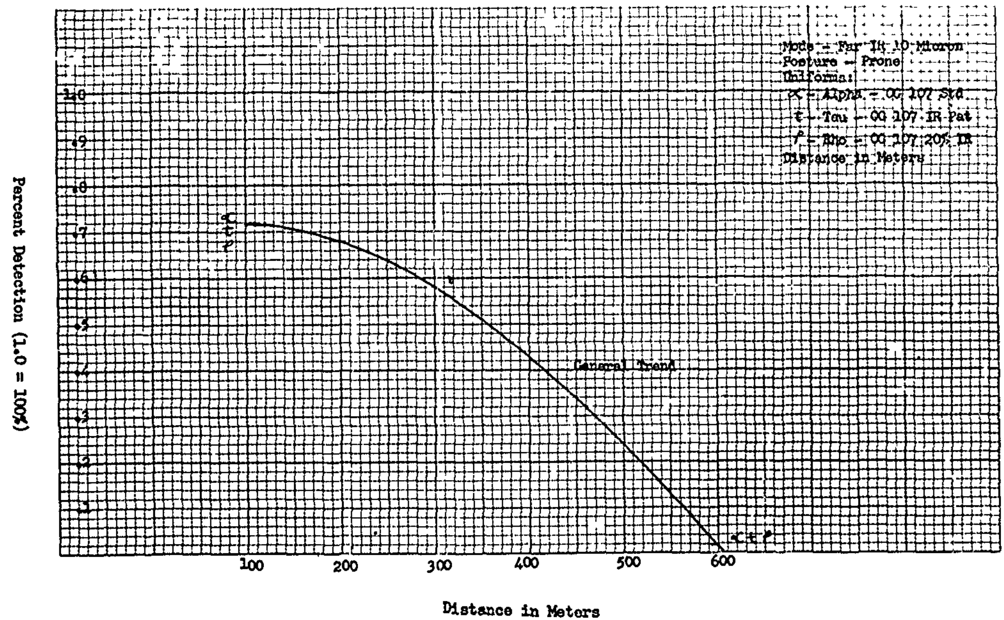
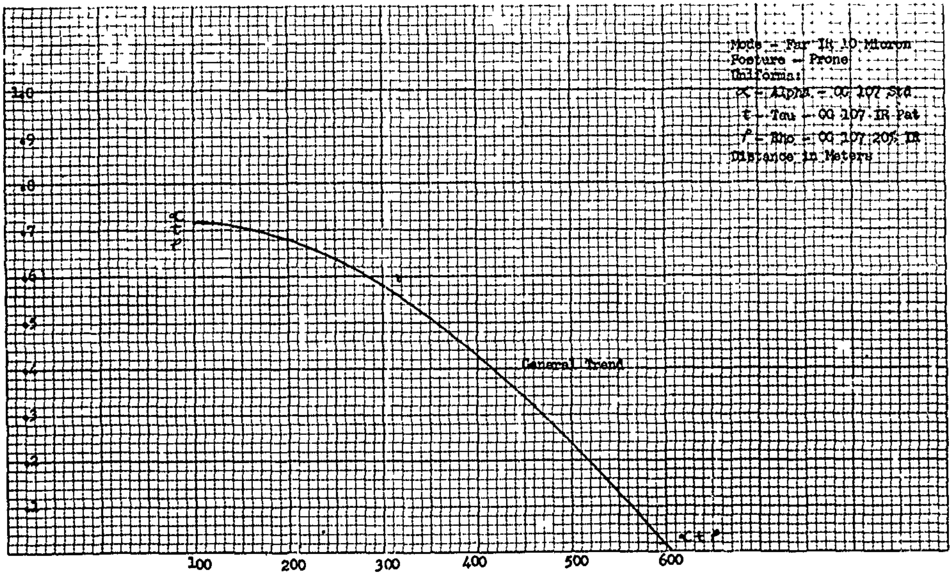


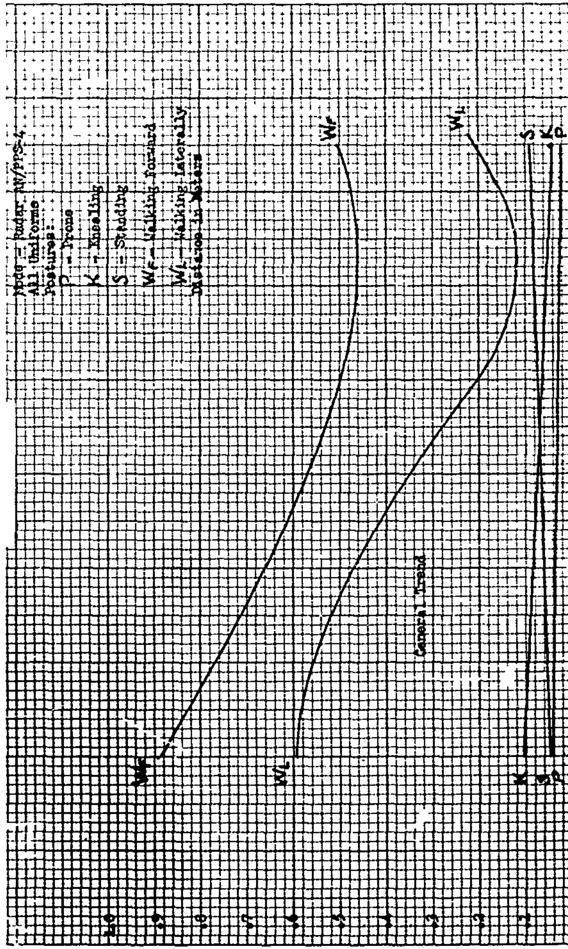
Figure 16. 12 Night Experiment (First 6 Nights)



Percent Detection (1.0 = 100%)

Distance in Meters

Figure 16. 12 Night Experiment (First 6 Nights)



Distance in Meters

Percent Detection (1.0 = 100%)

Figure 17. 12 Day Experiment

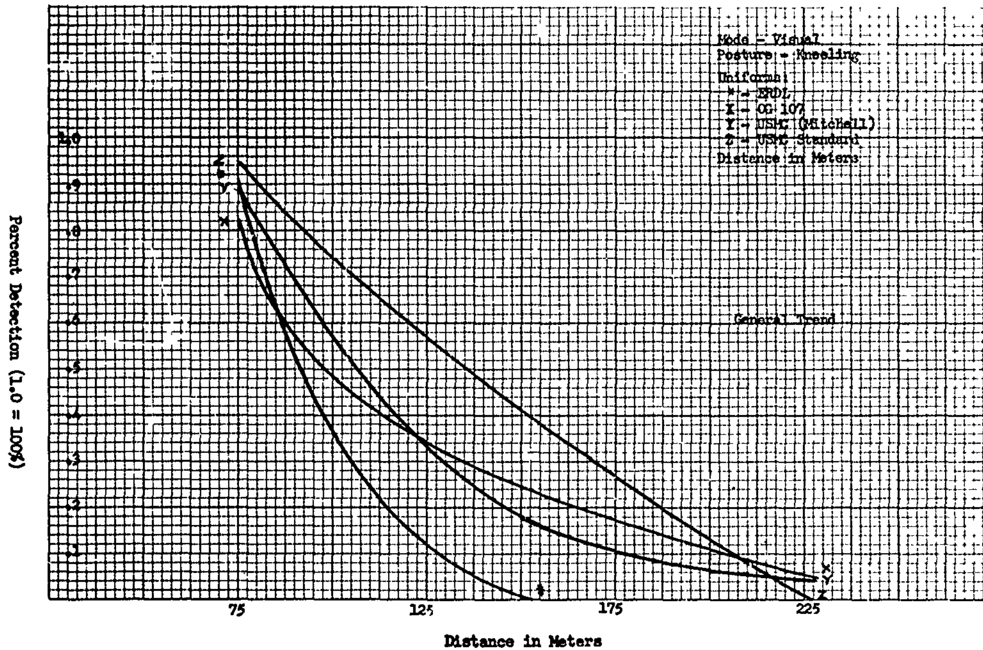


Figure 18. Simulated Infiltration

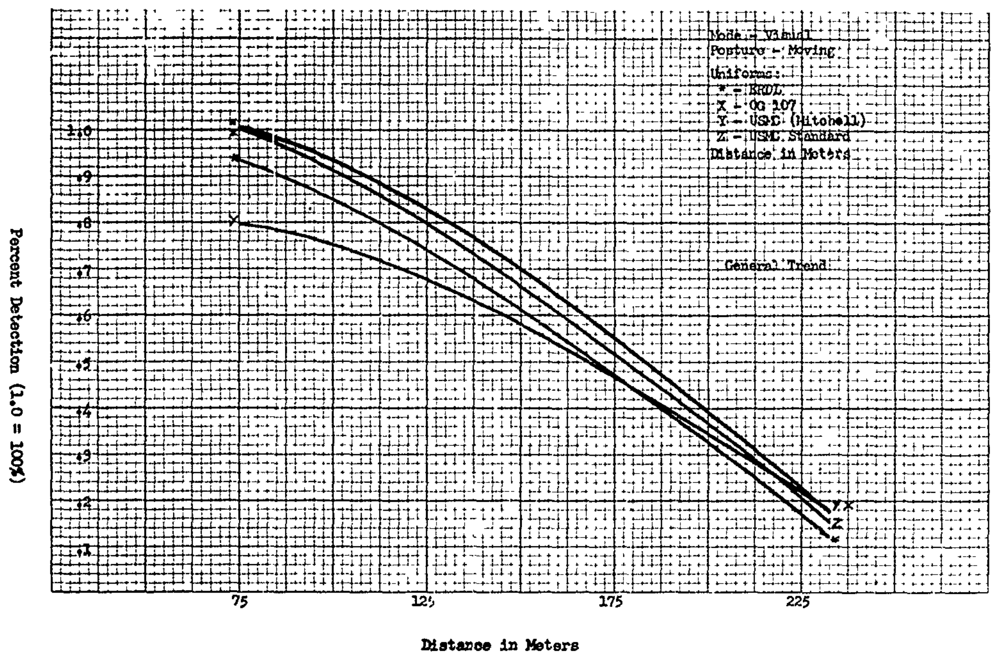


Figure 19. Simulated Infiltration

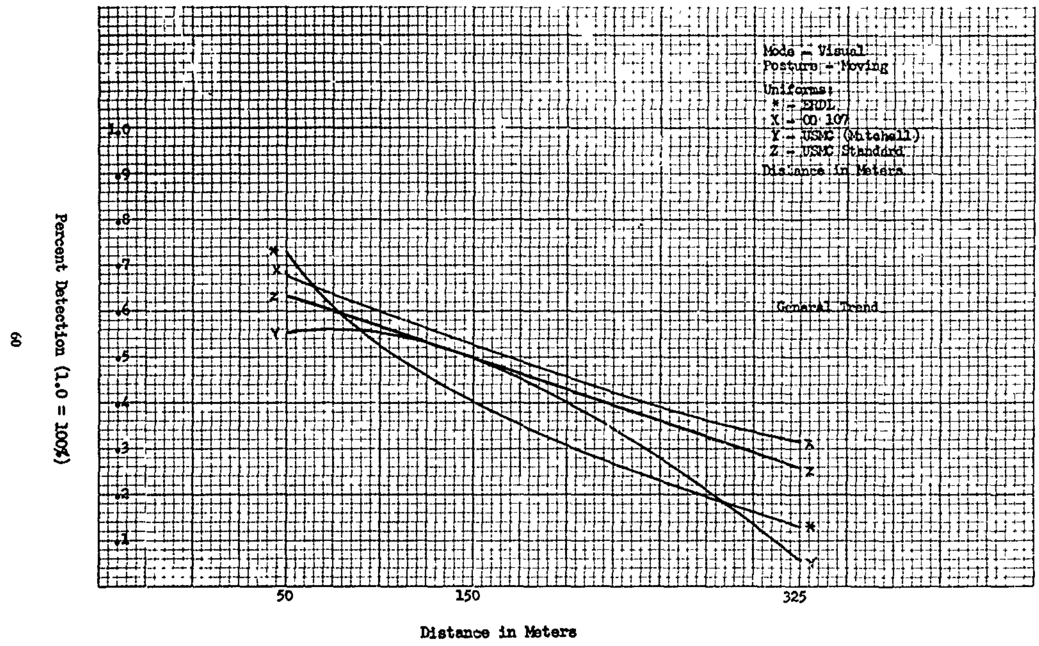


Figure 20. Simulated Ambush

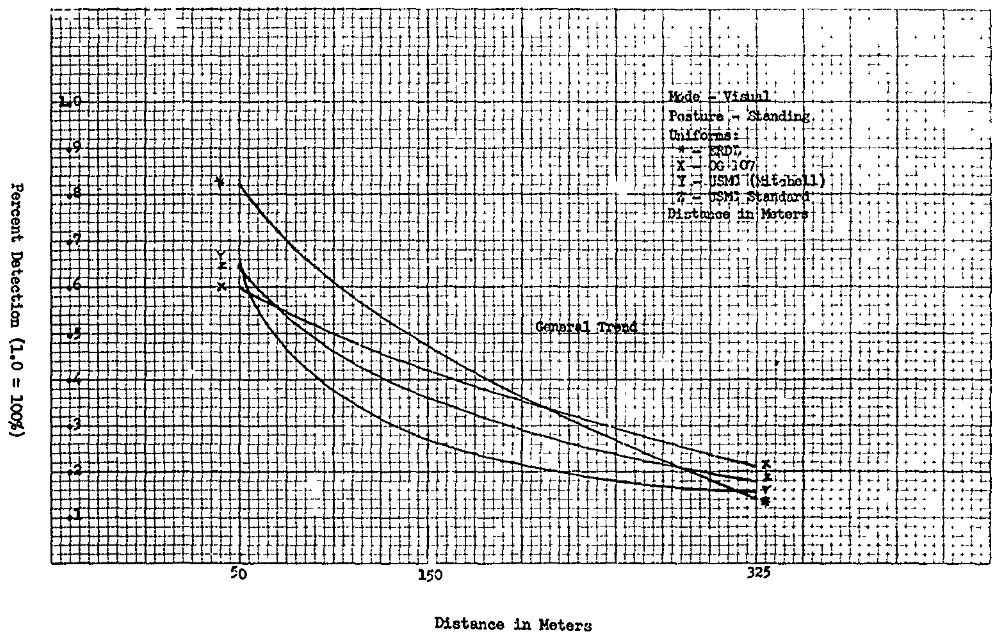


Figure 21. Simulated Ambush

D. HUMAN FACTORS AFFECTING RIFLE ACCURACY IN AUTO AND SEMI-AUTOMATIC FIRE by James P Torre, Jr., U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

(This is an unclassified abstract of the paper presented at the Conference.)

The U. S. Army Human Engineering Laboratories were requested by small arms designers to specify the effects of various rifle parameters on accuracy when the weapon was fired semi-automatically and automatically.

The paper describes several studies which were conducted by the Human Engineering Laboratories at Aberdeen Proving Ground during the past year.

Data were presented

(1) For semi-automatic fire, the effects on accuracy of three different types of sights in combination with two types of stock configurations for two levels of time to fire were reported.

(2) For automatic fire, methods of increasing accuracy were obtained and the results of studies conducted by Human Engineering Laboratories and Ballistic Research Laboratories were presented. The effects of several rifle parameters such as impulse, cyclic rate, stock configuration checking quality, etc., on accuracy when firing automatically were presented.

Additional studies on this problem were described and recommended for implementation.

E. OPERATIONAL ASPECTS OF INCAPACITATING AGENT BZ by Richard S. Kneisel, U. S. Army Chemical Corps School, Fort McClellan, Alabama

The presentation on Operational Aspects of Incapacitating Agent BZ, to the Eighth Annual Army Human Factors Engineering Conference, 17 October 1962, at the U. S. Army Infantry Center, Fort Benning, Georgia was given on a classified basis. The following represents an unclassified summary.

The ultimate objective of war is to subject one country's will to another. This involves the reduction of a country's manpower, resources and its will to fight. The foundation for all of a country's resources is the inner man.

The unclassified film "Armor for the Inner Man," shown to the Eighth Annual Army Human Factors Engineering Conference, depicts some of the basic research that the U. S Army Chemical Corps engaged in relative to incapacitating agents. The film describes some of the compounds that were utilized in the tests and describes the reactions of the individuals engaged in the experimental studies, showing specifically the effect of certain compounds upon a soldier's performance and a unit's performance in various types of situations such as marching, artillery surveys, and normal activities. Film emphasizes that there is a requirement to provide armor for protecting the inner man. The incapacitating weapon system could philosophically be called the "ultimate weapon" in that it theoretically causes no permanent physical damage to man or his materiel. It reduces theoretically the ability or will of a man to fight. It allows him, after a reasonable length of time, the capability of resuming his place in the scheme of activities.

Incapacitating agents offer a possibility of gaining control of an enemy where lethal and destructive weapons systems are not desirable. This incapacitation may be physiological or mental. The incapacitation, in order to be effective, must result in the exposed individual's being incapable of performing his primary military duties for a militarily significant period of time

The agent BZ is an incapacitating agent developed by the Chemical Corps and has been type classified as Standard B. Two munitions to disseminate this agent have been type classified as Standard B.

As in all combat operations, once a tentative decision to employ the incapacitating weapon system is reached, a detailed analysis of the situation, viewed in the light of target requirements and capabilities of the agent and munitions, must be undertaken. Such factors would include the following location of the target, nature of size and shape of the target area, the nature and temperament of the target population, time of attack, meteorological conditions, techniques of attack, munition and delivery requirements, exploitation requirements, and safety factors. The characteristics, capabilities, advantages, and limitations of incapacitating agent BZ and its associated munitions and delivery systems would be an integral part of the planning activities and the ultimate employment of the agent.

Incapacitating agent BZ has temporary physical and psychic effects sufficient to prevent an individual from going about his normal duties. The individual recovers in a matter of hours.

With the broad concepts of incapacitating agents in mind, paying particular attention to agent BZ, Human Factors Engineers should consider that a new dimension has been introduced into the combat situation. This new battlefield concept requires reorientation on the part of all personnel associated with military activities.

The use of incapacitating agents gives rise to many problems that Human Factor Engineers can assist in answering. For example How will casualties of incapacitating agents be treated and handled? What sort of specialized equipment can be developed for handling BZ casualties? What type of training problems need to be solved when considering incapacitators? Each participant in the conference should bring his thoughts to bear on the new field so as to see how his own special area of interest might be affected by the introduction of incapacitating agents into battlefield operations.

F MANAGEMENT OF THE U S ARMY HUMAN FACTORS ENGINEERING PROGRAM FOR THE PERSHING WEAPON SYSTEM by John R. Erickson, U S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

Several years ago human factors engineering personnel and missile system designers differed concerning the point in development of a system at which human factors engineers should be brought into the design picture to assure compatibility between the soldier and the equipment of large, complex weapon systems. During this period of the past the Human Engineering Laboratories (HEL) were not requested to evaluate a system until the system was fielded or in the final design phase. The results of these evaluations pointed up many deficiencies that should have been corrected. Design personnel generally adopted the view that had these deficiencies been pointed out earlier in the development cycle they could have been corrected. The cost at this point in time was prohibitive, therefore the change was withheld until such time that a major modification warranted the cost of incorporating the change recommended by the human engineers

This situation was, of course, unsatisfactory to all concerned. A solution was not forthcoming until the US Air Force refused to accept the JUPITER Missile System, in part, because of the excessive number of human engineering deficiencies in the ground support equipment. An outcome of this action by the US Air Force was the decision to give HEL authority to evaluate and recommend design changes which would correct the human factor deficiencies. One year later the vast majority of these deficiencies had been corrected, the Air Force accepted the JUPITER System and the Human Engineering Laboratories had convincingly demonstrated that they could make a contribution to the design of missile systems.

During termination of the redesign effort on the JUPITER System, the Director of the System Support Equipment Laboratory (SSEL) of the Army Ballistic Missile Agency (ABMA) invited HEL to develop and manage a human engineering program for the design of the PERSHING Weapon System (See Figures 1 and 2). The offer was accepted and the Human Engineering Laboratories were launched on a major development program at the beginning of the design effort. I think it advisable at this time to specify the ground rules by which the human engineering program was governed.

1. For all intents and purposes Human Engineering for PERSHING was established as a branch of the System Support Equipment Laboratory of ABMA with status equal to other branches of that laboratory. However, the personnel remained employees of HEL.

2. It was the responsibility of the Human Engineers to attend all design meetings which affected the design of the operational aspects of the system and to be prepared to contribute facts bearing on the operator's capabilities and limitations

3 It was the responsibility of the Human Engineers to bring to the attention of the Director of SSEL any problems concerning Human Engineering for which the Human Engineers could not obtain a satisfactory solution.

4. Although SSEL held primary responsibility for system design and development to the PERSHING Weapon System Office, ABMA, detail design was performed by the prime contractor, sub-contractors, other laboratories within the ABMA, other Ordnance Commands, such as Picatinny Arsenal, and Ordnance Tank and Automotive Command, and other technical services, primarily Corps of Engineers and Signal Corps. The Human Engineers were responsibile to the Director of SSEL to insure that the potential operators were given adequate consideration in the designs generated by all participants, and when the individual designs were put together, the Army would have an integrated system which could perform the mission specified within the requirements of the Military Characteristics with a minimum training requirement and a minimum requirement for specialized personnel

5. This would be primarily an exercise in Applied Human Factors Engineering. By this we mean that the Human Factors Engineer would act as the bridge between the Human Factors Research specialist and the weapon system designer. Another way to state this is that this was a four-year development program. We started with two Human Factors specialists—one a psychologist, the other an engineer. The pace of the program and the staffing would not permit many, if any, formalized studies, in the classical sense. The majority of decisions and inputs would have to be made on the spot with little time for cogitation but much time for regret. In order to make intelligent "on-the-spot" decisions, the human factors specialist had to have a wealth of experience and a thorough knowledge of the field of human engineering. He would have to be able to interpret results from previous research into applicability to the present design problem and then present this information to the design enginer in a manner which the engineer would accept. In addition, he would have to be able to pace the program and anticipate problem areas, early enough to permit obtaining an answer, in time to influence the design decision.

The following approach was taken by the Human Engineering Laboratories personnel to discharge their responsibility to the Director of the System Support Equipment Laboratory.

1. Provide guidance to representatives of other technical services on the design of PERSHING peculiar equipment for which they hold development responsibility, namely the Power Station and the Radio Terminal Set.

2. Provide guidance to other Ordnance Commands on the design of PERSHING peculiar components for which they hold development responsibility, namely the warhead, its tests equipment and container, and the system vehicles.

3. Participate in all design meetings between Army Ballistic Missile Agency personnel and the contractor, whenever the agenda included areas of interest to human factors.

4. Develop a close, personal working relationship with the contractor's human factors engineering group to insure that they are participating in the detailed design of the system on a continuing day-to-day basis and to uncover unsolved design problems of a human factors nature in order to bring about a solution as early as possible.

5. Develop a close personal working relationship with the following cognizant engineers at ABMA.

a. Electrical networks engineer for both ground support and airborne equipment. This was important because the electrical networks are the road maps of the system, they describe the flow of commands and responses, as well as the flow of information, and they are the means by which the operator controls his system. The electrical networks engineer also develops the layout of control panels and the arrangement and configuration of electrical test and checkout equipment.

b. Computer engineer. In this system, computation of the firing problem and transmission of this information to the airborne equipment is the responsibility of computer engineer. This engineer has to develop the means by which the soldier communicates with the computer, how he adjusts, repairs, and determines faults in the computer. He also determines the requirements which will be placed on the soldier and the requirements which will be placed on the computer.

c. Handling equipment engineer. Mechanical design engineers are responsible for the development of the handling equipment required to assemble, transport, and fire the missile. This is the area in which most of the system's manual tasks will be performed, and it is in this area that information relative to the soldier's physical characteristics is required. This is the area in which teamwork within the firing crew will be very important and this is one of the areas where the soldier can make or break the system.

d. Azimuth Laying engineer. This is the other area where the soldier can make or break the system. Physicists, mechanical and electrical engineers combine their talents to develop, to the limitations of the state of the art, the equipment required to accurately lay the missile.

e. Systems Engineer. The systems engineers are responsible for over-all system integration, particularly as concerns coordination with Ordnance Tank and Automotive Command for vehicles, Signal Corps for communication equipment, and Corps of Engineers for power generating equipment and other items such as winterization kits and shop sets.

It was not long before it became apparent to all concerned that in order to insure a uniform and systematic application of human factors criteria to the design of this system, an official document spelling out these criteria was required. As a result, the contractor's human engineering personnel and representatives of the Human Engineering Laboratories jointly developed a document which later became known as PERSHING Development Specifications for Weapon System Human Factors Design Criteria, Specification No ABMA-XPD-844. This document was staffed through the System Support Equipment Laboratory, PERSHING Weapon System Office, and concurred in by the Guidance and Control Laboratory and the System Analysis and Reliability Laboratory of the Army Ballistic Missile Agency. Incidentally, to the best of our knowledge, this was the first time that a human factors specification was developed for and used throughout the development of a major Army Weapon System.

About the time that the need for a Human Factor Criteria became apparent, it also became apparent that a full-time representative was required at ABMA to act as our liaison. As a result, one of HEL's representatives was placed on extended TDY to ABMA. At a later date, a Human Factors Engineering Requirements Coordination Office was established at ABMA. This office has recently been incorporated into the Engineering Requirements Coordination Office, which in turn is a staff office of the Director of Research and Development for the Army Missile Command.

To recap the foregoing, we are able to manage the Human Factors Engineering Program for the PERSHING Weapon System because:

1. Representatives of the Human Engineering Laboratories provided guidance to other Army Technical Services.

2. They provided guidance to other Ordnance Corps agencies.

3. They monitored the contractor's human factors efforts.

4. They worked directly with the designers at all phases of system development

5. They were accepted by the Army Ballistic Missile Agency as a part of their design team.

6. A Human Factors Development Specification was prepared early in the design effort and has been utilized throughout the program.

. A Human Factors Engineering Requirement Coordination Office was established at the Army Ballistic Missile Agency. Incidentally, this office appears to be developing a capability to handle more and more of the applied human factors responsibility in the development of Army Missile Systems.

It may be appropriate to spend a moment to reflect on the differences in the roles of a human factors engineer when employed by the Army as opposed to being employed by a contractor.

I believe that in both instances the individual human factors engineer is ultimately responsible to the soldier to provide him with a system which he is capable of operating in all types of environment with a minimum of training.

The major difference in the two positions is that the contractor's Human Factors Engineer is responsible for detail design, that is, nuts and bolts, knobs and dials, accessibility, determining operating times and operating forces for all components of the system as they are being developed.

The Army's human factors engineer is responsible to provide direction to overall effort, determine compatibility with the Army system, logistics, operation, training, etc. The Army's human factors engineer should also participate in the test and evaluation of the system. I believe that he should be required to train a crew to operate system components as they become available and later operate the system in a tactical configuration to insure that the Army is obtaining the system which it requires.

Steps which have been taken to improve the effectiveness of the contractors Human Factors Engineers includes: (1) requiring detailed accountability to the project office for all comments generated by the Human Engineering Laboratories representatives, (2) active participation in formal presentations to the Army, such as PERSHING Component Exhibits, (3) formal Human Engineering meetings, (4) Human Factors Development Specification, (5) Ordnance Procurement Instruction which directs the contractor to consider the human factor in the development cycle, and (6) frequent contact with the Army's human factors specialist responsible for the system under development.

Steps which have been taken to improve the effectiveness of the Army's human factors engineers include.

1. The acceptance by the Army Missile Command of Human Engineering as a contributing member of the design team.

2. The recognition of the need for and the development of a Human Factors Specification, ABMA XPD-844.

3. The development of a capable Human Factors Engineering Requirement Coordination Office at the Army Missile Command.

4. An Army Human Factors Program which reflects, in the area of weapon system development, experience gained from the PERSHING program

5. An increased awareness of the desirability of closer coordination between the Human Engineering Laboratories, Army Personnel Research Office and Human Resources Research Office.

In summary, I have discussed the following areas as related to managing the continuing evaluation of the development of the PERSHING Weapon System·

a. The Human Engineering Laboratories definition of APPLIED HUMAN FACTORS ENGINEERING.

b. Approaches taken to coordinate the human factors engineering activities at the several Army agencies holding design responsibility for portions of the system and monitor the efforts of the contractor's human factors engineering group.

c. The roles filled by the Army human factors engineers and the contractor's human factors engineer.

d. Steps which have been taken to increase the effectiveness of both types of human factors engineers.

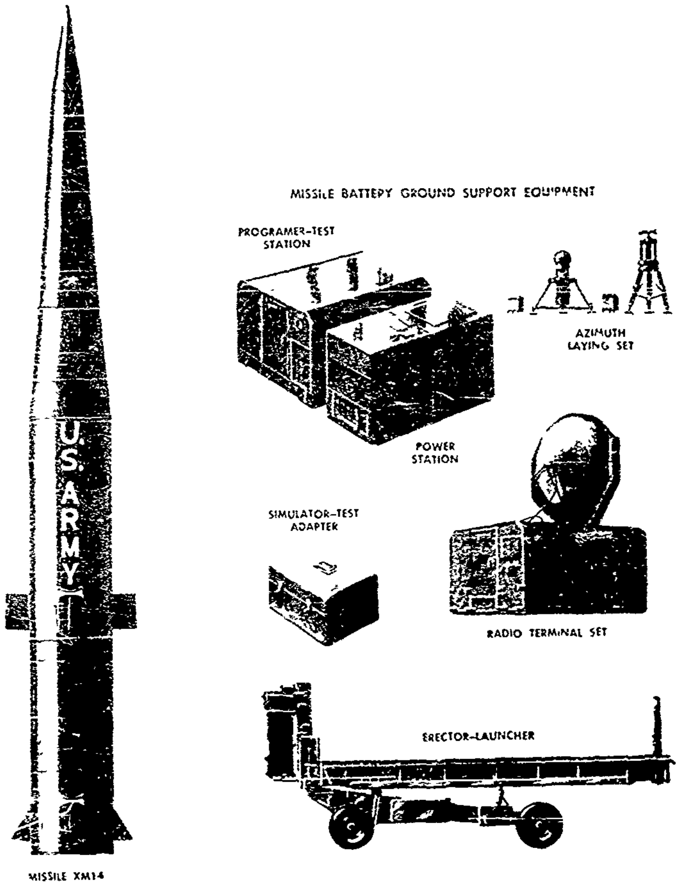


Figure 1 Major Components of the PERSHING Weapon System

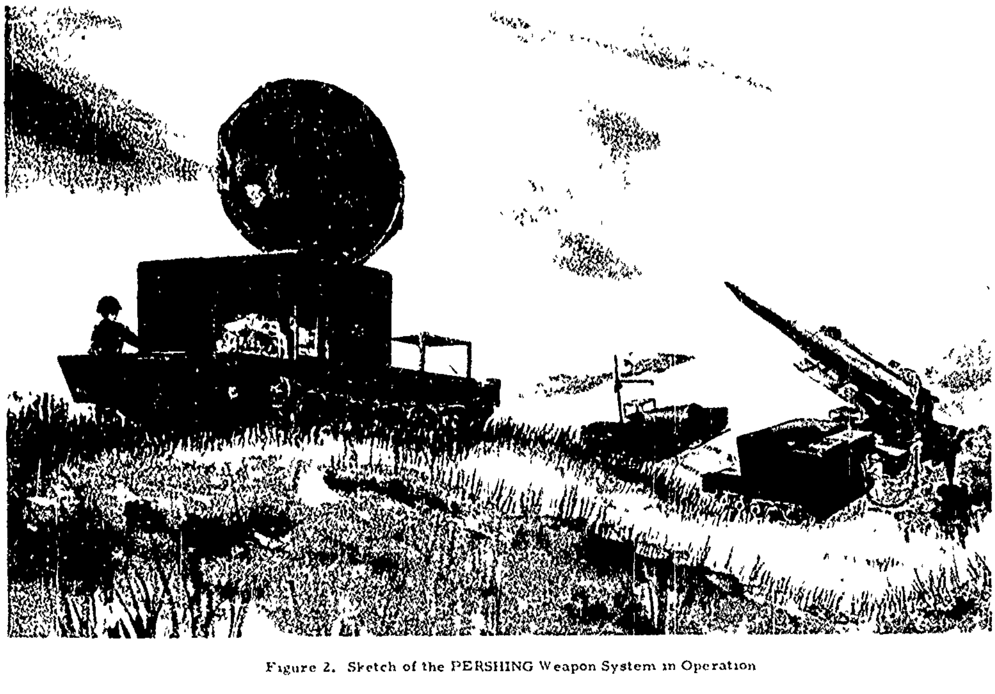


Figure 2. Sketch of the PERSHING Weapon System in Operation

CHAPTER 3

DESIGN FOR COMBAT SUPPORT
CONFERENCE SESSION II-B

A. AN EXPERIMENT IN QMC SYSTEMS RESEARCH by Alexander Levin, U. S. Army Quartermaster R&E Command, Natick, Mass.

INTRODUCTION AND BACKGROUND

In military operations, the performance of men working as a team or crew is of ever-increasing importance. Small units such as squads, gun crews, mine teams, etc., historically have formed the basic human composite for military tasks, and as contact with remote geographic regions continues, the value of the small, integrated, and self-sufficient unit becomes even more important. Recent activities in the Far East have re-emphasized the value of small groups of personnel. Moreover, in Polar Regions particularly, it is expected that such a unit (4-8 men) will work together, cook and eat together, and share the same shelter. Yet, at present, available information on measurements of groups of military personnel appears to be inadequate. While much research has been focused on individual performance, much less systematic work has been accomplished on small group and small system performance measurements [2].

If you have been to the Arctic, I need not emphasize the burden imposed by clothing and equipment which are essential merely for survival. For example, for a small operational unit, precise planning of an integrated assemblage of rations, fuel, shelter, clothing, and operational tools is always necessary. Moreover, considerable effort and time must be expended in procuring and assembling the myriad of required items and components from supply sources because of the manner in which these items are stocked. In spite of continuous efforts of Quartermaster Corps scientists and engineers to reduce the number of items used in military operations, continually changing requirements produced by changes in military and technological situations tend to expend the complexity of equipment required for the care and feeding of troops. However, some progress has been made. For example, tariffs of clothing sizes have been reduced, tentpole-stovepipe combinations have been tried, and a universal single combat uniform has been proposed [3].

One of the problems frequently experienced is that the evaluation of a new item or requirement is generally developed from measurements and analyses based on the relative merits of comparable items. Moreover, the parameters which help to define Quartermaster system design criteria are seldom specified. In the past, research has been carried out with a focus on those psychological, physiological, and biophysical parameters which are based upon the limitations of the individual rather than the group. Likewise, tests and evaluation of materiel have tended to focus on the limitations of individual items with little emphasis on overall system effects.

In 1959 an opportunity was presented for studying small military groups operating over the Greenland Ice Cap [1], always a logistically formidable problem. Probably there are not many other portions of the earth in which the capabilities of men, equipment, and organizations are stressed by unusual extremes of climate and terrain as they are in this Polar Region. It was felt that in such a situation some information could be developed on the following questions

a. Can operational factors influencing logistics at the lowest unit level be identified and measured objectively?

b. What is the relation of small system components to an overall objective measurement of effectiveness of the entire system?

c. Can a methodology be developed to assess Quartermaster Corps components on a system basis?

CONCEPT AND PROCEDURE

As was implied earlier, the complexity of modern military technology has intensified the need for system engineering. Even though individual components may satisfy all of their specifications, they may not fulfill their function when combined as a system. In general, a system is defined as an assemblage of objects functioning in interaction. In this study it is specifically an intimate interaction between assemblages of equipment and groups of men working to accomplish a common objective in an extreme environment.

The concept of the system investigated in this study is illustrated in Figure 1. Three discrete objects are distinguished as the interdependent system components. the module, the pomms, and the tasks. The module identifies a basic group consisting of six men. In this experiment the module, hereinafter called the group, was the basic decision-making unit and in addition performed the essential military tasks. The pomms, hereinafter called assemblages or materiel systems, were used by each group during some portion of the experiment.

The traditional basis for selecting a system of items has been to determine how well it protected one from environmental stress; however, the design and selection of system components may also be based on reduction of the load placed on support systems. This latter alternative was the viewpoint emphasized in this investigation. Thus, the measurement of fuel and food energy inputs was used as an index of relative load value placed on supporting systems. The value, however, cannot be judged on this factor alone, but must be related in some way to a measurable output which is representative of the operation of the system as a whole. The tasks designate related networks of daily actions in which groups of personnel and assemblages of equipment interact to accomplish a standard objective measured in standard units of time, distance, and mass.

The study was carried out on the Greenland Ice Cap near Camp Fistclench, at approximately latitude 76°59'N, longitude 56°4'W and an elevation of 7,000 feet. Figures 2 and 3 illustrate the conditions typical of the area, as well as the facilities developed to support the conduct of the study in three separate areas which were isolated from each other. The study was conducted during a six-week period from the middle of July to the end of August. This period of time was selected for the initial study to minimize exposure to extreme environments associated with seasonal changes. Nevertheless, this time frame gave adequately variable and increasingly severe climatic conditions for a reasonable study. Figure 4 shows the environmental conditions measured during the six-week period of the study. Note that temperatures above freezing were encountered for a very short time during the second period, and the decline in temperatures below freezing continued thereafter. The low of minus 18°F occurred during a non-experimental day.

The plan for the study included three possible assemblages of equipment typical of those intended for use by military units that will live and operate in the Arctic environment. Three groups of six men (Alpha, Bravo, Charlie, Table I) were associated with each equipment system used to accomplish a series of tasks on which measurements could easily be obtained. Each of the materiel systems was used by each group for six days. During this period each group followed a schedule of controlled activities. At the completion of a cycle (i.e., three weeks), during which each group used all three systems for six days each, the personnel of each group were realigned into three new groups, one of which had to be eliminated from the study for medical reasons, thus leaving data on two groups for the second cycle (Delta, Echo, Table I).

TABLE I

Average of Group Characteristics

	Age (Years)	Height (Inches)	Educ Level	Weight (Pounds)
Alpha	23.2	68.6	11.0	163.0
Bravo	23.2	69.2	11 2	153.4
Charlie	20.6	70.0	10.8	161.2
Delta	19.6	70.3	10 8	164.2
Echo	22.0	69.2	11.0	156.2

The groups were organized from volunteer military subjects. Each of the groups was composed of one officer, one noncommissioned officer, and four enlisted personnel. The characteristics of groups are shown in Table I. Physical conditioning, pretesting, and orientation took place at Fort Lee, Virginia. Indoctrination in the use of equipment and procedures took place on site in Greenland.

The materiel systems were selected on an empirical basis to provide three levels of accommodation which differed in the type of shelter, food, and heating equipment used. Each materiel system was divided into five subsystems to obtain manageable groupings of components. These functional groupings include (1) clothing, (2) shelter and protection, (3) heating, (4) food, food service and sanitation, and (5) operational equipment. The materiel systems used were limited to items of QMC cognizance. Therefore, weapon system components were not included. An example of a major difference between systems is illustrated in Figures 5, 6, and 7. Although several designs of the type of shelter shown in Figure 5 were preplanned and available, the groups were encouraged to and did apply their ingenuity to create their own <u>in situ</u> type shelter design and their own construction procedures.

Wherever possible, tasks and environmental conditions were equated for all three groups. The control of activities involved grouping daily tasks typical of those required of United States military personnel operating in such an environment. These activities provided for two types of experimental days one involving individual load movement as shown in Figure 8, and the other involving load movement by the group as pictured in Figure 9. The study was designed to evaluate the three types of assemblages as well as to provide measures of the interaction between the groups and the materiel systems.

Instrumentation was limited to that required to measure time to accomplish tasks, weight, volumes, and distances. Subjective measurements were obtained through questionnaires, diaries, and interviews (1).

RESULTS AND EVALUATION

In this study, emphasis was directed at obtaining measurements which could be used to discriminate between the effectiveness of each system as a complete, integrated unit. This was accomplished by studying the outputs produced with each system and the inputs required to maintain or support each system.

Output

Three categories of output effectiveness were assumed. These involved measurements to obtain habitational, restorational, and operational characteristic values.

The first (habitational) involved, summations of time to accomplish all jobs related to merely living in the environment, such as, erection and dismantling of shelters, preparation and consumption of meals, personal maintenance, etc Values for this category were found to be too complex and inconsistent because of inadequate time keeping. This occurred because of some overlapping of activity time and insufficient instrumentation.

The second category (restorational) involved the physiological effect of the materiel systems upon the groups as reflected by the net loss or gain in body weight for each period. The weight loss or gain of the groups using the different assemblages under the experimental conditions indicated a trend favoring the group shelter design. The net losses for systems A and B over the total of experimental periods were 4.5 pounds and 6.8 pounds, respectively. Groups associated with materiel system C had a net loss of 22.3 pounds.

To examine the third category, criteria of the operational output advantages of one system over another were evaluated. Accordingly, the rates of movement of groups when using the different materiel systems were studied Figure 10 focuses on the mobility factor and indicates that the rate of movement was not necessarily best for the lightest weight system. It is pertinent to note that the advance of lower temperatures with time improved trafficability and influenced the rates of movement for all systems significantly.

In Figure 11, the transportability factor is plotted based upon the rate at which the total operational tasks were accomplished. For the same unit load, differences in the two methods of transport are clear. Sled pulling can be seen to be superior to back-carrying.

Total system output was considered to be limited to the work done with the specific operational tasks of sled pulling and pack-carrying. Figure 12 charts the level of effort involved for each system. These data were obtained directly from the operational loads pulled or carried. Although a consistent level of effort should be expected, the variability in the data is due to load change as food and fuel were consumed and to alteration in distances over which the load was moved. Except for the first period, the mean of the data tends towards a fairly flat but gradually rising characteristic for two of the systems (A and B), which confirms the fact that load and distance were fairly constant. The trend of materiel system C is gradually downward and it is believed to be the result of living in splintered groups, that is, in 2-man shelters, when exposed to increasing severity of weather. This is also suggested by the net weight losses experienced by the groups associated with this materiel system, C.

Input

Two of the basic inputs to any man-machine system performance are energy supply and maintenance, and in the group-materiel system concept the energy supply was in the form of food and fuel. Figure 13 charts the food-fuel inputs for each of the three systems. Although some differences in food input were noted, they were not significant. The fuel input required by each of the systems is quite different and is responsible for the differences noted in Figure 13. The energy cost in fuel for assemblage B is immediately obvious. The low fuel requirement for assemblages A and C suggest that economies in fuel may be obtained by smaller group shelter designs. When the second and third experimental days of the sixth period are examined we find that although the operational output factor for assemblages A and B are reduced to zero because of intense Arctic fog or "whiteout," input requirements rose. It would therefore seem to be reasonable to conclude that fuel requirements for small dismounted units tend to vary inversely with level of operational effort, and the magnitudes will vary directly with fuel utilization capacity as well as with length of time used

In order to place an index or comparative evaluation number on each of the three systems, the ratio of measurable work output (Figure 12) to total measurable input (Figure 13) was derived The output-input ratio or index of effectiveness gives an approximate rank-order of the three systems. The general form of the index of effectiveness is shown below

Generalized Effectiveness Index

$$AISE = 0.001258 \frac{W_O}{Q_T} \cdot T_O = 12.6 \times 10^{-4}$$

$$\frac{W_O}{Q_T} \cdot T_O$$

Where

W_O = Total work done for all operational missions/day (mobility, habitability, and restorability).

Q_T = Total energy input to system (BTU's per day).

T_O = Ratio of actual time to total time for all operational missions per day.

In the study conducted, the values obtained from the computation of system effectiveness appear to be a representative index for each of the assemblages, that is, the pertinent physical variables are included in the formula.

By considering the groups as independent variables and averaging the values for their performance, we find that the indices of group performance are quite comparable. The column titled "Effectiveness Index" in Table II shows a consistency between at least four groups. On the other hand, the low value for the group Charlie was expected, since it was affected in the first period by the loss of one of its members. For all practical purposes it can be concluded that four groups were approximately equivalent in effectiveness. Thus differences found may be attributable to the materiel systems.

TABLE II

Summary of Group Effects

	Initial Weight Lb	Net Weight Change Lb	Average Morale Score	Rates of Movement Ft/Min	Effectiveness Index
Alpha	163.0	-8.25	-6.30	171/180	8.7
Bravo*	153.4	+6.50	+6.40	176/179	8.8
Charlie**	161.2	-1.75	-0.05	167/88	6.0
Delta**	164.2	-22.75	13 60	224/250	8.0
Echo*	156.2	-7.25	15.00	218/225	9.5

*, ** Identical leadership.

The values obtained for each of the materiel systems are shown in the "AISE" column of Table III. These effectiveness numbers may be interpreted as the relative value of a system. For example, in the most effective system, of every 100 energy units required to support it, at least twelve units are operationally useful; for the least effective, only about five. It also shows which system tends to minimize impact on supporting systems. By this method, the objective ranking is obtained and listed in the last column of Table III.

On the other hand, the subjective ranking shown in Table III was obtained from the groups directly by periodic questionnaires. If you compare the ranking of the systems based on the objective measurements with those based on subjective ratings, the disagreement in ranking is obvious. The explanation may be that the subjective ranking of efficiencies was expressed in terms of personal comfort. Thus the subjective selection of systems followed attitude preference and was to be expected. At the same time, the weight of the most comfortable system (Assemblage B) was heavily criticized and the lighter load and simpler food system of the lighter system (Assemblage C) was praised. Thus it may be concluded that while the subjective efficiency is indicative of user preference, the objective efficiency reveals the probable ranking of those charged with providing support to a combat group under such environmental conditions.

TABLE III

Summary of System Effects

	Value $	Weight Lbs	Volume Cu Ft	H.F. Load Lbs	Group Effect Lbs	Food Factor Cal per Man-day	AISE	Fuel Factor Gals per Sys-day	Subj. Rank	Obj. Rank
System A	1681	700	67	117	- 4.5	4114	7.5	0.78	3	2
System B	1834	908	80	151	- 6.8	4519	4.9	2.58	1	3
System C	1810	784	72	131	-22.3	4267	12.1	0.44	2	1

SUMMARY AND CONCLUSION

The research under which this experiment was conducted involved an attempt to focus on the interaction which human requirements and materiel design factors may have on supporting systems. In the future it may be possible to specify component design criteria on the basis of such work. The indices of system effectiveness, although not conclusive at this phase of the work, indicate the feasibility of obtaining objectively derived values of system performance when components are changed. When carefully measured subjective values, judgments on the compatibility of new system components, objective measures of system performance and of the economics of system support are obtained it should be possible to specify measurable criteria for new components and systems.

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3. U S. Army Quartermaster Corps R&D Annual Reports, 1949 thru 1959.

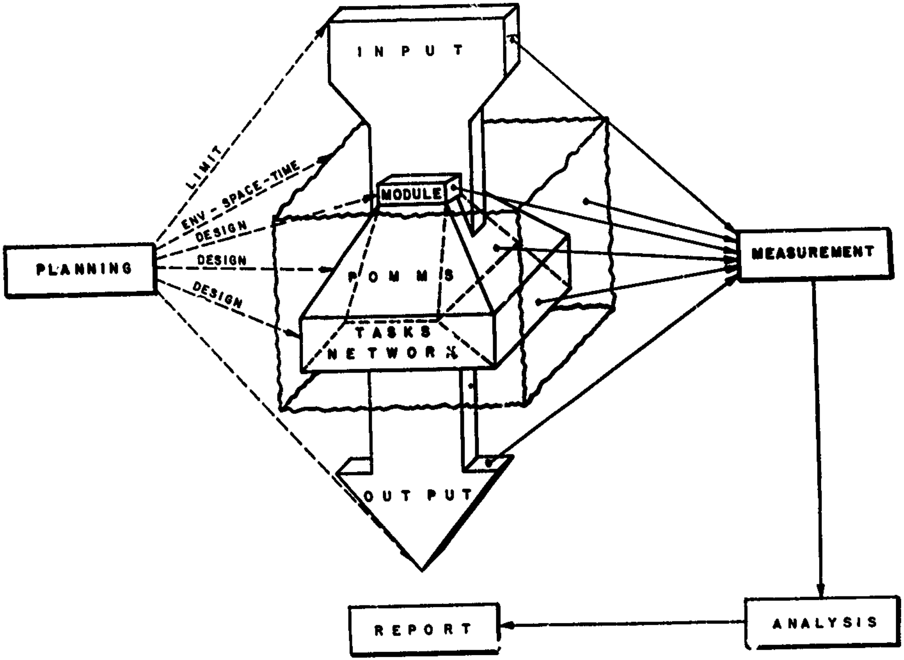

Figure 1. General Concept of QMC Systems Research Experiment

Figure 2. QMC Polar Systems Research Area in Greenland (July-August 1959)

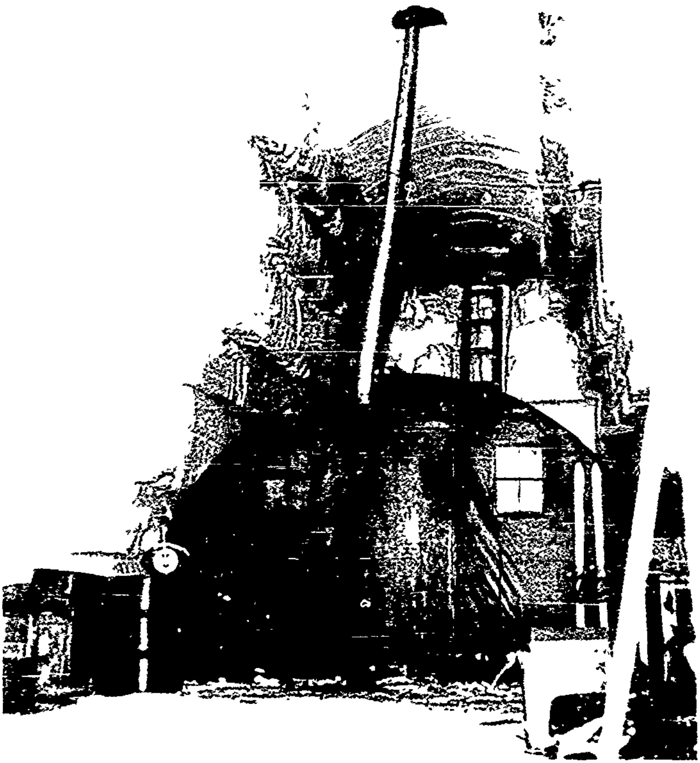

Figure 3 QMC Polar Systems Research Support Facility in Greenland (July-August 1959)

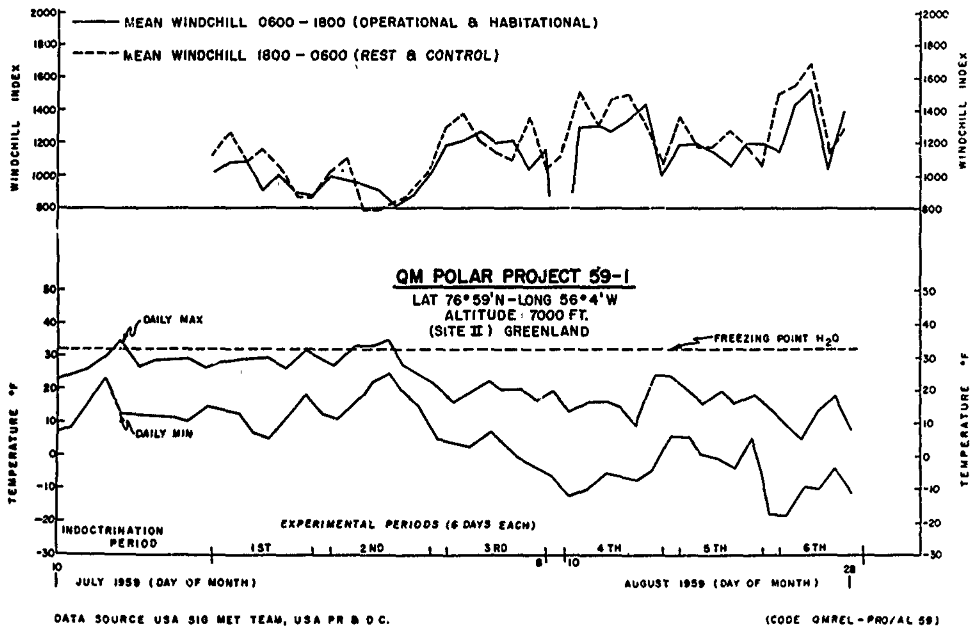

Figure 4. Environmental Conditions (Temperature)

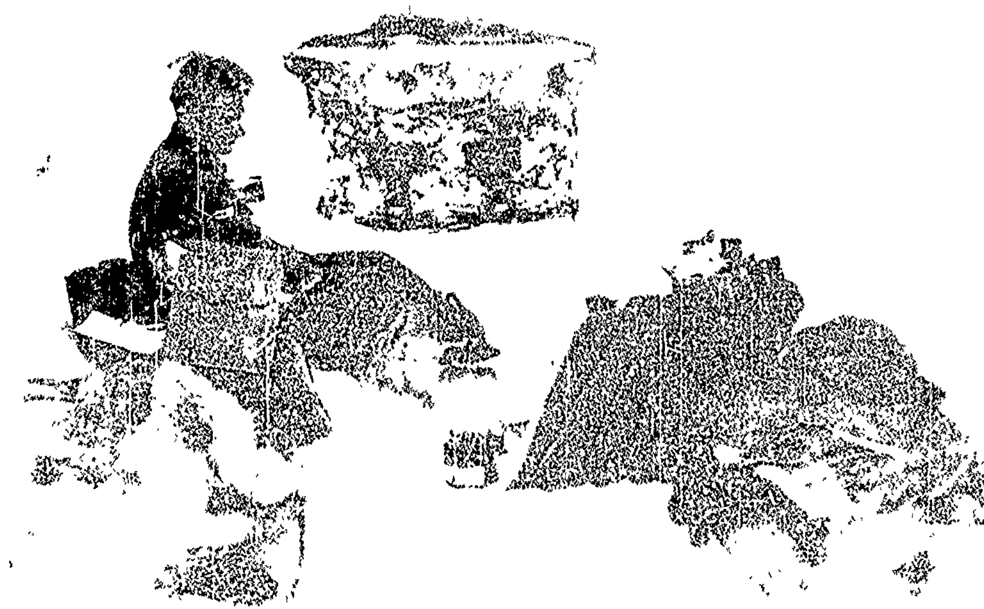

Figure [illegible] Habitability of [illegible] in Shelter of [illegible] system

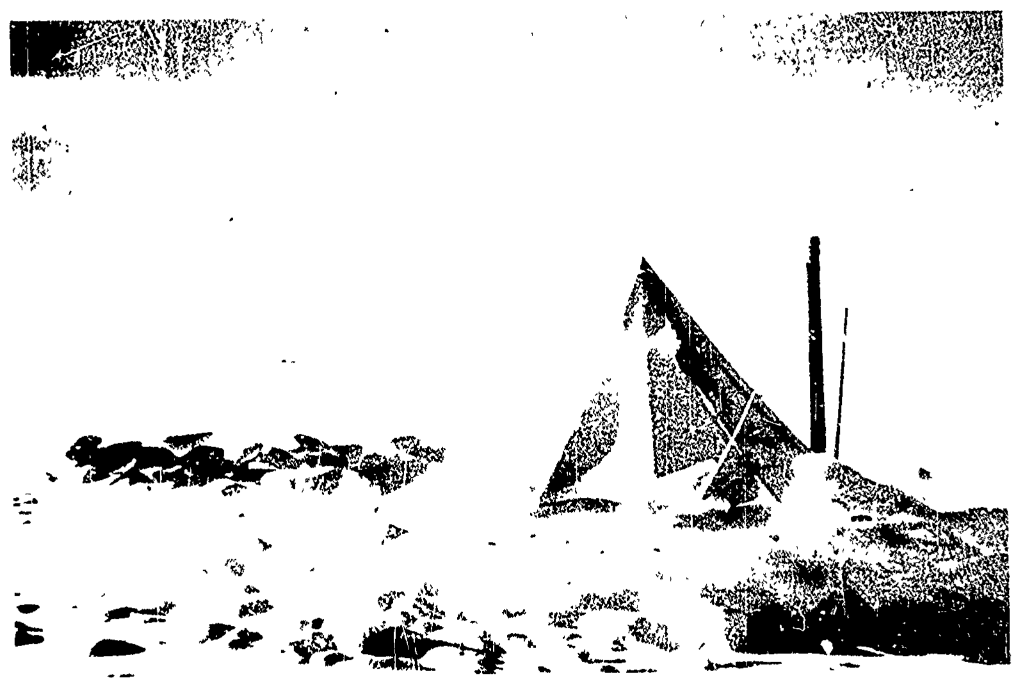

Figure 6. Habitability of 4-6-Man Shelter of Materiel System B

Figure 7. Habitability of 2-Man Shelters of Materiel System C

Figure [illegible]. Individual Back Packed Load Movement (All Systems)

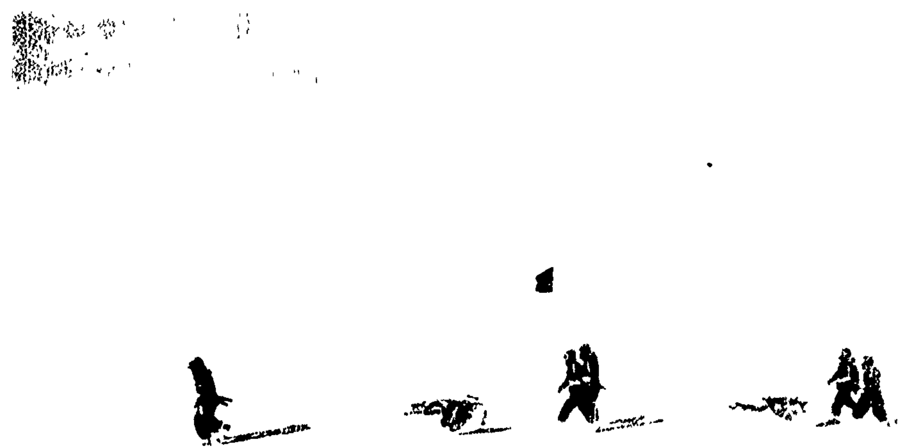

Figure 9. Group Sled Pack Load Movement (All Systems)

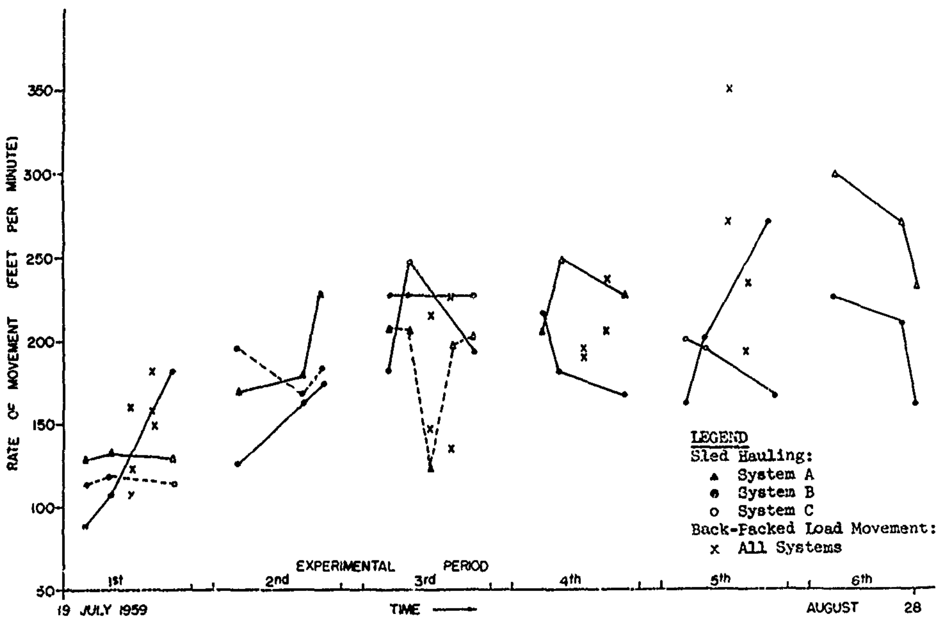

Figure 10. Mobility Factor

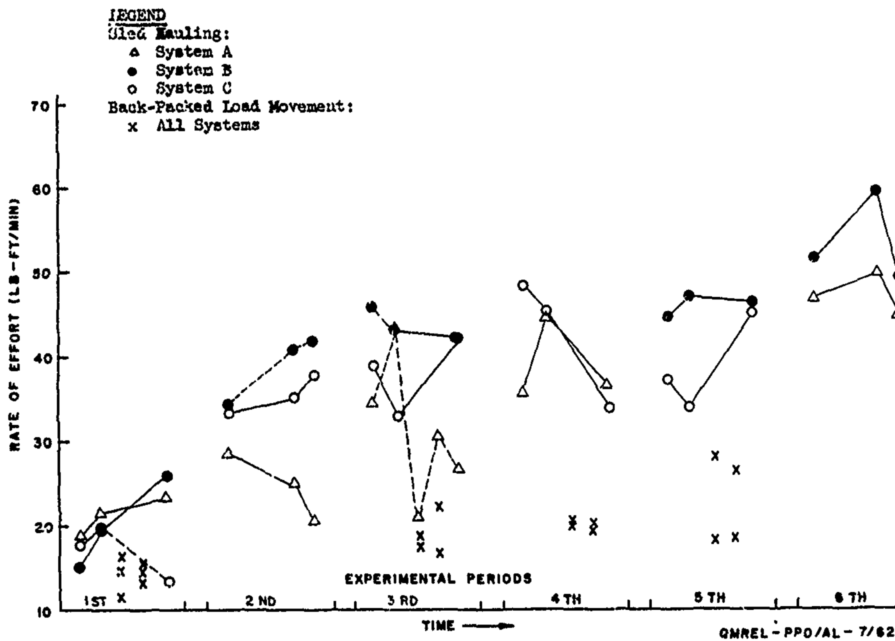

Figure 11. Transportability Factor

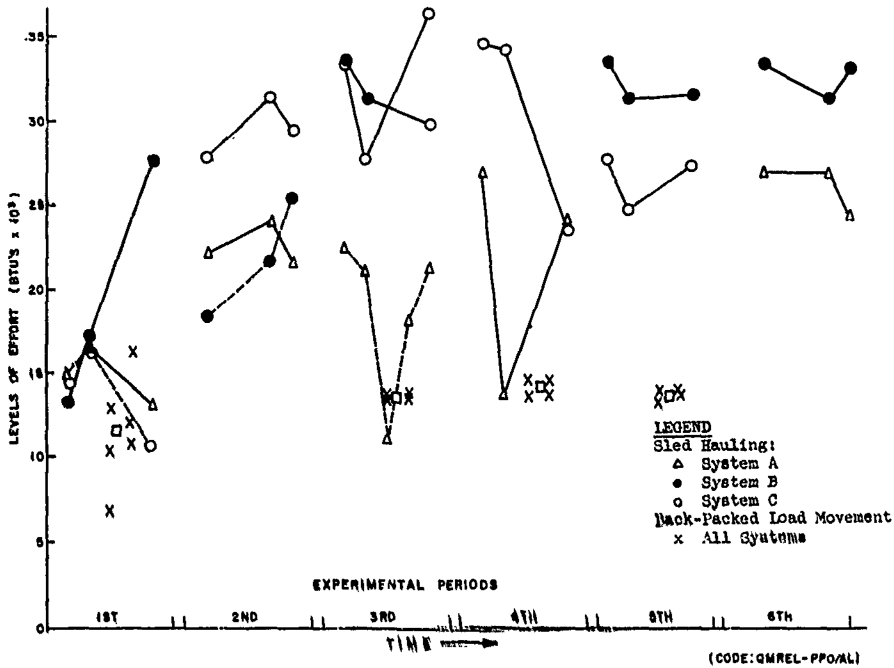

Figure 12. Output Level

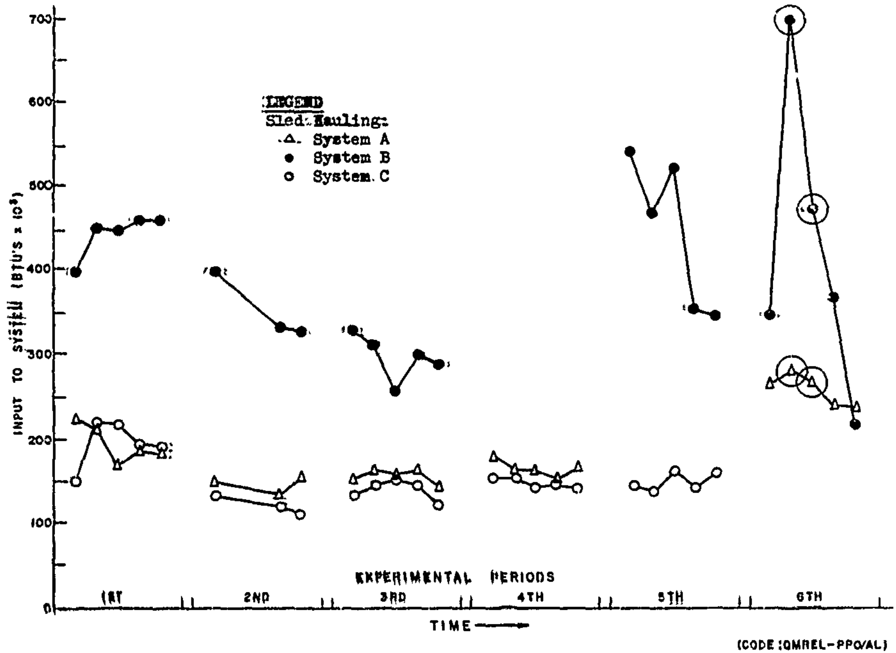

Figure 11. Input Factors

B EFFECTS OF ATMOSPHERIC NOISE LEVEL AND WORK METHODS ON RADIO TELEPHONE MESSAGE TRANSCRIPTION by Anthony E Castelnovo, U S Army Personnel Research Office, Washington, D C.

I. Introduction

The problem area underlying this research is that of improving the quality of transcripts of noisy radio messages. Even though limited improvement in the signal to noise ratio can be achieved by filtering and other techniques, noise continues to be a problem

In analyzing the methods by which transcripts are produced, it appeared that some improvement in accuracy and completeness might be afforded by utilizing available manpower in a somewhat different manner.

The normal procedure in the transcription of voice radio messages is to tape record the original message which is then given to a transcriber who makes a transcript In cases where the message is masked by noise, the transcriber may scan portions of the tape repeatedly until he is satisfied that he has gotten as much of the message as he can possibly get to make the most complete and accurate transcript

It was assumed that the quality of a second transcript would be better if produced by a second listener with the aid of the first transcript than if produced by the original transcriber. This assumption was based upon the belief that errors of perception would tend to be different from one listener to another, that some errors made by the first transcriber would be rejected by the second transcriber, and therefore the likelihood would be increased that the second transcriber would substitute correct words for these errors.

II. Work Methods.

On the basis of these notions, it was decided to test three methods of producing transcripts from noisy voice radio messages. The first method consists of having one individual listen to the same noisy message three consecutive times and produce a complete transcript on each occasion. At each successive exposure to the tape, he uses the previous transcript as an aid. Work Method Two consists of having a second transcriber listen to the same noisy message and with the aid of the first transcript produced by the original listener, produce a complete transcript. He then listens to the message a second time and with the aid of his own first transcript produces a second complete transcript. In Work Method Three a third transcriber listens to the noisy message once and with the aid of the first transcript produced by the second transcriber produces a complete transcript.

III. Stimulus Materials

The messages used to test these work methods were Sentence Intelligibility Lists developed at the Harvard Psycho-Acoustic Laboratory during World War II. There are a total of 68 lists, each of which consists of twenty sentences containing five scoreable words per sentence. Research has shown these lists to be extremely similar in difficulty. The noise used in the experiment was atmospheric noise taped from a short wave receiver. Atmospheric rather than white noise was used because it was considered to be homogenous enough for this study and at the same time represented the major obstacle to accurate transcription in the operational setting The messages were read onto one track of a two-track tape while the noise tape was reproduced on the other track. The speakers monitored their own recording level and the noise level by watching the recording of the two channels on a dual trace oscilloscope An attempt was made to maintain relatively constant amplitude of the peak for each word envelope The noise envelope was relatively flat, though it showed some random disturbances, and was maintained at a constant level throughout the message, each set of twenty sentences constituted a message. Six tapes of ten messages each were constructed in this manner to be used for training purposes and three messages were prepared in the same manner to be used in testing the alternative work methods.

IV. Subjects.

The subjects used in this study were a group of fifty reservists who had been activated in 1961 and were about to be released. The most pertinent characteristics of these subjects were that they were in their early twenties, all except three had some college training, and many had gone beyond a Bachelors degree. All were trained to receive and transcribe code except five who had other types of transcription training.

V. Experimental Procedure.

A. Pre-Test Training.

Previous research in the area of the perception of speech masked by noise indicates that there is a relatively rapid improvement in hearing through noise and that a plateau is reached after exposure of several hours a day for five days. Our group of subjects was therefore exposed to messages masked by various levels of noise over a three hour period for each of six days.

The six days of training served three purposes 1) to train the subjects to read through noise, 2) to get an index of each subject's ability to read through noise so that three groups of equal ability could be identified for use in the experiment; and 3) to determine three noise levels which would permit the subjects to understand correctly approximately 75% of the message, 50% and 25%

To obtain indices of noise which would result in the three levels of intelligibility desired, a range of signal to noise ratios was explored during the training session. These ratios were tabulated daily and those which most nearly approximated the intelligibility levels desired were rechecked on successive days. The noise levels were referenced initially to the message by setting the noise envelope peak equal to the word envelope peak. The noise was then varied about this value in decibel steps by a Davin attenuator which had initially been set at its middle position. This permitted varying the noise peak from ten db below the voice envelope peak to ten db above this peak. Previous work had shown that this range was sufficient to encompass the signal to noise ratios of interest. The signal to noise ratios used in this experiment were -4 db for the low noise level, -1 db for the medium noise level, and 3 db for the high noise level.

B. Assignment of Subjects.

Based on the total scores achieved over the six days of training, forty-eight of the fifty subjects were ranked and divided into three quality sub-groups of sixteen subjects each.

The best quality group contained the top sixteen subjects, the second the middle sixteen, and the lowest the bottom sixteen. Four equal quality groups of twelve subjects each were formed by randomly assigning four subjects from each quality category to each of four groups One of the four groups thus formed had been predesignated to be used for a final check of the signal to noise ratio setting of the three tapes to be used in the experimental session.

Each of the other three equal quality groups was randomly assigned to one of the noise levels. The group assigned to the low noise level, approximately 75% intelligibility, is designated group one, the group assigned to the medium noise level, approximately 50% intelligibility, is group two, and at the high noise level, approximately 25% intelligibility, group three. Due to such factors as quality of the noise and variation between messages due to the talker, the signal to noise ratios which were used in the experiment gave somewhat different intelligibility levels than these, but were relatively close and were within acceptable limits.

That the four groups were very similar in ability can be seen from Table 1 which shows the mean scores for the six training days were:

Table 1

Group Mean Scores

Noise Level	Low 1	Medium 2	High 3	S/N Check Group
Mean Score	46 98	47.06	47.92	45 05

C. Work Methods Test.

Three messages were used in the experiment. For a particular message, subject A was assigned to Work Method I, for the second message he was assigned to Work Method II, and for the third message he was assigned to Work Method III. These initial assignments of subjects to work method were made in a random manner but all subjects served in all work methods and no one combination of these subjects worked together on all three methods.

The same message at the same noise level was presented three consecutive times. The time lapse between presentations was only enough to let the subjects get ready to transcribe. Each message was presented to each group at the assigned noise level. The schedule of presentation of messages for a set of three subjects is diagrammed in Table 2.

Table 2

Work Method	Subject	Message Presentation 1	2	3
I	A	A1	A2	A3
II	B		B2	B3
III	C			C3

A-1 in the diagram, indicates that subject A listened to the message and made the first transcript which is designated A-1. A copy of transcript A-1 was given to subject B. On the second presentation of the message, both subjects A and B listened and independently prepared transcripts, although both used a copy of the transcript A-1 as an aid. On the third presentation of the message all three subjects, A, B, C, prepared independent transcripts. A used the transcript A-2 as an aid, B and C each used a copy of B-2 as an aid.

VII. Results.

The transcripts which resulted from the three methods of utilizing personnel were scored for Rights, i.e., the number of words transcribed correctly, and for Wrongs, i.e., the number of words which were included in the transcript which did not appear in the original voice message.

The average Rights and the average Wrongs for each message presentation for each Work Method at each noise level is shown in Figure 1. (These means are shown in Table 3.)

Table 3

MEANS AT THE THIRD MESSAGE PRESENTATION FOR EACH OF THREE SEPARATE WORK METHODS AND NOISE LEVELS

Noise Level	Work Method	Mean Rights	Mean Wrongs
Low Subsample 1 (N = 12)	I	90.00	10.42
	II	91.14	8.25
	III	91.82	8.58
Medium Subsample 2 (N = 12)	I	66 50	35.92
	II	70.42	31.00
	III	70.92	32.25
High Subsample 3 (N = 12)	I	20.92	61.67
	II	21.83	51.75
	III	23.50	54.58

A. Effects of Work Methods on the Response Functions for Rights and Wrongs.

As can be seen in Figure 1 the work methods show exactly the same relationship to each other for all three noise level groups. Notice that in the production of right responses, Method III is consistently better than either Methods I or II and Method II is consistently better than Method I. For wrong responses, Methods II and III also are better than Method I. That is, fewer errors are made with either of these work methods than with Method I. Although the differences among the three work methods are consistent, the amount of this difference, as can be seen, is small. The fact that these differences are quite small is reflected in statistical tests applied to the means. The mean difference between Method I and the average of Methods II and III was found to be significant (.05 level) for the third message presentation at the medium noise level for both Rights and Wrongs but was not significant for the low and high noise levels.

B. Effects of Atmospheric Noise on the Response Functions for Rights and Wrongs.

Notice that at all noise levels the response curves for Rights continue to rise with successive exposures to the tape. The curves for the high and low noise levels, however, appear to be leveling off more quickly than for the medium noise level. This leveling off for the low noise level is attributable to the fact that the limit of scoreable words is being approached. The mean number Rights for the third presentation for Method I is 90 words. Though there are one hundred scoreable words in each message the average for this group for transcribing similar messages in the absence of noise is approximately 96 words The curve for Rights for the high noise group is, as can be seen in Figure 1, very similar in form to that for the low noise group.

The curves for Wrongs, as we can see in Figure 1, are different from those for Rights. At the low noise level the number of Wrongs tends to decrease with successive presentations. This is to be expected since repetition usually results in improvement. This decrease in errors is also compatible with the increase in the number of right responses for the low noise level group. At the medium noise level, however, the number of wrong responses for Method I increases from the first to second transcript and decreases from the second to the third transcript. For the high noise level the function is clear enough. Here, the number of Wrongs introduced into the transcript increases with each successive exposure to the tape. Though several alternative reasons have been suggested for this increase in the number of Wrongs with successive presentations, no analyses of the data are as yet available to clarify this finding.

C. Individual Differences in Ability to Read Through Noise.

At the time of preparation of this paper some analyses of the training data had been completed which indicate that there are relatively stable individual differences in ability to hear messages masked by noise. The following bar graph (Figure 2) shows the percent of the fifty subjects above average for each of the number of days zero through six. Note that 22% were consistently below average, that is, they were above average zero days and that 32% were above average all six days. The stability of this difference is indicated even more forcefully by the correlation of the sums of scores obtained on the first, third and fifth days with the sums of those obtained on the second, fourth and sixth days. Thus r = .867. Further, as can be seen in Table 4, the correlation of the scores of the first days of training with the last days are substantial, which points to the possibility of identifying higher ability personnel for purposes of training and assignment. These differences in ability had been noted by personnel who had served in operational situations, and the present data

Table 4

A MATRIX OF INTERCORRELATIONS FOR TRAINING DAYS ONE THROUGH SIX REFLECTING STABILITY OF INDIVIDUAL DIFFERENCES
(N = 50)
(All noise levels)

Day[a]	1	2	3	4	5	6
1	1.00	.64	.74	.79	.81	.60
2	.64	1.00	.65	.68	.62	.57
3	.74	65	1.00	.77	.84	.54
4	79	.68	77	1.00	.88	.64
5	.81	.62	.84	88	1.00	.68
6	.60	57	.54	.64	.68	1.00

[a] r for composite of days 1, 3 and 5 vs. 2, 4 and 6 = .87.

confirm these observations Additional analyses to determine the effect of noise level on these individual differences and to relate other aptitudes and abilities to the ability to read through noise are being made.

VIII. Summary and Conclusions.

The data have led us to conclude that there is a tendency for Work Methods II and III, that is, those using two or more differ transcribers, to produce a greater accuracy, but that their superiority over a method using a single transcriber, though consistent, tends to be small and reaches statistical significance only at the medium noise level. Unless additional factors are discovered which might enhance these differences they are not large enough to be of practical value except in situations where a small improvement is of critical importance. Of greater practical value is the fact that pronounced individual differences exist in ability to hear through noise. It seems that personnel selection and assignment instruments which would result in the enhancement of the quality of transcripts produced under conditions of noise might be constructed with a minimum of difficulty. Such instruments would permit the selection of transcriber personnel who possess a higher basic aptitude and the assignment of the more capable personnel already within the system to more critical positions, thereby enhancing system capability.

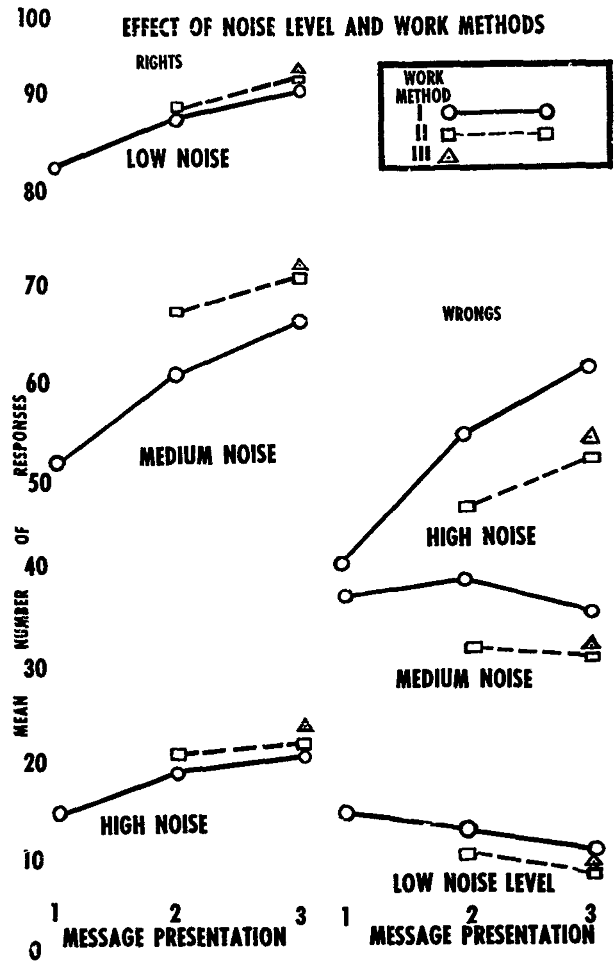
EFFECT OF NOISE LEVEL AND WORK METHODS
RIGHTS
WORK METHOD
I
II
III
LOW NOISE
MEDIUM NOISE
HIGH NOISE
WRONGS
HIGH NOISE
MEDIUM NOISE
LOW NOISE LEVEL
MEAN NUMBER OF RESPONSES
100
90
80
70
60
50
40
30
20
10
0
1
2
3
MESSAGE PRESENTATION
1
2
3
MESSAGE PRESENTATION

Figure 1

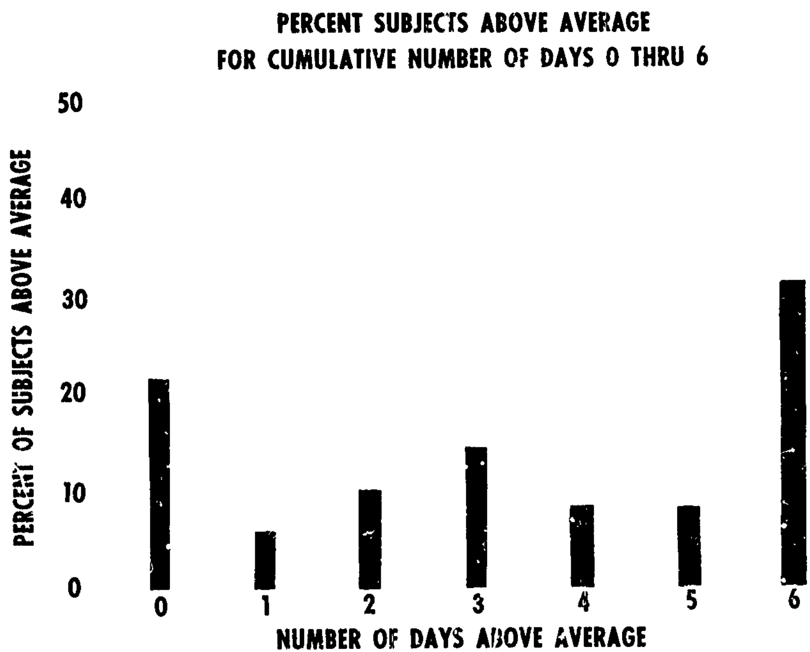
PERCENT SUBJECTS ABOVE AVERAGE
FOR CUMULATIVE NUMBER OF DAYS 0 THRU 6
PERCENT OF SUBJECTS ABOVE AVERAGE
50
40
30
20
10
0
0
1
2
3
4
5
6
NUMBER OF DAYS ABOVE AVERAGE

Figure 2

C CONSTRUCTION EQUIPMENT DESIGN RECOMMENDATIONS TO IMPROVE OPERATOR S & MAINTENANCE MEN'S VOCATIONS by Elmer A Kemp, Chairman, Subcommittee XVIII - Human Engineering, Construction, and Industrial Machinery Technical Committee, Society of Automotive Engineers

As chairman of the Construction and Industrial Machinery Technical Committee Subcommittee XVIII, pertaining to Human Engineering, my intent today is to give you a report of our actions and goals.

Basically this aim is to establish recommended values for human male physical dimensions for industry-wide use by equipment designers and manufacturers.

Late in 1960, when I was invited to establish and initially chair this interesting and intriguing effort, it was imperative to call on the best informed and experienced talent in this field in order to obtain the immediate practical results desired.

Active committee members and consultants participating in this effort are representatives from equipment designers and manufacturers, component designers and suppliers, engineering agencies, educational institutions, contractor and industrial equipment users, and the Military. These individuals are completely familiar with the design, operation, maintenance and servicing demands to meet the user's needs Our efforts to date have reflected the fine knowledge, experience, enthusiasm, and cooperation of this team, and it has been a real honor and privilege to be affiliated with them.

Just what is Human Engineering? How is it applied to the construction and industrial equipment field? One definition could state, "Human Factors Engineering is the application of the human physical senses, skill, and physical techniques to equipment design". To put it another way, it is the mating of man to the machine so that optimum compatibility is achieved, therefore designing the machine to the man, a truly revolutionary approach.

A good many of us can recall the day when equipment was designed to perform its basic function, and then a location for the operator, his controls and instruments was established wherever convenient and practical, without disturbing too greatly the overall configuration. Control lever and pedal efforts and travel were established, based on each designer's idea of what an operator was physically capable of exerting. Accessibility for lubrication, adjustment, and servicing was practically ignored. Operator comfort, space-wise, suspension-wise, visibility-wise, weather-wise or effort-wise, was of small concern even though the operator practically lived in the station.

Through the efforts of the Military for simplification on instructions, organized labor for physical ease and comfort, and through engineering field contacts, the construction equipment industry, since World War II, has made great strides to improve the lot of the operator and service man.

Power assisted or completely powered controls, greater operator physical comfort, and vastly improved service accessibility has been incorporated by the majority of designers and manufacturers in this, today's more competitive markets. However, until our group was established, there was no industry effort to standardize on control locations, control efforts or travel directions and limits. The real value and need for a recommended minimum standard for an operator's station, environmental-wise as well as accessibility-wise, has been magnified as a result of the Military's and contractor's training of personnel for these functions Because initial consideration indicated that this project warranted a concerted effort, the SAE Construction and Industrial Technical Committee established Subcommittee XVIII.

After this new group was organized in January of 1961, the Subcommittee agreed that the initial effort should be to offer maximum and minimum physical dimensions for a normally clothed operator and dimensions for a large operator dressed in arctic clothing as recommended standards for use in the industry.

The agreement for such a project was unanimous, as each manufacturer has his own version, which to date is as dissimilar as most of us, physically. This particular effort, requiring only five meetings to finalize, was comparatively simple to assemble because of the male physical dimensional data accumulated by various individuals, consultant organizations, and the Military. This information would have required many man-hours to obtain from scratch, and we are deeply indebted to several of our consultants for providing data and assistance. Using the data accumulated by these various agencies over recent years, the Subcommittee developed and submitted recommendations for SAE-CIMTC Standard usage. For practical reasons we offered a male clothed version only, as providing the realistic data that designers of this equipment would require.

The result of our effort is shown in Figures 1 and 2. We sincerely believe, although being the first to admit that someone may find a point for contention, that this information will prove a boon to our designers. The chart itself has been studied and set up to make it readily interpretable. You will note that we have established the 5th and 95th percentile as the most practical range for design purposes. This indicates that 5% are physically under the minimum and 5% are over the maximum and therefore are not included in the chart data. This chart has been approved and will be in the 1963 S.A.E. Handbook[1]

Currently we are studying the area of the operator's work station. You would be surprised at the discussion the Subcommittee has developed pro and con relative to this subject.

We all well agree that, in the past, insufficient concern on the part of the designer left quite a bit to be desired by the individuals who actually wound up operating that same equipment. Lack of riding comfort and excessive control efforts resulted in a very weary operator at the end of a shift, and more frequently than not, in tapering off of his efficiency and alertness late in the work schedule.

Broken down, for practical as well as expeditious reasons, this project will probably result in these categories

1. Controls-
   Foot and hand, (as depicted in Figure 3) can and do result in some confusion on the part of switching operators, training, efficiency, and safety-wise. Standardization of location, type, size and effort ranges, is a project the committee is exploring and hope to be able to offer a recommendation on in the near future.
2. Instruments-
   Location, type, visibility and legibility, are also components where similarity and standardization will benefit operator adaptability and efficiency.
3. Operator's Seat-
   The location relative to the controls and instruments, minimum size, height, and adjustment-limitations is on tap for future study by the group.
4. Operator Comfort-
   Noise, ventilation, temperature, and safety are important factors to be considered.
5. Operator's External Visibility-
   over-exaggerated on Figure 4, is certainly a factor worthy of study for improved operational efficiency and safety.
6. Compartment Size Minimums-
   need for which we indicate on Figure 5, will be reviewed and our proposals submitted later.

The Subcommittee recommendations will take a great deal of time to become realities, should we be so practical and fortunate to develop worthwhile proposals, but with the efforts of our industries' designers, we look forward to the ultimate from the operational viewpoint, as indicated on Figure 6.

Our responsibility as a Subcommittee is to offer a practical and adoptable set of standards for industry consideration.

Some additional future areas we plan to explore and investigate are service and maintenance space, effort, visibility, and safety minimums.

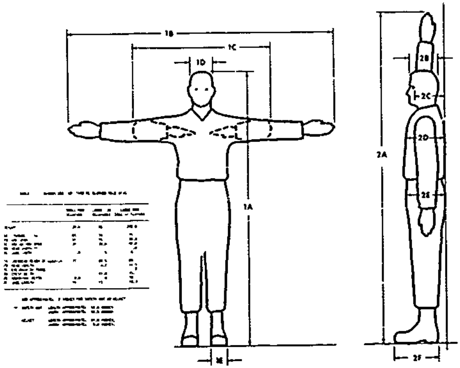

Figure 1. Standing Chart

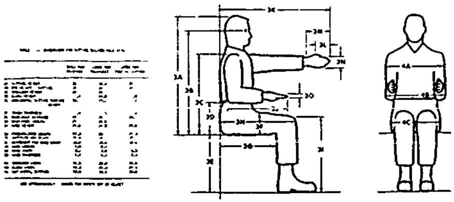

Figure 2 Sitting Chart

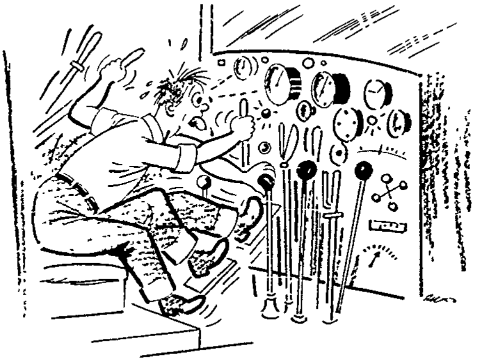

Figure 3. Confusion

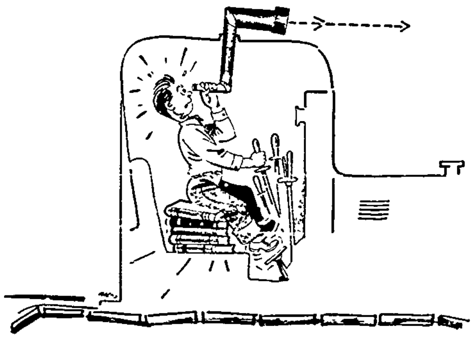

Figure 4. Inadequate Visibility

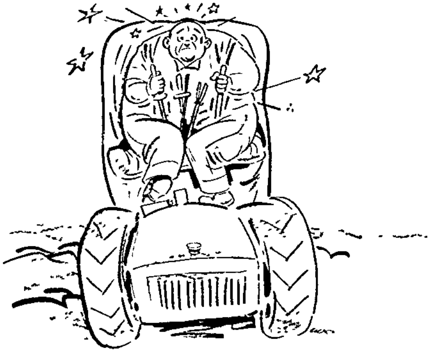

Figure 5 Compartment Comfort

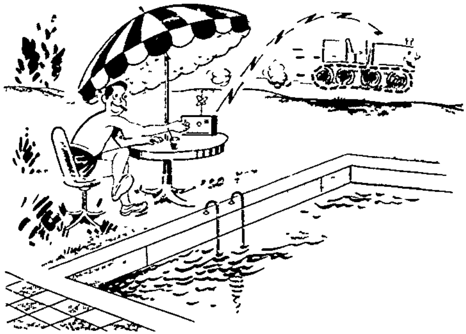

Figure 6. Ultimate In Operation

D AN EVALUATION OF PHOTO DISPLAY MODES FOR EXTRACTION OF INTELLIGENCE INFORMATION by Abraham H Birnbaum, US Army Personnel Research Office, Washington, D. C

In the eventuality of war, the Army has a critical need for information about the enemy's disposition of forces which must be relevant, timely, accurate, and complete. To meet these needs the Army depends on its image interpreters and the image systems within which they function. The interpreter of today and tomorrow must be able to extract the necessary information from all kinds of imagery, conventional, radar or infrared, the imagery may be of high or low quality, and on occasion the volume of the imagery may be so great that only very little time may be available to obtain the necessary information Regardless of conditions, the image interpreter is a key person who must provide the information on which many military decisions will be based.

Until fairly recently very little was known about basic psychological factors in image interpretation, particularly in the operational setting. To fill this gap the United States Army Personnel Research Office formulated a program to answer two broad questions. (1) What are the skills, abilities and techniques that are necessary to extract intelligence information from conventional and newer types of imagery? (2) How can the Army best utilize its available human resources in order to cope with the ever-increasing volume and variety of imagery and yet maintain acceptable standards of speed, accuracy and completeness?

In implementing our research program we have paid particular attention to problems that dealt with the determinations of how interpreters can best use the imagery, equipment, time, and skills to extract useful intelligence information. Findings such as those dealing with performance as a function of viewing time, repeated exposure to imagery and team work procedures were reported in a prior session of the Army Human Factors Engineering Conference.[1] The effort of these studies was directed primarily toward gaining insight into how interpreter performance might be improved via the mechanism of improving techniques and procedures of interpreter operations. We were, however, not unaware of the fact that the nature of the stimulus material itself has an impact on performance. Today's paper will deal primarily with interpreter performance as a function of selected photo display characteristics.

1 Sadacca, Robert New Techniques in Image Interpretation Systems. Presented at the Seventh Annual Army Human Factors Engineering Conference, 3-6 October 1961

Approach

The purpose of the photo-mode study is to determine what, if any, differences there are in interpreter performance, that may be attributable to photo-mode, i.e., to whether the interpreter views negative transparencies, positive transparencies, positive prints (non-stereo), or positive stereo prints. Findings of this study may have an impact on whether or not an electronic image reversal device has a place in an image interpreter facility.

Three analyses were conducted. (1) An analysis of accuracy and completeness as a function of mode, (2) An analysis of confidence in right and wrong responses as a function of mode; and (3) An analysis of accuracy as a function of time separately for each mode.

In order to conduct our studies we must be able to measure interpreter performance. This requires the use of photographs the content of which is known to the researcher but, of course, not to the photo interpreter test subject In addition, the photographs used and the requirements imposed on the interpreter should be as realistic as possible. Also, the interpreter is provided with relevant materials and information normally available to him, such as maps and specific information about the deployment of friendly and enemy forces, as well as equipment that is part of his PI kit. Essentially, then, the performance measure constitutes a work sample with a known input and with the opportunity for measuring interpreter output.

The determination of what constitutes the content of a given photograph depends in all cases on the consensus of independent interpretations by expert interpreters. In addition, available records were studied to verify the basic analyses. In those rare instances when agreement could not be reached on the identification of a particular object, the object was scored neither right nor wrong

The performance indices used in these studies are a direct function of the nature of the responses the interpreter makes. The interpreter can correctly identify an object. The number of correct identifications (number of rights) therefore is one measure of interpreter performance. The interpreter can misidentify objects. Number of wrongs therefore is another measure of his performance. Further, he can fail to respond where he should. Number of omits thus constitutes a third measure. In addition, two derivative measures were developed, one, accuracy the other, completeness. Accuracy is the proportion of correct to total responses an interpreter makes, it is the ratio of number of rights to number rights plus wrongs $\left(\frac{R}{R+W}\right)$ Completeness is the proportion of correct responses to total extractable information that is in fact extracted from a photograph, it is the ratio of number of rights to total number of significant identifiable objects $\left(\frac{R}{T}\right)$

Four sets of photographs representing four different performance measures were used in this study Table 1 describes these measures The first two measures have a tactical content, the other two, strategic. The scales of these photo sets are 1:5,700, 1 8,000, 1 10,500 and 1 10,500, respectively.

Table 1

DESCRIPTION OF PERFORMANCE MEASURES

Measure	Content	Scale
1	Individual Objects (e.g., vehicles)	1:5,700
2	Individual Objects (e.g , small structures)	1:8,000
3	Object Complexes (e.g., R.R. yards)	1:10,500
4	Object Complexes (e.g., fuel storage)	1:10,500

Each set of photographs consists of the same photograph reproduced in four modes, positive transparency, negative transparency, positive stereo prints, and positive non-stereo prints. Each of these was also reproduced at a lower quality level thus providing two photo qualities and making possible an analysis of mode-by-content-by-quality.

The design employed was a replicated Latin-Square, separately, for each quality, with eight entries per cell. Thirty-two subjects were used for each photo quality. Each subject was administered the four different measure contents each in a different mode in a counter balanced design to eliminate effects attributable to order of test administration.

The sample consists of 64 experienced photo interpreter test subjects, 32 of the Air Force, 17 of the Army and 15 of the Marines. Their average on-the-job experience was five years and ranged from two months to thirteen years. All subjects were assigned at random to each photo quality and to each cell within photo quality.

Time allowed for each test was thirty minutes.

Accuracy and Completeness as a Function of Mode

Within each quality four performance measures were analyzed separately, accuracy after six minutes of work, accuracy after thirty minutes of work, and similarly completeness after six and thirty minutes of work. Table 2 shows the accuracy results for the four different modes of high photo quality.

The comparison here is for each row. None of the differences is significant. Table 3 presents completeness results for the four different modes at high photo quality. Again the differences attributable to mode were not found to be significant. Table 4 presents the accuracy results for low photo quality.

Once again mode differences were not found to be significant. However, when we come to completeness at low photo quality (Table 5) we find a difference attributable to mode that is significant at the five percent level of confidence, and this for completeness after thirty minutes of work. In view of the fact that eight different analyses were conducted, four for low and four for high photo quality, it is not too surprising, on a probability basis, to find one that exhibits differences that appear to be significant for the case where in fact no differences exist. The large number of analyses therefore casts some doubt on the significance of the finding of mode differences for completeness at low photo quality after thirty minutes of work.

When we examine the effect of photo quality on performance we can unqualifiedly say that we have succeeded in reducing photo quality.

Table 2

PERCENT ACCURACY BY PHOTO MODE FOR HIGH PHOTO QUALITY

Accuracy	Positive Transparency	Negative Transparency	Stereo Print	Non-Stereo Print
Initial	53	53	54	47
Final	42	38	44	40

Mode differences are not significant.

Table 3

PERCENT COMPLETENESS BY PHOTO MODE
FOR HIGH PHOTO QUALITY

Completeness	Positive Transparency	Negative Transparency	Stereo Print	Non-Stereo Print
Initial	14	10	9	10
Final	33	27	31	30

Mode differences are not significant.

Table 4

PERCENT ACCURACY BY PHOTO MODE
FOR LOW PHOTO QUALITY

Accuracy	Positive Transparency	Negative Transparency	Stereo Print	Non-Stereo Print
Initial	40	41	52	39
Final	30	33	39	37

Mode differences are not significant.

Table 5

PERCENT COMPLETENESS BY PHOTO MODE
FOR LOW PHOTO QUALITY

Completeness	Positive Transparency	Negative Transparency	Stereo Print	Non-Stereo Print
Initial	8	7	7	7
*Final	21	16	24	18

*Mode differences significant at $P < .05$

Without exception performance on high-quality photos was better than on low quality ones as can be seen in Table 6.

It can also be seen that accuracy drops as a function of time. For six-minute performance accuracy is higher than for thirty-minute performance. Conversely, completeness goes up as a function of time.

Content differences were significant throughout, i.e., performance varied as a function of "content." However, this is not too surprising in view of the fact that the photograph sets differ from each other in scale, quality, density and kind of objects. Since the factors that cause these differences cannot be pinned down specifically in this

Table 6

PERCENT ACCURACY AND COMPLETENESS
BY PHOTO QUALITY

	High Quality	Low Quality
Initial Accuracy	52	43
Final Accuracy	41	35
Initial Completeness	11	7
Final Completeness	30	20

Quality differences are significant at $P < .01$

study, I will pass over these findings and go on to the next.

Interpreter Confidence

As a part of their regular work routine, interpreters assign probability indices expressing their confidences in each of the identifications that they make. In a prior study, a significant difference was found in the mean confidence for right and wrong identifications and in favor of the right identifications. The present study provided an opportunity to look at confidence for rights and wrongs as a function of photo mode and of photo quality. For each object identified, the interpreter assigned a percentage that represents what he considers to be the likelihood that the object is correctly identified. Preliminary analysis exhibited no significant interactions between confidence in right and wrong responses as it relates to photo mode, content, and quality. Table 7 shows the results obtained for high photo quality. Note that the right responses are invariable associated with greater confidence than the wrong responses and significantly so in three out of the four modes. This significant difference for confidence in right and wrong responses carries over to the total. Similar findings are obtained for the low photo quality as can be seen in Table 8.

Table 7

PERCENT CONFIDENCE FOR RIGHTS AND WRONGS BY MODE FOR HIGH PHOTO QUALITY

	Right	Wrong
*Positive Transparency	57	46
Negative Transparency	60	56
*Stereo Print	73	61
*Non-Stereo Print	75	62
*Total	65	56

*Right-Wrong differences significant at $P < .05$

When we compare total mean confidence for the right responses for the high and low photo qualities we find that they are substantially the same 65 and 68 percent, respectively. This is also true for the mean confidence for the wrong responses, 56 percent in both cases. This implies that across the four modes, the probability of correctness of identification based on confidence is the same for both high and low photo qualities.

Table 8

PERCENT CONFIDENCE FOR RIGHTS AND WRONGS BY MODE FOR LOW PHOTO QUALITY

	Right	Wrong
Positive Transparency	67	64
*Negative Transparency	61	44
*Stereo Print	73	59
Non-Stereo Print	66	56
*Total	68	56

*Right-Wrong differences significant at $P < .05$

Length of Viewing Time

We have already seen some evidence that accuracy goes down and completeness up as a function of time. We have also noted interpreter performance with the exception of the tenuous finding for 30-minute completeness at low photo quality is not affected by photo mode. On the other hand, there are significant performance differences attributable to photo quality. A performance over time comparison was therefore only for photo quality.

Figure 1 shows the cumulative number of right and wrong responses for five-minute intervals of viewing time, plotted separately for high and low photo qualities. Notice first the far larger number of wrong than right responses at all time intervals and regardless of photo quality. When we look at quality separately we find for high photo quality that the number of new identifications scored right tapers off much sooner than the number of those scored wrong. Moreover and very significantly when we compare the performance for high and low quality photographs, the high quality photographs provide more right and fewer wrong responses than do the low quality ones.

Figure 2 shows accuracy which relates right to right plus wrong responses, plotted as a function of time for the same performance measures. For high photo quality there is a continuous decrement in accuracy as time increases, a finding which conforms to previous ones. For low photo quality, on the other hand, accuracy remains relatively constant at a lower level at all time intervals as time increases, although toward the end it begins to decrease. Actually, if additional time had been provided to the interpreters working on the low quality photographs, a continuing drop in accuracy would not be unexpected, since any responses that go beyond the limits of what there is in the photograph would have to be wrong. Moreover as the interpreter addresses himself to objects that are increasingly more difficult to identify we would expect the ratio of wrong to right responses to increase and hence for accuracy to decrease

Implications of the Findings

To the extent to which the test materials and conditions and test subjects are representative the findings of these studies are generalizable However, it should be noted that there are many limitations to this study. Among others there are those dealing with the nature of the images, their content, quality and scales, the nature of the setting in terms of the specific task requirements imposed on the interpreters and the experience of the interpreters in working with materials that differ in mode. Assuming that these do not have an effect on the findings, the following conclusions can be made.

Accuracy and completeness in general do not seem to be dependent on whether or not an interpreter views a positive transparency, negative transparency or print, although a further study needs to be made to check on the finding for 30-minute completeness at low photo quality.

Good photo quality does result in better accuracy and completeness than does poor photo quality. However, this finding applies only to the materials at hand. Our "good" photo quality is actually not fixed. We have no way of measuring the quality of our "high" quality photos and we degraded these photos to a barely acceptable level. Since we were not able to improve the photo quality of our "good" photos, we are unable to say that an increment in photo quality beyond that of our good quality would likewise yield an increment in accuracy and completeness Therefore the finding does not argue for improved photo quality What should be done first is to develop a measure of photo quality and then systematically for different quality levels determine the accuracy and completeness of interpretations to establish the point of diminishing returns, which would then be the goal for the desired level of photo quality.

Photo interpreters generally tend to have more confidence in their right responses than in their wrong ones This means that the probability of accurate identification will be higher for responses associated with high confidence than for those associated with low confidence However, the use of this knowledge should await a more definitive determination as to whether or not one mode is favored over another with respect to confidence differential between right and wrong responses. If a more rigorous test should identify such a mode, this mode would be preferred, everything else being equal, since it would make possible the identification of correct responses with a higher degree of probability than any other mode.

Mode differences most likely don't have much of an effect on accuracy as a function of time, however quality does. The accuracy curves do not taper off in the same way for the time period of concern. There is a continuing very evident drop in accuracy for high photo quality, whereas accuracy for low quality remains fairly constant until almost the very end of the period where there are beginnings of a loss in accuracy. The use of specified work time to establish desired accuracy levels therefore requires the establishment of accuracy-over-time-functions for different levels of quality.

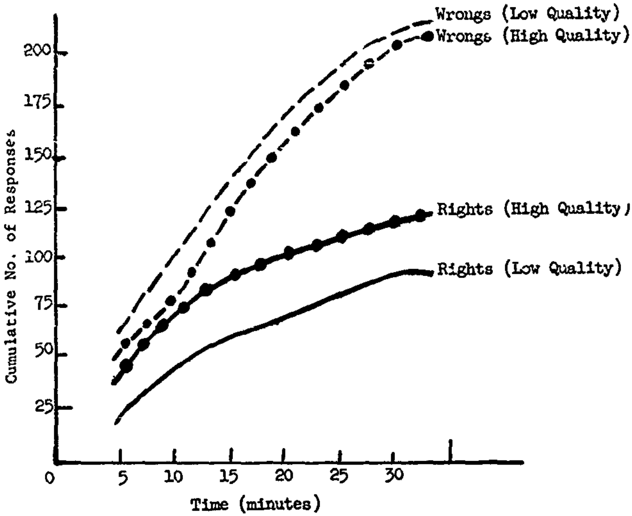

Figure 1. Cumulative Right and Wrong Responses as a Function of Time by Photo Quality

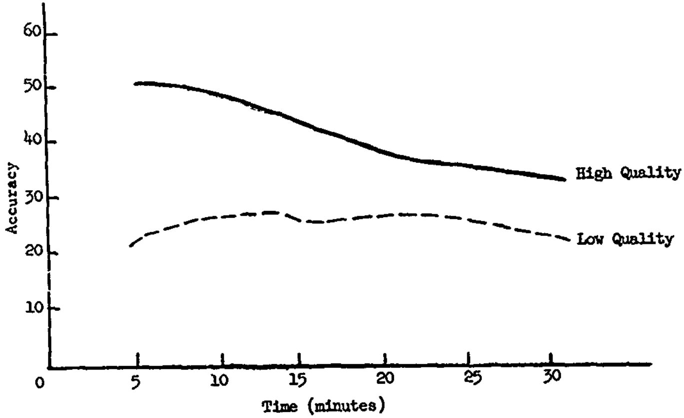

Figure 2. Accuracy as a Function of Time by Photo Quality

E. HUMAN FACTORS EVALUATION OF MASK, ANTIFLASH, ROCKET LAUNCHER M19

by Samuel E. Jackson and Maj. E. R. Clovis, MSC, US Army Chemical Research and Development Laboratories, Army Chemical Center, Maryland

Under tropical or temperate conditions the gunner of a rocket launcher team can fire his weapon without facial protection. Under arctic conditions, however, there occurs a backflash, formed of unburned particles of rocket propellant, arming wires, and other rocket debris, which constitutes a serious hazard to the gunner's face. The M19 mask was designed to afford protection against this backflash. Chemical Corps Engineering Command was directed by CONARC to make design improvements When we received the mask, we were told that it had previously been subjected to various tests to determine its ability to protect the user and was to be type classified pending our evaluation. We were asked to determine whether gunners could effectively fire their weapon while wearing the mask.

Figure 1 shows the M19 mask on a model - The mask consists of a leatherette-faced, stiffened apron approximately 15 cm in length to which has been sewn the eyepiece assembly from a pair of type I industrial goggles.

In order to evaluate human factor characteristics of the prototype mask, we studied:

1. Extent of the visual field for detection of movement.
2. Fogging and frosting of eyelenses
3. Effect of the mask on the ability to track a moving target with the weapon.
4. Ease of carrying and donning the mask
5. Effect of right vs left eye preference on the part of the user. Our subjects were four medical research volunteers with previous training and experience with rocket launchers. In previous training, these men had used the M9A1 Protective Mask, with the cannister removed, as an approved field expedient for protection against rocket backflash. One subject had had combat experience as a bazooka gunner.

In brief our results were as follows

I. For visual field. (See Figure 2 - Perimetric Maps). Figure 2 shows a comparison of the visual field for detection of movement for three subjects when they wore the M19 Mask, the M9A1 Protective Mask, and without any mask Wearing either the M19 or the M9A1 resulted in definite limitations of the field of vision for detection of movement. These limitations existed in three of the four quadrants, becoming insignificant only in the superior temporal quadrant. In the inferior quadrants the limitation commonly exceeded 30° and reached 45° at one place.

II. Fogging - We found by conducting tests in climatically controlled chambers, that soldiers who were active enough to perspire moderately experience fogging of the eye lenses sufficient to obscure vision within one-two minutes after donning the mask. Frosting occurred in less than 10 minutes.

III. Tracking - While wearing the M19 Mask experienced rocket launcher gunners tracked moving targets only with great difficulty. The principal sources of difficulty identified were (1) The harness strap did not prevent the facepiece from shifting when the stiffened length of the apron hit the body (e.g. shoulder, chest), or some other object. This caused the entire facepiece and thus the eye lenses to be displaced so that vision was obscured or denied. (2) Stray light entered through the venting mesh causing undesirable reflections with the resulting decrease in relative brightness of the reticle-sight picture. (3) The eye lens retaining ring caught on the sight rim. Even steady sighting in the prone position was frequently impossible because the bottom of the apron touched the ground and shifted the mask.

IV. Donning and carrying - We found that the mask could not be donned easily over the helmet and parka hood, if donned in this way by any means, the eye was so far from the eye lens that effective sighting was impossible. We further found that when the mask was folded and snapped as intended, the mask did not fit any easily accessible outer pocket of cold weather clothing. Furthermore, in this folded configuration the glass lenses were extremely vulnerable to damage.

V. Effect of right vs left eye preference - Soldiers who were normally right-eyed experienced all the difficulties enumerated above. Soldiers who were normally left-eyed, and who used their left eye to sight the weapon by canting their head when firing without a mask, were completely unable to use their preferred eye when masked.

On the basis of these test results, we recommended that the prototype M19 Mask be declared unsatisfactory because minimum human engineering standards were not met. We recommended alterations in the mask design that would appreciably raise user efficiency. Figure 3 shows a rough mock-up of a new mask incorporating suggested changes. Note that we have discarded the goggle assembly and replaced it with, (1) For the sighting eye, a cushioned annulus of a diameter sufficient to accommodate the exit pupil of the sight, no more; and (2) For the other eye, a sturdy transparent plastic strip of sufficient flexibility in cold weather to eliminate excessive replacement and of sufficient strength to resist penetration by rocket debris. Some provision could be made for easy replacement of the plastic lens when necessary, i.e a slip-in pocket. In this way the weapon sight itself protects the sighting eye, while the other eye is given a broad visual field for the detection of movement and target line-up. This arrangement also provides for positioning the sighting eye at the eyecup rather than 1 cm- 3 cm behind it, and at the same time eliminates a superfluous glass barrier in the sighting path - a glass barrier, incidently, which provides two surfaces susceptible to fogging, frosting, and scratching. The removal of the goggle assembly allows the mask to be used with equal ease by right or left-eyed persons through the simple act of flipping the nose channel in or out.

We have also reduced the apron length to 11 cm at each lateral edge and the length of the nose channel midline to 11 cm. This provides good facial coverage while at the same time allowing much better clearance of the shoulder bulk of the arctic clothed infantry soldier.

The harness strap attachment points have been lowered 3.5 cm, thus bringing the harness as worn into the same plane as the eye openings of the mask and the pupils of the wearer. This should reduce considerably the shifting of the facepiece.

It should be noted that in this study we did not evaluate, and our recommendations do not take account of (1) the strength of the materials employed in either the M19 or the mock-up, (2) the degree of physical protection these materials provide against such blast or firing debris hazards as may exist (3) durability of the mask under conditions of field use and (4) the effects of decontamination procedures on the condition of the mask.

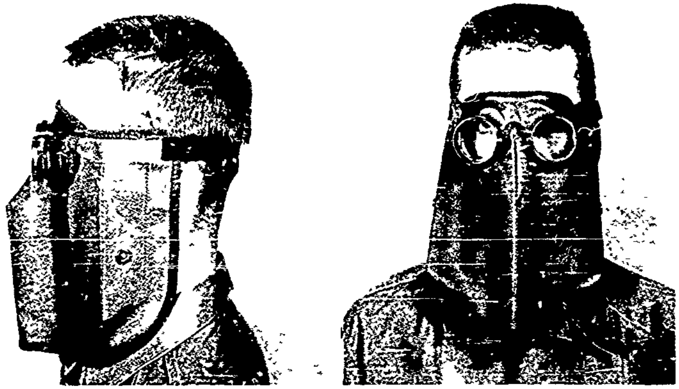

Figure 1   The M19 Mask

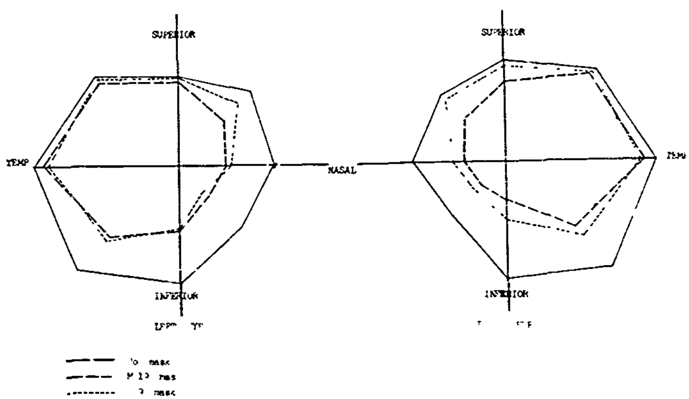

Figure 2. Visual Fields for the Detection of Movement

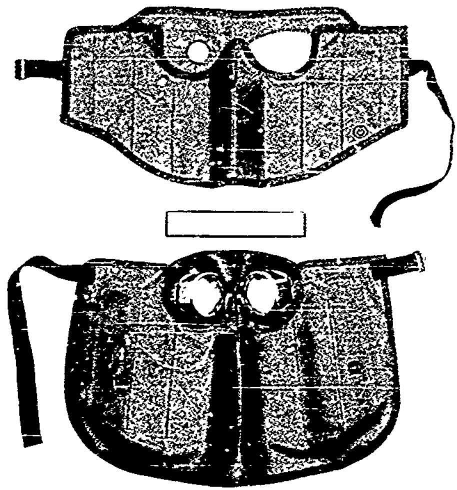

Figure 3 [illegible]e proposed Mask (top) Compared with M19 Mask (bottom)

F. THE DISPLAY EVALUATIVE INDEX. A TECHNIQUE FOR EVALUATING THE DISPLAY-OPERATOR DECISION-CONTROL ACTION LOOP IN DISPLAY SYSTEMS by Arthur I. Siegel, William Miehel and Philip Federman, Applied Psychological Services, Wayne, Pennsylvania

With the advent of more complex Signal Corps' systems and the concomitant increased time span between system concept development and actual hardware production, the need has arisen for methods and techniques for comparatively evaluating various design concepts before prototype systems and sub-systems are actually produced. While subjective standards and appraisals possess merit in the absence of more objective and reliable measurement and evaluative techniques, the provision of quantitative system effectiveness measurement techniques which can be applied early in the design stage might do much to eliminate costly design errors and expensive retrofits.

Accordingly, Applied Psychological Services under contract with the former Engineering Science Department, U.S. Army Signal Research and Development Command, has been engaged in a research program for evaluating the ability of the displays in a system to transfer information to the operator in the system and for the operator to act on the information received. Specifically, it is the purpose of this technique to allow comparative answers to questions such as:

1. Can it be expected that the operator will receive, interpret, and act on the information presented by design A in a superior manner than to design B?
2. If we change a display, what will be the relative effect on the equipment's ability to transfer information to the operator and on the operator's effectiveness?

This technique is referred to henceforth as the display evaluative technique. The index number which emerges from application of the technique is referred to as the display evaluative index or DEI. The DEI is based on five factors, each consisting of a base raised to a power. Except for the fifth or cost factor, the exponents are constant and fixed. The base values depend on the system (including the operator) under consideration and are based on axioms dra[illegible] from communications engineering c[illegible]. For the ideal system, each factor ([illegible] exception of the cost factor) possesse[illegible] [illegible]ue of unity, the values approach zero as a limit for the worst equipment design case. In actual practice the cost factor will also be less than one. Since the value of each base may range from zero to one, the range of each base raised to any power is also from zero to one and the DEI (the product of the five factors) also ranges from zero to one.

$$DEI = A^a B^b C^c D^d E^e$$

where A to E are the bases and a to e are the exponents which weight the various bases. If cost is of no consideration, the cost factor, E^e, may be suppressed by setting e equal to zero.

Each of the five bases involved evaluates (a) different system design factor(s)

<u>Base A</u> Base A provides an evaluation of the adequacy of the design from the point of view of number and complexity of the display-operator decision-control action loops in the system.

<u>Base B</u> Base B considers system complexity in terms of the number of indicators, number of controls, used and unused indicators and controls, and display-control linkage.

<u>Base C</u> Base C involves the time required by the "average" operator to complete a desired sequence of subtasks, the allocated time for subtask sequence completion, and mismatch between display information and operator control action information.

<u>Base D</u> Base D reflects the complexity of the system or the total number of displays and controls in the display-human operator-control loop.

<u>Base E</u> Base E reflects cost factors. All other things being equal, the system that costs the least to acquire, operate and maintain, is assumed superior.

To calculate the DEI, a "transfer chart" describing and linking the displays, decisions and controls of one or more task sequences performed by the operator in the system is prepared. Bases A, B and D are found from the transfer chart. Base C comes from a separate calculation of estimated operator time requirements, critical time requirements, and information mismatch. Estimated information processing time is based on a formula derived from data presented by Woodworth and Schlosberg (1955): $T_K = .15 + .49\ I_d$, where

T_K = minimum time required for link K

I_d = number of digits in display

The bases are calculated as follows.

$$A = \frac{1}{1 + \sum_i W_i},$$

where W_i = weight of i^{th} link

and W = 1/2 for a corroborative (two state) indicator

W = 1 for a corroborative multiple choice indicator

W = 1 for a one bit indicator

W = 2 for a multi bit indicator

W = 4 for a computation, table look-up, etc

W = 0 for links which are of a conjunctive nature and for links from "and" element

$$B = \left[\frac{(n + m)_u}{2N}\right] \cdot \left[\frac{(n + m)_u}{(n + m)_t}\right],$$

where n = no. of indicators

m = no. of controls

N = no. of forward links

$(n + m)_u$ = sum of elements used (connected to forward links)

$(n + m)_t$ = total no. of indicators and controls

$$C = e^{-\Sigma_k (T_k - t_k) - \Sigma_k |M_k|}, \quad t_k < T_k$$

where T_k = minimum time required for link k

t_k = time allotted for link k

M_k = mismatch in digits between elements connected by k^{th} link

$$D = \frac{2}{Q + n_o},$$

where n_o = number of "other elements" (neither display or control)

Q = number of individual components

$$E = e^{1 - \frac{\$i}{\$r}} \cdot \frac{1}{1 + \frac{\$0}{\$r}},$$

where \$i = initial cost

\$0 = operating cost/year

\$r = reasonable cost

Development of the DEI

The DEI was first worked out on the original (o), and four hypothetical variations (1,2,3,4) of the AN/MPQ-4A intercept radar set. Two human factors specialists who are members of the Applied Psychological Services' staff, were asked to rate these systems. The ranks assigned by the two experts were 3,2,0,4,1 and 3,2,0,1,4 (in which 3 is best). These agreed with the unweighted DEI 3,2, original, 4,1 To increase the sensitivity of the index, the base values were transformed as follows

$$DEI = A \sqrt{E} \cdot \sqrt[4]{C} \cdot \sqrt[3]{D}$$

Following this the technique was applied to a special purpose radar system, the AN/FPS-56. Again the original (O) and four hypothetical variations of the original (1,2,3,4) were judged from the point of view of the adequacy of the display reading → operator decision → control action loop in the system. The DEI technique produced a hierarchical ordering of 3,4,0,2,1 while the rankings of the experts were 4,3 (tie) 0,1,2 and 4,3,2,0,1. Similar agreement between the technique and Applied Psychological Services' staff members judgement of the relative merit of design variations of a public address set and a complex situational target monitoring and assignment task were obtained. Thus it appeared as if the technique might be generally applicable and that more rigid validation was appropriate.

Validity of the DEI Technique

The validity of a technique such as the one described can be supported from several points of view. One point of view is the conceptual validity of the technique. By conceptual validity is meant the reasonableness of the concepts from which the technique is drawn and upon which the technique is based. The conceptual basis of the DEI technique and its roots in communications engineering constructs have been discussed elsewhere (Siegel and Miehle, 1961). Some persons would argue that conceptual validity alone is sufficient for an acceptable technique. The present authors maintain, however, that if a technique can be shown to possess conceptual validity and if it can also be shown that the new technique correlates well with some other acceptable measure of the function being evaluated, then the new technique gains additional support.

Four prominent men (three psychologists and one engineer) in the fields of human factors and information theory were asked to evaluate various system and contrived variations of these systems. The major considerations examined by the authoritative raters were the various displays in the respective systems and the ability of the displays to transfer the requisite information to the operator, the manipulations of controls, the various decisions and judgments required by the operator in each system, and the estimations and calculations that the operator makes in fulfilling his functions in the system. Correlational analyses were performed between the ratings of these experts and the

DEI values Insofar as the DEI values correlate well with the evaluative opinions of the outside expert raters, it may be claimed that the technique is valid for discriminating between variations of the same system

The results for each of the four systems and their variations were averaged over the four raters and ranked hierarchically. Rank order coefficients of correlation were calculated between these data and the ranked data obtained from the application of the DEI technique. These correlations are presented as Table 1

An analysis of the agreement between the individual experts and the DEI is presented as Table 2.

Table 1

Rank Order Correlations Between the Authorities' Mean Ranks and the DEIs

System	Correlation
Radar Set AN/MPQ-4A and four variations	1.00
Radar Set AN/FPS-56 (Tracking and Plotting) and four variations	.90
Radar Set AN/FPS-56 (Target Definition) and four variations	.80
Radar Set AN/FPS-56 (Target Ranging) and four variations	1.00
Public Address Set AN/UIH-3 and four variations	.90
APS-251	1.00

The obtained correlations between the raters' evaluations and the calculated DEI values indicate relatively high agreement between the two variates for predictive purposes. These findings suggest that the purported purpose of the development of a technique for evaluating the effectiveness of displays in systems to transfer information to an operator and for the operator to act on the information has been, at least to some extent, achieved.

Reliability of the DEI Technique

In actual use of a technique such as DEI method, there is always the possibility of some variation in the analysis if different users apply the technique to the same system. This variation may result from different interpretations of the system's design and function and of the task. There may be differences in the evaluators' backgrounds and the users may lack a precise description of operator's tasks and the systems. Another source of inconsistency may lie in differences of interpretation of the rules for applying the technique.

Therefore, for each equipment and its variations reported here, a separate DEI technique application was made by two or three people The purpose of these separate applications was to obtain an indication of the uniqueness or agreement between the equipment rankings obtained by different users of the DEI technique.

Rank order intraclass correlations were calculated to indicate the extent of agreement among the rankings obtained by the various evaluators who applied the technique to the systems considered. The obtained correlations are presented for each base as well as for the total DEI in Table 3.

In computing correlations, only rank orders were considered and the correlation between users was determined for the individual bases as well as for the DEIs In cases in which two variations possessed close DEI values, the variations were nevertheless considered as having distinct ranks rather than being considered as ties. This makes the test quite severe, especially for the individual bases, where there is no essential difference between two variations for the aspect which that base evaluates.

Table 2

Rank Order Correlations Between Individual Raters and the DEI

Rater	Radar Set AN/MPQ-4A	Radar Set AN/FPS-56 (Tracking and plotting)	Radar Set AN/FPS-56 (Target Definition)	Radar Set AN/FPS-56 (Target Ranging)	Public Address Set AN/UIH-3	APS-251
A.	1.00	.90	.40	.80	.70	.80
B.	1.00	.70	.80	.40	-.40	.40
C.	1.00	.67	.80	.80	.90	.80
D.	1.00	1.00	.40	-.40	.90	1.00

Table 3 reveals high reliability coefficients. With the exception of six coefficients, there was perfect agreement among the evaluators who used the DEI technique. It was pointed out at the outset that the goal of the current program is the determination of a technique for determining the relative merit of equipment design variations from the display → operator decision → control action point of view. Thus, even if different values are derived by different users of the technique, the present results suggest that the obtained relative order of merit between the users will agree and that the technique does not suffer from this point of view.

Table 3

Reliability Coefficients for the Total DEI and the Bases

System	Total DEI	Base A	Base B	Base C	Base D
Radar Set AN/MPQ-4A	.93	.86	.80	1.00	1.00
Radar Set AN/FPS-56 (Tracking and Plotting)	1.00	1.00	.90	1.00	1 00
Radar Set AN/FPS-56 (Target Definition)	1.00	1.00	1.00	1.00	1.00
Radar Set AN/FPS-56 (Target Ranging)	1.00	1.00	1.00	1.00	1.00
Public Address Set AN/UIH-3	.93	1.00	1.00	1.00	1.00
APS-251	1.00	1.00	1.00	1.00	1.00

Discussion

The results of the work completed suggest that the DEI technique possesses sensitivity for evaluating the adequacy of the design of an equipment from the information transfer (display → operator decision → control action) point of view. The display evaluative index (DEI), as the technique has come to be called, was applied to six distinct tasks over four different equipment types and hypothetical variations of these equipments. In all instances the results suggested the DEI technique to possess capability.

In the application of the DEI technique, a transfer chart must be prepared. It is possible that subjective variation among different analysts or users who might prepare the transfer chart, could introduce a degree of inter-analyst inconsistency into the technique. Such inconsistency could limit its effectiveness. This variation could be caused by different interpretations of a system's design, function, or task, as well as differences in the analysts' backgrounds. The inter-analyst reliability study performed to estimate the extent of this effect among the various analysts employed by Applied Psychological Services indicated very close agreement among the analysts using the DEI technique. While this finding does not negate the fact that analysts may vary somewhat from one another, it suggests that the technique does not suffer from this constraint. Moreover, it may be pointed out that the preparation of the transfer chart is a relatively objective process which involves listing the displays and controls and linking those that affect each other. Beyond this point, a set of ground rules are applied for deriving the resultant DEI value. Thus, the emergent index value is largely a function of the objective individual base formulas and mathematical technique. The resultant DEI may be compared and contrasted with an evaluative figure derived from alternative approaches, checklists, and rating scales. In these approaches, the derived scores rest considerably upon the subjective evaluations, biases, and ideosyncratic tendencies of the observer involved. Little opportunity for introducing these effects exist in the DEI technique.

The validity of the DEI technique rests on two pillars. The first pillar is "concept" validity. The technique is drawn from a series of principles logically related to and drawn from information theory constructs. To the extent that the user accepts these constructs and the derived principle, to that extent will the DEI technique be acceptable to him. On the other hand, information theory or the present extrapolations therefrom, may not be impressive to some persons. Accordingly, we point also to the second pillar upon which contentions supporting the validity of the DEI technique rest, the empirical validity. The validational studies suggested that the technique empirically correlated in a strong positive manner (medan rho = .95) with the opinions of accepted human factors authorities. While the validity of the technique has only been demonstrated for three classes of equipments, future studies are planned which will extend the empirical validity to other equipment classes

It has also been demonstrated that the bases are theoretically independent of each other However, the question of whether this independence is true in application remains open Studies in this regard are currently being performed.

It is not believed that the sensitivity, reliability, and validity here indicated can be obtained by users with no training in the use of the technique. While the requisite training is believed minimal, nevertheless standardization of approach and application is required. For this reason, a handbook or manual for the use of the DEI is also under preparation. The handbook of instructions attempts to present a concise, step-by-step procedure for applying the technique.

It is noted that only single operator equipments were considered in the present work. Multiple operator systems present situations of a different magnitude and nature and must be studied separately for the development of evaluative techniques. Additionally, the displays involved in the system studied were two dimensional visual displays, with standard controls. Although three dimensional displays are possible on Signal Corps' equipment, the extent to which the DEI technique may be applied to three dimensional and to auditory displays remains open.

Conclusions

The results of the work here summarized and reported suggest the following conclusions

1 The DEI technique possesses adequate sensitivity for quantitatively distinguishing between variation in the display → operator decision → control loops in classes of equipment similar to those here tested.
2. With trained users, the between user reliability of the technique is adequate.
3 The index number (DEI) emerging from application of the technique to a series of equipments correlated acceptably with the relative ratings of authorities.
4. By implication, the DEI technique represents a useful tool for aiding in the selection of an equipment design from several alternative early equipment designs.

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CHAPTER 4

HUMAN FACTORS AND THE INFANTRYMAN

CONFERENCE SESSION III-A

A. THE ASSESSMENT OF HUMAN FACTORS IN LAND NAVIGATIONAL ABILITY Theodore R. Powers; U.S. Army Infantry Human Research Unit, Fort Benning, Georgia

B. PROBLEMS IN THE DESIGN OF AN ARTICULATED ARMOR VEST USING RIGID COMPONENTS Edward R. Barron, U.S. Army Quartermaster Research and Engineering Command, Natick, Massachusetts

C. DESIGN AND DEVELOPMENT OF GLOVES. Herman Madnick, U.S. Army Quartermaster Research and Engineering Command, Natick, Massachusetts

D. LIMB SENSITIVITY TO TRIPWIRES Gino R DeTogni and Paul S. Strauss, Picatinny Arsenal, Dover, New Jersey

E. SURVEY OF THE EFFECTS OF LOADCARRYING AND EQUIPMENT DESIGN UPON TASKS PERFORMED BY THE COMBAT INFANTRYMAN Martin A. Tolcott and Morris Kolnicker, Dunlap and Associates, Inc., Stamford, Connecticut

A. THE ASSESSMENT OF HUMAN FACTORS IN LAND NAVIGATIONAL ABILITY by Theodore R Powers. US Army Infantry Human Research Unit, Fort Benning, Georgia

INTRODUCTION

It is probable that some groups in our society feel that the Infantryman's job is a simple, straightforward task, requiring no more than the strength to carry a rifle and the ability to follow a multitude of orders This hypothesis is not sustained when the various skills areas, making up the Infantryman's MOS, are closely examined. If this examination is made, it is found that what was once conceived to be a unitary task of minimum complexity, has become a multidimensional complex performance area that is not easily learned nor always remembered. Because of this shift from simplicity to complexity, human factors research should offer guidance in all skill areas where there appears to be a military problem.

In World War II, Korea, and now the Far East, unit commanders have reported that troops in their command have oftentimes been unable to move accurately from point to point across unfamiliar terrain. This type of movement will be referred to hereafter as land navigation. Land navigation can be accomplished by either dead reckoning in which compass azimuths are used for direction and paces are counted to measure distance traveled, or by map terrain association in which location is determined by associating represented terrain features on the map with those same features on the ground.

During the design of an Advanced Land Navigation program to be used in Infantry Advanced Individual Training, many facets of the land navigation process were examined, particularly with reference to the human factors relationship to the Infantryman. Today, I am going to tell you about the results of some of this research.

STUDIES

The first study I shall discuss deals with the area of land navigation as an integrated complex performance task. As a place of departure for our studies, a job description and an analysis of land navigation were completed and seven basic navigational skills were identified These are compass sighting, check-point recognition, map orientation, position location, azimuth determination, accuracy of pacing, and map-distance measurement. These skills were arranged into a proficiency type skills test where each skill was tested separately.

In the next step in the research, the question of navigational difficulty was considered. We found that the major variable in controlling navigational difficulty was the identification and subsequent variation of certain physical features which are present on a representative sample of terrain. Accordingly, eight terrain factors were selected as difficulty-determining parameters These are total route length, individual leg length, number of legs, obstacle size, amount of vegetation, check-point recognizability, degree of slope, and objective size.

By varying these eight parameters, avigational routes of three levels of difficulty (easy, moderate, difficult) were constructed and used to assess performance of the intergrated job of land navigation at these three levels. A counterbalanced design was used in which half the subjects received the individual skills test before navigating a route, and half received it afterwards.

Sixty Infantrymen, selected from 24 rifle companies of an Infantry Division, were evaluated. Varying in rank from Private First Class to Corporal, all subjects were graduates of Basic Combat Training and Advanced Individual Training, and had participated in an average of three months of Basic Unit Training.

The procedure, for any one Infantryman, was as follows He was given a general orientation concerning the activities he would undergo for the day. He was then given the individual skills test, if he was in the appropriate group, and next taken to one of the navigational routes. There the soldier was given a map, a compass, a pace cord, and a route card, which had magnetic azimuths, distances, and check points recorded on it. He was next given a route briefing covering all pertinent aspects of the route

As the Infantryman navigated over the route he was accompanied by an observer. This observer walked about ten meters behind the navigator and carried a checklist of navigational behaviors. As significant behavior occurred it was noted by the observer on the checklist. At the completion of the route the Infantryman was given an interview in which he was asked to explain some of the behavior he exhibited while navigating the route.

The methods of assessment just outlined proved to be excellent diagnostic tools. The proficiency of various skill areas was established and appropriate action has been taken in the Advanced Land Navigational Program to stress those skill areas which were found to have a low level of proficiency in the present investigation.

As a result of this investigation, the validity of the terrain difficulty parameters was established. It was found that 55 per cent of the Infantrymen reach the objective on the easy routes, 45 per cent on the moderate routes, and 5 per cent on the difficult routes.

Since there were no background data on which to scale the various route difficulty dimensions, it had been decided to use a mathematical average of the difficult and easy route parameters for determining the quantification of variables for the moderate routes. For example, the easy routes were one mile in length, the moderate routes one and one-half miles, and the difficult routes two miles. Although this type scaling turned out quite well in general, it is obvious that, with a 55-, 45-, 5-per cent split, some of the determining parameters are probably curvilinear in form rather than simply linear.

An interesting side light developed when the data of this study were analyzed. It was found that there was no statistically significant relationship between scores on the individual skills test and navigational behavior on the routes where the skills were required to be integrated. This implies that land navigational ability should only be tested in the operational setting, as a proficiency type individual skills test will not be able to predict with validity.

From this general study several specific human factors questions arose on which there were no empirical data. Accordingly, a further series of studies was designed in order to answer specific questions.

One question that had arisen during the conduct of the previous investigation was the effect of various hand-held weapons upon the magnetic field of the compass. Although Field Manual 21-26 gave some general rules for several weapons, it was found that these rules were not based on empirical data and, further, did not cover some of the newer weapons available to the Infantryman. Accordingly, a study was prepared in which all hand-held weapons ordinarily available to the soldier in an Infantry battle group were studied as to their effect on the compass. Specifically these were the M1 rifle, M14 rifle, M60 machinegun, M79 grenade launcher, .45 Cal pistol, M26A1 hand grenade, and bayonet. Further, such items or equipment as the helment, entrenching tool, canteen, and the web harness and pack were included in the study.

It is well known that a magnetic field is not circular in shape but instead exhibits concentrated lines of force at both the north and south poles of the specific field. Therefore, the compass was placed in a stationary position and the various weapons and items of equipment were moved toward and away from it using eight different directions. A modified method of limits was used, with a compass needle deflection of five degrees serving as the criterion of effect.

As expected, there was a direct relationship shown between the direction from which the equipment approached and the deflection distance of the compass needle. In general, the least effect was shown when the approach was from either a north or south direction and the greatest effect was exhibited when the approach was from the east or west.

For purposes of simplicity, the greatest distance, regardless of direction, at which the criterion effect was shown was labeled the danger distance for the particular piece of equipment under study.

It was found that the danger distances varied from 0 to 15 inches depending on the specific piece of equipment tested. In general, as the mass of the equipment increased, the danger distance also increased so that the maximum danger distance recorded was for the M60 machinegun which was also the largest piece of equipment tested.

Because of the small danger distances for the smaller items of equipment, it was found that, if an Infantryman was equipped with a web belt, harness and pack, had an entrenching tool and a canteen in the usual positions, had two M26A1 grenades clipped on the harness near the soulders, had his rifle slung over either shoulder, and was wearing a helmet, he could use the compass without laying down any of this equipment. However, it is suggested that for the larger hand-held weapons a distance of at least one meter should be considered as the safe limit for the operation of the compass.

The question of whether to lay down equipment when using the compass evolved into another area of research. The usual compass holding position, taught in the navigational courses, is called the sighting technique. This requires that the navigator hold the compass at eye level, sight through a pair of slots at the desired object, and then focus a glass eyepiece so that he can read the directional azimuth which appears under the index line. Altogether, there are seven different steps that must be completed to ensure a correct reading when using the sighting method.

We had found that trainees often did not bother to complete all the steps required for sighting and thus many times obtained an incorrect reading on the dial of the compass. The question arose as to whether another compass method could be found that was just as accurate as sighting but was less tedious to use.

It had been known for some time that there was a different compass holding technique used by many experienced navigators. This was usually called "shooting from the hip" and was known to be a faster way of using the comapss. Essentially this required the navigator to simply open up the compass all the way, hold it at about waist level, and to look out over the cover of the compass at the object in question. He then read the directional azimuth directly under the index line without the aid of the magnifying lens. This technique reduced the number of steps required for efficient operation from seven to two. The question to be answered, however, was whether when the trainee used this hip shooting technique he could be as accurate in his determination of azimuths as he was when he used a sighting technique.

Accordingly, a study was designed which varied the compass holding techniques under two conditions. The first condition had the subjects sight on a number of panels and give the magnetic azimuths to the panels. The second condition required the subjects to navigate from point-to-point while using the compass in a specified holding position. Compass positions were counterbalanced and varied so that all subjects used all compass holding positions on various navigational routes. This test was held under both day and night conditions of illumination.

It was found that, in the test which required sighting on the panels, there was no difference between the two compass holding positions. Thus, it appeared that the hip shooting method of compass usage was just as accurate as was the standard sighting method when used in a stationary position. However, in the route navigation part of the test, it was found that, when subjects used a hip shoot procedure, they hit their objective more often (statistically significant at the five-per cent level) than they did when they used the sighting position. We believe this was due to the fact that the hip shooting method, while being just as accurate as sighting, was much easier and quicker for the trainee to use and thus the subjects were more proficient when using this technique.

Since that study was completed, we have refined this technique and now call it the center-hold method of compass usage. We recommend that the trainee hold the compass in the center of the body and vary the vertical position up and down until his personal visual acuity gives him a good focus on the dial. This is the only compass holding technique that will be taught in our Advanced Land Navigation Program.

While I am reporting to you some studies that we did involving the compass, I will mention a survey we carried out concerning the condition of fogging that was reported to occur on occasion inside the cover glass of the compass dial.

The present compass has two main glass surfaces. One glass acts as a cover to the bowl of the compass, and the other glass is immediately above this and has several technical uses for navigational purposes. It had been reported that sometimes fogging would occur between the two glass surfaces and since the top piece of glass can not be easily removed in the field, especially if you are moving, this proved to be a real problem to the reading of the compass dial.

With the help of the Ranger Department and the Map Reading Committee of the U.S. Army Infantry School (USAIS) a compass fogging survey was conducted at the Mountain Ranger camp at Dahlonega, Georgia, the Florida Ranger Camp at Eglin AFB, Florida, and also here at Fort Benning. Altogether there were 604 observations made over a period of about two months. It was found that, although there were differences in frequency of fogging among the three installations, the over-all means indicated that 79 per cent of the compasses remained free of fogging at all times (range 70 - 92), 14 per cent became partly fogged but still readable (range 8 - 18), and 7 per cent became completely fogged and unreadable (range 0 - 11).

Further analysis yielded three conditions under which the majority of fogging occurred. The first condition was if the compass was well worn. When this occurs the cover glass becomes loose from the frame, the distance between the two glass covers enlarges and thus there is a greater chance of moisture entering and condensing between the two glass surfaces.

The second condition under which fogging may occur is when the temperature of the air is very cold and the compass is either carried in the hand or worn on a thong around the neck inside the clothes and next to the body. When the compass is used under these conditions the difference in temperature between body heat and colder air causes the glass to "sweat" and thus fogging may occur. I might add a note here and say that in extremely cold weather we recommend the compass be carried in a belt pouch when not in use or if it is carried around the neck it should be hung outside the clothing where it can assume the same temperature as the air.

The third condition in which the compass may fog is when there is an abundance of humidity in the air. Although we found that if it were raining, or if it were extremely humid, more compasses did appear to fog than when it was clear, we found no direct relationship here as the great majority of compasses did not fog even in a severe tropical rainstorm.

I have discussed, rather thoroughly, some of the directional aspects of land navigation specifically with relationship to the compass. Next I will talk about an area that is just as important as far as navigation is concerned and that is the determination of distance traveled.

There are various methods of measuring or estimating distance traveled available to the navigator. One of the most common, and one that is a major part of the dead-reckoning process, is the counting of paces. This is usually called pacing and the navigator records one pace each time either foot strikes the ground. In the literature one can find many references to the fact that the pace of an individual will vary in length depending upon the amount of illumination, degree of slope, direction of wind, type of terrain, etc.

However, on closer examination we found that there was no precise data on which to support these claims and since we had an interest in this area, because of our Advanced Land Navigation Program, a systematic study was done testing two of the variables.

It was decided that the two types of variables the average navigator constantly comes in contact with when navigating are level of illumination and variability of terrain. To study the terrain variable, two pacing courses, each exactly 800 meters long, were laid out. One course traversed an area of the Fort Benning reservation where the land was gently rolling, where there was quite a few trees, but there was little underbrush. The total difference in elevation occurring on the course was about 35 feet. The second course was laid out on a flat, dirt road that was completely clear of any vegetation. The total differences in elevation occurring on this course was less than one foot.

Subjects were split into two groups for control purposes, and each group paced the two courses both by day and by night. A counterbalanced design was used in which the variables were presented to the groups in alternate order to obviate for any serial or practice effects.

It was found that there was a statistically significant difference between the number of paces taken by the subjects on the various pacing courses under changing conditions of visibility. When the data were combined, there was a difference at the .001 level between the day and night conditions of illuminations During the day, the subjects took shorter paces than they did at night. When the variables were analyzed separately it was found that there were also significant differences between the day road and the day field, the day road and the night road, and the day field and the night field. There was no significant difference between the road and the field when all data were combined nor between the night road and the night field when the data were considered separately.

These data lead us to believe tnat the question of the effect of varying types of terrain upon the pace count still has not been completely answered. It is suggested that further research in this area should select pieces of terrain that are quite dissimilar in characteristics, but nevertheless representative of the basic types of terrain found in many places in the world. By conducting such research the question of the individual pace count can be answered.

However, the results of this study definitely indicate that the individual pace count does change under differing degrees of illumination. The taking of longer steps at night, as compared to daytime, cannot yet be explained but one of our staff has suggested that this is due to an increased drive by the trainees to get the night exercise completed and to move back to the barracks We have no data to support this conclusion

In the analysis of the pacing data, an interesting and significant finding came to light As stated previously, the various pacing courses were exactly 800 meters in length. Part of the procedure involved collecting data every 100 meters and thus for any one individual we essentially had eight pacing standards. When we computed the mean for all 800 meters and considered that as the normal pace count, we found that 80% of the deviation from the normal pace occurred within the first 400 meters of the course. This suggests that if a pacing course is to be established for training purposes, it should be no less than 400 meters in length as having a course shorter than this will give an unrealistic picture of the individual pace count.

The last study I shall report to you involves the question of detouring from a base azimuth when using the dead-reckoning process in navigation. In order to detour correctly four 90-degree turns must be made by the navigator. If he is careful in making these turns, and keeps an accurate count of the distance he has moved off the base azimuth, he can return to the base azimuth after he has passed an obstacle and be sure he is back on his correct route. The usual procedure has been to tell the trainee to do facing movements (right face, left face) when attempting to make the 90-degree turns necessitated by an obstacle.

However, past research had indicated to us that trainees were not making these turns accurately enough and thus becoming lost due to being unable to return to their correct route. Accordingly, a study was designed to give us guidance in this area.

Subjects were supplied with a compass and given a base azimuth. They were told that they must detour around an obstacle and that to accomplish this they would have to make a 90-degree turn to the left and then to the right. Each subject completed this procedure three times during daylight and three times in darkness.

We found that during daylight the subjects had a mean deviation from the 90-degree turn of about 11 degrees for turning both right and left. During darkness this deviation increased somewhat to about 15 degrees for both right and left turns. Since it had previously been decided that accuracy demanded the facing movements be made within five degrees of the base azimuth, this method of detouring using facing movements was rejected.

SUMMARY

Today, I have discussed with you several human factor studies the US Army Infantry

Human Research Unit has completed during the past year. Although these studies were specific to land navigation, we feel that many of the methods reported here can be used in research in other areas. Perhaps our major finding has been that it is not always valid to test the separate skills of a complex performance task when you are attempting to predict the proficiency of the integrated performance. It is obvious that, if this is true for one area of human factors research, it is probably true for other areas also.

B. PROBLEMS IN THE DESIGN OF AN ARTICULATED ARMOR VEST USING RIGID COMPONENTS by E. R. Barron, U.S. Army Quartermaster Research and Engineering Command, Natick, Massachusetts

The origins of man-made body armor are probably almost as old as man himself. Beginning with a rough shield of tanned skins stretched on a wooden frame, gradual improvements have evolved over the years. Many ideas were undoubtedly copied from the natural armor of animals, but progress accelerated abruptly with the advent of metal technology.

Such body armor was adapted to combat conditions and tactics of the times and was of course limited to available natural materials of sufficient hardness to deflect a blow, the velocity and intensity of which were limited to human force. Man also discovered that the toughness and strength of metals created other problems since a sheet of iron or bronze was rigid. Armorers realized early that the rigidity of an armored garment limited body movement, caused discomfort, and affected the combat efficiency of the warrior. These same problems face the designer of present-day body armor.

One usually envisions armor as the ornate equipment of the Knights and the wealthy, used mainly for jousting tournaments and parade, and made-to-order by an army of skilled workers. However, large quantities of armor were also developed for use by the common foot soldier and made on a mass production basis

The Battle of Wisby [5] which was fought between the Danes and Gottlanders in 1361 demonstrates quite vividly the armorers technical skills and efforts to obtain maximum mobility. Additional evidence of armorer technology was gained from a mass grave of 1800 soldiers (see Figure 1) uncovered accidentally in 1905 at the Swedish Island of Gotland, which presented the pathetic picture of the horrors that accompanied a war of those days [5]. The army was made up of peasants who patched up and donned old suits of armor for the hand-to-hand struggle. Twenty-five complete sets of different armor were found. It appeared that different detachments wore different kinds of armor. The Swedish Museum of Antiquities undertook a comprehensive study of these discoveries which was published in 1939 [5] and could serve as a primary design handbook for the present-day armor technologist involved with rigid materials. Mass findings point out a progressive development of armor from a small number of large rigid plates to a large number of small plates in order to obtain maximum mobility. This is illustrated in Figures 2-5.

Among the finds were six different designs and two basic construction (See Figure 2). There were coats of plates of French and German origin, consisting of from six to 600 plates using a rivet construction There were also lamellar armor of Tibetan origin of up to 600 plates using a leather thong construction (Type VI), and front openings (Type V).

Figure 3 is a typical coat of plates of Type I, found at Wisby using 22 plates with a one piece rigid pivot-type shoulder and opening in the back. Note the extent to which the armorer went to have the plates conform to body contour.

Figure 4 represents the extreme to achieve maximum articulation, a Type V coat of plates. This armor is unique among the finds, consisting of 495 plates, and is a short armless coat open in front where it was held together with buckles. The reinforcing consisted of small narrow plates riveted to the inside of a leather covering.

The actual dimensions and pattern layout of Type V armor are shown in Figure 5. Note that the front bottom is longer than the back by two rows of plates to form a pendant skirt.

Figure 6 illustrates the extent to which shoulder protection and mobility were achieved. This construction, incidentally, has been utilized in the latest QMC Composite Armor Vest. By the time of the Middle Ages, intricate and ingenious suits of armor had been developed, capable of withstanding shattering blows and vicious sword thrusts.

With the advent of firearms, the use of body armor declined and the armorer's skill became a lost art. However, occasional use of armor occurred from time to time. Even in the Civil War there is valid evidence that metal body armor was used to protect the thorax and abdomen. Experimentation with various metals and designs was sponsored by the Germans and Allies in World War I. Toward the end of the war fairly large numbers of thoracico abdominal vests were made, but were never satisfactorily tried upon the field of battle.

Throughout the history of armor, including the present, garment rigidity is the principal problem inherent in all armor design. In World War II body armor was successfully used only in protection of flight personnel in a static and seated position, since materials with good ballistic resistance were rigid and heavy. The infantryman could not wear such equipment without affecting his efficiency.

Body armor followed an erratic path after World War II. Basic problems had to be solved in order to provide protection against missiles of various velocities and sizes without immobilizing the soldier. In modern warfare, top priority has been given to mobility and a vigorous campaign has been waged to reduce the weight of equipment.

Increases in fire power have greatly augmented the density of wounding agents. Wound ballistic studies and field research under combat conditions, directed by the Surgeon General's Office (2), established the frequency and distribution of wounds according to anatomic areas of the body. Studies were also made which indicated the maximum energy loads that soldiers could carry which showed that each additional pound of garment weight reduced proportionately the individual soldier's combat efficiency. In fact, soldiers burdened with the weight of body armor, which, as yet, had not proved itself, threw their vests away or refused to wear them.

During 1947 the QMC developed Body Armor which covered the torso from the base of the neck to just below the waist. The ballistic material consisted of laminated fiberglas (Doron) in the form of flat, square or oblong rigid plates, held in place by a jacket with seamed pockets to hold the plates in position. The plates were arranged in an overlapping manner to avoid separations while the wearer was moving. The rigidity of the Doron plates restricted movements and caused discomfort. Bending from the waist was difficult and shifting of the plates aggravated the possibility of unprotected areas.

The Korean War and its high mortality rate emphasized the need for armor (2), and as a result certain Marine Corps troops were provided with Doron plate vests. However, since the QMC considered "Doron" rigid plates too heavy and restrictive, they developed a vest on the basis of research which they had available using multiple layers of 12 oz nylon fabric. This was a significant accomplishment since the resulting item weighed only eight lbs. The soldier could now perform his mission without immediate fatigue or discomfort. This was a first step to provide practical protection to the combat soldier. However the significant reduction in mortality rate engendered a feeling of safety in wearing an armored vest and produced a dramatic effect upon troops in contact with the enemy. The eager acceptance of ballistic protection for the vital areas of the body stimulated several approaches to develop a still more efficient, nylon-type, armored vest.

In the preliminary work conducted by the QMC on the nylon vest, it became evident that even though it consisted of cloth, there were major problems, chiefly rigidity in certain areas, bulk, compatibility with other field clothing and weapons and articulation requirements.

Therefore, preliminary studies to solve these problems were conducted by the QMC on movements which take place when the body assumes typical combat positions. Some of the findings are shown in Figures 7 and 8.

Gross body dimensional changes in back length are shown in Figure 7. The total back length is diminished some three inches. The complexity of the problem is evident by the relationships involved in these data. As the arms are moved forward, the shoulders are raised and a wide range of dynamic changes takes place in seven areas of the back.

Figure 8 shows torso distortion in a firing position and how shoulder breadth is greatly reduced. The contraction of the distance between the base of the neck and the acromion is three inches. The length of the torso on one side is 15 inches and on the other side is 17 inches.

It became evident that because of these gross and interacting dimensional changes of the body, major design changes were required in the nylon vest. These changes were made possible by using articulating ballistic panels. In this connection, articulation is defined as a joint between two separable parts or a moving joint between parts. Articulation was proved in the back of the vest by an action back construction located approximately at the level of the lower tips of the scapulae. (See Figure 9). This action compensated for the increase in body dimensions due to scapular rotation or elevation of the shoulder. By this simple design technique, two major things were accomplished. First, lifting of the vest was minimized, thus decreasing the gap at the lower edge. Note this lower edge of the vest in both figures. There is a minimum loss of body coverage when the soldier is in the firing position. Second, the articulation or overlap at the back also compensated for excess material caused by the decreases in back size for certain movements. The ballistic panels slide over each other, shortening with body movement and preventing the helmet from being pushed forward.

Finally, this construction was extended to the side openings where overlapping of the front and back pieces fully protected the axillary area of the body from the armpits to the waist during all movements. This was accomplished without bulkiness or discomfort, and was a considerable advancement over earlier vests which were prone to gapping and thus exposed the sides of the body.

Figure 10 illustrates that even these improvements did not provide complete accomodation for full articulation of the shoulder area and chest. Bunching up of the ballistic material still occurred, causing pressure of the material against the neck.

Advances in research on ballistic materials made other new rigid metals available, particularly titanium. In order to devise means of using these, a pre-design study of free moving body armor systems was conducted (4) to further study the work originally initiated by the QMC during development of the Korean vest. The results are shown in Figure 11. It is clear that as the surface of the human body twists and stretches, its curvature changes from concave to convex, both separately and simultaneously. Also, contortions are different at various locations.

The technique used in this study was to mark the center line of the back and front of a typical torso with dots spaced three inches apart. When the torso bent forward, the first three-inch space was shortened by one-half inch, the second three inches remained constant and a gradual shrinkage or compression from three-quarters inch to three inches occurred in the lower torso. The distortion of the front of the torso in bending backward was in the reverse direction and represented a one-quarter to one-half inch increase in space between the dots. At the same time the line on the torso back had a shrinkage of from one-quarter to one-half inch between segments except in two areas where the dimensions remained constant. In bending forward the back line was expanded from one-half to one and one-quarter inches between the dots. Bending to the left and right showed the largest change, from ten inches to 25 inches. This information was applied in the development of the composite armor vest.

Using newly designed front and back articulating panels consisting of four-ply ballistic nylon and .032" Titanium, a prototype composite armor vest was designed, utilizing initially 249 titanium plates. (See Figure 12). As the overlap area represents 20 per cent of the total weight, 3-1/4" square and 2-1/4" square plates were found to provide the least amount of overlap, consistent with required articulation. Plates were attached by either stitching, stapling or in individual cloth pockets, and articulation was dependent upon a sliding movement of the panels over each other to compensate for the dynamic movements of the body. This original vest weighed ten lbs.

The final prototype selected for field testing had 149 plates and a Velcro front-closure system and weighed 8 lbs. 15 oz. (See Figures 13). It can be seen that the articulating armored pivot shoulder pad appears to solve one of the major obstacles in applying rigid metal plates to the shoulder. The vest is considered to be capable of mass production at a cost of approximately $60-$80 per unit. Tests conducted at Mt. Washington, and at Fort Lee from June to August, 1961, using standard cold-wet, cold-dry, and hot weather clothing and the new QMC integrated clothing ensembles indicated that of the four models tested, the 8 lb. 15 oz. vest, with 129 plates interfered least with performance in simulated combat activities and was preferred by all test subjects [3]. A concurrent engineering and service test of this model is now being conducted with type classification scheduled during FY 63.

Now, the question arises, can the newer nylon felt or batting materials be used in this same vest design? Vests of felt/titanium using the same construction have been made leading to the conclusion that bulk is materially increased, and the articulating panels do not function as well as ballistic nylon because of the nature of felt-type materials. Enlarging the plate size, reducing the number of plates and overlay might solve some of these problems. It was determined at this point that an approach involving empirical or trial-and-error methods would be costly and inconclusive. Progress in this area has already been made as a result of more recent study of the changes in body dimensions associated with movement, so as to delineate those areas which did not require articulation. This study may well provide a handbook of design criteria for modern rigid armor systems [1].

Instead of merely marking off the center line as in our previous studies, the torso is marked off in a grid of two-inch squares. The subject then assumes a series of positions, subsequent to his assuming a position measurements are made of the changes in grid dimensions. These changes serve as a guide to the plate size and articulation requirements. (See Figure 14).

Very significant changes occur when the arms are raised. The lower third of the torso remains fairly constant, whereas the chest and shoulder grids change from horizontal to curved lines. The center line however remains fairly constant (Figure 15). This photograph of the back is representative of these changes and indicates the complexity of providing articulation comfort with rigid materials in the shoulder area.

The recording, plotting, charting, and analysis of data were completed for the ten body positions studied. Initially, an attempt was made to establish maximum values of distortion (expansion and contraction) for the complete torso, i.e., the abdominal, thoracic, and shoulder regions. However, quantitiative values could not be obtained initially for the shoulder area because of the complexity of the shoulder structure and the need for specialized techniques for studying this region.

Figures 16 and 17 are diagrams of the data for distortion on the grids on the back and chest respectively which occurs when the arms are raised. Remember the grids are normally 2" square. Figures 18 and 19 illustrate the gross dimensional changes given in the previous Figures.

The range of distortions associated with movements involving the abdominal and thoracic areas was successfully established. This was accomplished by measuring and analyzing the effects of all ten body positions from a system of vertical and horizontal grid lines applied to the torso of a test subject. By selecting maximum values of compression and extension for each of the grid lines, it was possible to develop a series of graphs. In these graphs, the extreme limits of body surface distortion are clearly illustrated Figure 22 illustrates the maximum changes in the vertical dimension which occur at the anterior (front) of the torso. For example Line 3 in Figure 20 may be displaced downward as far as the dotted line, upward as far as the solid curved line. Similarly, Line 7 may be displaced downward to the dotted line or upward to the curved solid line.

Following the completion of this study, criteria for the design of abdominal and thoracic regions were established, based on the data provided by the Phase I investigations. The shape and arrangement of plates for the thoracic and abdominal-lumbosacral areas were developed from a combined study of body position photographs and grid distortion layouts. These data indicate the extreme distortion and articulation requirements of the abdominal-lumbosacral region, hence the requirement for a relatively large number of narrow plates oriented in the horizontal mode (Figures 21 & 22). Similarly, the rigid mid-thoracic region enables the use of relatively large, square configurations of plates, the upper thoracic regions, adjacent to the shoulder area. initiates the need for special plate shapes which are narrow in the vertical mode. A rough prototype incorporating these findings has been made (Figure 23). The vest has 65 plates as compared to the present titanium vest which utilizes 135 plates.

To the developer, the culmination of all research is an end item. Thus for the designer of armor, success requires the application of the findings of the material researcher and the human engineer, as well as his own accumulated knowledge on the activities of combat soldiers. In this way he can be assured that his item is compatible with the spectrum of hot and cold weather clothing and with the functions and duties of the combat soldier.

The research which has been described in this paper is an excellent example of the types of significant item improvement which can be obtained if human factors research is closely coordinated and integrated with the designer at the earliest phase possible in the development cycle.

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5. Thordeman, Bengt—Armour from the Battle of Wisby, 1939, Upsala Press, Stockholm, Sweden, Volume I Chapter 2, Volume II Chapter I.

Figure 1. Grave Uncovered at Gotland

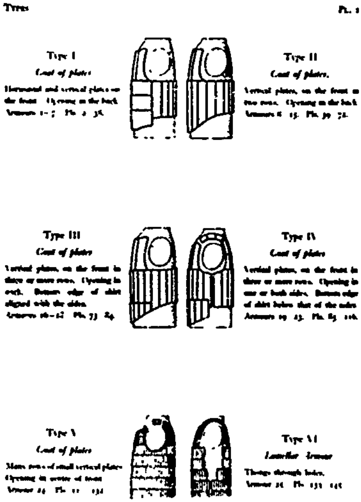


Figure 2. Typical Armor, Battle of Wisby

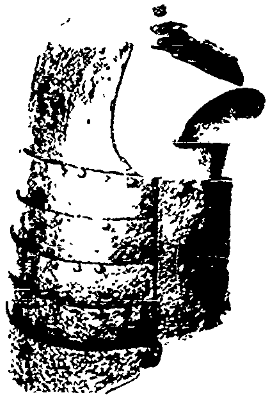


Figure 3. Plate Armour

Figure 4. Lamellar Armour

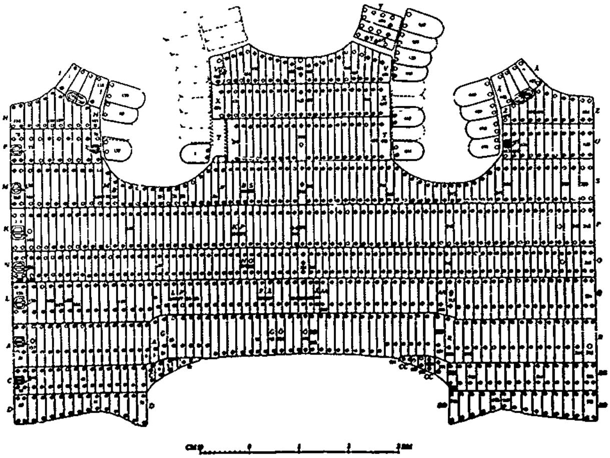


Figure 5. Armour Pattern

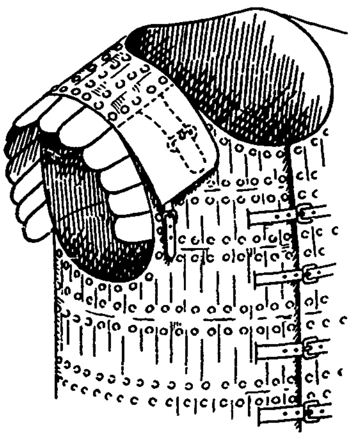


Figure 6. Shoulder Armour

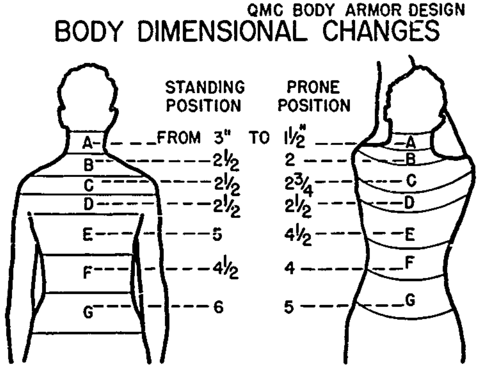


Figure 7. Dimensional Changes

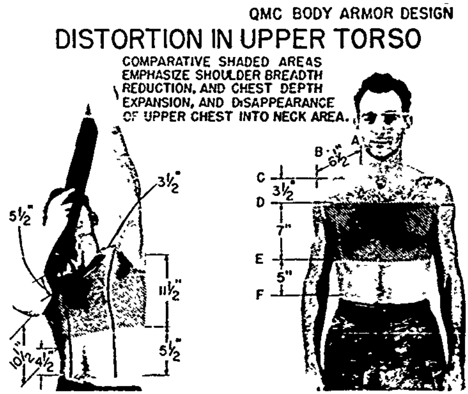


Figure 8. Upper Torso Distortion

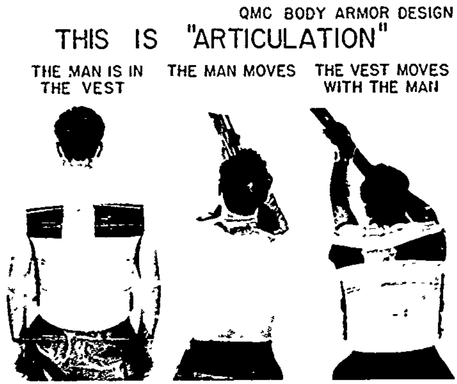


Figure 9. Vest Articulation

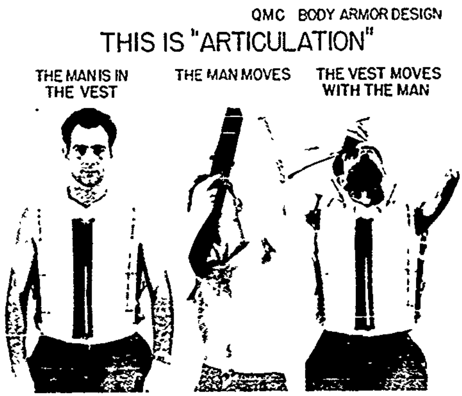


Figure 10. Vest Articulation

TYPICAL MAXIMA AND MINIMA SURFACE DIMENSIONS
FOR STRETCH AND COMPRESSION OF HUMAN BODY (TRUNK)

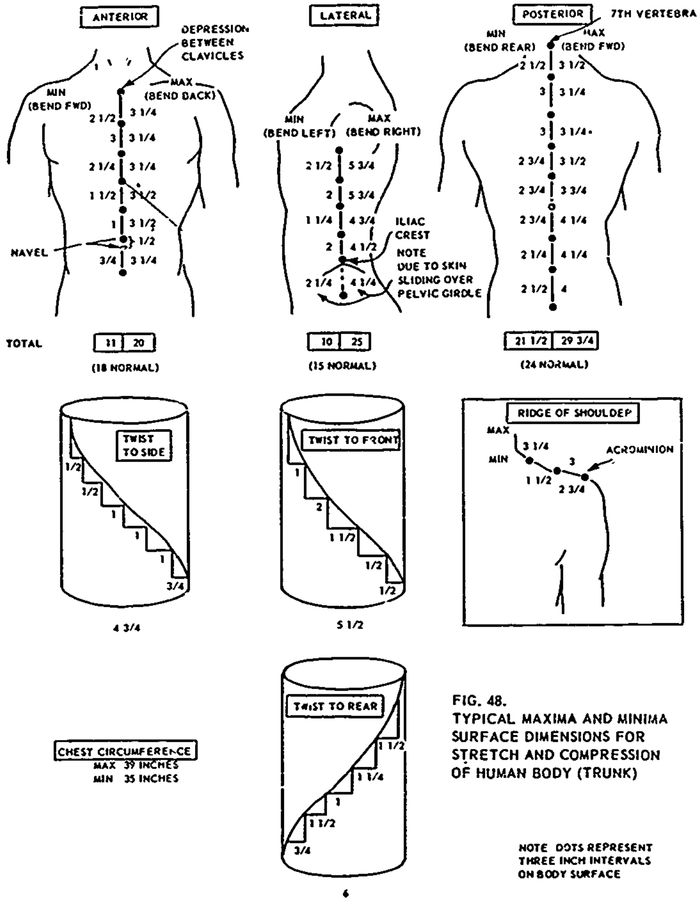


Figure 11. Torso Stretch & Compression

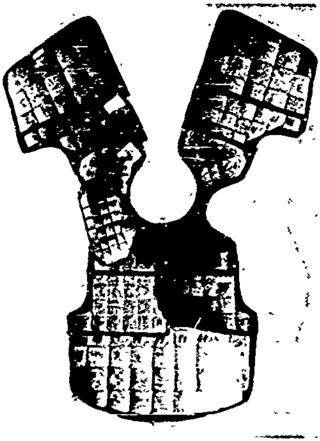


Figure 12. Plate Layout of Titanium/Nylon Composite Armor Vest

Figure 13. T62-5 Composite Titanium/Nylon Armor Vest

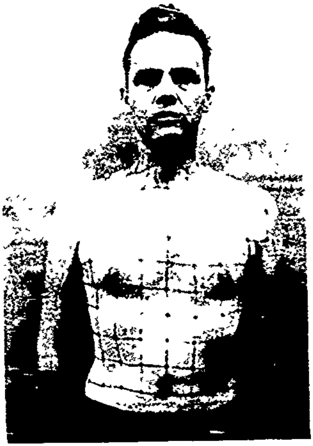


Figure 14. 2 Inch Grid Marked on Torso

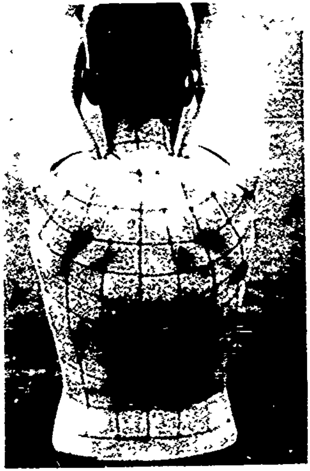


Figure 15. Grid Distortion when Arms are Raised

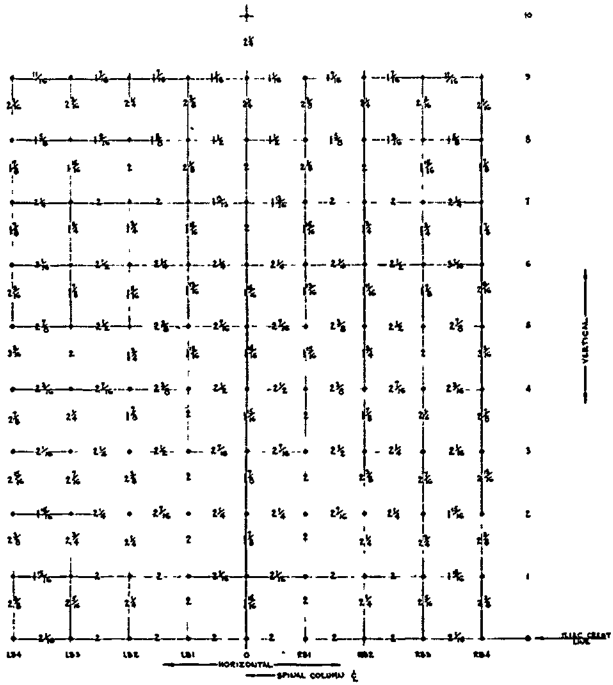


Figure 16. Chest Grid Distortion Data

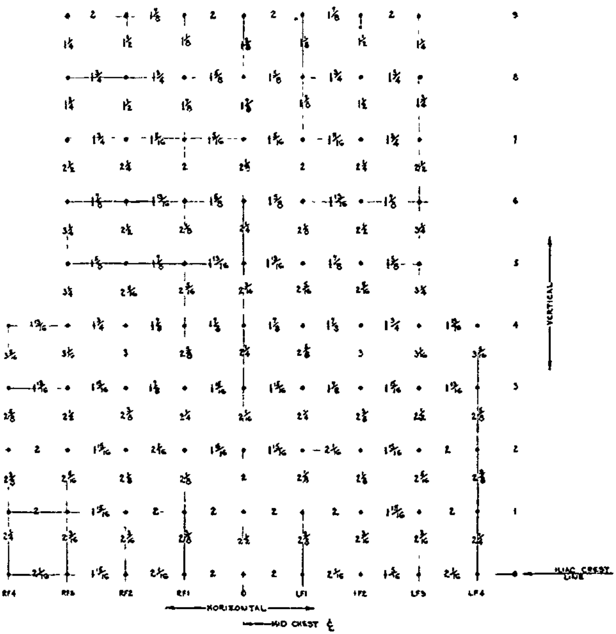


Figure 17. Back Grid Distortion Data

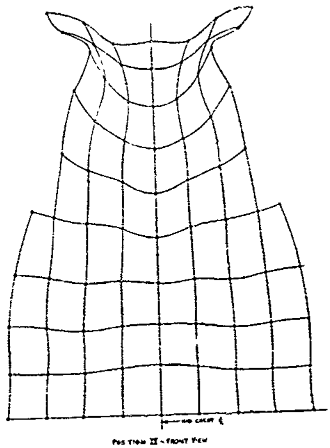


Figure 18. Front Gross Dimensional Changes - Arms Raised

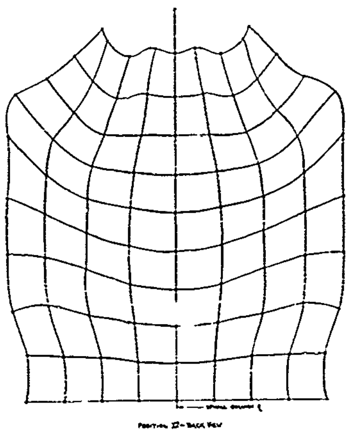
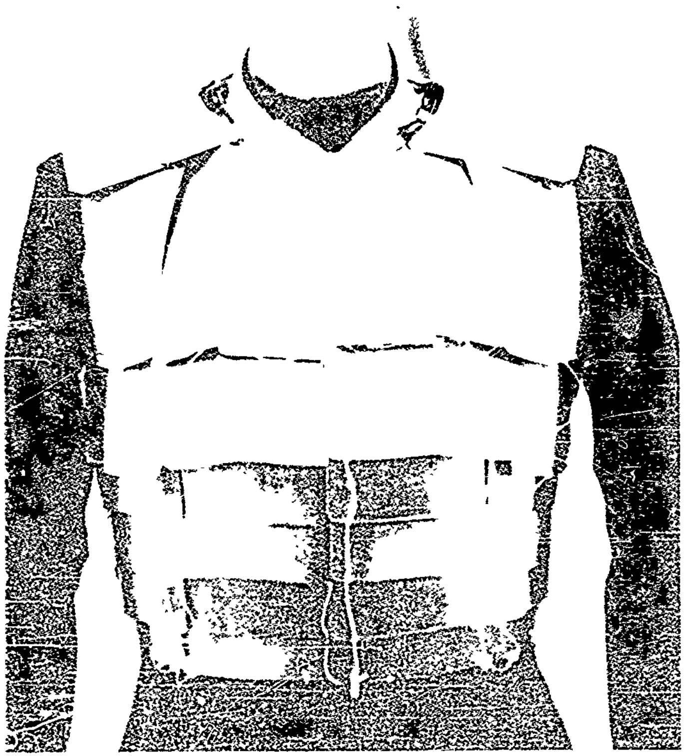


Figure 19. Back Gross Dimensional Changes - Arms Raised



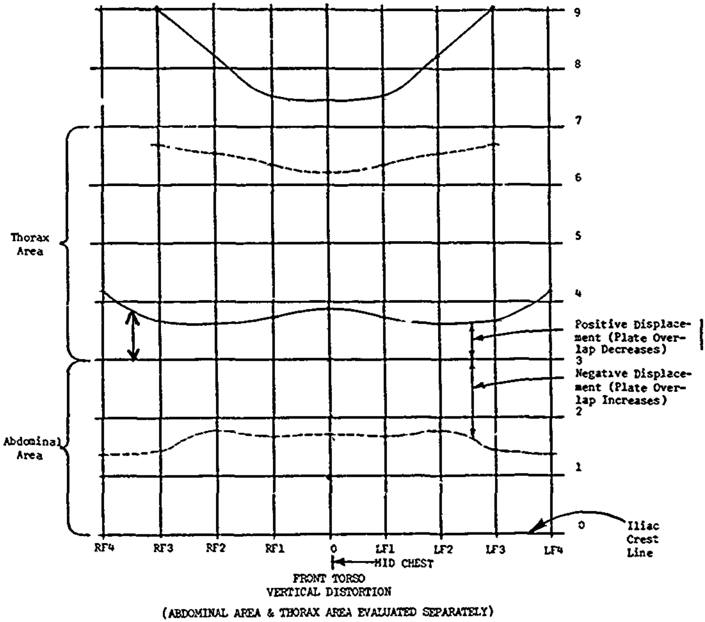
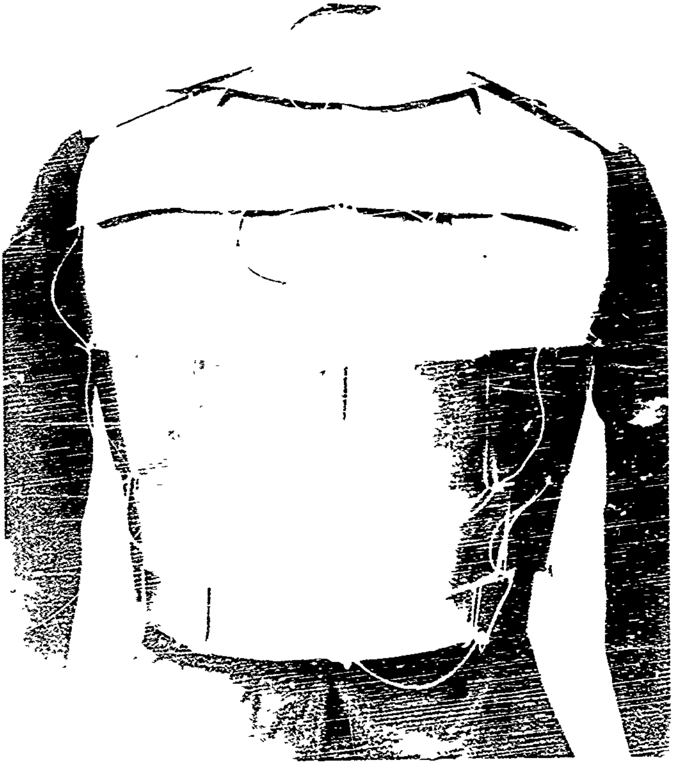


Figure 21. Maximum Compression and Extension Values



.. 22. Back View - Mockup Vest Embodying Plates Based Upon Anthropometric Study

C. DESIGN AND DEVELOPMENT OF GLOVES by H. Madnick, U. S. Army Quartermaster Research and Engineering Command, Natick, Massachusetts

INTRODUCTION

Historians have discovered that the use of gloves is an ancient practice, known even to prehistoric cave dwellers Statements of this sort, which appear all through the literature on history of handwear [9], are apparently based upon analogies to the Eskimo in the Paleolithic culture In all probability the various groups of upper Paleolithic peoples in Europe and those living in other regions of the Holarctic Zones used some sort of hand covering. However, there is no positive evidence that such was the case Such perishable materials as would have had to be employed would not have withstood the ravages of time.

A sophisticated fourchette glove was found in the tomb of Tutankhamen [9]. King Tut's glove belongs to the lineage of the dress glove associated with ceremonial occasions and symbolizes the social gulf between the nobility and the Fellaheen. The earliest concrete evidence bearing on some form of hand covering for work came to light in the Hallstatt Salt Mines of Lower Austria. These mines were exploited during the early part of the first millennium B.C. [14].

In modern times, with the increasing use of gloves for protecting the hands of workers has constituted a major area of development. Durable construction and low-cost production characterize present-day work gloves above all else. Gloves having special construction features, such as gauntlets, extra reinforcing patches, reinforcement with metal-bearing abrasion-resistant surfaces, and special acid-resistant or other similar special types of materials, dominate the work glove field today. The concept of functionality of this handwear, maximizing what the man can do when wearing the glove, is clearly not emphasized if it is considered at all. Since workers will not pay very much for a glove, it must be cheap and durable; whether the individual can bend his fingers while wearing the glove, or whether his hands become fatigued from "working against" the glove has received little consideration in work glove design From the standpoint of military handwear, however, the man's ability to perform his assigned tasks with dexterity and minimum fatigue is a primary consideration. Soldiers are not sent to the battlefield to demonstrate the durability or low cost of their clothing, any more than to show off its appearance. They are there to perform certain tasks, and the efficiency of their performance will help to determine whether they or their opponents will win, and more important, whether our nation may be able to survive. Hence, the handwear of the soldier affects the degree of skill with which he can perform many of his most critical battlefield tasks. This constitutes a very important area for research and development in which there is a continued attempt to increase the combat soldier's efficiency.

FIT AND DESIGN CHARACTERISTICS

The design of handwear, like other elements of the soldiers' equipment, bears a definite relationship to the natural and enemy-imposed environments in which the soldier finds hemself His handwear must provide insulation against the cold, protection against rain and snow without getting wet, and it must be able to withstand physical forces which it encounters such as abrasive surfaces, muck, ooze, wet snow and mud. It must also evoke no important psychological or physiological performance decrements. The man must not feel that his gloves are "in the way" so that he must remove them to get his job done, and they must not unduly fatigue his hands and forearm muscles. The objectives, therefore, in the QM hand protective program are:

1. To provide adequate environmental protection and allow the soldier to perform required tasks. Soldiers are frequently unable to utilize costly and sophisticated types of equipment because the available handgear does not allow the soldier to properly perform the required hand functions.
2. To provide a minimal number of sizes for ease of logistics, yet allow the population of wearers to complete their assigned tasks efficiently.
3. To provide handwear with the characteristics of a synthetic skin and to allow the covering to change its dimensions to conform to the varying positions of the hand with a minimal amount of discomfort and fatigue.

To meet these objectives and yet provide a second skin, soft and flexible materials are most desirable. As in many areas of clothing where origins are lost in the ruins of antiquity, the feasibility of using certain types of materials was worked out so long ago that we tend to take their availability for granted today. Who would think of leather as a radical type of material for gloves? Yet, over the centuries, as a prime example of artisanship and craftmanship, special types of leather for gloves have been produced that have many of the desired characteristics and function like a second skin.

Knitted materials are used as hand coverings and also give a tight fit. In part, this is also taken for granted. Use of knitted handwear not only provides the needed stretch required in the hand covering, but also provides excellent insulation.

Why do we need stretch in glove materials? The answer to that is found in the changes in dimension of the hand which occur in normal use and which must be accommodated by the glove material if the hand is not to be unduly constricted. For example, the length of the back of the hand increases by almost an inch in the simple process of bending and flexing The palmar side, similarly, is shortened substantially, approximately 5/8 inch (Figure 1). The problem of the glove designer is what to do with the material on the palm side of the glove which is not needed when the hand is flexed and where to get the extra inch of length on the back. Part of this can be obtained from stretching of the material itself. The surplus material on the palm can be dealt with only by careful designing to shorten the palm of the glove or to obtain a curved finger glove. This is easily said but the difficulties of actual construction are certainly not small. Similarly, there is the problem of width and girth changes in the hand (Figure 2). When the fingers are extended, the girth of a typical hand might be 7-1/2 inches but when the hand is closed, it will be an inch larger. Again, the problem is where to get this extra material.

The advantages of a knitted material in providing two-way stretch with minimum effort is evident. A knitted construction easily stretches within any direction and avoids any serious limitation on the bending of the hand or significant muscular effort to bend the fingers

Stretch can also be built into leather. In ancient times, glove makers and designers learned to treat animal skins to retain stretch in natural leather. The careful control of stretch in both tanning and cutting is a basic characteristic associated with high-priced leather gloves. Commercial types of dress gloves, however, though made from leathers having desirable stretch characteristics, tend to be so tight fitting that despite the stretch in the leather which can be used in bending the fingers, considerable effort is required, fatigue develops, and blood flow is constricted

In order to relieve constriction in gloves the only practical solution is to provide enough space around the fingers and hands so that even when a glove insert is used to provide warmth, there is still enough room in the glove to allow the hand to bend without serious constriction. This is achieved in part by the design of patterns and by drawing excess material back from the palmar side to the back of the glove by use of a strap just above the wrist. In this way, extra dimensions have been worked into each pattern element without broadening the working surface of the glove unduly with material.

One factor of this approach is to insure that the glove finger length (Figure 3) is sized so that the finger tips of short-fingered wearers will always be at the finger tips of the gloves, with sufficient dimensions elsewhere in the gloves to accommodate extra long-fingered hands.

The importance of adequate fit of handwear was stressed at the conference on "Protection and Functioning of the Hands in Cold Climates" conducted at the Quartermaster Research and Engineering Command, N .ick, Massachusetts, on 23 and 24 April 1956 [8]. As a result, a new approach was taken [2] to design handwear to satisfactorily fit military personnel. In addition, work done in 1956 under contract to the Quartermaster Research and Engineering Command by Dr. John Lyman of the Department of Engineering of UCLA [4] confirmed the criticalness of fit at the finger tips that had been recognized intuitively during the development of the U.S. Army Glove, Shell, Leather, during World War II.

In an effort to apply the results of such work as well as to initiate the design of basic anthropometric hand forms, three sizes were picked as a starting point. For the reference hand forms, Size Small was based on the broadest and thickest measurements of the 30th percentile population level, Size Medium on the 75th, and Size Large on the 95th percentile. To insure fit for short fingers, the small size was based on the 5th percentile level, the medium on the 31st, and the large on the 76th percentile.

Another concept of glove fit was developed more recently. Based on Air Force studies of hands [1] and a general manumetric survey [11], conducted by the anthropologists of the Quartermaster Research and Engineering Command, a study of the relaxed hand was also initiated to obtain measurements which could be utilized in designing basic hand forms to fit the relaxed hand. Since standard anthropometric measurements are customarily made with the hand in an unnaturally flat position which makes it easier to get consistent results, these data were not usable directly for the design of hand forms to fit a relaxed hand. Thus, the dimensions actually employed were corrected to suit a natural rest or ready-for-work pose by recording the differences in hand dimensions, using data from a dozen widely varying pairs of hands measured in both positions. It was found that the differences of each measurement were quite consistent regardless of hand size or type. The dimensions derived from the manumetric studies previously mentioned were utilized as the basic measurements for the master model hand forms. These measurements were converted to three-dimensions by application of the skill of a recognized professional sculptor. It was assumed that with available anthropometric data and a sculptor's artistry, forms for glove design could be developed which would result in a great improvement in handwear fit.

It was intended that three basic sizes (small, medium and large) would be utilized for bare-hand fit and the basic measurements corrected for the relaxed shape. To provide the space for an insulating material for environmental protection, an increase in all dimensions of the large size master hand was made. This was accomplished by the addition of approximately 3/32" to the initial dimensions of the large hand to accommodate the thickness of the standard wool glove insert. Additional forms were made with increased dimensions in the wrist area for ease in donning and doffing. The dimensions for the wrist circumference were established by measuring the hand girth of personnel within each range group at the knuckles with the fingers converging and the thumb displaced to li as close to the palm as possible.

In order to evaluate the design of the forms, a quantity of vinyl gloves was fabricated, and a fitting and sizing study was conducted using 285 test subjects [10]. This study consisted of trial fittings of the test gloves worn with and without the standard wool glove inserts. Twenty-one anthropometric hand dimensions were obtained. Information on ability to don and doff the glove was obtained on 102 of the subjects. The following information was recorded: anthropometric measurements, fit of the glove over the base hand, fit of the glove over the wool insert, and ease of donning and doffing each combination.

The fitting phase indicated that a high percentage of the male military population can be expected to be properly fitted with the four sizes provided. The high percentage of "good fits" and the comments of the test subjects were indicative of a well designed glove. A tariff for this glove based on the bare hand dimensions would be as follows 22% small, 57% medium, 16% large, and 5% extra large. Since over half of the subjects required a large glove when the wool insert was worn, the size tariff listed above would not be applicable if wool inserts were worn. In such a case the estimated tariff would be 5% small, 35% medium, 51% large, and 9% extra large.

Since the shape and fit of supported and unsupported handwear made of vinyl or butyl materials is controlled by dipping forms, development of anthropometrically derived reference hand forms provided a basis for developing accurate master model dipping forms, resulting in a logical way of standardizing fit of this type of glove. This has been successfully done, and some of the principles developed in its accomplishment are being extended to the patterning of leather gloves. In addition, a new mechanism has recently been developed by the QM Corps which will contour a leather glove to a predetermined degree of curve (Figure 4) so that such handwear can be developed to conform to the hand's true shape. Thus, maximum efficiency can be obtained from any insulation material used by eliminating compression points.

PROTECTION AND HANDWEAR DESIGN

We have already discussed changes in hand dimensions and the approach being followed for sizing handwear to allow the man to accomplish his assigned tasks. However, the problem of incorporating insulation in handwear for cold weather operations without decrement to a soldier's ability to perform remains as a difficult goal to be achieved through a balanced handwear system. One of the simplest ways to improve environmental protection is to place large amounts of insulation over the entire hand. However, with the increase in insulation the efficiency of manual dexterity is reduced to a minimum. Thus, techniques for hand insulation are required which minimize losses of dexterity. The best compromise between environmental protection and dexterity has been sought. Several approaches have been followed to obtain the desired compromise. In making a fist it was belived that the inner hand surfaces could be kept warm by heat exchange between the distal ends of the fingers and the mass of the hand, reducing the area of the radiating surface.

Preliminary Research Studies have been conducted wherein greater insulation was placed over the back of the hand, thumb, and wrist in an effort to extend the tolerance time of man exposed to cold environments [9]. During 1956 the first study was undertaken to evaluate the manual performance associated with such differential insulation. Tests indicated that when more insulation was placed over the back of the hand rather than on the palmar side, the relative performance scores were significantly higher than those achieved with the standard Arctic handwear components. Additional studies have been conducted which indicate that the use of added insulation on the dorsal surface of the hands causes a significant reduction in the rate of finger cooling under severe cooling conditions. Additional insulation, added to the palm of the hand, however, did not alter finger cooling characteristics.

A laboratory study was conducted during 1961 wherein three different levels of dexterity requirements were studied through the use of three different performance tests [3]. The results indicated (Figure 5) that from the standpoint of manual performance, the new handwear which was evaluated should be given further consideration. Although the new system was not dramatically superior to the standard handwear in reducing the impediment to manual performance, it could be considered as equivalent. Thus, new features of physical protection contained in the new handwear did not create additional interference. Since the results of these tests were highly satisfactory, handwear was designed and fabricated which incorporated most of the features of the previous test handwear. In addition to placing insulation over the back of hand, thumb, and fingers, it was also placed over the front wrist section (Figure 6). Thus, it could be assumed that only the working surfaces of the hand would be unprotected with added insulation. For handwarming, the hand could be formed into a fist thus primarily exposing the part having the most insulation. In cold-dry areas, a handwarmer would be worn over the glove for rewarming and during gross manipulatory tasks. The same principle of redistributing the insulation was followed in the mitten handwarmer as in the glove. These items have been laboratory [3] and field tested. Also, it was concluded that manual dexterity was greater when this handwear was worn [12].

A new articulated hand calorimeter has been developed for evaluating the "clo" values of various sections of handwear [5]. A "clo" is a method of measuring insulation. For all practical purposes, a men's business suit is equal to approximately 1 "clo". The calorimeter has been divided into 23 separate zones so that heat loss of each zone can be determined separately. When evaluating the new handwear on this calorimeter, it was found that there was an increase of approximately 7% in "clo" value when compared to the standard Army handwear items [6]. In evaluating the "clo" values of the various sections of the standard leather glove shell as compared to the new experimental lightweight insulating gloves, it was found that in every instance the test item was superior to the standard.

In addition, laboratory dexterity and hand cooling studies have been conducted on a systematic basis [3]. The results indicated that in general the new system is equivalent or superior to the standard system. In several respects, increases in manual dexterity were observed while environmental protection remained equivalent to that in the standard system. Most of the new items were less bulky, allowing greather capability in performing manual tasks. Conclusions reached as a result of wearing the new handwear were that they provided more effective insulation and greater manual dexterity than the standard system. Results thus far obtained from both field and laboratory studies have indicated that tolerance time of man operating in the cold can be extended by the addition of insulation to the more exposed areas of the hand. The optimum placement and optimum amounts must yet be established in order to exploit this principle.

Calibration of the sectionalized hand calorimeter to simulate the temperatures of the human hand must yet be established in order to predict the efficiency of various types of handwear designs [7]. The approach being followed calls for the collection of cooling data from a large number of test subjects for bare hand and various gloved conditions when exposed to defined environmental temperatures. The hand cooling data will be used to set up the han[illegible] lorimeter so that it may be used to com[illegible] gloves under conditions closely simul[illegible] those obtained from human subjects. T[illegible] data will provide a basis for the validi[illegible] sing the calorimeter in testing gloves, and will provide input data for better programming of the device. Through such research we hope to give the soldier handwear that has optimum protection and dexterity characteristics.

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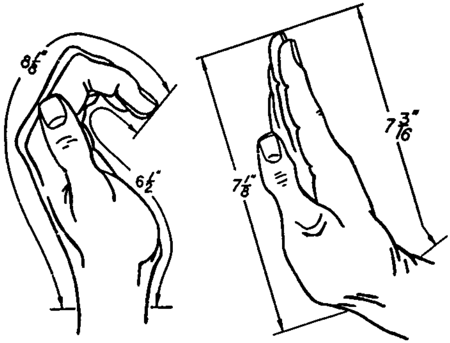

Figure 1. Hand Length Changes (Approximations from designers' data rather than anthropometric measurements).

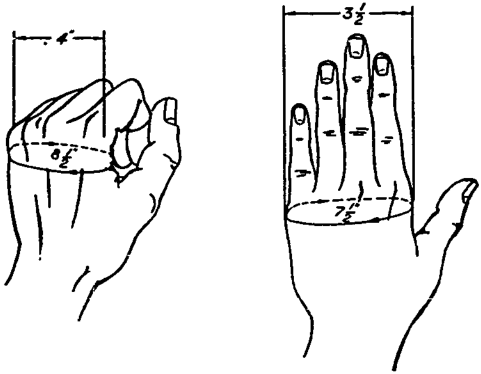

Figure 2. Hand Width Changes (Approximations from designers' data rather than anthropometric measurements).

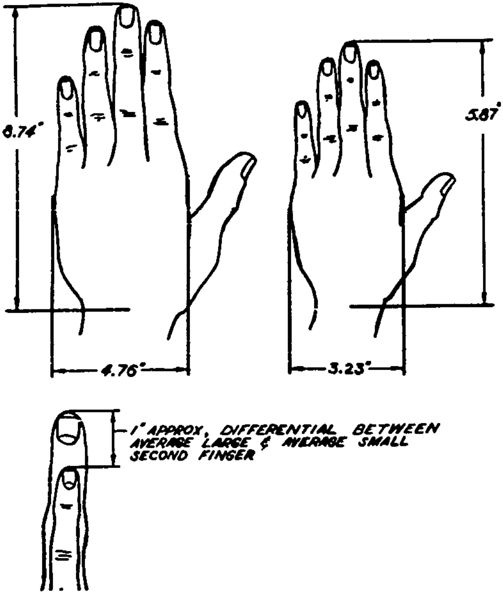

Figure 3. Range of Hand Lengths and Widths (Approximations from designers' data rather than anthropometric measurements).

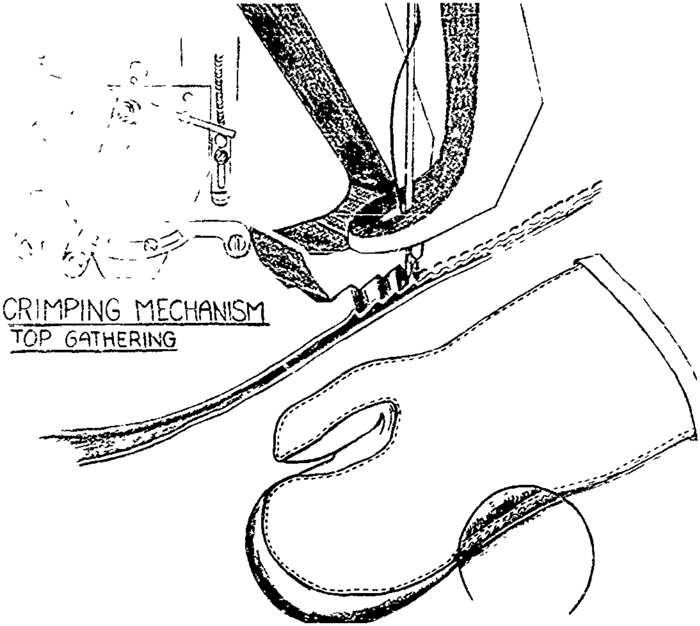

Figure 4. Machine Action Indicating Crimping Mechanism Top Gathering

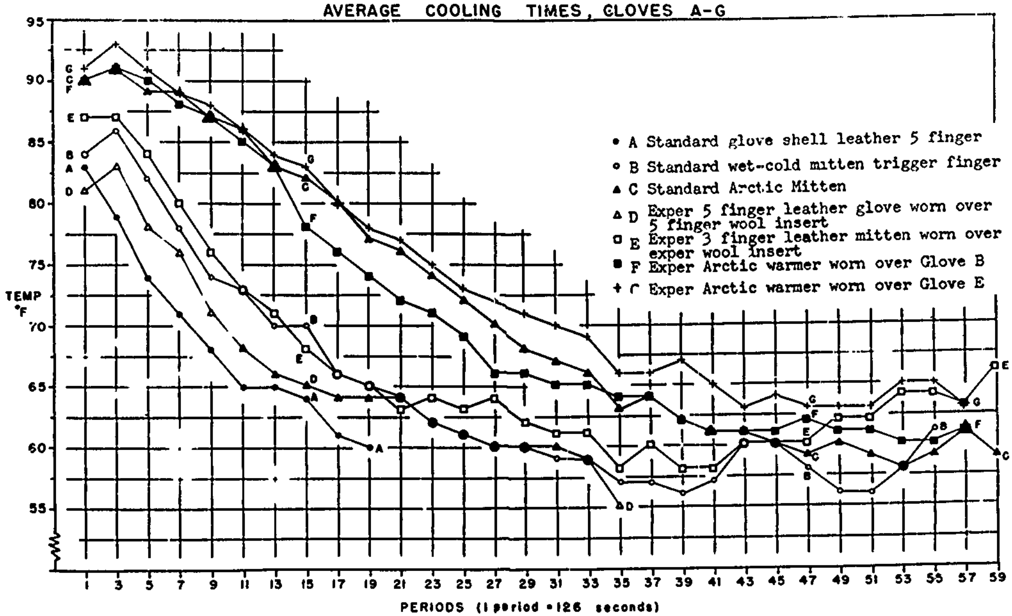

Figure 5. Average Cooling Time for Gloves

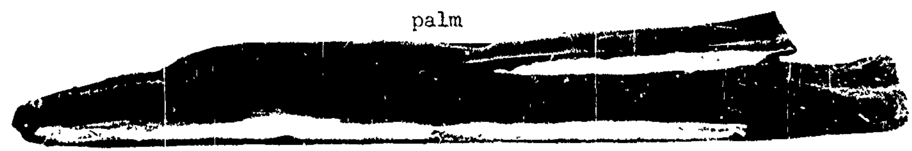

Figure 6. Placement of Insulation on Gloves

D LIMB SENSITIVITY TO TRIPWIRES by Gino R. De Togni and Paul S Strauss, Picatinny Arsenal, Dover, New Jersey

The use of tripwires to activate military or hunting devices is widely known. In recent years, more and more of the anti-personnel mines and small flares developed at Picatinny Arsenal have incorporated this type of remote initiation feature. Naturally, questions have risen regarding the detectability, optimal placement and general usefulness of the tripwire technique. In an effort to provide guidelines for tripwire employment and design, a modest series of human factors studies on wire barriers was programmed.

Previous work by Peters and Drumm [1] has indicated that visual detection of tripwires is rather poor, and depends primarily on height of wire from ground in relation to available concealment or blending rather than upon length of wire. Once the wire is tripped, however, activation of the mine, flare, or trap depends upon the force applied to the wire and transferred to the control mechanism. In order to optimize the setting of the control mechanism, a force must be chosen that is high enough to prevent accidental activation by natural objects (branches, small animals, wind, etc.) yet low enough to prevent the intended victim from detecting the wire before activation.

Although the extensive work done in the field of human locomotion [cf. 2] and human force application [cf. 3] provides useful data for many areas such as clothing and control design, virtually no parameters could be found for the establishment of tripwire activation forces for items such as land mines and field emplaced flares. It was decided to explore experimentally the range of forces to be expected when unseen wire barriers are struck by cautiously approaching subjects (Ss) who realize the wire barriers may be present.

In order to limit the possible measurements to those most useful in the military situation, only heights corresponding to upper and lower leg and arm heights during walking and crawling attitudes were used. Since the running, unsuspecting or careless enemy would have little chance of tactually detecting the wire before applying considerable force, these modes were not considered for this preliminary experiment.

PROCEDURE

An apparatus was constructed (Figure 1) to facilitate manipulation of the study variables.

A steel wire, .0475 in. diameter, was stretched across the large frame at randomly alternating heights of 4, 8, 18, and 24 in. One end of the wire was fixed to the frame, and the other attached to a 15-lb. Chatillon push-pull gage, scaled from 0 to 15 lb. in 1/4-lb increments.

Each of 4 male Ss was clothed in coveralls, blindfolded, and instructed to stop his movement toward the wire immediately upon detecting a wire barrier. Each received four series of trials in randomized order, a slow walk series (1.5 ft./sec.), a fast walk series (3 ft./sec.), a slow hands and knees crawl series (1.5 ft./sec.), and a fast hands and knees crawl series (3 ft./sec.). Only the 4 and 8 in. heights were used for the crawling trials.

S's starting distance from the wire was randomly varied between 2, 4, 6, and 8 ft. for each trial in order to reduce expectancy cues. Before each trial, the wire was set to 2 lb then reduced to 0 on the scale, so that it was just taut.

RESULTS AND DISCUSSION

Scale readings, reflecting lateral pull on the gage spring due to wire displacement, were converted to actual force applied to the wire using the formula $F=[(S/2MD)(L)] / [(D+M)(L-D)]$, where $\underline{F}$=force exerted by the subject on the wire, $\underline{S}$=actual scale reading, $\underline{M}$=linear movement of scale pointer in in., $\underline{D}$=distance from point of force to scale in in., $\underline{L}$=length of wire between fixed points.*

As a rapid means of securing many between and within variable comparisons, a complete series of $\underline{t}$ tests was performed, using the Engineering Sciences Laboratory's IBM 709 computer and suitable programs. Table 1 presents the mean detection force and its standard deviation for Ss under each approach condition. A series of $\underline{t}$ tests reveal that all differences between condition means (pooling Ss) are significant beyond the .01 level. As expected, faster approach speeds cause significantly greater forces. The significant differences between crawling (arm) and walking (leg) forces may be accounted for by the arm's faster reaction time and/or a difference in sensitivity.

Table 2 lists the mean force and its standard deviation for each wire height under each approach condition over Ss. A series of $\underline{t}$ tests for this data reveal that there are significant differences between the mean forces produced at the highest and lowest heights for the slow walk condition only. During this approach condition, the force applied by the leg becomes progressively greater as the wire is lowered. These force differences may be understood in terms of the ballistic type movements of the lower leg during walking in contrast to the controlled extension

*$\underline{L}/(\underline{L}-\underline{D})$=2, as all $\underline{F}$ is assumed to be at the midpoint of L.

TABLE 1

MEAN DETECTION FORCES AND SDs FOR Ss UNDER APPROACH CONDITIONS

S	Leg*				Arm**			
	Slow Walk		Fast Walk		Slow Crawl		Fast Crawl	
	M	SD	M	SD	M	SD	M	SD
I	6.04	2.03	10.62	1.46	4 03	0 63	10.27	3.05
II	3 59	1.59	8.59	2.26	2.83	1.43	6.17	1.74
III	4.04	1.50	8 12	2 65	4.18	1 82	5.97	1.80
IV	4.92	2.52	7.60	2.20	1 85	0.98	4.52	1.56
Mean Total	4.65	2.12	8.64	2.36	3.22	1.57	6.73	2.96

* 16 trials for each S on leg conditions.
** 8 trials for each S on arm conditions

TABLE 2

MEAN DETECTION FORCES AND SDs FOR HEIGHTS UNDER APPROACH CONDITIONS

Height	Leg				Arm			
(in.)	Slow walk		Fast Walk		Slow Crawl		Fast Crawl	
	M	SD	M	SD	M	SD	M	SD
24	3 23*	0.94	8.79	1 96				
18	3.74	1.58	7.69	2.15				
8	5.56	1.97	9.34	2.93	3.06	1.42	7.24	3.36
4	6 09	2.37	8.77	2.20	3.39	1.74	6 23	2 52
24 + 18	3.48	1.29	8 24	2.10				
8 + 4	5.83	2.16	9.06	2.57	3.23	1.54	6.74	2.92

* Forces are in lb.

of the upper leg That is, it would be more difficult to stop or control lower leg movements than it would upper leg movements when the barrier is detected. At faster approach speeds, both upper and lower leg tend toward more ballistic type movement which would be reflected by the similarities in the forces they exert upon the wire. Under the fast walk condition, the difference in force between highest and lowest heights (0.02 lb.) is not significant.

Since both upper and lower arm are moved in a uniform, controlled manner during crawling, one would expect to find small differences between upper and lower arm forces. In this case, the mean differences are less than .35 lb. and 1.01 lb and are not statistically significant

The technique of varying Ss starting distances to minimize expectancy cues was successful, since there are no significant mean differences between distances within conditions

CONCLUSIONS

The limited nature of this study precludes extensive generalization. However, the mean force measurements obtained seem fairly stable within the variability expected by chance factors associated with S's length of stride and starting distance. It is felt that the forces presented maybe used for the development of approximations of detection threshold forces. For slow and/or controlled type limb movements, the forces are surprisingly low. However, faster and more ballistic type limb movements produce considerably larger forces.

In the placement of tripwires, the data suggest that heights should be limited to 12 in. to take advantage of the greater forces produced by the lower leg during slow walking approaches. Final determination of activation force must still remain dependent upon the expected field use of the device itself.

The data presented seem to have implications for the problem of preventing or minimizing accidental activation of controls in confined working areas, as well. Peripheral controls are more subject to accidental, ballistic type movements and may require appropriate shielding or higher activating force requirements than those central to the work area. Obtaining force measurements by methodology similar to that used in this study might be a practical approach to this problem.

Further work in this area, including more controlled study of the effects of site of stimulation, clothing, and type of movement appears promising.

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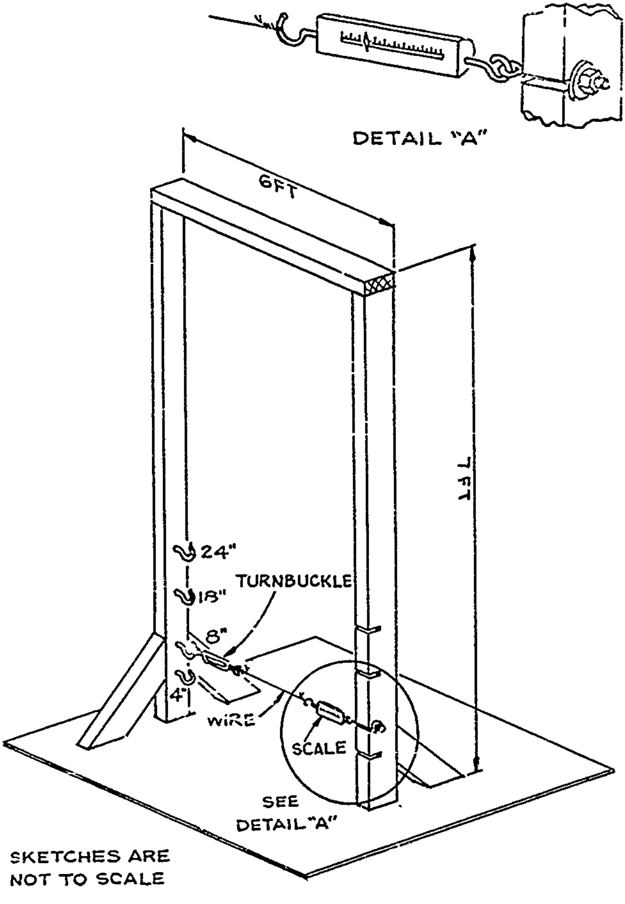


Figure 1. Schematic Representation of Experimental Apparatus

E SURVEY OF THE EFFECTS OF LOAD-CARRYING AND EQUIPMENT DESIGN UPON TASKS PERFORMED BY THE COMBAT INFANTRYMAN by Dr. Martin A. Tolcott and Mr. Morris Kolnicker, Dunlap and Associates, Inc., Stamford, Connecticut

I. Introduction

This study developed out of a conviction that information about the effects of equipment design and load-carrying devices upon the performance of the combat infantryman was scattered and incomplete. It was felt that a survey and summary of the work that has been done in this field would serve two useful purposes First, such a study would provide an organized summary of information from a variety of sources which would be of interest and value to designers, evaluators, and users of hand-held infantry equipment. And, second, a review of the literature and other information sources would permit an identification of gaps in this field of knowledge, and thus form a basis for the planning of research aimed at filling the gaps and expanding the data base upon which future design decisions could rest

The focal point of the investigation was the combat foot soldier and the manner in which his performance was affected by the design of hand-held equipment, the design of man-portable crew-served equipment, and load-carrying techniques and devices. Although obviously related, factors such as the design of clothing and the effects of weather and terrain, were not of central interest here They were covered only insofar as they were included as variables in the studies which were examined, or to the extent that certain types of clothing, as for example, the battle jerkin, could be considered as essentially a load-carrying device. Furthermore, the performance measures of central interest in the survey were those characterizing tasks performed by soldiers under conditions of actual combat, studies utilizing physiological measures such as pulse rate, body temperature and electromyograph readings were covered only to a limited extent in this survey

Source materials of various types were drawn upon They varied markedly in their quality when evaluated as pieces of experimental research. However, the intent of the survey was to identify information of any type bearing on the central question, to organize it systematically, and to identify promising leads for future research Therefore, although reports of laboratory experiments were drawn upon to the extent that they were relevant and available, other types of sources were also used. In approximately decreasing order of scientific validity, these other sources included

- Field test and evaluation reports
- Reports of training exercises under simulated combat conditions
- Army staff studies and conference reports
- Opinions of combat officers and field personnel
- Reported observations of other cultural groups
- Miscellaneous published articles

In all, over 341 literature sources were given at least a preliminary screening These were drawn primarily from various Army libraries throughout the United States. On the basis of availability, relevancy, and time, 62 items were selected for intensive study. As each study was reviewed, an attempt was made to determine

- Major hand-held or man-ported equipment unit or load-carrying device used (e.g., M1 rifle, hand grenade, rucksack, etc.)
- Task or activity the soldier or subject performed while using, wearing, or carrying the equipment unit
- Weight of the equipment
- Mode of carriage (i e., how it was held or carried, or to what part of the body it was affixed)
- Conditions under which the study was performed (i.e., the laboratory or field, weather, mode of hiking, terrain)
- Measures used to assess the performance (i e., task performance, physiological measures, time, or other measures, time, or other measure of capability)
- Results (particularly design implications)

In addition to surveying existing literature, field trips were made to Army establishments in the United States to gather additional data, and inquiry and correspondence directed to many organizations and individuals to determine on-going research concerned with load-carrying and equipment design not indicated in the existing literature or available from discussions with other military personnel. The results of the survey were then summarized in handbook form, organized by type of equipment. In the final report, conclusions are presented in the following areas. loads and load-carrying devices, equipment design, performance measures, and areas for future research. Some of the major results are presented here.

II. Load-carrying

Many recommendations have been made concerning the maximum load that a soldier should carry into combat. Typical recommendations are shown in Figure 1, and contrasted with some loads presently being carried.

Except where indicated, the figures shown relate to "combat" loads, which include only existence items (basic clothing and equipment) and battle items (weapons and ammunition). In the case identified as march conditions, the load would include so-called comfort items (extra clothing, etc.) which would normally be dropped by the soldier before entering combat. In no case does the figure include clothing worn by the soldier.

In the two cases identified as "snow conditions," the men were pulling loaded sleds with a gross weight of about 145 pounds.

It will be noted that the recommended maximum loads range from 28 to 55 pounds, depending on the tactical conditions (combat or marching), the terrain, and the type of soldier. As an order of magnitude recommendation, 40 pounds may be specified as the maximum combat load for a rifleman, 45 pounds as the maximum combat load for a non-rifleman, and about 55 pounds as the maximum marching load, under reasonably normal conditions.

Some typical loads presently being carried by infantry soldiers (shown on the two bars to the extreme right of Figure 1) are: 62 pounds for a rifle squad leader, and 77 pounds for an M60 machine gunner. The latter two figures are taken from the report of the U.S. Army Infantry School Rifle Squad and Platoon Evaluation Program, conducted in 1961.

It should be noted that, on the whole, the recommended maximum loads are based on observational reports or on physiological measures. There is a serious lack of data based on controlled experiments in which the load-carrying situation is varied and standard measures of task performance are obtained. Furthermore, no studies were found in which measures had been obtained of tasks performed after load-carrying (which is a frequent requirement imposed on the foot soldier); studies of this type might show significant performance degradation with loads even lighter than those specified as "able to be carried."

However, in view of the relatively close clustering of the recommended values, and the excessive loads actually being carried, it is suggested that prior research attention be given to developing techniques for reducing the loads being carried, rather than to obtaining more precise estimates of maximum load-carrying capability.

III. Load-carrying Techniques and Devices

A review of studies dealing with load-carrying techniques leads to the following conclusions:

- Carriage low on the back appears preferable to high pack carriage for most purposes, and for any loads above 46 pounds.
- Thigh carry is undesirable. Fifteen pounds carried in mid-thigh pockets (7-1/2 pounds per thigh) were found to produce energy expenditure equivalent to that caused by carrying 45 pounds on the back.
- The weight of the load should be distributed over a wide area, the weight of a load on the back should be at least partially balanced by a load on the front, and load-carrying devices should be designed so that local strain is eliminated by transmitting load weight to the ground through bone.
- Size and shape of loads have not been systematically studied.
- Results of studies of a wide variety of specific load-carrying devices indicate several advantages in the Bell "Hip Pack," the T53-8 Experimental Pack, and the jerkin concept. However, the specific design features associated with these advantages cannot be identified from the reports.
- Techniques for load reduction which should be explored include: use of light-weight materials, special packs for special missions, use of multipurpose equipment, training for survival with minimum equipment, and revamping of supply and logistics techniques to meet infantry requirements.
- There are reports in the literature of African porters carrying loads up to 150 pounds (and in some cases up to 250 pounds). Although these reports are of questionable reliability, they suggest that more careful anthropological study might lead to the development of training methods or to the use of novel techniques to enable soldiers to carry their loads with greater ease and comfort.

IV. Design of Equipment (other than load-carrying devices)

- The rifle has been more extensively studied than any other equipment.
- Studies of marksmanship with the M1 rifle indicate that:
  - Performance is improved by:
    - Loop sling (as compared with other slings)
    - Use of sling during training
  - Performance is unaffected by:
    - Rifle weight from 9.8-14.25 pounds (when fired from the prone position)
    - Use of personalized stocks or preferred comb configurations

- Upper limit recommended for recoil is 19.3 foot-pounds.
- The M67 recoilless rifle (which weighs 44 pounds, including one round of ammunition) hinders mobility of the rifle crew.
- Indigenous personnel of Southeast Asia prefer the M2 carbine, which is shorter and lighter than the M1 rifle.
- Soldier maneuverability as a function of rifle size and weight has not been studied (except for the M67 recoilless rifle), nor have the effects of prior load-carrying upon marksmanship.
- Equipment evaluation of the T201 mortar revealed many design deficiencies, several of which would presumably hinder set-up and maintenance, as well as operation. These deficiencies are noted in the report to focus design attention on an area requiring significant improvement, namely, design of equipment for ease of set-up and maintenance.
- The relationship between human engineering design features and performance for other types of infantry equipment has not been studies to any appreciable extent
- Design requirements of indigenous personnel have not yet been determined, nor have the requirements of U.S. troops for guerrilla warfare in jungle terrains. However, studies in this area are now in progress.

V. Performance Measures

- Physiological measures, although frequently used and relatively precise, have not been systematically correlated with other behavioral measures, and are usually insensitive to subtle design variables. They are useful, however, in determining metabolic cost of load-carrying and other physical activities.
- Gross bodily activities related to mobility and maneuverability are commonly rated by observers in evaluating loads and load-carrying divices. Observer ratings of these activities could be made more reliable if principles of experimental design were followed in field tests.
- Primary tasks (e.g., weapons firing) have been measured for the most part in evaluating rifle design. However, with highly trained subjects, even these measures are not likely to be sensitive to minor design variations unless the tasks are made more realistically difficult by combining them with maneuvering activities and load-carrying.
- Secondary tasks (e.g , set-up, calibration, maintenance) assume major importance in evaluating crew-served equipment, and should be used more extensively. Task-equipment analysis can help identify critical tasks, and motion study can aid in obtaining precise measures
- Human engineering evaluation of hand-held infantry equipment is severely limited by the lack of basic design data for use as criteria There are ro checklists or design guides comparable to those now avail. .le for more complex electronic systems. The systematic collection of performance data on which tc base such a guide, is a major requirement.

VI. Research Problems

Fruitful areas for research are l--ted below, in approximate order of importance:

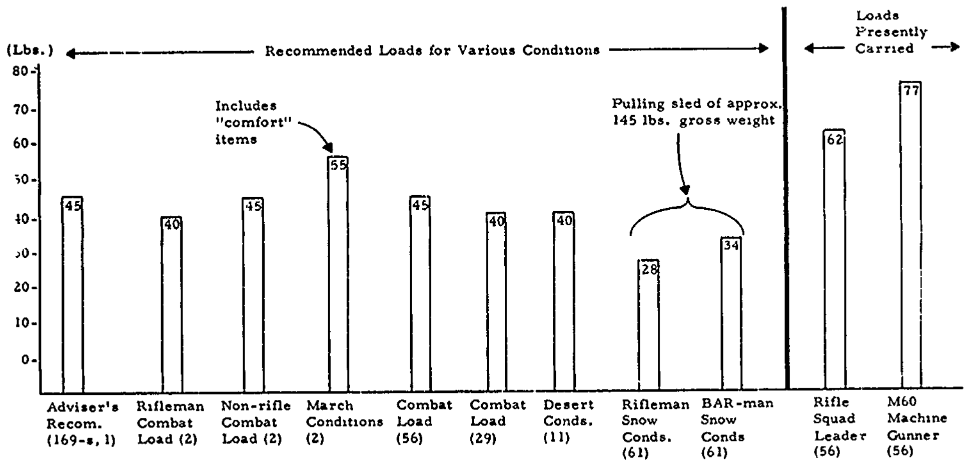
- Development of load-reduction techniques, through
  - Continued efforts to develop lightweight materials
  - Exploration of the concept of loads for special missions"
  - Exploration of the use of indigenous burden carriers, animals and wheeled vehicles
  - Exploration of new techniques of supply and logistics
- Research aimed at designing pack-carried items for easier load-carrying as well as for meeting performance requirements
- Trade-off studies comparing cost and effectiveness of special-purpose vs. multi-purpose equipment for special combat missions.
- Collection of basic anthropometric, behavioral and cultural data on indigenous personnel, on which to base design or selection of weapons, tools and other equipment furnished to them by the U.S.
- Methodological studies to develop more reliable performance measures during simulated combat operations.
- Analyses aimed at determining relationships among several types of activity measure (e.g., physiological measures, observer ratings, performance, etc.), and between these measures and other more fundamental criteria of infantry performance effectiveness.
- Systematic study of load-carrying techniques employed in other cultures, to determine the extent to which load-carrying might be facilitated through training or the use of novel techniques.

Summary

In summary, a review of literature was undertaken to identify, organize and summarize the results of studies concerned with the relationships between the design of infantry equipment and the combat performance of the foot-soldier. It was found that studies of this type were scattered, and that the available data are inadequate to provide a solid basis for developing a design guide for man-carried equipment.

It is recommended that standardized performance tasks be more widely used as a basis for evaluating design features of infantry equipment. The U.S. Army Infantry Human Research Unit has recently identified a set of critical tasks and skills of the infantryman, and although these were developed primarily for training purposes, they might well serve as a basis for studying equipment design features. It is also recommended that these measures of task performance be obtained more frequently under simulated field conditions, such as after marching and maneuvering with loads. Such measures would help determine the realistic limits of infantryman performance, not only as a function of equipment design, but also as a function of load carried. A related requirement is the development of improved methods for scoring performance in the field, such as that developed by the Human Research Unit at Fort Benning.

Finally, it is recommended that a procedure be established whereby the various Army groups performing research in this area would furnish summarized results, including general design implications, to a central group charged with maintaining, updating, and periodically publishing this information. Eventually, it might be possible to furnish equipment designers with a set of Human Engineering Design Specifications for Infantry Equipment, as an integral part of their design objectives.



Note: Numbers in parentheses refer to reference sources.

Figure 1. Recommended and Actual Combat Loads Carried by Infantry Personnel. Includes "existence" items (basic clothing and equipment), and "battle" items (weapons and ammunition). Excludes normal clothing being worn, and "comfort" items.

CHAPTER 5

TACTICAL ASPECTS OF SOUND
CONFERENCE SESSION III-B

A. THE RHESUS MONKEY IN HEARING LOSS RESEARCH John J. Romba, U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

B. AN EXPERIMENTAL STUDY OF AURAL DETECTION OF RADAR TARGETS Robert T. McCay and Jack Wm Dunlap, Dunlap and Associates, Inc., Stamford, Connecticut

PANEL ON TACTICAL ASPECTS OF SOUND, consisting of the following presentations

C. NOISE AND WEAPON SYSTEMS: Ray Donley, U. S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

D. BASIC RESEARCH IN HEARING APPLIED TO FIELD PROBLEMS: Maj. John L. Fletcher, MSC, U. S. Army Medical Research Laboratory, Fort Knox, Kentucky

E. STUDIES OF TEMPORARY THRESHOLD SHIFT CAUSED BY HIGH INTENSITY ACOUSTIC TRANSIENTS Norman L. Carter and Karl D. Kryter, Bolt Beranek and Newman, Inc., Cambridge, Massachusetts

F. PANEL SUMMARY: Dr Aram Glorig, Director, Subcommittee on Noise Research Center, Los Angeles, California

A THE RHESUS MONKEY IN HEARING LOSS RESEARCH by John J Romba US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

Several years ago, the Human Engineering Laboratories began a program of hearing loss research in monkeys. The immediate problem we encountered at the time was the absence of an established method whereby hearing loss and recovery could be measured in the monkey. A number of earlier investigators, Elder in 1934, Wendt in the same year, Harris in 1942, and Seiden more than a decade later, had reported reliable auditory acuity thresholds in various sub-human primates. A characteristic common to all the previous methods used was the length of time involved in the measurement of a threshold—this often took several hours. Normally, the greatest recovery occurs during the first few minutes following exposure Since our interest is in hearing loss, a rapid means of threshold measurement is indispensable An increase in speed will yield a greater number of threshold determinations and, consequently, a more reliable trend estimation of hearing recovery is possible during this early critical period. A method which satisfies the criteria of testing speed and reliability must further be examined for use with animals which may be in a state of nervous tension or excitement Available evidence suggests that animals are under some emotional stress during noise exposure, and we should like to insure that they will perform well while in this state.

The purpose of this paper is to report on the development of a workable approach to the study of hearing loss in monkeys.

First, I will discuss such factors as mode of tone delivery, type of indicator response, reinforcing agent, and sequence of trial events as they pertain to a rapid and reliable method of audiometric testing, then will be given a description of the Human Engineering Laboratories' method, and this will be followed by an experimental test and evaluation of the method.

Factors Involved in An Audiometric Method

The use of earphones for tone delivery to monkeys has been a long-standing problem because of their head shape, small head size, and aggressive temperament. For this reason, the prevalent method of presenting the tone in monkey audiometry made use of a free field situation with a loudspeaker as sound source. Elder found that earphones could be used with chimpanzees with no restraint to the animal.

While the initial difficulty in finding a way of securing earphones around the monkey's ears is not to be underemphasized, in the long run the advantages over the loudspeaker method are realized by features of flexibility and accuracy. Earphones permit excellent control of inter-trial stimulation of the same magnitude of stimulus intensity. In order to accomplish the same with a loudspeaker, continual head restraint with respect to position and direction of stimulus source must be used.

The lever press is a commonly used indicator response in behavioral studies Although the lever press can be emitted occasionally by an animal purely on an incidental basis, probability of spontaneous occurrence is relatively low. Though the time taken to establish a lever press response is substantially longer than is required for the occurrence of a running, jumping, or eyeblink response, it can be conditioned to appear on and only on cue. Once the lever press is firmly established as a conditioned response, trials, as in the audiometric test, can be programmed with speed and, furthermore, greater reliability is expected.

An animal's jump or lever-press responses, which serve as icators to the experimenter that tone stimuli are perceived, is learned and strengthened with appropriate reinforcing agents. Electric shock is effective in a variety of circumstances and may easily be administered in varying intensities. Food usually evokes a more cooperative attitude in subjects, but maintaining a high motivational state for good performance is difficult.

The sequence of events found in the audiometric test frequently begins with a "ready" signal and terminates with the subject's response The "ready" signal, usually visual but occasionally auditory, has the function of preparing the subject to listen for a tone, which, if given, appears soon afterward. A long interval between a "ready" signal and a tone tends to reduce the usefulness of the signal as an attention-drawing cue. The eight- or 16-second interval used by Wendt seems unnecessarily long, especially if consideration is given to obtaining quick thresholds A constant interval between the onset of the "ready" signal and tone requires the use of frequent checks on the subjects honesty so that the animal does not learn to make a time discrimination. A check for a proper response can be made by eliminating the tone completely from an occasional trial. A response, indicating that a tone was heard, then would be punished under the circumstances of the tone-off trial condition.

The test tone, another event in the sequence, usually lasts for a few seconds, during which time an animal is to make an appropriate response. If the response does not occur, shock is administered or food is withheld, depending on the type of reinforcer used. During the audiometric test, assuming the completion of sufficient and appropriate training, the absence of response should mean that the presented tone was below the subject's threshold. In this case, the response would be considered appropriate and followed by a reward

The Human Engineering Laboratories' Method

During laboratory testing, sound resistant rooms are used. The control room, where the experimenter conducts the audiometric training and testing, is situated in another part of the building The training and testing schedules are programmed by a series of relays and timing circuits. Data recording is manual.

The audiometer was made by our Engineering Laboratory It consists of an audio oscillator capable of producing any one of nine predetermined sine wave frequencies, a balanced amplifier controlled by an electronic switch, and a decade attenuator. The tone is administered through headphones. This arrangement provided good stability and eliminated audible transients in the headphone when switching on and off at low signal levels During a five-day test of audiometer stability, the attenuation level did not deviate more than one decibel. In order to flatten the frequency response of the Beyer dynamic headset used, a frequency compensating network was incorporated into the audiometer

The audio helmet device, shown in Figure 1, served to reduce the test area noise level at the ear primarily through the operation of built-in liquid-filled ear cushions and also functioned in part as an earphone holder. In order to assure a good fit, the inner surface of each audio helmet is foamed in place to a plaster cast made of each animal's head.

Animals are initially conditioned to respond to a 2,000 cycle per second tone and refrain from responding during blank trials in a test chamber with a lever and a loudspeaker. Training is then extended to all nine frequencies and continued in a restraining chair, with the tone being delivered through earphones. After the completion of this training, periodic audiometric testing is begun and pre-exposure normative data is gathered The animals are usually ready for use as subjects after about two months of this training and testing.

For testing, an animal is placed into a contoured seat, as shown in Figure 2, and restrained about the waist and neck Movement of its hands and arms is permitted only to neck level by means of wrist cuffs and cord so that the helmet and earphones cannot be reached. The chair is adjusted so that the animal can assume a comfortable position. The audio helmet is placed on the animal's head and electrode leads are attached to its legs.

Essentially two types of trials are used in threshold determination—tone-on and tone-off. A tone-on consists of. (1) a visual ready signal in the form of a sudden reduction of ambient light intensity, (2) an interval of 5 second before the tone comes on, and (3) a four-second tone presentation. A tone-off trial consists of the same ready signal and a "blank" interval of 4.5 seconds. The reduction of the light intensity persists for the duration of all trials. Trials are terminated when a response is made.

Prior to audiometric testing, a failure by an animal to respond to tone is punished by a moderate shock at the end of the trial If it makes a conditioned response within the four-second tone interval, shock is avoided. The animal is also trained not to make a response solely to light, i e , during the condition of a tone-off trial nor during the .5 second preceding the onset of tone in a tone-on trial. Responses to light are punished with shock. An equal number of tone-on and tone-off trials are randomly presented. Performance without error for three consecutive days is followed by audiogram testing.

During the audiometric test, no shocks are administered for failure to press the lever. It is presumed in this case that the tone given is below the animal's threshold. Otherwise the same conditions and consequences prevail as during training. As checks for indiscriminate responding, tone-off trials are given only occasionally during audiometric testing To keep the animal on the alert, it is shocked two or three times for non-responses to subliminal tones.

In summary then, let us consider a trial in detail The experimenter depresses a button on a control box (marked A in Figure 3), which automatically activates the entire trial sequence through the programming equipment shown in the background, except for the tone, which is independently controlled. In the event a tone is scheduled for a particular trial, another button on the audiometer (marked B in Figure 3) is manually depressed by the experimenter 1/2 second after the trial's start, and released either four seconds later or after a conditioned response is made The occurrence of a response is indicated by a light (marked C in Figure 3) on a control panel. The data is recorded manually.

The trials are carried out in the manner of the Method of Limits. For any particular frequency, the trial sequence is first begun with an audible tone and reduced by steps of five decibels until the animal fails to respond. The next sequence is given in the ascending order, starting with a tone which is not heard, until the level is reached where a tone is heard. Two such trial series, one descending and one ascending, are given and averaged for a threshold estimation. In a study just completed, comparison between a two-determination and ten-determination estimate of threshold indicates that the thresholds obtained are approximately equal. It appears that the variation within sessions is very small. Therefore, it matters little if the threshold estimate is obtained from two or ten threshold determinations The use of the short method for obtaining thresholds gives us the desired speed without sacrificing reliability

An Experimental Test of Method

The adequacy of this laboratory's method was tested with a noise-exposed animal which was a healthy, young, adult, female Rhesus monkey with no previous history of experimental noise exposure The animal was given one noise impulse of a few milliseconds' duration and an intensity of approximately 165 decibels. The noise treatment was given in the driver's position of an M48 tank chassis on which a T95 turret with an XM81, 152 mm gun was mounted.

The animal received three days of adaptation training prior to exposure. On the first day, it was put into the driver's position of the tank. Ten shots from a cap pistol noisemaker were given to supposedly provide additional stress on the animal in this novel situation. An audiogram was taken soon afterward in the laboratory. On the next day, it was again put into the vehicle, where two audiograms were taken after an adaptation period of ten minutes. On the last day of adaptation, the animal was put into the vehicle once for two minutes and another time for 30 minutes and tested in the laboratory after each period.

Laboratory audiograms following each period of adaptation showed no abnormal threshold change. Audiograms taken inside the vehicle indicated that the variability appeared to be within normal limits. However, an apparent upward threshold shift was noted Apparently, the audio helmet did not fully compensate for the ambient noise in the vehicle Time did not permit the collection of normative threshold data in the vehicle environment.

The complete audiometric test, which included the frequencies of 125, 250, [illegible]00, 2000, 4000, 6000, 8000, and 12,000 cycles per second, was taken in ten daily sessions prior to noise exposure Post-exposure audiograms were taken 0.17, 0 5, 2 5, 8, 24, 72, and 120 hours from exposure time (See Figures 4, 5, & 6)

The experimental animal did not seem to be especially aroused by the noise treatment. No difficulties were encountered during the hearing tests which followed the shot The time taken to obtain a post-exposure audiogram for all nine frequencies was about five minutes.

The zero baseline, shown for the various curves, in Figures 4, 5, and 6, represents the animal's pre-exposure mean hearing threshold from which changes in auditory acuity were measured. The shaded area [illegible]ow the baseline encompassed all but .5 percent of the values normally expected from one test audiogram to another Once these pre-exposure confidence limits were set, the post-blast audiometric values which fell outside this confidence interval were considered hearing loss

The single impulse exposure seemed to have little or no effect for the lowest frequencies, but a shift in acuity for the middle frequencies was demonstrated. Generally, a slight hearing loss for the high frequencies was obtained Recovery was complete within 120 hours.

The method was found to meet the requirements of testing speed and reliability of measurement for determining both pre-exposure normative thresholds as well as hearing loss and subsequent recovery thresholds. The four and one-half to five minutes needed to take an audiogram of nine frequencies by the short method described approximates the time needed for human audiometric recording.

Problems of Hearing Loss Research

The tasks set forth for the present fiscal year with Rhesus monkeys will include the establishment of some of the quantitative relationships between auditory acuity shifts and noise parameters such as sound pressure level in the range of 145 to 170 decibels, number of exposure rounds from 1 to 10, and rates of fire of 1 per minute and 2 per second. We will also continue to study the procedural, environmental, and organismic factors which contribute to variability in tone detection during the audiometric test—the acuity measuring tool may thereby be improved.

Probably the most efficient approach which we can take for the study of hearing loss is through the analysis of individual behavior. An examination will be made of individual long-term trends in stable threshold states alternating with transitory threshold states under repeated identical experimental conditions The knowledge of the stability of effects for identical conditions is a necessary means of interpreting the findings of future noise exposure studies.

A factor which loomed importantly in our decision to primarily study individual animals was that of individual differences in susceptibility to injury In view of this differential susceptibility, an experimental design will be tried in which the subjects are equated in terms of the dependent variable, hearing loss The patterns of hearing behavior could thus be studied for various levels of susceptibility. That such an approach could bring forth a test for the detection of individual susceptibility to hearing injury stimulates the imagination.

The later direction of our work must be predicated largely on the results of experiments which will be accomplished during the current fiscal year.

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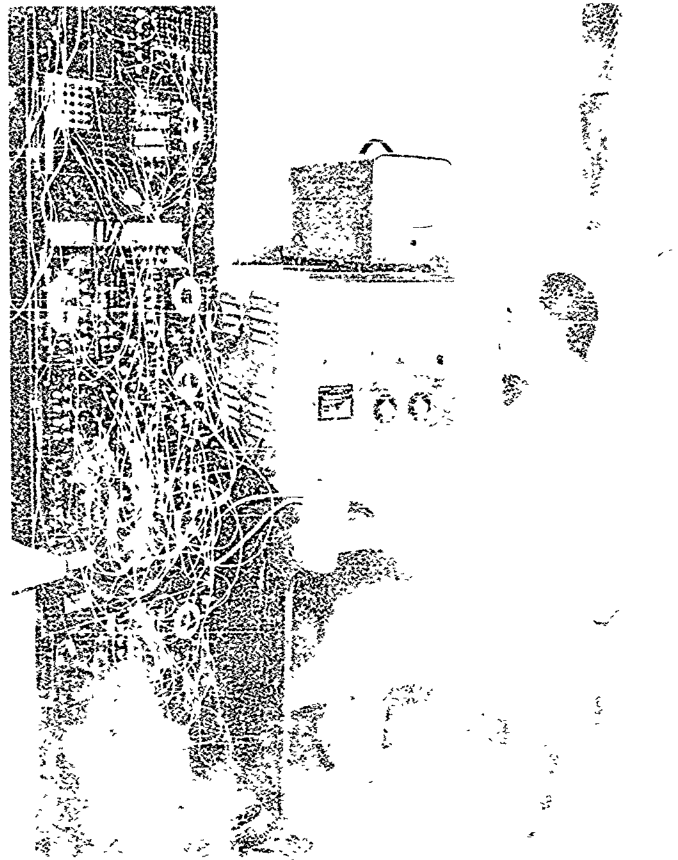
AS A FUNCTION OF DURATION

AS A FUNCTION OF NOISE



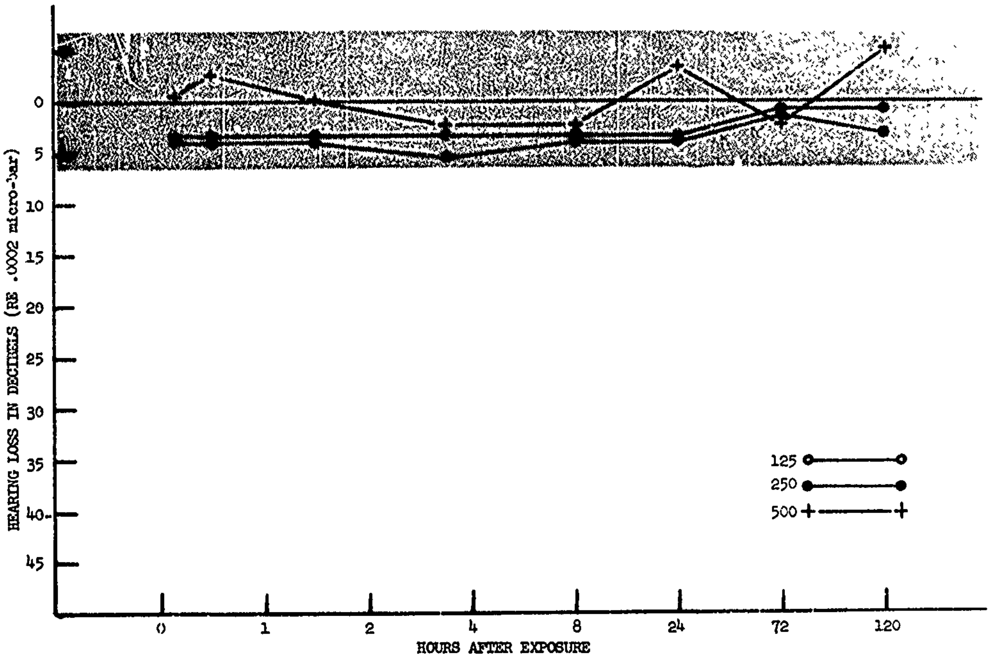


Figure 4. Thresholds at 125, 250, and 500 cps Frequencies Following Exposure to 1 Shot of Approximately 165 db

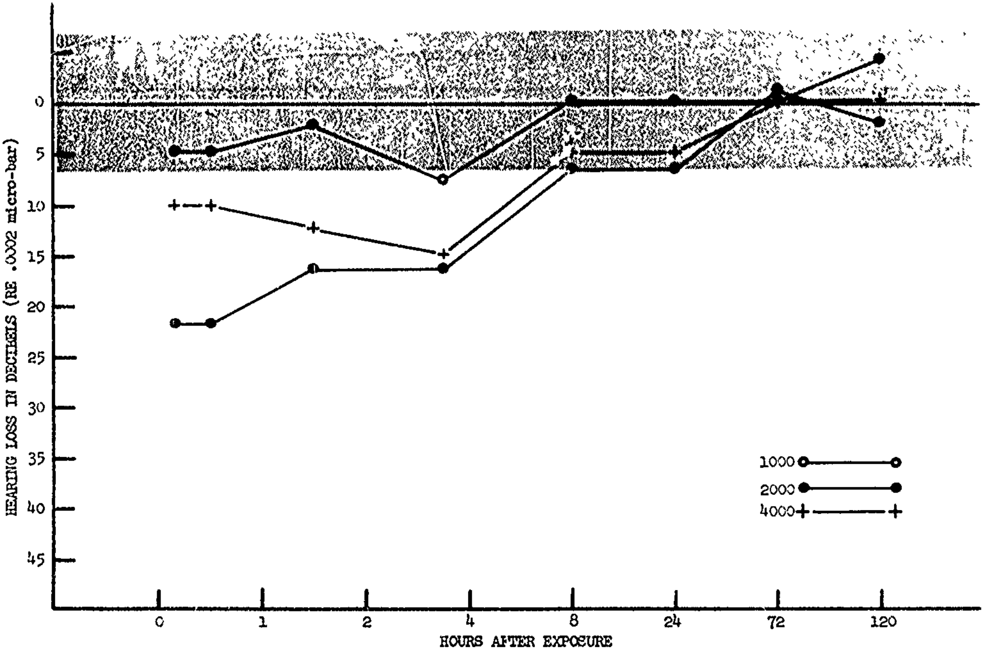


Figure 5. Recovery of TTS at 1000, 2000, and 4000 cps Frequencies

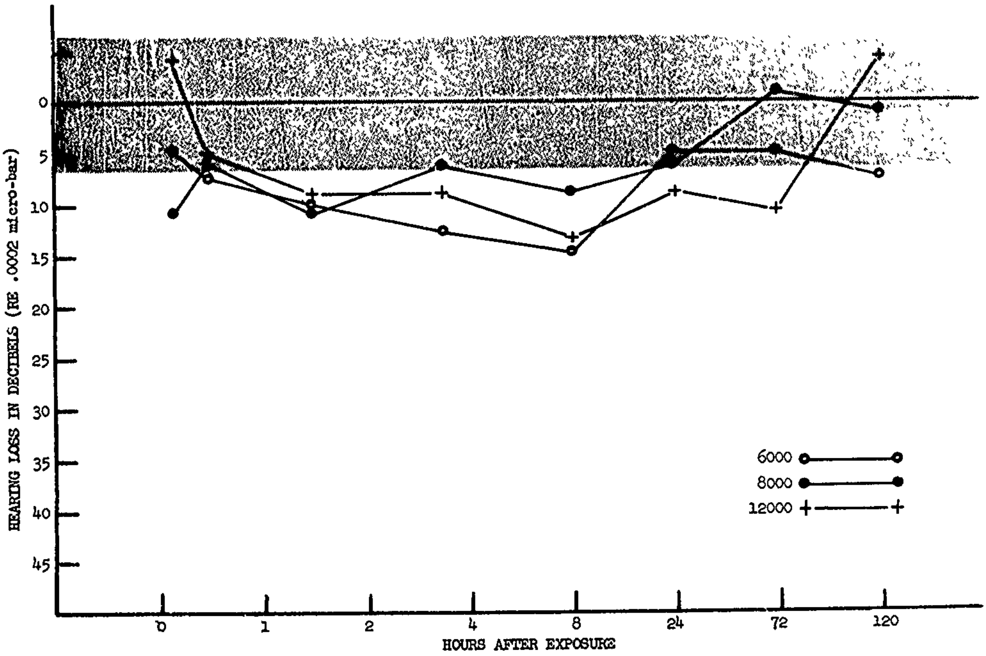


Figure 6. Recovery of TTS at 6000, 8000, and 12000 cps Frequencies

B. AN EXPERIMENTAL STUDY OF AURAL DETECTION OF RADAR SIGNALS* by Robert T. McCay and Jack Wm Dunlap, Dunlap and Associates, Inc., Stamford, Connecticut

The work herein described was concerned with determination of the appropriate dwell time in doppler, ground surveillance radars for detecting personnel and vehicular targets Figure 1 shows schematically some of the characteristics of an entirely hypothetical radar of this type. This equipment is capable of searching automatically in two dimensions range and azimuth. The primary display is the audio signal resulting from the movements of any objects within the gate. The gate is bounded by the edges of the beam and by a pair of arbitrary time constants corresponding to the bounce-back times from the near and far edges of the gate. Nothing outside this gate is heard.

In search, the gate is "strobed," or moved in range, by systematically changing these time constants. Azimuth changes in search are usually accomplished by traversing the antenna. Dwell time is the length of time that a given piece of real estate is within the gate.

In an operational context, there are pressures both for increasing and for decreasing dwell time The pressure for decreasing follows directly from the necessity of searching an area of responsibility as rapidly as possible If we consider the search parameters of the hypothetical radar shown in Figure 1 we can see that it will require 100 times the dwell time to move the gate the entire depth of the sector of interest from point A to point B. It will require eight such excursions to cover the entire sector without overlap. If dwell time for this hypothetical system were one-half second, it would take over six minutes to cover the area of interest. If things start to break on the battlefield, six minutes could be a long time to leave a portion of the area of responsibility unsearched. Thus, a great deal of interest has been aroused over the prospect of increasing strobe rate and, hence, decreasing dwell time.

The second pressure comes into play at this point, however. As long as the operator must use audible radar returns as his primary source of information, we are limited by the sensing or detecting capabilities of the operator in how short dwell time may become. This is because aural returns must be processed on a real-time basis by the operator and cannot be stored for him, as is possible on a PPI scope. The question of how long dwell time must be in order to maintain operator performance is the focus of the research being reported here.

This work was done in three phases: field work, stimulus tape preparation, and laboratory experimentation. Figure 2 shows a schematic of the field work phase. This work was done at Fort Monmouth, New Jersey. Recordings were made of the returns from an AN/TPS-25 radar. Separate noise and signal tapes were made and the stimulus tapes synthesized in order to be able to exert more control over the experimental conditions than would have been possible with "live" recordings. The noise used was generated by an area of trees stirred by a breeze of five knots or less. The personnel and vehicular signals were taken in an open field which had been selected for its low background noise level. Although many different signals were recorded, only one personnel target signal and one vehicular target signal were used in the subsequent study.

Figure 3 shows a schematic of the stimulus tape preparation. The field recorded tapes were distilled via a process of selective re-recording and editing. At the same time, identification tones were added on the second channel of the two signal tapes Although the original recordings and the ultimate stimulus tapes all played at 7-1/2 inches per second, the re-recording and program splicing was done at 15 inches per second for two reasons: first to help maintain fidelity and, second, to ease the stress of reliably splicing short bits of tape. After the program splicing, noise was added, thereby completing the construction of the stimulus tapes

Figure 4 illustrates the organization of the experimental sessions. The stimulus material was presented to five subjects simultaneously over headphones. The identification tones triggered one channel of a six-channel chart recorder, establishing the time and type of signal. Subject responses were attempted identifications of the targets. These were registered via pushbuttons on a small box in front of the subject. An "Unknown" category was permitted. Thus, a response implied a detection, while a correct response also implied an identification. These subject responses were recorded on the remaining five channels of the chart recorder, thereby providing a permanent record of the entire experimental session.

Figure 5 shows a tabulation of the experimental conditions investigated. Eleven dwell times, or signal durations, were used. These ranged from four seconds down to about four milliseconds. Two signals were used: one walking man and one Jeep moving at a rate of about 20 miles per hour. These signals were presented in five different levels of background noise. In the very low-level noise condition, the total signal power exceeded the total noise power by approximately 10 db. This situation was reversed for the very high noise condition. The other three conditions were intermediate.

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*Based upon Work Done for U S. Army Signal Research and Development Laboratory Fort Monmouth, New Jersey Contract No DA 36-039 SC-78921.

Empirical probabilities of detection and identification were calculated from the tabulated responses. Figure 6 shows detection performance with the vehicular target. The ordinate of both graphs is probability of detection expressed in percentage. The abscissa of the left graph is signal duration, while that of the right graph is signal level relative to noise level. The same data are represented in both graphs, and the abscissa of one is shown as parametric lines on the other. The lines drawn at 50, 75 and 90 percent correspond to several arbitrary criteria which were applied to the data. Since detection is basically a binary proposition, any performance level below 50 percent was considered to be clearly unsatisfactory. Performance above the 75 percent level was considered to be acceptable and that above 90 percent, desirable.

We can see that for vehicular targets, detection performance on the two shortest durations was clearly unsatisfactory regardless of noise level. All durations longer than one-eighth second, or 125 msec., showed desirable performance under all noise conditions used The intermediate durations showed desirable or acceptable performance under some of the noise conditions.

Figure 7 presents identification performance found for vehicular targets under the experimental conditions. It can be seen that, while identification performance is quite similar to detection performance, there is more sloughing off at the intermediate durations. Only signals of one-half second or longer showed consistently desirable performance across all of the tested noise conditions. The one-eighth second (125 msec.) duration showed consistently acceptable performance across all noise levels. It is probable that the range of noise levels in the present study is representative of the majority of wind and weather conditions, excluding precipitation, which would be encountered in the field. These data suggest that, if attention can be restricted to vehicular targets, then dwell times as short as 125 msec. are permissible from the standpoint of operator performance. This was the shortest signal duration in this study which showed both consistently desirable detection performance and consistently acceptable identification performance.

Going on now to performance with personnel targets, we see in Figure 8 that it is quite a different proposition. Here we show detection performance with one walking man as the target. It is obvious that noise level is much more critical than with a vehicular target. With the two highest noise levels used, we found only unsatisfactory performance, as defined by our criterion of 50 percent detections. The half-second, or 500 msec., duration was the shortest which showed at least reasonable performance at the medium noise level, although this fell short of the 75 percent criterion of acceptability. Under the most favorable noise condition tested, desirable performance was found for the 125 msec. duration, but detections fell off sharply for this duration at higher noise levels.

Figure 9 shows identification performance found for the personnel target. These data are so similar to the related detection data that almost all of the same comments apply. The conclusion which one must make from these data is that it is extremely hazardous, from a performance standpoint, to reduce dwell time below one-half second if personnel targets are of interest and if the signal characteristics of X-band radar sets are to remain the same. Considering the probable operational application of ground surveillance radar equipments, it is almost certain that the personnel target is of interest and is very likely to remain so.

Two complete sets of data were collected for the very low noise condition with two different groups of subjects Figure 10 shows detection performance in the left graph and identification performance in the right graph for these two independent groups of subjects. The correspondence between these two sets of data is very pleasantly close. In fact, performance of the two groups correlated .998. For the group which experienced the whole range of experimental conditions, first-half performance yielded coefficients of .981 for detections and .974 for identifications. These correlations indicate a remarkable stability in the task and performance measures

Individual differences were found, as one might expect, but no pronounced subject interactions with either target type or noise level. Figure 11 shows four graphs of individual subject performance. The abscissa of all graphs is noise level. The ordinates of the two left graphs are frequency of detection, while those of the two right graphs are frequency of identification. The two upper graphs are concerned with performance related to vehicular targets and the two lower graphs, with performance related to personnel targets.

It was characteristic of the experimental apparatus that all responses were recorded, whether or not they correlated with a signal presentation. Those responses which did not correlate with signal occurrences were tallied separately as false alarms These have been excluded from all data presented to this point. Tables 1 and describe the false alarm performance under the various experimental conditions. It will be noted that the total number of false alarms was 66. These occurred in 50 subject hours of simulated radar listening. This is a rate of 1.32 false alarms per subject hour, which does not appear to be unreasonable or excessive. There is quite an evident experience factor operating here as shown by the right marginal totals in the upper table. One-third of the false alarms occurred on the first experimental day, and over half occurred in the first two days.

From the lower table, we see evidence of pronounced individual differences. Two of the subjects, each accounted for one-third or more of the false alarms. It is of interest that these subjects were also two of the best performers on detections and identifications. We had, of course, tested all subjects for normal hearing A comparison of the audiograms of these two subjects with those of the others did not show any significant differences. There is no ready explanation for the apparently higher response rate of these two subjects.

Table 1

FALSE ALARMS
by Experiment Day and Noise Level

Exp Day	Low +10	+5	Noise 0	-5	High -10	Total
1	7				15	22
2		5		7		12
3			2/0			2
4		4		1		5
5	3				1	4
6	0				6	6
7		0		1		1
8			2/2			4
9		1		3		4
10	4				2	6
Total	14	10	6	12	24	66

Table 2

FALSE ALARMS
by Subject and Noise Level

Subject	Low +10	+5	Noise 0	-5	High -10	Total
1	2	1	0	0	2	5
2	2	5	4	3	8	22
3	0	0	1	2	2	5
4	3	0	0	0	2	5
5	7	4	1	7	10	29
Total	14	10	6	12	24	66

Although it is almost completely hidden by the experience factor, there also appears to be a trend toward more false alarms with the higher noise levels. This would be predicted by most models of signal detection.

In review, then, the evidence gained by this experimentation leads us to conclude that dwell time should not be decreased below one-half second for the detection of personnel targets, but dwell times as short as one-eighth second are probably quite acceptable for vehicular targets. Let us explore the practical implications of these conclusions. The operational problem which started all this was the question of how to improve the efficiency of automatic search with ground surveillance radars using a doppler-based aural display for detection. There are a variety of possibilities, some including changes in dwell time and some not, others involving operational strategy alone, some involving equipment modifications alone and various combinations involving all of these.

One possibility is to generally ignore personnel targets while in automatic search, thus allowing a shorter dwell time for faster general coverage. Personnel targets might be picked up accidentally. However, manual search would usually be conducted of areas where the detection of personnel targets was important. A direct reversal of this solution would be to maintain dwell time at a level where there is a reasonable probability of detecting personnel targets and restricting assigned areas of responsibility to those which can be searched within an operationally determined optimum time period. This probably implies that more equipment would be needed than is currently thought necessary, since these areas of optimum search time may not correspond well with maximum ranges and unit responsibility sectors.

Another possibility is that circuitry changes can be made in the audio portion of the equipments which will enhance the detectability of the personnel target. This approach is being followed in a continuation of the work reported here. The current approach is a linear frequency addition to the aural signal intended to bring the signal frequencies from X-band sets into closer alignment with the more sensitive portions of the human ear. Other approaches, such as selective filtration are also possible and should be explored.

A substantial portion of most areas of assignment may be expected to be shadowed from the radar and could not be a source of detectable targets. If these areas could be sensed and the search pattern programmed to skip over them, a considerable saving in search time would be realized in most operational situations. This, however, implies a great deal of equipment sophistication, if it were to be done automatically, and perhaps an inordinate amount of time if the shadows had to be surveyed manually and then set into the equipment.

Most, if not all, ground surveillance radars are capable of detecting vehicles at significantly greater ranges than personnel. If a slow strobe and hence longer dwell time were used within the maximum range for personnel, and a faster strobe were automatically switched in beyond that point, then a saving in search time should be realized without decreasing the probability of detecting personnel. With this ability to change dwell time in the equipment, it might also be desirable to allow a choice to be made by the operator to correspond with the specific tactical mission.

Dwell time can also be changed by varying the gate size as well as by varying strobe rate. In order to maintain a long dwell time and still increase search speed, a large gate, or even the entire range could be displayed for search, and then a smaller gate switched in for target location and identification. To some extent, this is already possible in sets with a choice of beam widths, but a choice of gate depths should also be possible and might be quite beneficial.

In conclusion, then, let me say that there certainly are improvements which can be made in search speed. But care must be taken to assure that making these improvements does not lessen the probability of detection or identification of important targets.

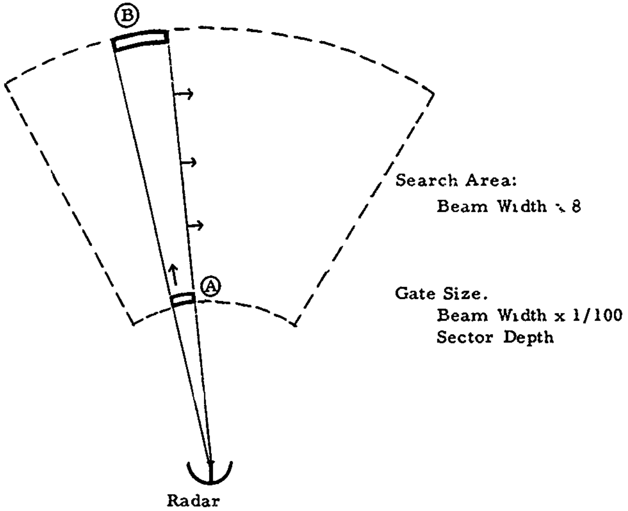

Figure 1. Hypothetical Ground Surveillance Radar Search Pattern

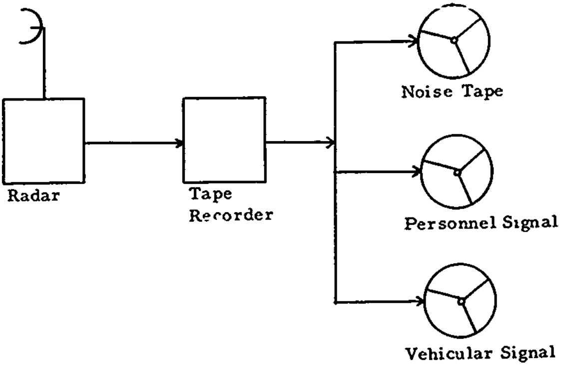

Figure 2. Schematic of the Field Work

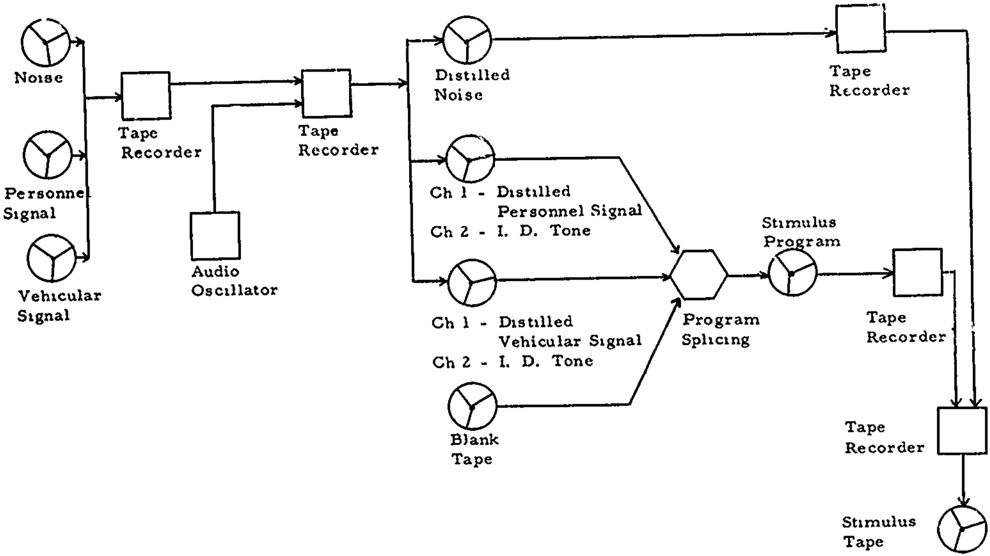

Figure 3. Stimulus Tape Preparation

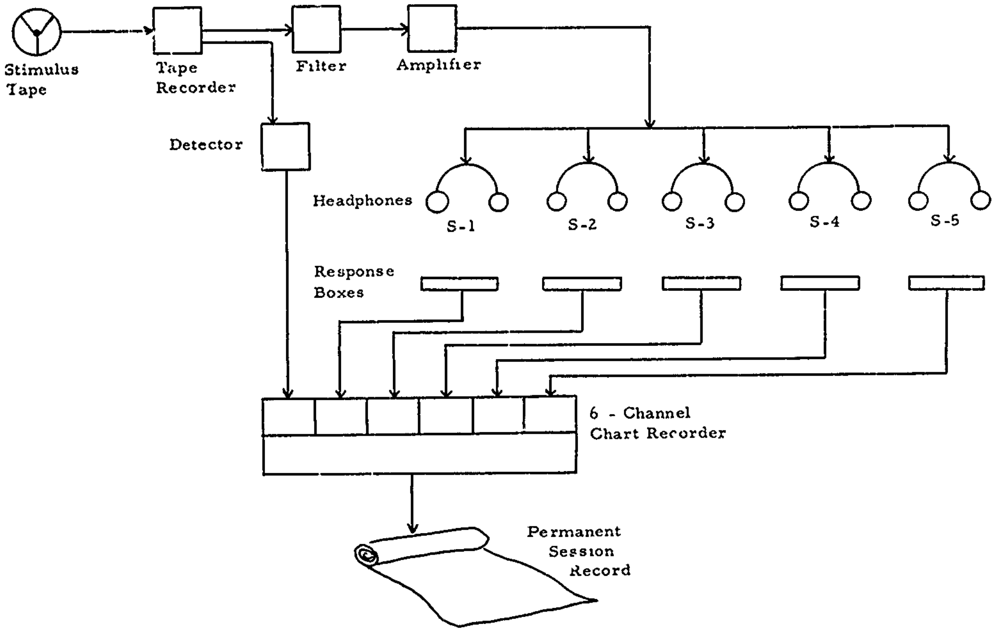

Figure 4. Schematic of the Laboratory Experimentation

Dwell Time (msec)	Target Type	Noise Level	
		Qualitative	Approx. S/N (db)
4000	Personnel	Very low	+10
2000	Vehicular	Low	+ 5
1000		Medium	0
500		High	- 5
250		Very high	-10
125			
62.5			
31.3			
15.6			
7.8			
3.9			

Figure 5. Experimental Conditions

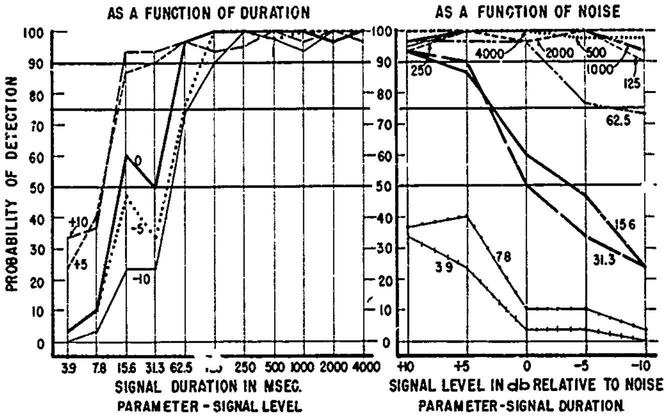

Figure 6. Probability of Detection of Vehicular Targets

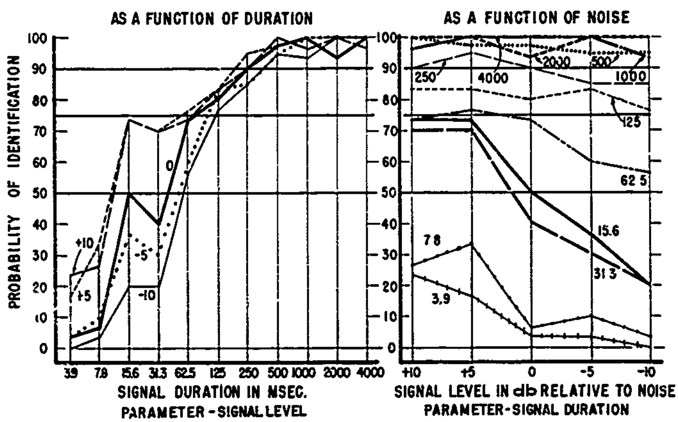

Figure 7. Probability of Identification of Vehicular Targets

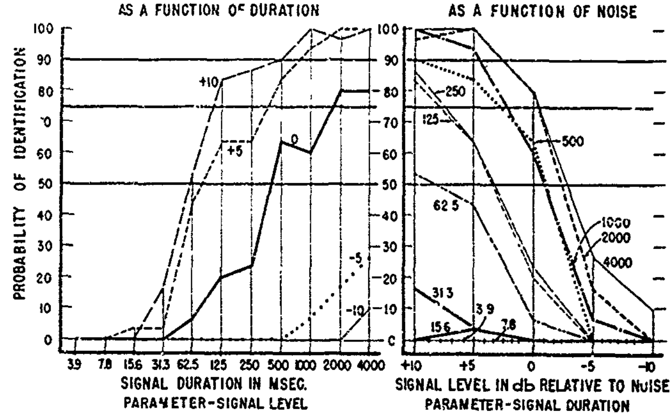

Figure 8. Probability of Detection of Personnel Targets

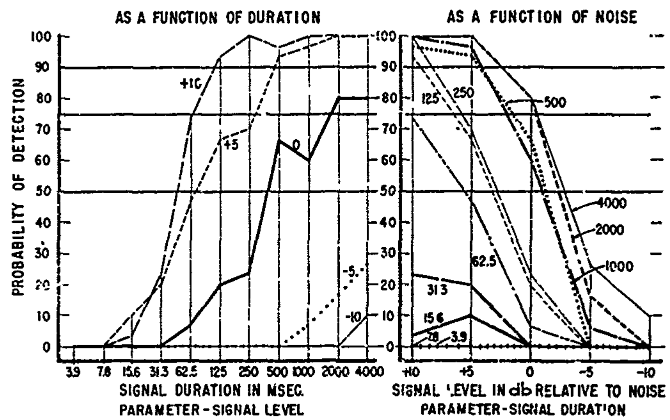

Figure 9. Probability of Identification of Personnel Targets

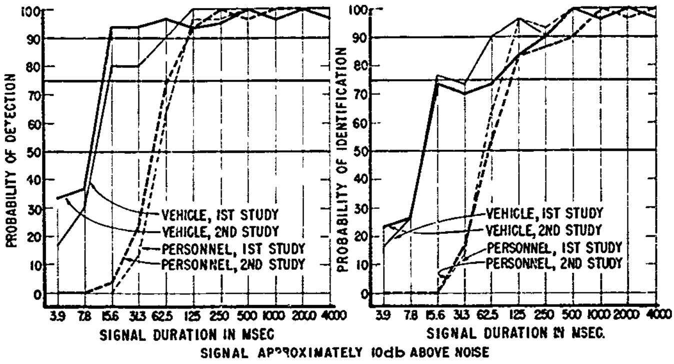

Figure 10. Performance of Two Groups of Subjects Under Identical Conditions

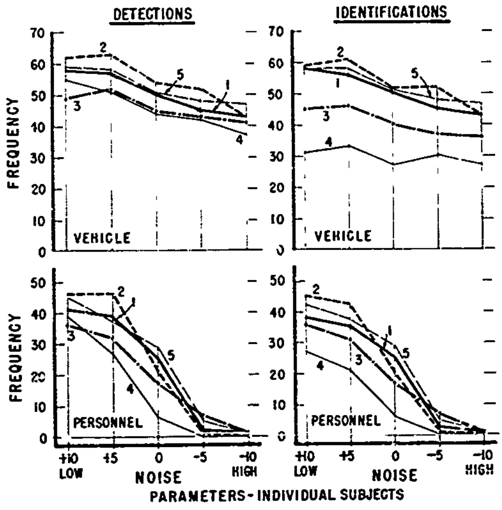

Figure 11. Individual Subject Performance as a Function of Noise

C NOISE AND WEAPON SYSTEMS by Ray Donley, US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland

Noise control in weapon systems for the modern Army is admittedly a difficult problem However, this problem can be solved. The conflict between light-weight equipment with its greater radiated power from panels and from engines, and the tools of noise control has, in the past, created very serious problems In the future these problems will become worse However, effective noise control may be performed on the systems if one is willing to look at each weapon system individually. Indeed, complex noise control problems, such as are encountered in missile weapon systems, are best handled with respect to the entire weapon system. Noise control is basically a system problem, whether working with a complex problem or an elementary problem.

Briefly, a system, in noise control is divided into three parts the source, the path, and the receiver. Some of the more common sources may be rotating components such as gears, bearings, fan blades or a series of repeated impact noises, such as the sprocket engaging the track in driving track-laying vehicles.

The path is the medium by which the sound energy is transferred from the noise source to the receiver Sound may be transmitted through air, through structures such as building walls or machinery supports, or through a combination of the two. In general most paths are a combination of structural borne and airborne noise, each having completely different transmission characteristics.

The receiver is either man or a piece of equipment. Man's reactions to noise are generally statistical concepts which vary either with his task or with his psychological or physiological characteristics at a given time.

Another point which is important is that noise control is not necessarily synonymous with noise reduction. It is quite true that most noise control problems do require some sort of noise reduction. However, some noise control problems are solved by changing the shape of the noise spectrum. Many annoyance problems are solved by spectrum changes. Occasionally, one needs to add noise. An example of this is in telephone booths in which the fans have been made sufficiently noisy to mask the noise from outside the booth and to the speech from nearby phone booths.

The ultimate goal of noise control is to achieve a specific environment at the "lowest total effective cost". The phrase "lowest total effective cost" includes the direct cost of noise control and the indirect costs of operational restrictions and system limitations. Indirect costs in a military system include any cost which results from a change in the desired use of the system, restrictions on operating time, addition of men or equipment, or adverse community reaction. Operational restrictions are the most insidious contributors to the total effective cost. An operational restriction to protect personnel from deafness may require more men This means a change in the Table of Organization and Equipment and more vehicles. In addition, this means the men must be fed, clothed and housed. The additional vehicles require fuel and maintenance. The cost of adding one or more men to a mobile weapon system is frequently more expensive than the direct cost of conventional noise control.

The specific noise environments required in a given military situation are

(1) freedom from permanent hearing loss
(2) freedom from temporary hearing loss
(3) freedom from annoyance
(4) freedom from speech interference
(5) freedom from identification
(6) freedom from detection
(7) freedom from adverse community reaction

Generally, the most imperative requirement in any military situation is freedom from permanent hearing loss. Since the noise levels permitted for safety are above the levels which create annoyance or speech interference, noise levels to preclude hearing damage are the easiest to achieve.

Of course, one must look into the possible restrictions on how one may achieve a military environment of the proper characteristics. From the requirements established before the system is designed, we may obtain the military characteristics. The MC's specify the tactical use, the training use, and the limits on size, weight and bulk. These limitations are frequently indirect but may be inferred by size limitations or weight limitations imposed for air transportability. The military characteristics also give a limitation on procedures. This, again, is a somewhat indirect limitation, it is generally not specified. However, these limitations may be inferred from the military characteristics from a desired or maximum reaction time. Obviously, extending the countdown time or time to emplace a weapon is undesirable.

The possible methods of control must be cheap, reliable, and simple. Noise control methods also cannot be subject to variations by temperature, since we deal with temperatures from -65° to +125°, humidity, as we deal with humidities from 0% in the desert to 100% in the jungle; vibration, since they must be carried on track-laying equipment; blast, since many pieces of equipment are in the direct blast of a rocket taking off, or mechanical abuse, including field modifications.

Additionally, noise control methods may not be unhygienic. This is particularly important in developing mouthpiece noise shields used for protecting microphones from extraneous noise. Within the Army, policy dictates that each piece of equipment belongs to the particular system rather than to the individual. This means that one may not consider methods of noise control which would create any health problem. Noise control procedures also must not be distasteful or complicated. An example of the simplicity required in noise control methods was noted recently in a system in which, until adequate noise reduction could be provided, the soldiers were required to wear a typical earmuff temporarily. The local commander had issued an order for the men to wear blocked fatigue caps. Blocked fatigue caps are somewhat fragile and break when the earmuff headband is placed over the cap. The men, in an obvious effort to please both the local commander and comply with the requirement to wear earmuffs, developed a somewhat novel solution. They placed the headband of the earmuff behind their ears without placing the ear inside the muff which completely nullified any favorable attentuation characteristics gained by using the earmuff. So, with these particular restrictions, what are the possible solutions?

First, we may change the source by obtaining different, quieter, equipment. This is generally the most expensive method of noise control. However, it is also the most reliable. The changes which may be considered are restricted, too. In many cases, the equipment design has exceeded the so-called "state of the art" in an attempt to obtain the maximum power output for the minimum weight. The methods by which the desired characteristics are obtained are generally to take an undersized piece of equipment and literally "hot rod" it. This leaves little or nothing in the way of characteristics which may be modified in the particular noise source. In many cases obtaining an alternate piece of equipment requires an excessive amount of time. Alternate types of, say perhaps generation equipment, must also be checked for their weight and affect on the system. So, in summary, to change the source we may either redesign the piece of equipment, obtain a new source of the same general class of equipment, or change the type of equipment.

Most modifications for noise control are modifications to the path. These changes are conventional and commonly include inclosures, panel damping, mufflers, vibration isolation, and redirection of airflow.

To obtain the lowest total effective cost it may be wise to offer ear protection thus changing the receiver. Another method is to use a change in schedules or the operating time to which a man is exposed to a given noise source. Of course, there is another method which may be used. That is to eliminate the job, such as to buy some sort of automatic control or perhaps to redesign the equipment in such a way that the man is not required to be near the noise source. In general, the best solution is a combination of all three methods of noise control: changes to the source, changes to the path, and changes to the receiver.

However, let us look at a specific set of system procedures which may be used for effective noise control. First, one must analyze the job of every man to yield the proper environment for communications requirements, the effects of annoyance on efficiency for the job, and the expected exposure pattern with respect to time and sound pressure level. Next, one must verify how the equipment is to be used in reference to its location with relation to other components and how long the equipment can operate. The methods for obtaining this information are frequently indirect and must be deduced. An example might be relating fuel consumption rates with fuel tank size. This effectively restricts the operating time of a piece of equipment. Another method is to check cable lengths. There are only a limited number of ways in which equipment may be placed if they must be interconnected by a number of cables of a given length. Another aspect of equipment usage is in its tactical use—is identification critical? We usually separate identification from detection. Identification, for our purposes, generally refers to the noise characteristics which allow a specific piece of equipment to be identified as that specific piece of equipment belonging to a given weapon system. Detection is still the simple problem of how far away can we perceive that there is some sort of noise. Both of these considerations are quite important. However, in many respects identification as to a specific weapon system is the more important of the two considerations. Another thing which must be checked in equipment usage is what sort of abuse to the equipment can be expected. By abuse we do not generally refer to it as what can be considered as malicious damage. Abuse to pieces of equipment can be simply defined as to what happens when the equipment is air-dropped, is there a deleterious effect on the equipment from missile blast during takeoff, is the equipment well-designed such that there should be no field modifications, is the equipment to be carried on tracklaying vehicles, will it be subjected to unusual vibration, is it a piece of equipment which will be operated in rain, snow, mud, or any of the many unusual environments to which military equipment is normally exposed. The third aspect of a system noise control procedure is to measure the noise of each component. It must be measured for prediction purposes, obviously, and to locate those particular problem areas which can exist in a given system. It also must be measured for corrective action, and in this particular respect the more detailed the information the better one's chances of not being forced into measuring the equipment noise again later. It is best to measure noise levels by one-third octave bands which allow identification of specific problem areas. From these one-third octave bands we can easily calculate the octave bands in order to evaluate damage-risk speech interference and annoyance. If the major source consists of many small sources inclosed within a box, it is a good idea to use constant sound pressure contours to identify the specific location of air leaks and their particular frequency range The fourth step in the systems analysis of a noise problem is to examine the military characteristics for limitations on time, physical limits, and proposed usage, then examine, for the fifth part, the path change methods for controlling noise with respect to how much may be obtained practically at the lowest cost with the least schedule interference and within the limitations of the military characteristics examined in part four. Schedule interference is a rather unusual problem. Unless the problem is particularly pressing, there is a natural reluctance on the part of the manufacturer to redesign or change pieces of equipment which are scheduled for production. This does not necessarily mean that he is not interested in noise control, however, he may have certain other objectives to attain before he can consider noise control problems Some of these are that he has production dates to meet. There is a time limit which has been placed upon him for producing a given piece of equipment He also must make the equipment work. It is quite easy to forget that the manufacturers, too, have a serious problem in making a piece of equipment that not only works but which may be worked by the man. The sixth step is to compare the reductions with a criterion for the particular environment. The criterion for a given environment is obtained from a consideration of the previous five portions of the system noise control evaluation. If the man has a stringent communication requirement, this can be the highest allowable noise level. If the man has a job in which annoyance could affect his efficiency, then this will establish the upper limits of the allowable noise of a given component of the system. In this it is presumed first that one can eliminate damage-risk. The final environment must be selected by a function of "trade offs". In many cases, one may work to some sort of damage criterion and increase the efficiency of a communication system so that the reductions are feasible and relatively inexpensive, not only in time but in effort and possess the possibility of working correctly. If the expected reductions are inadequate, one can then also examine changes to the source or to the receiver. As pointed out before, the lowest total effective cost is then achieved by a series of trade-offs, of what can be done to the system, what must be done to the system, and what is desirable for the system with the ultimate goal of achieving the proper environment for the man at the least total effective cost.

To illustrate an application of the procedures and principals which have been discussed, I am going to spend a few minutes discussing the Pershing Power Station (Figure 1).

Normally this piece of equipment is carried on the same track laying vehicle as the programmer test station. It supplies the weapon system with electric power, conditioned air, and high pressure air.

When the first unit arrived at Aberdeen for road-test we conducted a noise analysis. Results of the analysis showed that operating personnel were subject to hearing damage. As a result of this test and subsequent tests by the contractor, several changes were made to the Power station. These included redesign of the air-conditioner, which was a major source of noise, redirecting the flow of air by placing both the gas turbine and cooling air inlets and outlets on top of the pack, increased insulation on the side panels to further attenuate the sound being transmitted through the panels and several other design changes.

Figure 2 depicts the sound pressure level at the position of the Power Station operator. You will note that prior to modification the sound level at this position exceeded 90 decibel at all frequencies above 90 cycle per seconds with a few pure tones going as high as 128 decibels. The previously mentioned modifications resulted in a dramatic decrease in sound level at this operating position. Figures 3 through 8 demonstrate how the sound level was not only lowered but the sound field was modified. The contour lines are constant pressure lines. The power station mounted on a track laying vehicle is shown at upper center in each figure.

Figure 3 shows the sound field around the unmodified power station in the 75 - 150 cycle per second frequency band. After modification the sound field shifted and changed in intensity for this frequency band as shown in Figure 4.

Earlier in the discussion, knowledge of the system was mentioned as being important

In the previous figure we had 106 and 107 DB in some areas where an operator had to stand, now that noise level no longer exists in those areas, however we now have 126 DB in other areas but nobody has any reason to be in those areas. Therefore, the noise is of lesser importance

Figure 5 depicts the noise level in 2400 - 4800 cps frequency band before modification. In this same frequency band, noise levels have dropped off considerably following modification (Figure 6).

Figure 7 depicts the noise level in the 4800 - 10,000 cps frequency band before modification. Some of the noises on this figure and on the previous figures will cause hearing loss. Here again the modifications reduced the noise level considerably as shown in figure 8.

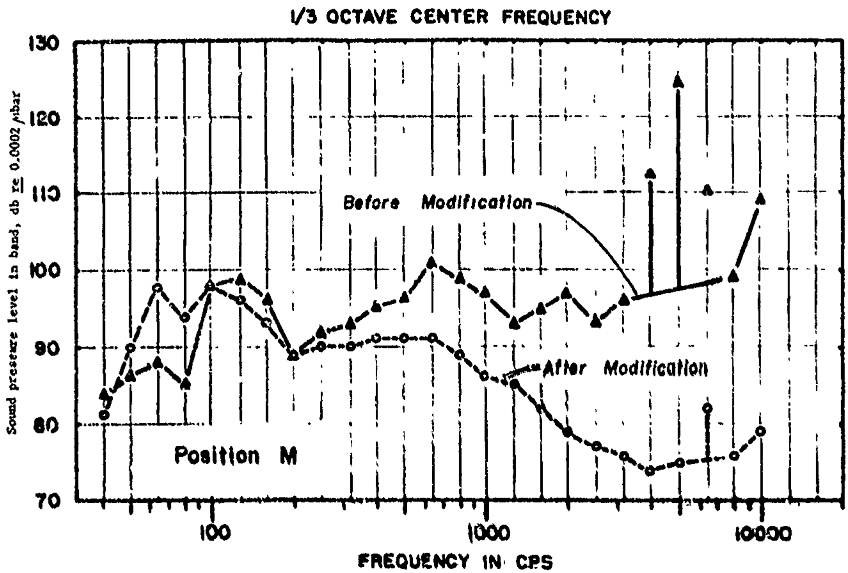

Figure 2. Sound Pressure Levels of the PERSHING Power Pack

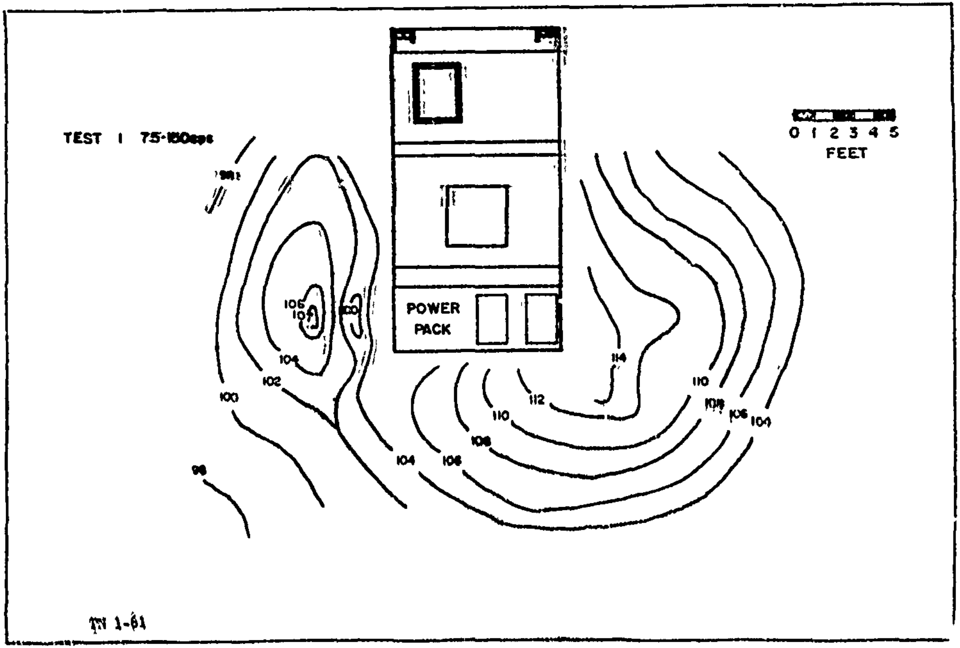

Figure 3. Sound Levels Prior to Modification of the PERSHING

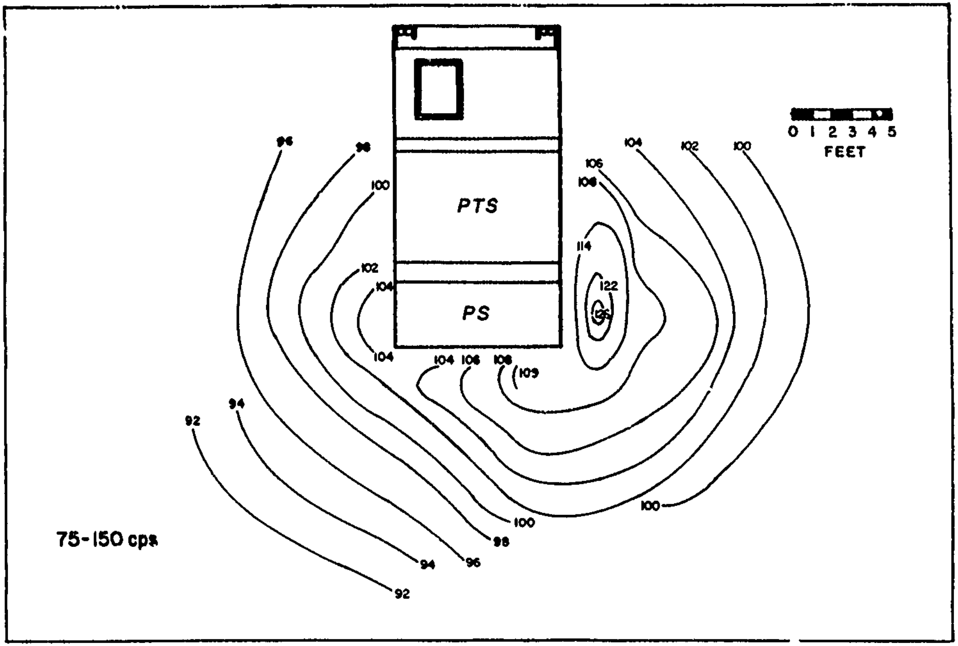

Figure 4. Sound Levels After Modification

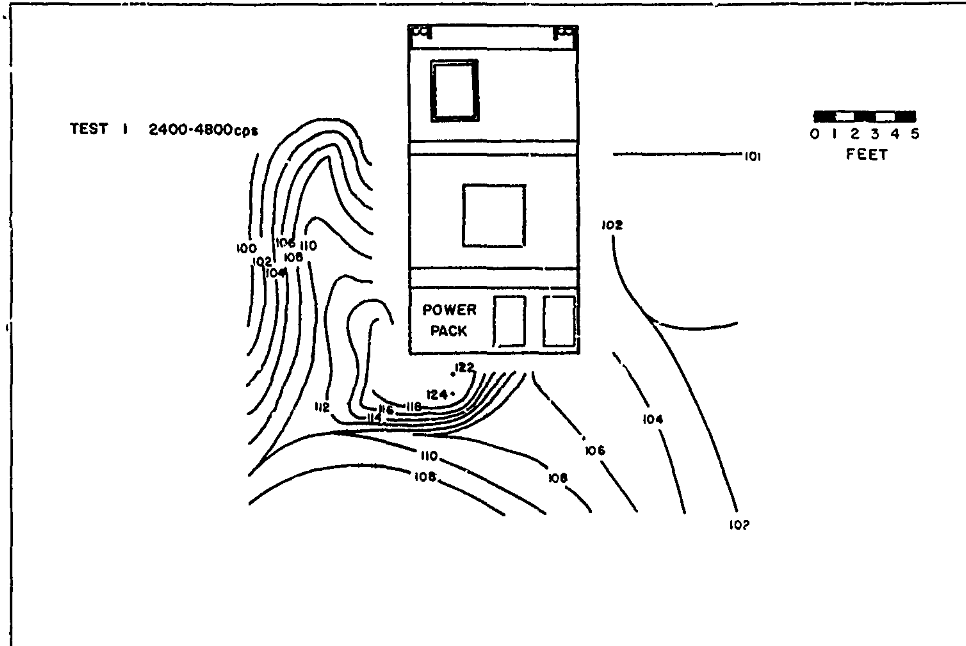

Figure 5. Sound Levels Prior to Modification of the PERSHING

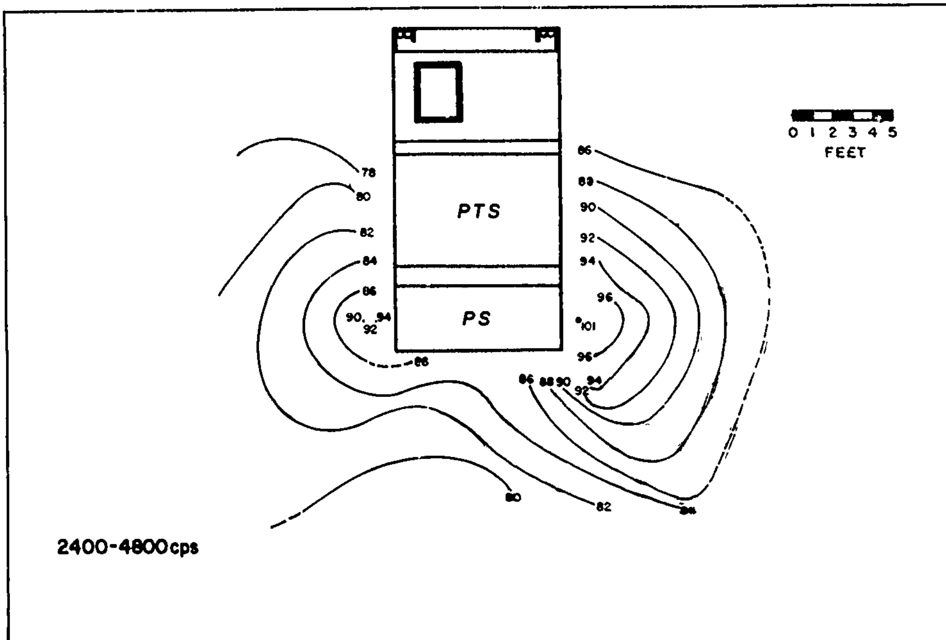

Figure [illegible]. Sound Levels After Modification

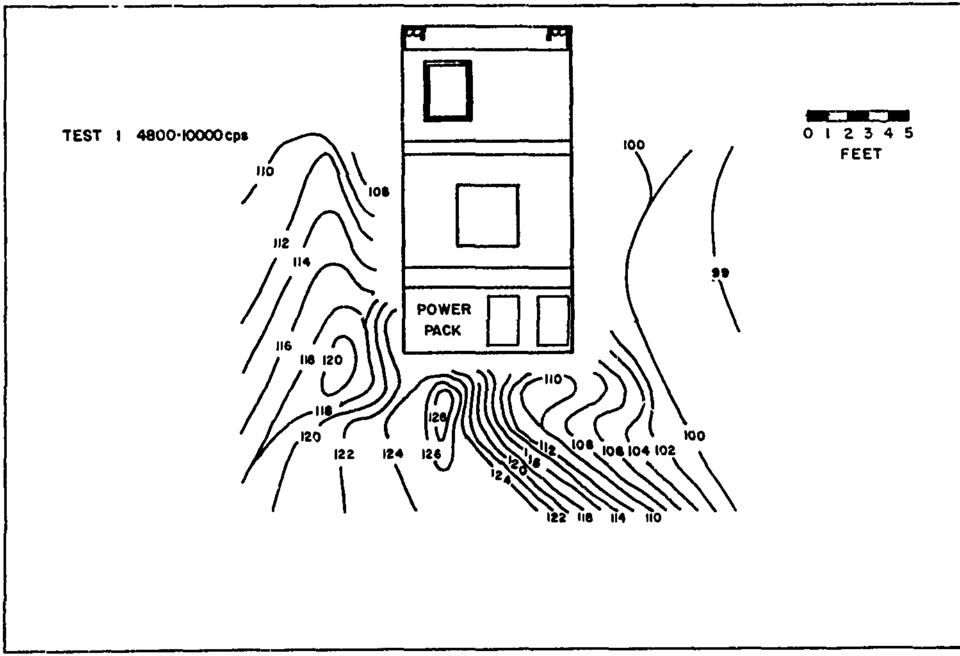

Figure 7. Sound Levels Prior to Modification of the PERSHING

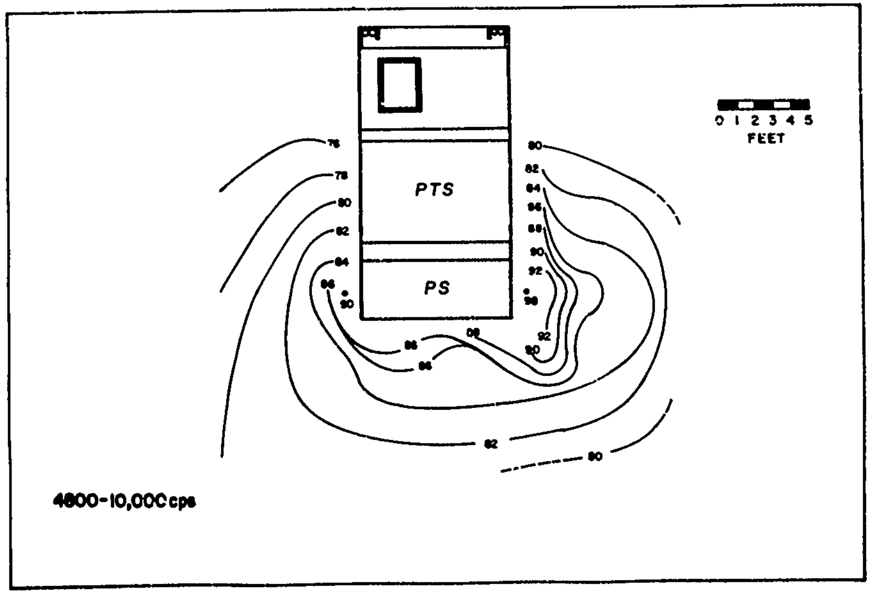

Figure 8. Sound Levels After Modification

D. BASIC RESEARCH IN HEARING APPLIED TO FIELD PROBLEMS by Maj. John L. Fletcher, MSC, U S. Army Medical Research Laboratory, Fort Knox, Kentucky

Basic research in audition performed at USAMRL includes research relating noise exposure to hearing loss, studies to determine the susceptibility of individuals to trauma from different types of acoustic exposure, psycho-physical studies, and investigations of the ability of humans to detect various types of signals for prolonged periods of time while simultaneously exposed to various physical stimuli. The latter type study is frequently referred to as vigilance research.

Facilities for the above research include an anechoic or echoless chamber, several sound treated rooms, and a mobile sound laboratory built into a 26 ft. trailer. This unit has its own 10 KW power source and is provided with both heating and cooling systems. It can be towed to a field location and be used as a completely independent laboratory there. Present personnel include two Ph. D. level researchers and three technician assistants. We also have partial use of facilities and personnel of the Complex Processes Branch (one Ph. D. and two technicians) and, on contract, of the Psychology Department, University of Louisville.

An immediate application of our research relating noise exposure and hearing loss is that of providing suggestions useful in the establishment of hearing conservation programs. The Post Surgeon and Chief of Preventive Medicine, Fort Knox, have recently initiated such a program within the training command at Fort Knox. Our contributions to the program will include consultation regarding the appropriate protective devices, help in the indoctrination of personnel concerned with the program, suggestions regarding the conduct of the program, and the monitoring of the hearing of those included in the program. In conjunction with the above efforts we have, from time to time, been involved in the testing of various ear protective devices with respect to specific aspects of suitability and usefulness.

Another basic physiological problem investigated by our laboratory has been that of the operational characteristics of acoustic reflex action. As you perhaps know, inside the middle ear there is a series of small bones, the malleus or mallet, incus or anvil and stapes or stirrup. These bones together constitute the ossicular chain. The ossicular chain serves to connect the outside physical stimulus world of sound with its physical stimuli of sound waves to the inside ear, thence to the brain. Air conducted sound is faithfully transmitted by the ossicles through the middle ear to the inner ear. Attached to the ossicles are two muscles, the stapedius and tensor tympani. When stimulated by a sufficiently loud sound these muscles contract and act to reduce the transmission of sound through the middle ear by rotating the ossicular chain out of its usual mode of operation and essentially locking it in place. Normally, the AR, then, serves to protect us from loud sounds. However, the neural latency, or lag time between stimulation and muscle contraction is so long, at least 9 milli sec. -that some sounds are already transmitted through the ear before the reflex can respond. Gunfire, for example, has a rise time (time from 0 to peak SPL) of less than 500 micro sec. -or 1/2 of a milli sec. So the reflex, for gunfire, only locks the barn door after the horse is gone. But, if there was advance knowledge of when the impulse sound was to occur we could elicit the reflex in advance of the sound and protect the ear by its usual physiological protective mechanism. So we tried stimulating people with gunfire and seeing how much reduction of TTS the AR provided. This was done by stimulating the reflex in advance of the gunfire and comparing TTS with that observed when they were not so stimulated prior to exposure. We found that it provided significant protection (see Figure 1). The next step was to compare it with conventional ear protective devices. We did so and found it did quite well - as well as having the advantage of being used only when necessary and not needing fitting, not interfering with communications, or requiring supervision in wearing (see Figure 2). We then went about determining ways it could be improved, once having established its usefulness and feasibility. Our research indicated the optimal stimulus for eliciting AR action was a series of clicks. Using clicks we found we could prolong contraction so that some reflex protection could be observed for exposure to continuous noise where formerly it could be shown only for impulse noise.

Based on the research cited above, a device was constructed, tested, and given a field evaluation to determine suitability for operational use. It was found to do in field use as it had been observed to perform in the laboratory. Additionally, interposing the AR device into the combat vehicle system in no way interfered with communications or with gunnery. The reflex protective device described above is now in the process of final electronics consideration and, hopefully, for a complete CONARC field test.

As consultants, we have participated in the solution of many applied problems. A recent one was here at Fort Benning. A requirement was made of the Weapons Department, USAIS, for the development of a range for the Guard and Reserve Components. The prototype design was such that exposure of those firing was in excess of that normally incurred on conventional ranges. Attack on the problem was diversified to include both redesign of the range to quiet it and prescription of appropriate ear protective devices for those firing on the range. Table 1 presents the results of the redesign and quieting of the prototype range. When you consider the costs and difficulties associated with quieting, accomplishment of this magnitude of reduction at the estimated $125 cost of this operation was most reasonable.

Another merger of basic research and field needs is illustrated in one of our recent studies. Basically, the purpose of the study was to examine various ways of testing the efficiency of ear protective devices. During the course of the experiment a rather thorough evaluation was made of the effectiveness of three different ear protective devices, two plugs and the CVC helmet. Efficiency of the devices was tested not only for pure tones, the usual standard, but also when used in continuous noise, such as engine noise, and when used against gunfire or impulse sound. This was considered necessary because some devices, helmets in particular, are known to resonate and to perform differently in high intensity noise fields than at lower levels. A realistic test of such a device should include, then, one of performance in such a sound field. Also, there is evidence suggesting that impulse noise (gunfire) attenuation is not readily predictable from the results of pure tone threshold evaluation. Results of the investigation suggested that the pure tone method of test was minimally acceptable, but that the additional information revealed by tests in noise and gunfire plus the high face validity of such tests for devices to be used in such environments made the additional testing highly desirable. Another result of the experiment was to show that any of the three ear protective devices, when worn, reduced the temporary hearing losses of the wearer to a reasonable level. One other valuable piece of information was extracted from this experiment. As part of the experiment, subjects were exposed, unprotected by ear protective devices, to gunfire sufficient to induce a temporary hearing loss of a moderate amount. They were later exposed to noise sufficiently long to duplicate the hearing loss incurred by exposure to the gunfire. By comparing the relative amount of noise exposure necessary to induce a temporary loss equal to that caused by the gunfire, indications could be derived of the relative susceptibility of an individual to loss from impulse and from continuous noise. These results showed that individuals differ widely in susceptibility to noise induced hearing loss, with some quite susceptible to impulse noise and little effected by continuous, and the reverse true of others and some equally susceptible to both types of sound. These data have been of considerable value in the formulation of criteria for hazardous exposure to impulse and to steady state noise.

Our experiences have shown repeatedly that the results of basic research are applicable to field problems. They have also indicated many times that the obvious time and place for use of basic information is in the design state of a weapons system or piece of equipment. Money as well as invaluable time is wasted when a system comes out that is unacceptable because of a lack of coordination and knowledge of basic facts. Realizing this, farsighted regulations were promulated requiring human engineering coordination in systems design. If these regulations could be more carefully and knowledgably observed, the task of assuring compliance of systems to various human limitations would be much easier.

In presenting this paper, I have hoped to inform you of the personnel and facilities that our laboratory has, of our specific research interests and capabilities, and, most of all, of the way all of the above capabilities can be applied to the problems facing us in field operations. If I have succeeded, perhaps more of the problems facing us will be brought in for attention and eventual solution.

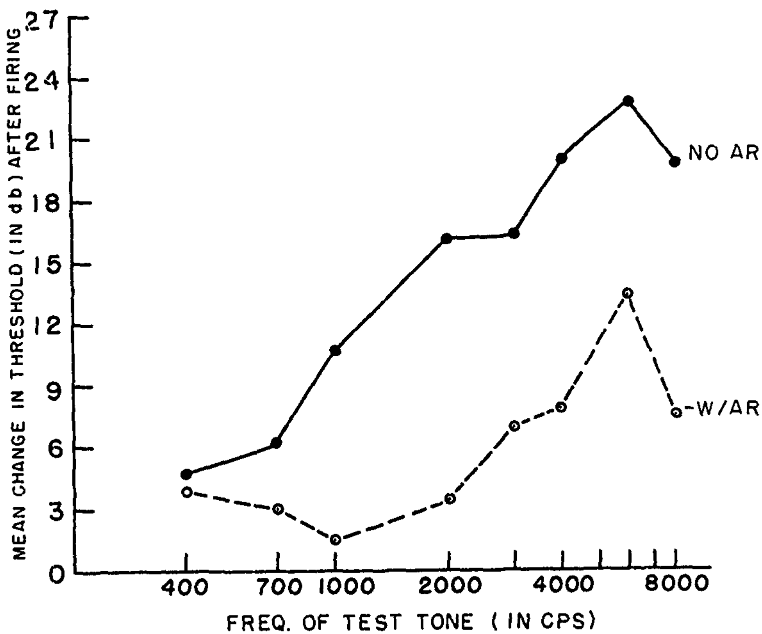

Figure 1. Mean Temporary Threshold Shift Following Exposure to Impulsive Noise With and Without Activation of the Acoustic Reflex

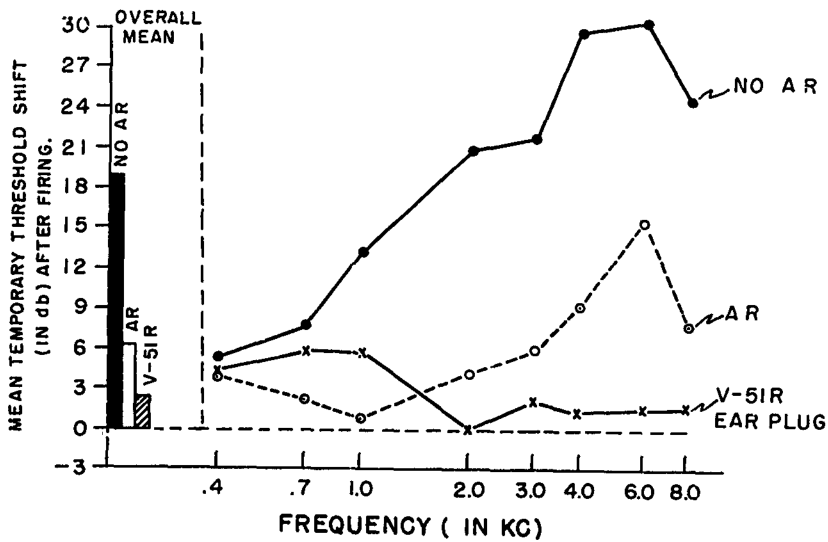

Figure 2. Mean Temporary Threshold Shift Induced by Three Experimental Conditions

Table 1. Peak and Temporally Integrated Sound Pressure Levels (in db re. 0002 dyne/cm^2) from the M14 Rifle.

	Peak	Integrated (.02 sec)	Integrated (.002 sec.)
Free Field, Open Range*	161.00	129.50	142.00
25m Range (original)*	162.00	141.00	152.00
25m Range, (redesigned)*	161.50	138.00	148.00
25m Range, (redesigned, sound treated)*	160.50	134.00	144.00
25m Range (original)**	159.00	136.00	147.00
25m Range (redesigned)**	158.00	--	143.50

* Sound measurements taken at the left ear of a right handed firer.
** Sound measurements taken at the right ear of a right handed firer.

E. STUDIES OF TEMPORARY THRESHOLD SHIFT CAUSED BY HIGH INTENSITY ACOUSTIC TRANSIENTS* by Norman L. Carter and Karl D. Kryter, Bolt Beranek and Newman Inc. Cambridge, Massachusetts

INTRODUCTION

The present series of experiments follow from a preliminary study described in BBN Report No. 916, [1] That study, now called Experiment I, was concerned with the effect of pulse repetition rate (pulses per second) and the number of pulses upon thresholds for pure tones in the frequency range of 2500 to 10000 cps. Each pulse had a triangular acoustic waveform, with a rise time of 0.5 millisecond, duration 1 millisecond and peak sound pressure level 168 db re .0002 microbar. Pulse rates used were 1, 5, 10, 20, 40 and 80 pulses per second (PPS). The numbers of pulses were 5, 10, 20, 40 and 80.

That study allowed the following tentative conclusions: (1) the frequency of maximum loss is in the region of 4000-5000 cps; (2) the repetition rate most likely to produce temporary threshold shift (TTS) was 1 PPS; and (3) the TTS increased with the number of pulses.

One feature of the results was that even though the hearing losses were for the most part small and unreliable, there was no doubt that those moderately large losses that did take place were "real" and not artifacts of the hearing tests. It was supposed that the explanation for this might be that people have 'thresholds' for acoustic trauma similar to absolute thresholds for hearing, and that apart from day to day variations in the ear there is an 'acoustic trauma threshold value' of x number of pulses for each person (assuming other revelant parameters such as repetition rate, peak to peak level, rise time, etc., are constant). If this were true the variability in the results of Experiment I could be due to the characteristics of the particular subjects involved as well as the particular values of rise time, duration, repetition rate, number of pulses and peak to peak level that were used.

The assumption of an acoustic trauma threshold (ATT) for pulses also implies that once this threshold is reached, TTS will show the same function of number of pulses for all normal ears, regardless of their particular ATT values.** If this is so, then prolonged and expensive experimentation would be avoided by selecting subjects from the low end of the ATT continuum.

*The work herein reported was performed under Contract DA 49-007 MD-985 with the Surgeon General's office, U.S. Army

**In this discussion the type of function of TTS above ATT for any parameter had not been mentioned. It may be continuous or a step function (e.g., O db to X db TTS) for any parameter. This and other experimental problems, such as the relation of ATT to other auditory thresholds, are considered in experiments reported below.

EXPERIMENT II

Cursory examination of the data of Experiment I suggested that an average of one out of four normal hearing young adults could be expected to show moderate hearing losses (over 20 db) 30 seconds to two minutes after exposure to 80 triangular acoustic pulses (0.5 millisecond rise time, 1 millisecond duration, 168 db peak to peak) at a repetition rate of 1 PPS. Accordingly it was anticipated that if such an exposure were given to 60 college students 15 of them would show losses greater than 20 db. Caution dictated, however, that in the present context, where large numbers of subjects are involved and the range of sensitivity to this stimulus is unknown, subjects should first be exposed to 40 pulses only, at lower peak to peak levels. The number of pulses, and possibly their level, could then be increased for those subjects showing no significant threshold shift, until a criterion (say, 10 db TTS) was reached.

Apparatus and Procedure

The apparatus used in generating the acoustic stimuli has been described in detail in a previous report.[2] It consisted of an arbitrary function generator, or photoformer, capable of generating any desired electrical waveform (voltage by time), an amplifier for amplifying and controlling the peak voltage and a small, high intensity loudspeaker (KLH 6.5) mounted on a headband and held firmly against the subject's head during exposure. The level of the acoustic pulse was measured by placing the earphone on a dummy head with a microphone (Altec 21 BR 200) in the simulated ear canal and leading the output of the microphone to an oscilloscope (Dumont type 304 AR). The vertical axis of this scope was previously calibrated using a BBN acoustic calibrator (308-C-3). The rise time and duration of the pulse were read off the scope in a similar way, after calibrating the horizontal axis with a 1000 cps sine wave. Photographs of the photoformer mask, electrical output of the amplifier, and the acoustic pulse as shown on the oscilloscope are presented in Figure 1.

Hearing losses were measured by a subject-operated Bekesy audiometer (Grason Stadler type E-800). As in Experiment I tests were made before and after exposure, but it was decided to drop the method of recording hearing losses in terms of a single 'loss number,' as was done for Experiment I, in favor of the usual method of db threshold shift at each test frequency.

Test frequencies were 2000, 4000, 8000 and 500 cps, tested in that order for 30 seconds each, before and after exposure. The first frequency tested after the train of high intensity pulses was 2000 cps, begun 30 seconds post exposure. As is usual in this type of pure tone threshold, audiometry threshold at any frequency was the average of the midpoints of the excursions over the time the frequency was tested.

Forty-five normal hearing college students (29 male, 16 female) were exposed to the acoustic transients in the sequence, and at the levels indicated in Table 1. In some instances the pure tone thresholds were tested a second time after exposure. This generally indicated that the losses were "real" and not due to some artifact connected with the subject's inexperience with audiometry.

Results

The results presented in Table 1 confirm that there is a considerable range in the susceptibility of young adult subjects to TTS induced by this type of 'impulse' noise. Large individual differences in susceptibility to impulse noise can also be seen in Figure 2 where for the 45 subjects we have plotted the distribution of thresholds following exposure to impulse noise and the distribution of pre-exposure thresholds. Similar variability among subjects with respect to their susceptibility to auditory fatigue from acoustic impulses was found by Ward et al [4].

The second aim of this experiment was to select subjects for later work. Eighteen of the 45 subjects of Table 1 show a greater than 10 db loss at one or more frequencies following 120 pulses (or less) of 168 db peak to peak (or lower). These subjects are indicated by an asterisk, the initialled numbers are the subjects who proved available for the later experiments.

EXPERIMENT III

Experiment I indicated, as might be expected, that TTS increased as a function of the number of pulses. The present study was intended to get quantitative data on the shape of this function.

Apparatus and Procedure

The apparatus for producing the stimuli and determining pure tone thresholds was identical with that used in the Experiment II condition. Rise time of the pulses was again 0.5 millisecond, duration 1.0 millisecond, and repetition rate 1 PPS. The audiometry was also similar. Pre-exposure thresholds were the mean of at least two audiograms giving threshold as a continuous function of frequency from 2000 to 10000 cps. Each audiogram took 70 seconds to complete. Post-exposure audiograms were begun 30 seconds and usually also 3 minutes after the last pulse. Audiograms were also run 6, 12 and, in many cases, 24 minutes post exposure if recovery was not complete and the schedule allowed. Sixteen subjects were used. Fourteen of these are shown with initials and asterisks in Table 1. Subject number 43 was not available, but was replaced by a non-sensitive subject (E.S.) to increase (hopefully) the variance in our sample. One other subject (T.H.) was included because of his experience of audiometry in other experiments and because an initial exposure gave significant TTS.

The experimental procedure consisted of repeated exposures for each subject (one day between exposures) in a trial and error approach to a criterion maximum threshold shift of between 30 and 40 db in the first audiogram after exposure. The usual method was to guess at an exposure capable of minimal significant TTS (i.e. the ATT for number of pulses) using, in all but two instances,* a peak pulse level of 168 db. If the criterion TTS was reached quickly, the number of pulses was dropped in the ratio of 3/4, 1/2 and 1/1 that number; otherwise the procedure was to increase the number of pulses during subsequent exposures.

Results

The foregoing experimental procedure resulted in measures of temporary threshold shift at 13 frequencies 30 to 95 seconds after exposure, 180 to 245 seconds after, etc. depending on the frequency measured and the post-exposure audiogram. In order to compare our data with those reported by other investigators it was decided to use recovery curves previously determined from exposure to steady state noise to estimate the hearing loss two minutes after exposure, from the first post-exposure audiogram. The curves used for this are given in Figure 3.

The extrapolated TTS_2 values were plotted for each subject as a function of the number of pulses in the exposure. Separate figures were prepared for test frequencies 2000 cps (see Figures 4, 6, 8) and the means of TTS_2 at 2200-2500 cps, 3000-3500, 4000-4500 (see Figures 5, 7, 9), 5000-5500, 6000-7000, and 8000-9000 cps.

Data already given have shown that wide individual differences exist in susceptibility to impulse noise. Preliminary examination of the present data indicates that this is true

*One subject (B.K.) objected to peak to peak levels above 162 db on the grounds that they hurt. The other (W.B.) proved highly susceptible to the pulses. Pulse level was, therefore, dropped in W.B.'s case to 156 db peak to peak and the experiment continued as with the other subjects.

even for the selected group of 16 subjects used in the present study.

For this reason the results from the 16 experimental subjects were divided into three groups. Results for the six most sensitive subjects are plotted in Figures 4 and 5, the three next most sensitive in Figures 6 and 7 and for the seven least sensitive in Figures 8 and 9.

Clear association between number of pulses and TTS_2 at any frequency is present in only the first two of these groups, totalling nine subjects. Data from the remaining seven subjects (Figures 8 and 9) are not included in the figures following Figure 9 because they show no significant hearing loss

The considerable degree of variation still present within each group suggested further classification of the two most sensitive groups into four sub-groups. The most sensitive sub-group now comprised subjects W.B., C.G., the second most sensitive subjects S.C., W.H., D.M. and W.R.; the third, subject H.P.; and the fourth most sensitive sub-group, subjects J.H., B.K. Mean TTS_2 at each of the test frequencies were plotted for each of these four sub-groups as a function of the number of pulses. Examples of the test frequencies of 2000 and mean of average and 4000 and 4500 cps are presented in Figures 10 and 11. The smoothed curves fitted visually to these data are redrawn in Figures 12-15 for each frequency and each sub-group. The curves are superimposed in Figure 15 and average curves over all test frequencies drawn for each sub-group of subjects in Figure 16.

Discussion

In setting up the experimental procedure and initial plot of the data of Experiment III three assumptions were made. First it was assumed that a series of impulse-type noises acts cumulatively in producing temporary threshold shift, i.e. that hearing loss can result from a series of otherwise harmless impulsive noises if they occur close enough together in time. Second, it was assumed that individual differences in the amount of TTS_2 following a series of acoustic pulses were due to differences in the number of pulses necessary to produce initial threshold shift. The number of pulses thought to be necessary to produce temporary threshold shift persisting for two minutes after exposure was called "acoustic trauma threshold (ATT) for number of pulses." The third assumption was that the rate of increase of TTS_2 as the number of pulses is increased is the same for all ears once the critical number of pulses known as "ATT for number of pulses" was reached.

The fact that all of the smoothed curves of Figures 12-16 are exponential in form suggested that a family of curves of the same general form could take account of the diversity of the data and still provide a general account of the relation between TTS_2 and number of pulses.

Our assumption that the function relating number of pulses and TTS_2 is the same form for all individuals can be maintained while still keeping a good fit to the data by use of the set of curves illustrated in Figure 17.

The plausibility of this as a general hypothesis of the relation between number of pulses and TTS_2 was aided somewhat by the fact that in extrapolating the uppermost curve the line can be made to merge quite easily with the 50 db level, commonly taken as the point beyond which the likelihood of permanent damage is increased. At this level also the rate of recovery of TTS_2 is reduced [5]. While the reasons for these phenomena are obscure, their occurrence after "TTS_2" of 50 db or more suggests that this is the "threshold" of permanent damage, which may have a different mechanism to TTS, and produce a curve of different shape to the rather complete appearing pattern of curves suggested in Figure 17.

Comparison of Figures 15 and 16 shows the general similarity of the curves with those in the hypothetical case of Figure 17. Such curves are generally known as Gompertz curves, the general equation of which has the form

$$Y = Vg^{h^X}$$

i.e. the dependent variable is a double exponential function of X, and V is a constant which gives the hypothetical or empirically determined upper limit for Y. The equation generates both the negatively accelerating function shown by our most sensitive subjects and an initially positively accelerating function, depending upon whether or not the constant g is more or less than 1/e. In both cases g and h must be fractional and positive to give the initially positively accelerated and then negatively accelerated functions suggested in Figure 17. In the present context Y and X are the variables TTS_2 and number of pulses respectively, V is the empirically determined (or guessed) 50 db upper limit of TTS_2, g is the Y intercept, or amount of TTS_2 after a single pulse and h is the rate of growth of TTS_2 with number of pulses.

Tests of this hypothetical relation are given in Figures 18 and 19. The data points of Figure 18 are the average TTS_2 over all test frequencies (2000-9000 cps) for designated groups of subjects as a function of number of pulses. Figure 19 gives the same information for average TTS_2 at 4000 and 4500 cps. X_1 is the point of inflection of the smoothed curves, i.e. that value of X at which the curve changes from a positively to a negatively accelerated slope. It is noteworthy that this occurs in all cases at about 17.5 db TTS_2.

For three out of the four sub-groups (seven of the nine subjects) the second exponent h is very close to the same value (.982). The same exponent for the fourth sub-group averages .950. The relatively small degree of variation in this exponent, which represents the rate of growth of TTS_2 with number of pulses, is regarded as justifying the original assumption that the rate of growth of TTS_2 with number of pulses was the same for all ears regardless of their "acoustic trauma threshold."

Since the smallest number of pulses to which the ear can be exposed is one, the constant "g," or the point of origin of the growth function, is the proportion of 50 db TTS_2 produced by a single pulse. It is interpreted roughly as the extent to which the subject's ATT's have been overreached by the peak to peak' SPL's of the particular pulse used in this experiment. In this sense it is a measure of individual differences in susceptibility.

Most of the difference between the smoothed curves of Figures 18 and 19 can be attributed to variation in this constant, supporting the third assumption that the source of individual differences is in the point at which TTS_2 first appears rather than the rate at which it grows after the subject's "acoustic trauma threshold" is reached. It is important to note, however, that the equation $Y = Vg^{h^X}$ implies that if "g" equals zero (there being no loss after a single pulse) TTS_2 will continue to equal zero no matter how many pulses are presented. This implication is confirmed empirically in our data by the failure of seven of our sixteen subjects to show significant TTS_2 after as many as 200 successive pulses. Our second assumption that individual difference consist in part of the number of pulses necessary to produce initial threshold shift should therefore be dropped in favor of specifying the ATT in terms of parameters of the single pulse necessary to produce an infinitely small but significant TTS_2 and hence "g." In practice this will, of course, involve exposing some subjects to more than one pulse, unless the methods of detecting TTS_2 are improved.

The usefulness of these values of "g" as a measure of individual susceptibility to this type of pulse is limited, since the particular values derived in this experiment obviously apply only to this repetition rate and peak to peak levels. In order to derive a scale of susceptibility to this type of pulse which would be applicable to all people it would be necessary to know the lowest level at which a pulse of the type we are using was capable of producing some TTS_2, no matter how small, in the least susceptible ears. The same exposure could conceivably produce the maximum (50 db) TTS_2 in some ears, whose "g" would then equal one. Presumably there would be a distribution of TTS_2 between these limits and hence a distribution of "g" to be entered in the equation $TTS_2 = 50(g)^{.982^x}$. If, for example, S showed a TTS_2 of 8 db following exposure to one pulse at this level, then it could be calculated that his TTS_2 after 80 such pulses would be

$$TTS_2 = 50(.16)^{.982^{80}}$$

$$= 50(.16)^{.2333}$$

$$= 32.6 \text{ db.}$$

Such a calculation procedure would still be limited to triangular acoustical waveforms with a rise time of 0.5 millisecond, duration 1.0 millisecond, and a repetition rate of 1 PPS. It would also apply to only one peak to peak pulse level.

However, arriving at the corrections to be applied for alterations in peak to peak of the pulse, rise time, and duration should be relatively straightforward, and work is progressing under U. S. Army sponsorship at our laboratory and elsewhere on these questions. Further confirmation of the 50 db "guessed" "safe" upper limit for TTS_2 is also required. Although we feel that the hypothesis developed above for growth of TTS as a function of the number of exposures may have promise as a general description of the growth of TTS from acoustic impulses, it is put forth here as but one possibility worthy of discussion.

In an exploratory study on TTS from impulses, Ward et al [4] concluded that the growth of TTS for most frequencies is linear with time, or number of pulses when given at a constant rate. We are not all sure that the fitting of straight lines to our data to indicate a linear growth in TTS as a function of number of pulses would not ultimately prove to be the best procedure. The necessity of averaging data such as ours across a limited number of subjects can easily result in misleading, though suggestively interesting, curvatures.

EXPERIMENT IV

This experiment was designed to explore the effect of peak to peak pulse level upon TTS_2. The audiometric test procedure was the same as that used in the previous study. The subjects were the nine most sensitive subjects (W.B., C.G., S.C., W.H., D.M., W.R., H.P., J.H. AND B.K.) of Experiment III.

For this study we exposed the subjects to impulses at peak to peak sound pressure levels of 156 and 162 db. Comparable data for a level of 168 db was available from the results of Experiment III. All other variables, including the number of pulses and the repetition rate, were held constant.

Results

Examples of the results of this procedure are given in Figures 20 and 21. The hearing losses, from first audiogram begun 30 seconds after exposure, were corrected to 2 minutes post exposure by using the recovery curves of Figure 3.

While the data for each subject and test frequency shows many inconsistencies, the mean TTS_2 over all subjects and test frequencies, as shown in Figure 22, appears to be linear, and to increase 3 db with each 6 db increase in peak to peak level.

EXPERIMENT V

The final experiment in this series was undertaken because of the wide differences observed between subjects in amount of TTS_2 following comparable exposures to triangular pulses, differences which appeared to be greater than those commonly found following exposure to steady state pure tones or octave band noise. Because our subjects were selected on the basis of susceptibility to impulse type noise,* this experiment was aimed at finding the degree of correlation between susceptibility to impulse noise and octave band noise rather than at estimating the size of the variance in TTS_2 due to the two types of noise in the population at large.

The sixteen subjects used for Experiment III were exposed to 10 minutes of prerecorded octave band noise in the frequency range 1200-2400 cps. The noise was obtained from a GR noise generator and altered to a cutoff characteristic of 36 db per octave. The overall sound pressure level of the exposure in all cases was 110 db, as measured in the ear canal on an artificial head.

Audiometric procedure was the same as in Experiments III and IV. The first audiogram after exposure began 30 seconds post.

Results

Hearing loss, TTS_2, at 2000 and 4000 cps are given in Table 2. Also given in Table 2 are: (a) the estimated average TTS_2 at 2000 and 4000 cps following exposure to 60 impulses at a level of 168 db (these estimates are derived from the data in Figures 4-9), (b) the rank orders of the average TTS_2 for the two noises, and (c) the rank order correlations for the average of the TTS values for 2000 and 4000 cps and for other test frequencies.

These coefficients indicate no significant positive correlation in these 16 subjects between susceptibility to the impulse type noise and hearing losses due to noise in the octave band 1200-2400 cps. Although the pattern of increasingly higher negative correlations with test frequencies is perhaps interesting the highest correlation at test frequencies 8000-9000 cps is negative and accounts for only 25% of the variance.

The results of this experiment show a striking difference between the ranges of individual differences in susceptibility to impulse and steady state noise. This is shown in Figure 23 where we see that a difference of about 20 db separated the largest and smallest TTS following exposure to steady state noise in contrast to a range of about 55 db for impulse noise. It is interesting to note that the range between the least and most sensitive ear is about the same for the pre-exposure thresholds (see Figure 2) as it is following exposure to steady state noise.

The most obvious, but as yet unproven explanation for this greater variability is, of course, that the auditory reflex relaxes at different rates for different subjects or conversely, is not readily elicited in some persons as in others. Although it is believed that the muscles involved in the auditory reflex relax in the typical ear in a matter of a few hundred milliseconds, our data suggest that in the "tougher" ears perhaps the muscles are at least partly constricted after as long as one second, thereby affording some protection from succeeding impulses given at the rate of 1 per second; whereas in our "tender eared" subjects the muscles are completely relaxed in one second. It is also possible, of course, that our "tender eared" subjects completely lack this reflex. We are planning additional studies on this point.

Reliability of Audiogram

During the course of the experiments just reported we accumulated a number of "pre-exposure" audiograms (the audiogram given prior to exposure to noise) for 18 of our subjects. Hopefully, these audiograms should, for each subject, be quite similar; if so, the rather small threshold shifts noted as the result of exposure to impulse and steady state noise could be taken as significant.

The general reliability of the audiograms obtained from our subjects is given in Figure 24. The mean difference between the first pre-exposure audiogram and succeeding pre-exposure audiograms (given at least 1 day apart) is -1.2 db, indicating perhaps some slight improvement by these subjects in

*However, because of the small degree of TTS observed in most persons in our selection test (see Table 1), we are not certain that our "moderately" sensitive subjects do not really represent the average of the general population.

Table 1. Temporary Threshold Shift in 45 Subjects at 500, 2000, 4000 and 8000 cps Following Acoustic Pulses with Rise Time 0.5 millisecond, Duration 1.0 millisecond and a Repetition Rate of 1 Pulse Per Second (1 PPS).

S No.	Pulse Level in db Peak to Peak	No. of Pulses											
		40				80				120			
		2000	4000	8000	500	2000	4000	8000	500	2000	4000	8000	500
1	158 db	-3	-1	-7	-5								
2	" "	-1	7	1	5	-1	-5	4	7				
* 3	" "	2	14	8	5								
* 4(C.C.)	" "	6	13	-1	0								
5	" "	-5	4	1	3	-4	4	4	3				
* 6(W.H.)	159 db	5	-2	24	4								
7	" "	2	-4	-1	5								
8	" "	-1	5	4	0	-3	-4	6	3	-3	-7	-1	1
9	" "	1	-1	2	-5								
10	" "	8	1	8	6								
11	" "	3	-1	9	-2	-7	-10	-12	3				
12	" "	-11	9	5	-4	-8	-3	-3	1				
13	" "	7	-1	8	8								
*14(B.K.)	" "	-2	3	11	-2								
*15(W.B.)	" "					37	12	16	4				
		Begun 7'30" Post---				15	7	3	-1				
*16(B.F.)	" "	19	10	18	-8								
		4	4	7	1	---Begun 6'00"Post							
17	" "	2	0	10	-4								
*18(J.C.)	" "	4	-5	20	-5								
				12-----		----Begun 5'00"Post							
*19(S.C.)	" "	2	8	11	6								
20	" "	-1	-1	0	-2	2	0	1	1				
21	" "	-2	-3	4	2								
22	" "	-7	2	-5	0	-8	3	9	5				
*23	" "	5	17	25	3								
24	" "					0	1	1	4				
25	" "					3	0	10	2				
26	" "					1	6	1	3				
*27(J.H.)	" "					14	2	6	2				
28	" "					4	0	2	9				
*29(C.G.)	" "					9	10	19	4				
30	165 db	1	0	-6	3								
31	" "	4	0	3	4								
32	" "	-3	5	7	6								
*33(D.M.)	" "					-1	-2	32	-1				
*34(A.McD)	" "					2	0	38	-1				
35	" "					4	3	-1	1				
36	" "					4	8	-5	4				
37	" "	Begun 3'30" Post---				(-5	1	-2	-2)	-1	-3	4	-3
	" "					(-1	-3	2	-3)				
38	" "					2	-2	-4	4	3	1	0	6
	" "	Begun 6'20" Post---				4	-1	1	-4				
39	" "					-1	0	0	5	4	2	5	11
*40(W.R.)	" "					6	10	22	4				
41(E.S.)	168 db	-1	5	4	3								
42	" "	1	1	-7	-7								
43	" "	12	1	4	0								
*44(H.P.)	" "					1	9	24	9				
*45(S.T.)	" "					10	5	1	1				

Table 2. Rank Order Correlation between TTS_2 from Acoustic Impulses and Steady State Octave Band of Noise

TTS2 from 1200-2400 cps Octave Band of Noise, 10 Min. Duration, SPL 110 db					Estimated TTS2 from 60 Pulses, 1 P/Sec, 168 db, (See Fig. 2)					
S	2000	4000	Aver. 2000+ 4000	Diff. from Mean	Aver. of 2000+ 4000 cps	Diff. from Mean	TTS_2 1200-2400 cps Band Noise Rank	TTS_2 Impulse 60 P/Sec Rank	Diff. in Rank	D^2
WB	23	14	19	-1	55	+41	7	1	6	3
SC	20	22	21	+1	20	+ 6	5	4.5	0.5	.25
CC	23	40	32	+12	2	-12	1	12	11	121
CG	14	15	14	- 6	50	+36	13	2	11	121
JH	19	17	18	- 2	7	- 7	9	9	0	0
WH	21	16	18	- 2	22	+ 8	9	3	6	36
BK	14	18	16	- 4	9	- 5	11.5	7	4.5	20.25
DM	28	18	23	+ 3	10	- 4	4	6	2	4
HP	19	17	18	- 2	8	- 6	9	8	1	2
WR	20	27	24	+ 4	20	+ 6	3	4.5	1.5	2.25
ES	18	17	17	- 3	- 1	-15	10	14	4	16
S"	16	17	16	- 4	- 1	-15	11.5	14	2.5	6.25
TH	27	25	26	+ 6	4	-10	2	10	8	64
JC	14	27	20	0	- 1	-15	6	14	8	64
BF	11	8	9	-11	3	-11	14	11	3	9
			Mean — 20 db		Mean — 14 db					

ρ (Rank Order Correlations) at Specified Test Frequencies.

2000 + 4000 cps = +.1
2000 = +.24
2200 + 2500 = -.004
4000 + 4500 = -.005
5000 + 5500 = -.39
6000 + 7000 = -.33
8000, 9000 = -.51

$$\rho = 1 - \frac{6\Sigma D^2}{N(N^2-1)}$$

ability to find their thresholds with continued use of the audiometer. The standard deviation of 1.4 db demonstrates, however, that even with a large amount of audiometric testing (each subject had an average of 10 pre-exposure audiograms) the audiograms are very consistent.

Actually, the effects of noise on hearing is taken as the difference between two audiograms taken in fairly close succession. This testing procedure is approximated if we take the first two pre-exposure audiograms for each subject and compare the difference between them. Doing this, we found, mean differences of +.5 db and -.7 db and standard deviations of 2.4 db and 2.4 db at 2000 cps and 4000 cps respectively.

These test-retest reliability data indicate that consistent differences between pre- and post-exposure audiograms of but 2-3 db at several critical test frequencies will usually be found with further experimentation to be statistically reliable differences and presumably attributable to some interviewing factor, such as exposure to intense noise.

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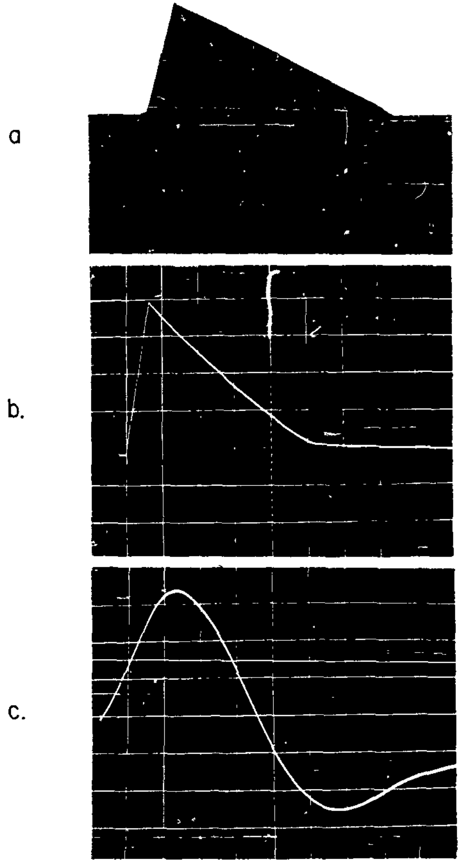

Figure 1. Photograph of
a. Photoformer Mask
b. Electrical Output of Amplifier
c. Acoustical Output of Speaker as shown on Oscilloscope
(The horizontal (time) scale in b. and c. is 0.2 millisec per div.)

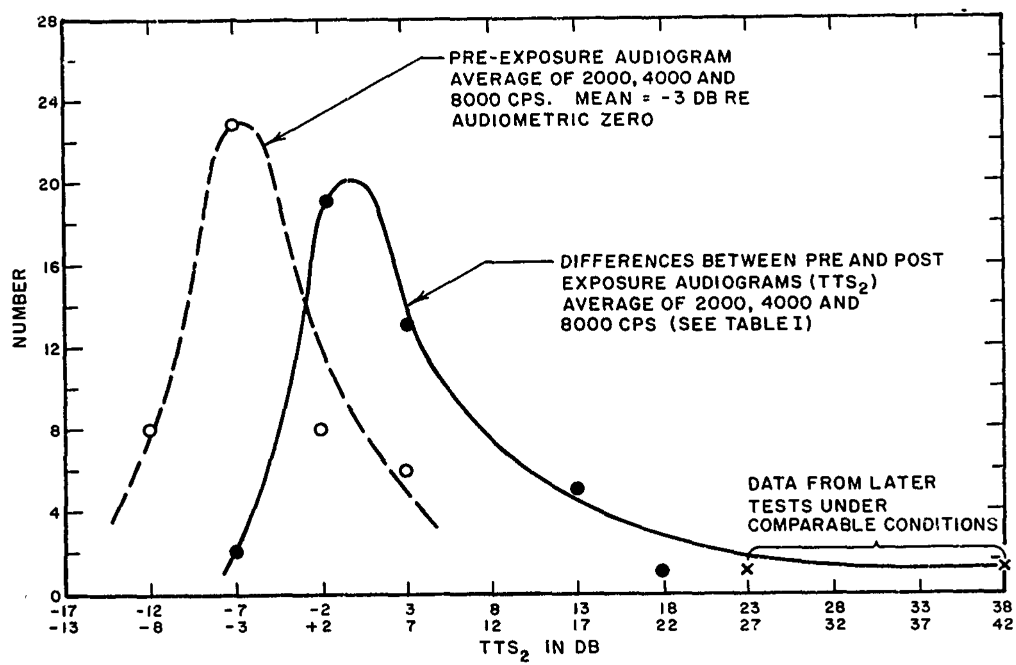

Figure 2. Pre-Exposure Thresholds and Difference Between Pre and Post Exposure Thresholds to Impulse; in DB

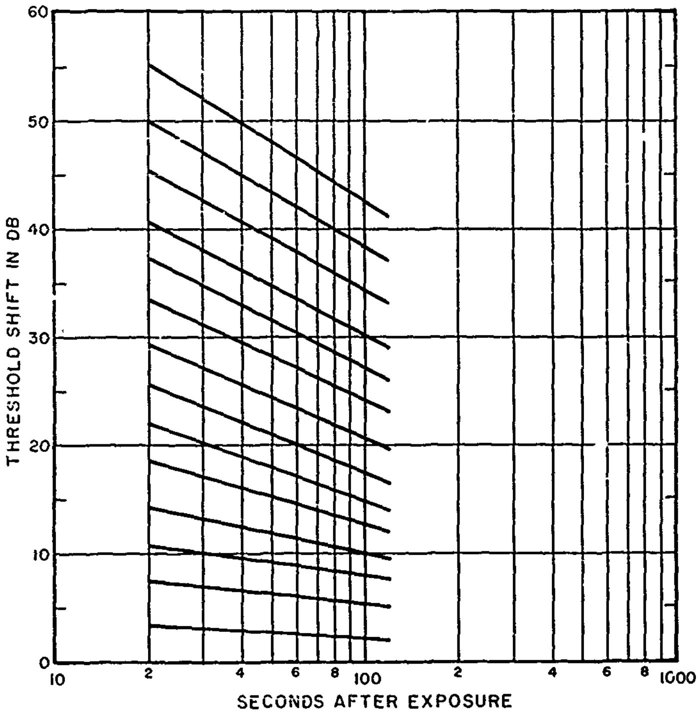

Figure 3. Recovery Curves Used in Estimating the Amount of Hearing Loss Two Minutes After Exposure (TTS_2) From Measurements Made 30 Seconds Etc. After Exposure

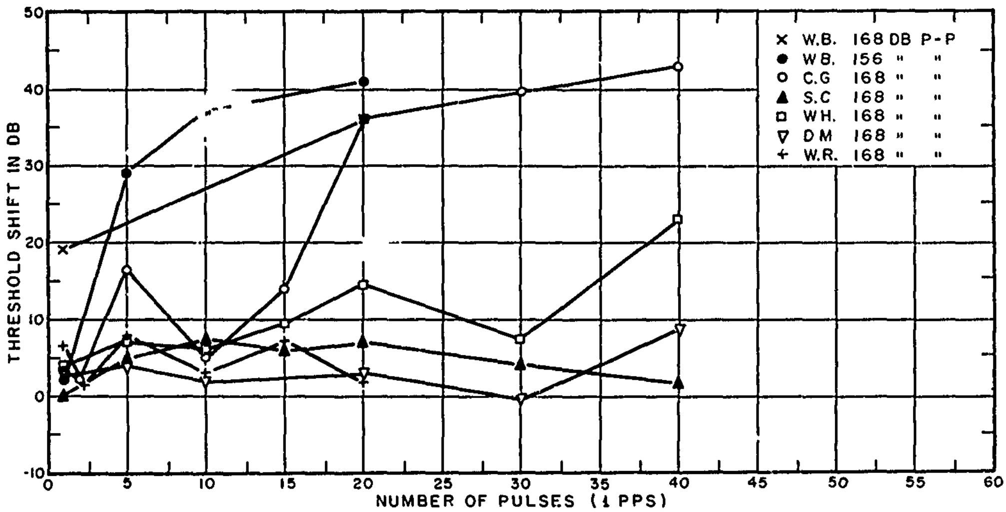

Figure 4. Temporary Threshold Shift for the Six "Most Susceptible" Subjects at 2000 CPS Two Minutes After Exposure. Parameter Is the Subject and the Peak to Peak Level of Pulses in DB

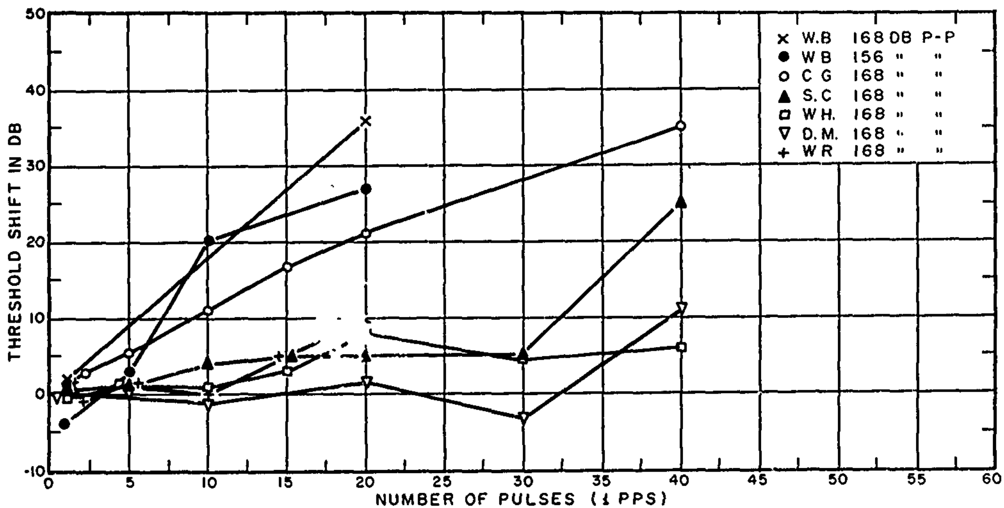

Figure 5. Average of Temporary Threshold Shifts for the Six "Most Susceptible" Subjects at 4000 and 4500 CPS Two Minutes After Exposure. Parameter Is the Subject and the Peak to Peak Level of Pulses in D

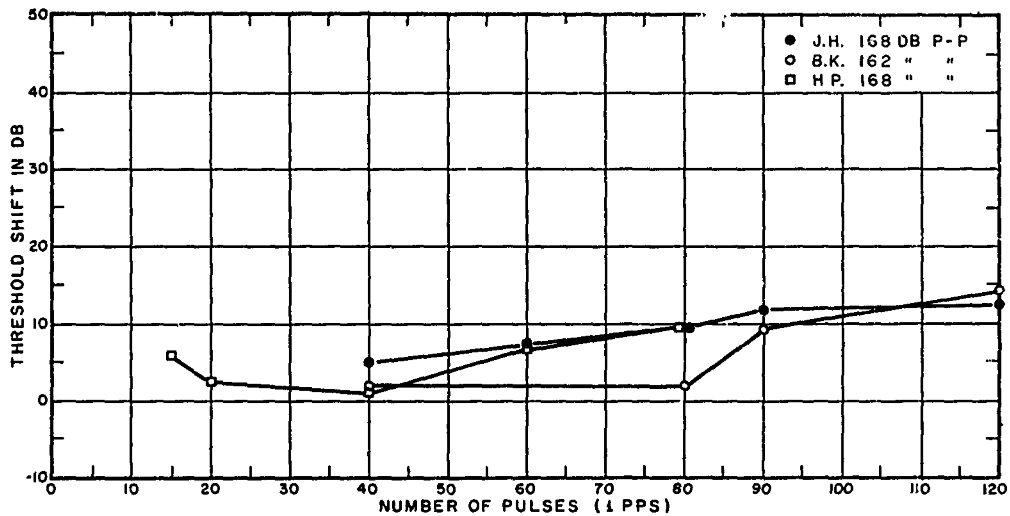

Figure 6. Temporary Threshold Shift for the Three "Next Most Susceptible" Subjects at 2000 CPS Two Minutes After Exposure. Parameter Is the Subject and the Peak to Peak Level of Pulses in DB

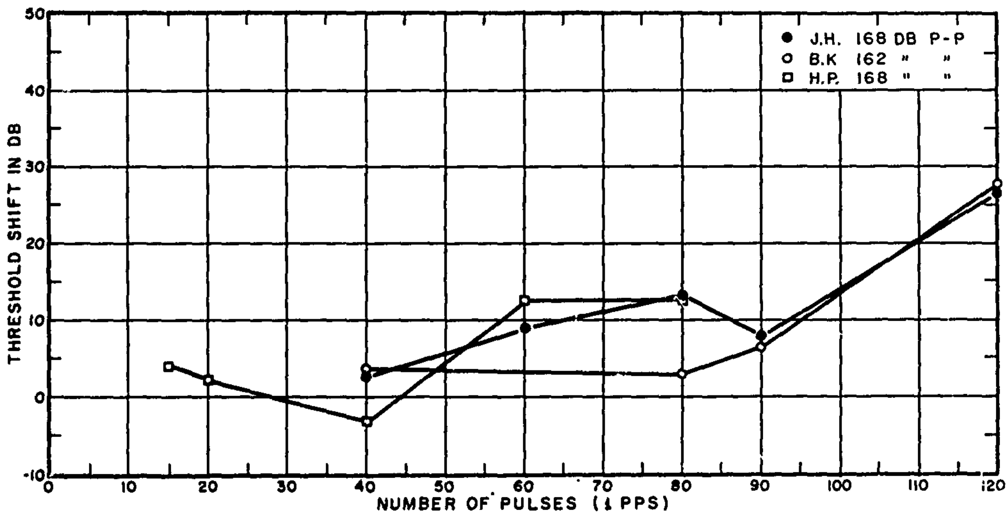

Figure 7. Average of Temporary Threshold Shifts for the Three "Next Most Susceptible" Subjects at 4000 and 4500 CPS Two Minutes After Exposure. Parameter Is the Subject and the Peak to Peak Level of Pulses in DB

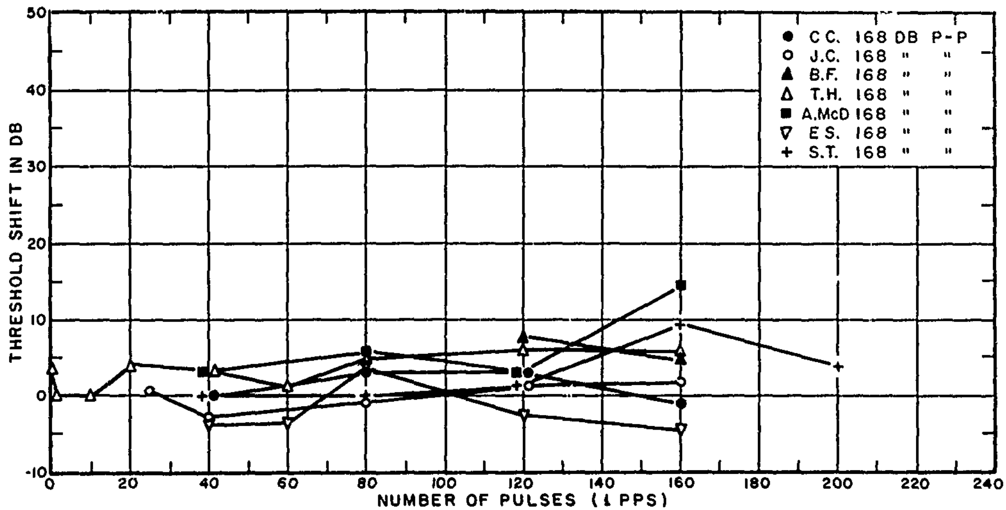

Figure 8. Temporary Threshold Shift for the Seven "Least Susceptible" Subjects at 2000 CPS Two Minutes After Exposure. Parameter Is the Subject and the Peak to Peak Level of Pulses in DB

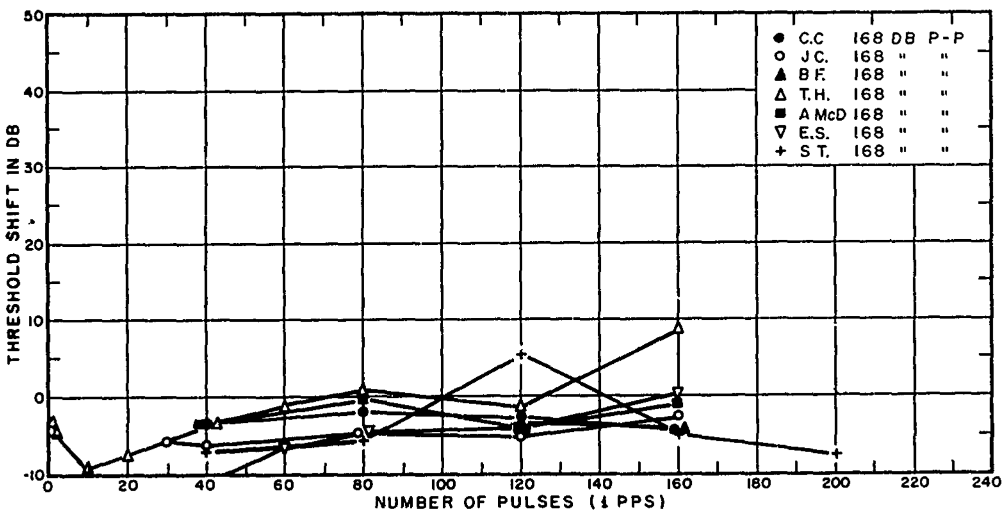

Figure 9. Average of Temporary Threshold Shifts for the Seven "Least Susceptible" Subjects at 4000 and 4500 CPS Two Minutes After Exposure. Parameter Is the Subject and the Peak to Peak Level of Pulses in DB

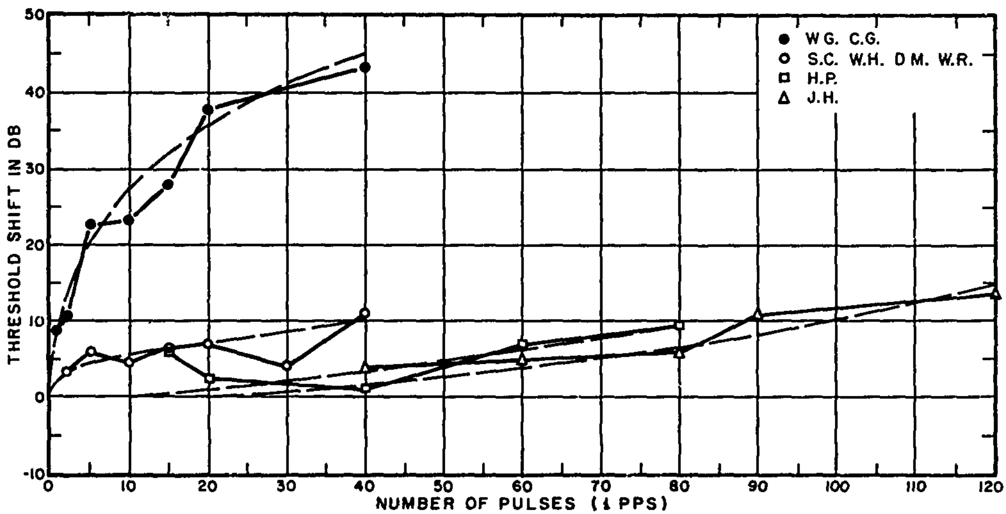

Figure 10. Mean Threshold Shifts at 2000 CPS Two Minutes After Exposure. Parameter Is the Subgroup of Subjects Used to Obtain Mean TTS_2

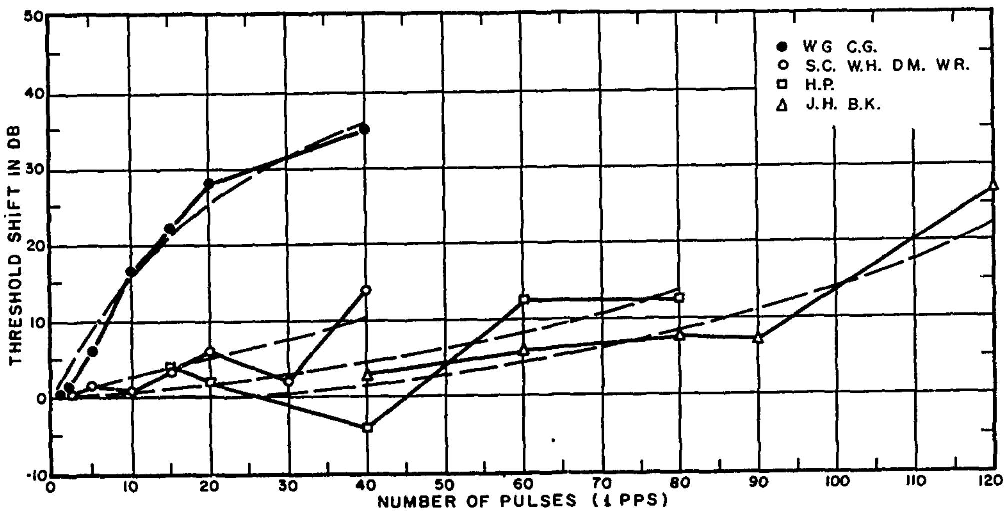

Figure 11. Mean of Average Threshold Shifts at 4000 and 4500 CPS Two Minutes After Exposure. Parameter Is the Subgroup of Subjects Used to Obtain Mean TTS_2

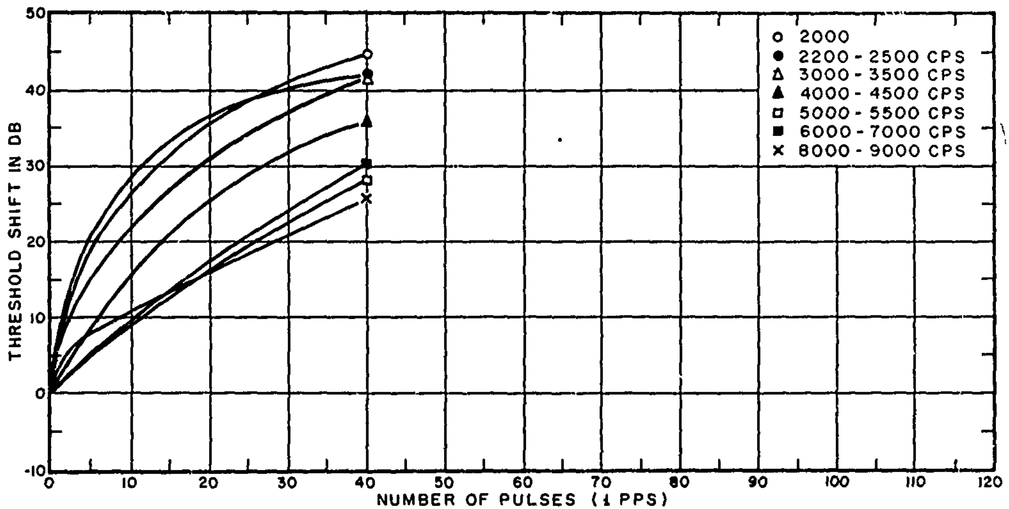

Figure 12. Smoothed Average TTS_2 of Subjects W.B. and C.G. Two Minutes After Exposure as a Function of the Number of Pulses. Parameter Is the Frequency of Test Tone.

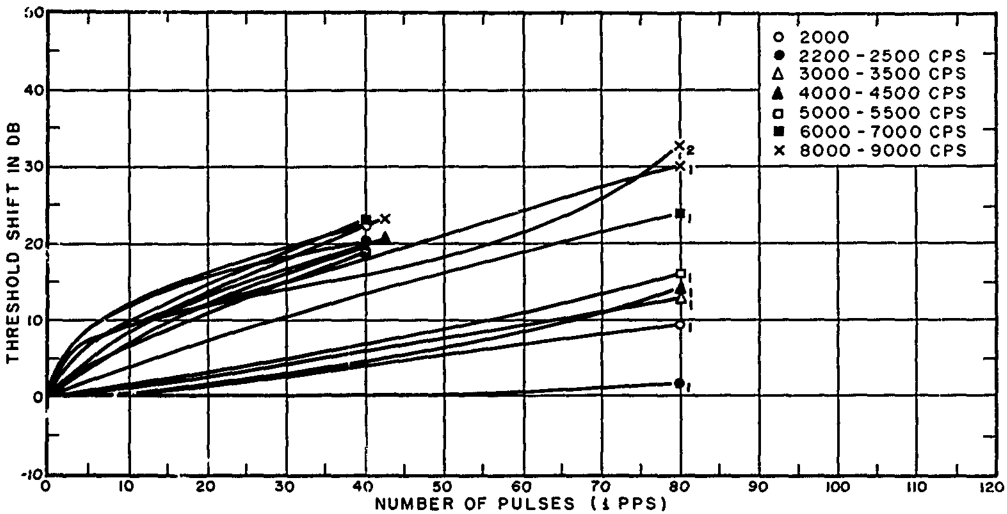

Figure 13. Smoothed Average TTS_2 of Subjects H.P. (With Subscript) S.C., W.H., D.M. and W.R. as a Function of the Number of Pulses. Parameter Is the Frequency of Test Tone

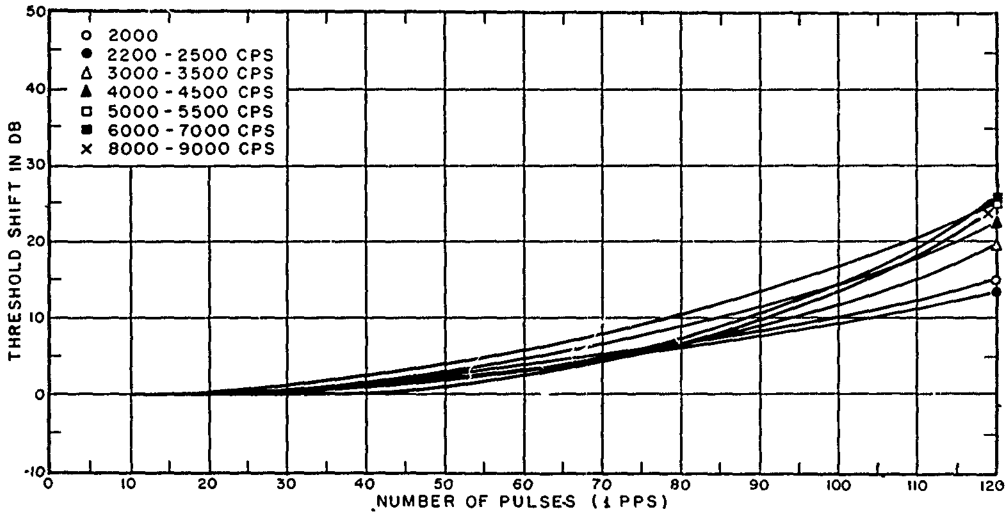

Figure 14. Smoothed Average TTS_2 of Subjects J.H. and B.K. as a Function of the Number of Pulses. Parameter Is the Frequency of Test Tone

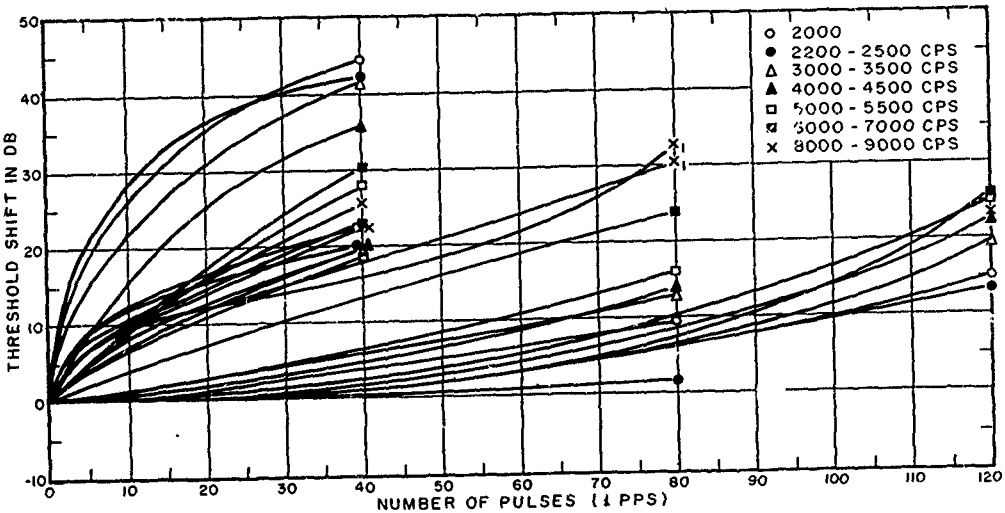

Figure 15. Smoothed Average TTS_2 of Nine Subjects as a Function of the Number of Pulses. Parameter Is the Frequency of Test Tone

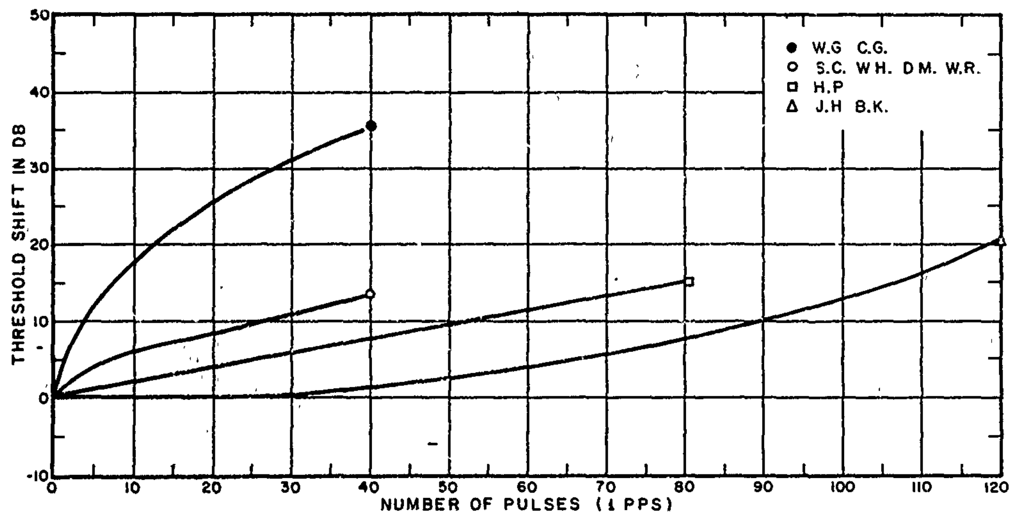

Figure 16. Average of Smoothed Curves of Figure 15 Over All Test Frequencies. Parameter Is the Subgroup of Subjects

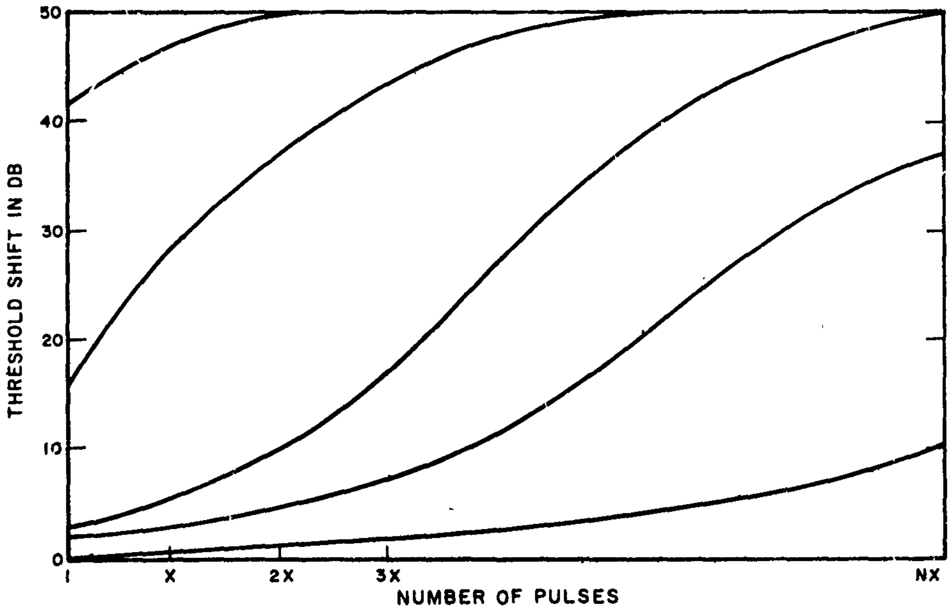

Figure 17. Hypothetical Relation Between Number of Pulses and TTS_2

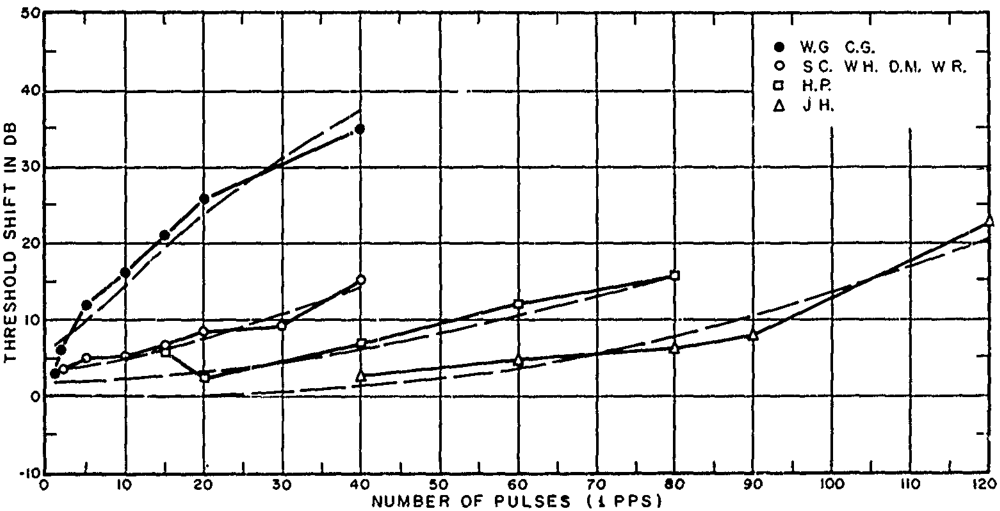

Figure 18. Average TTS_2 Over All Test Frequencies. Smooth Curves are Hypothetical Functions Relating TTS_2 to Number of Pulses. Paramete. is the Subgroup of Subjects

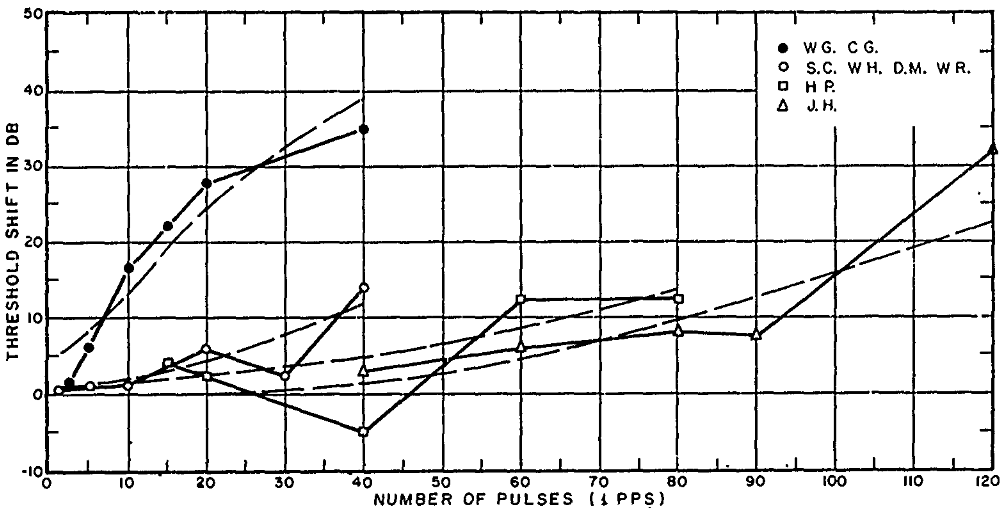

Figure 19. Average TTS_2 at 4000 and 4500 CPS. Smooth Curves are Hypothetical Functions Relating TTS_2 to Number of Pulses. Parameter Is the Subgroup of Subjects

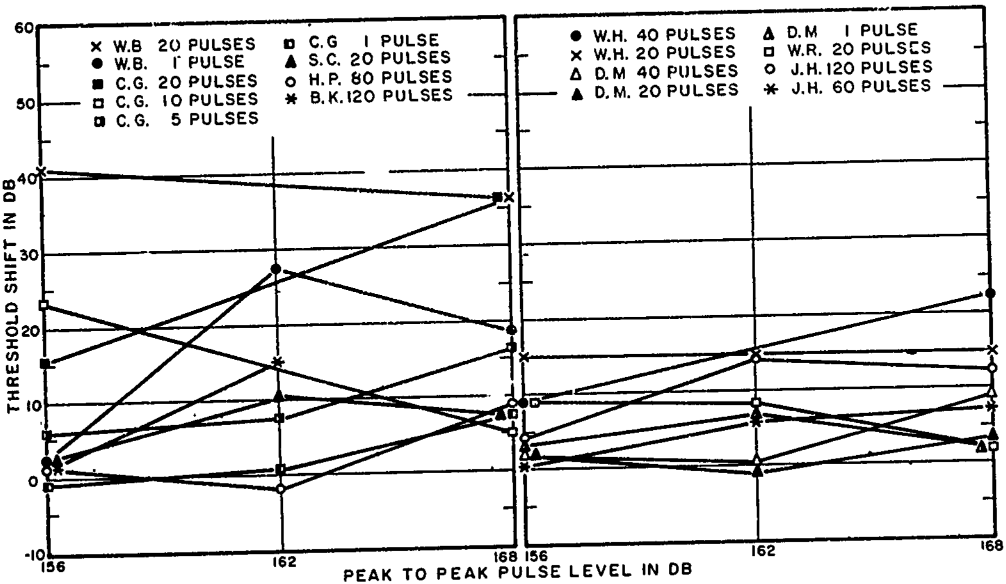

Figure 20. Temporary Threshold Shifts at 2000 CPS Two Minutes After Exposure to Triangular Acoustic Transients, 156, 162 and 168 DB Peak to Peak. Parameter Is the Subject and Number of Pulses. Repetition Rate is One Pulse per Second

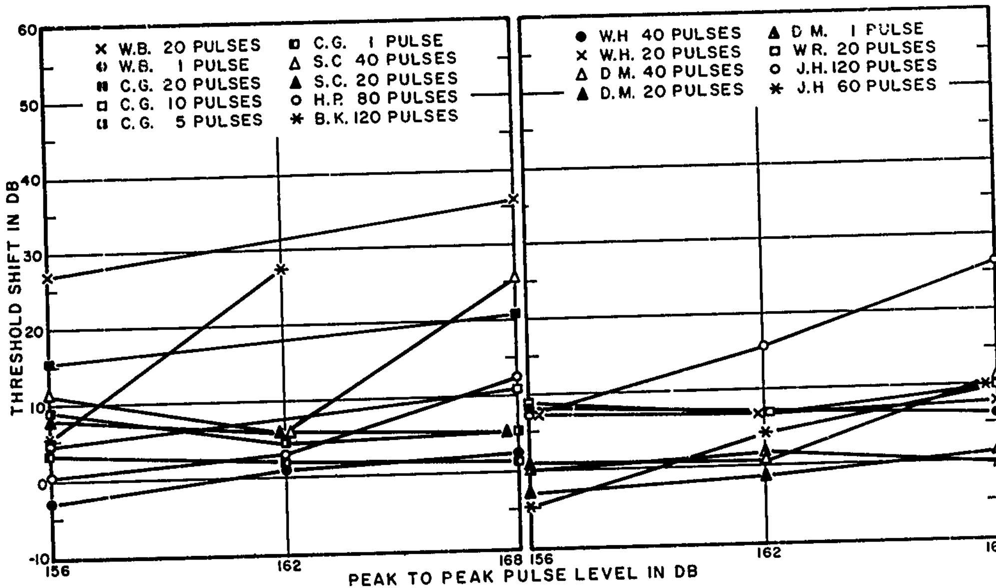

Figure 21. Average of Temporary Threshold Shifts at 4000 and 4500 CPS Two Minutes After Exposure to Triangular Acoustic Transient, 156, 162 and 168 DB Peak to Peak. Parameter Is the Subject and Number of Pulses. Repetition Rate is One Pulse per Second

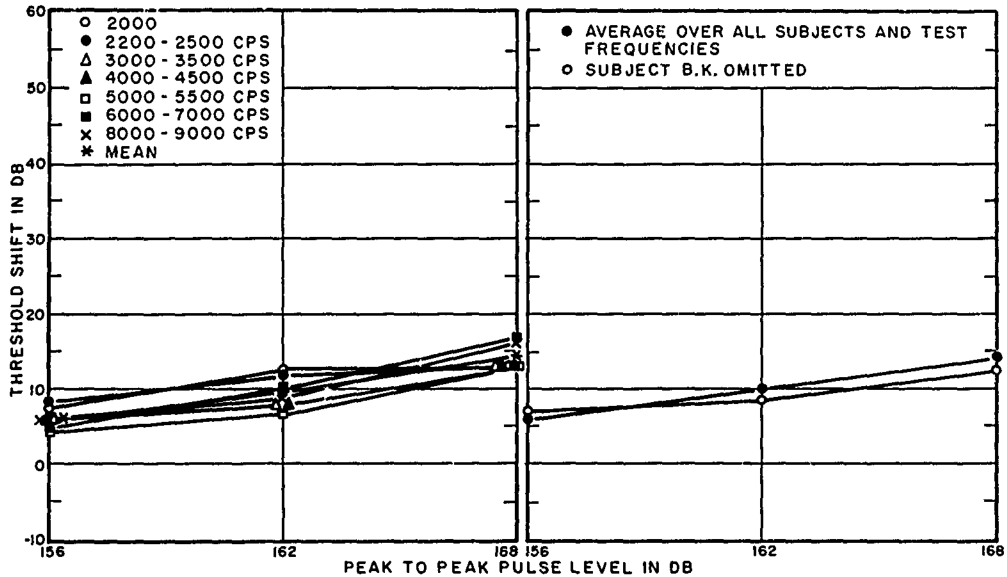

Figure 22. Average of Temporary Threshold Shifts Over All Subjects Two Minutes After Exposure t~ Triangular Acoustic Transients, 156, 162 and 168 DB Peak to Peak. Parameter Is the Test Frequency

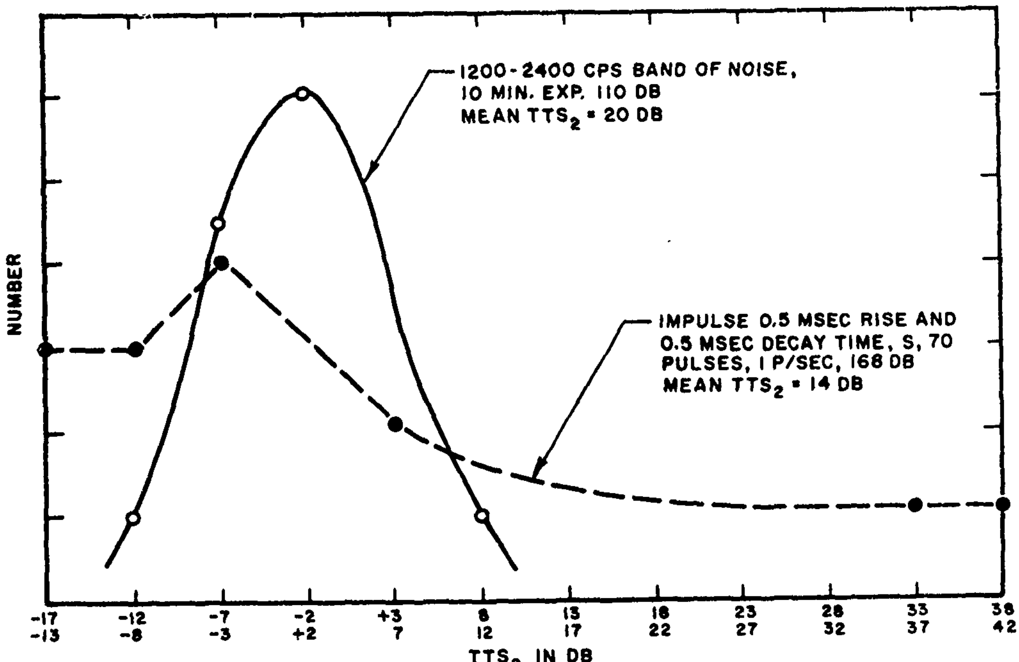

Figure 23. Distribution of Differences Between Mean of Differences and Differences Between Pre and Post Exposure. Average TTS_2 at 2000 and 4000 CPS

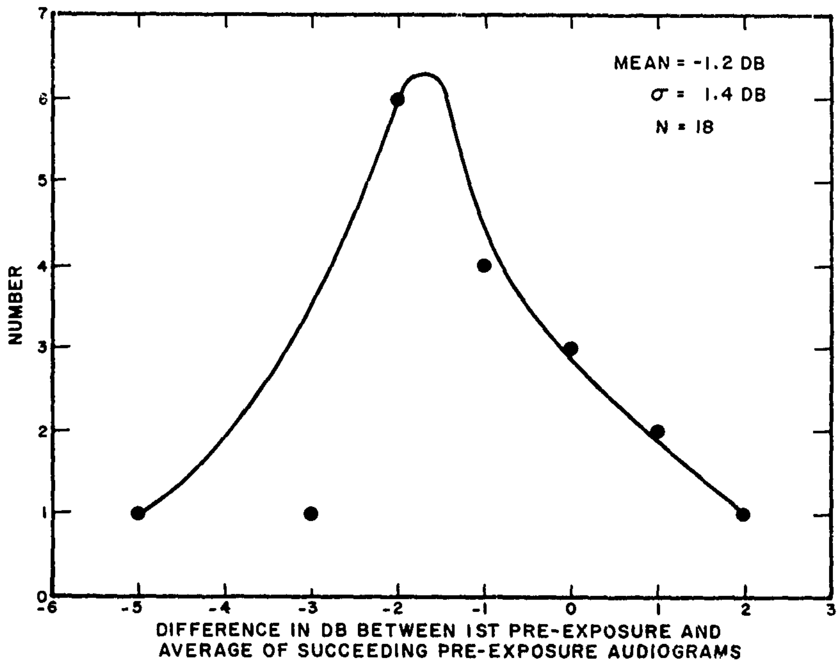

Figure 24. Mean of Average Differences at 2000-4000 CPS Between 1st Pre-Exposure Audiogram and Succeeding Pre-Exposure Audiograms for Each Subject

F. PANEL SUMMARY by Dr. Aram Glorig, Director, Subcommittee on Noise Research Center, Los Angeles, California

It is quite a pleasure for me to be here. It has been 10 to 12 years since the last time, and I remember it quite well because at the time I was carrying a 22-pound analyzer on one shoulder and a 3-pound sound level meter on the other. By the time I finished the trip through various military bases the analyzer must have weighed 75 pounds. At least I was sure it was over 22 pounds. At any rate the early work on some aspects of the military noise problem was, as you know, sponsored through Walter Reed Army Medical Center.

As far as industry is concerned noise was acknowledged as a problem in 1802 when it was first reported in blacksmith shops. The problem has been with us for a long time, but not much has been done about it until recently.

Believe me, it gives me no end of pleasure to see the work Dr. Fletcher and Dr. Karl Kryter and his group are doing for the military noise problem; it is high time. Although, as a very practical man, I sometimes wonder about controlling gun fire during war-time since it doesn't seem very important to save a man's hearing when he may get killed at anytime. However, I don't think this applies to the peacetime Army. If one considers the number of people who are sustaining severe hearing losses from gunfire it seems to me it is about time to do something about the human component of a mechanized Army and the conservation of hearing is a good place to start. It is about time we began to save wear and tear on humans as well as vehicles.

Mr. Erickson's paper clearly points out that the problem is not only noise control but noise exposure control. There isn't much need to quiet a machine if no one will be exposed to its noise. If we think of this in terms of noise exposure, the human relationship is much clearer. It might be well to remember that the military mission to be accomplished is something which can be done better over a longer period of time if human senses are protected against damage. We must take into account wear and tear on the human.

Dr. Fletcher's paper, presents a very fascinating subject. We are doing considerable work on the aural reflex in our laboratory. We should consider this type of research as more than "ivory tower" thinking. In this case the "ivory tower" has become the workshop. I think one can see a very practical result of basic research in the device that Dr. Fletcher has described. However, I would like to warn the group that this device does not necessarily eliminate other means of protection. There are advantages and disadvantages, and one of the disadvantages clearly evident in Dr. Fletcher's paper is that the protective effect of the aural reflex mechanism is extremely variable. There are so many factors that influence its action and even though it is proposed as a standard device we must remember that for some people it will provide a large amount of protection and for others very little. I am sure Dr. Fletcher did not intend the device to be a replacement for ear plugs or muffs but instead to furnish additional protection.

The work of Dr. Kryters group and of our staff on Temporary Threshold Shift (TTS) as a function of impulse noise clearly demonstrates that the TTS is not by any means the same sort of process as that which accompanies exposure to steady noise. The literature will state that TTS can be used to predict the amount of permanent threshold shift (PTS) that will occur on an average over a long period of time. We made certain assumptions in our laboratory several years ago which we are now finding to be more than mere assumptions. For example, we believe that if there is no TTS there will be no PTS (Permanent Threshold Shift). We now have shown this to be true in field studies where steady noise is concerned, but we do not know if it is true for impulse noise. From the data Dr. Kryter presented it may even be true for impulse noise. Dr. Kryter's data are encouraging to say the least. We also know that a certain amount of TTS can be sustained without producing a PTS.

We also know from TTS studies that some octave bands are more hazardous than others. If one looks at individuals with elevated thresholds one finds that noise exposure does not raise the threshold any higher than it would in individuals who have a normal threshold. The amount of shift is more, but the maximum hearing level is no higher. We can also determine quite well that adequate damage risk criteria can be proposed on the basis of TTS studies. As a matter of fact the International Standards Organization has recently proposed criteria on the basis of TTS studies done in our laboratory and confirmed in others.

The experiments that were described by Dr. Kryter have in the main substantiated the experiments conducted in our laboratory. We found that when steady noise is the exposure TTS increases as the logarithm of time. This is a very definite law that holds quite well for steady noise, but not with impulse noise. Impulse noise seems to have a linear relation to time. The mechanism of the change from steady noise is not well understood. We think it is a biochemical change that takes place over a long period of time. Dr. Kryter called it fatigue; I am not too sure fatigue is the proper word, but at least it is descriptive enough for the present. In the case of the impulse noise I don't know what happens in the inner ear. We know that in animals high level blasts produce actual displacement of the organ of Corti. It appears that there must be a combination of mechanical change and a biochemical change in the presence of impulse noise. The variability of the effects of impulse noise is quite evident. One should expect this. The effects of such rapid transients on the ossicles with all the individual differences in ossicular function and the changes in transmission through the canal are bound to produce variability. The aural reflex action itself is as different as individuals. Some people can contract the stapedius voluntarily. We have 2 or 3 men in our laboratory who can produce about 30 dB of attenuation on demand.

There is one last remark I would like to make that I think is extremely important. Out of all the work on impulse noise there is slowly emerging the beginnings of a hazard criteria for impulse noise. If one searches the literature one will find that all kinds of criteria have been mentioned for steady noise, but everyone studiously avoids damage risk criteria for impulse noise. We are beginning to see a way out of the dilemma from work like Dr. Kryter's, Dr. Fletcher's and our own.

When the peaks in impulse noise reach 140-145 dB one should be sure ear protection is available. Below this it seems to be an individual problem. Most people do not show much change if the level is below 140 dB. At 130 dB impulse noise produces very little TTS. If we leave this conference with no more than the suggestion that we can do something about impulse noise criteria it will have been worth while.

Thank you.

CHAPTER 6
ADVANCED METHODS IN HUMAN FACTORS RESEARCH
CONFERENCE SESSION IV

A. THE ENGINEERING OF TRAINING: Meredith P. Crawford, Director, Human Resources Research Office of The George Washington University, Washington, D. C.

B. COMPUTER SIMULATION IN HUMAN FACTORS RESEARCH. Lee W. Gregg, Carnegie Institute of Technology, Pittsburgh, Pennsylvania

A. THE ENGINEERING OF TRAINING by Meredith P. Crawford, Human Resources Research Office (HumRRO), George Washington University, Washington, D. C.

The topic for this presentation "The Engineering of Training" has been chosen for several reasons. First, since this is a Human Engineering Conference, I thought I might capture your attention by the use of the term Engineering As you will see, however, I plan to use it in a different way than is ordinarily understood in human engineering circles. Second, the title was selected because all of us human factors people in the Army are concerned with the fabrication of useful products for the Army, and in that sense we are all engineers. Third, as I review the research and development work done in HumRRO over the past eleven years, I find that the concept of engineering is helpful in clarifying my thinking about where we have been and where we should go. Finally, I believe that an examination of the meaning of the term engineering and, in parallel, a review of the meaning of the term research may be helpful in our consideration of the areas in which and the means by which the several Human Factors agencies and laboratories within the Army map compliment and supplement each others' work for increased benefit to the Army.

Webster defines engineering as "the art and science by which the properties of matter and the sources of power in nature are made useful to man in structural, machine, and manufactured products". I would emphasize the "...useful to man" aspect of this definition Research, by contrast, is defined as ". diligent and systematic inquiry or investigation into a subject in order to discover facts or principles". While not wishing to deny the ultimate utility of research, the contrast I wish to emphasize between engineering and research is the immediate utility of the final product.

The entire research and development effort of the Army is concerned with the design and construction of both new and improved man-machine or man-weapons systems. The engineers and scientists within the R&D family devote primary attention to one or the other of the two kinds of components to these systems - hardware or human. It is apparent that the main effort and expenditure goes into the hardware component because revolutionary breakthroughs in physical sciences and the traditional branches of engineering have markedly extended the capabilities of the hardware component, improving the system's ability not only to move, to shoot, and to communicate, but even to sense, to compute, to remember and to handle information. These gains in the capability of hardware components of systems have clearly improved the effectiveness of the man-machine systems of the Army, so that, for example, the fighting soldier is no longer a man-musket system with limited offensive potential but is a man-missile system with tremendous power. In view of these remarkable advances in the improvement of hardware components, some observers may be inclined to ask: "Is the Army trying to fit a relatively primitive M-1 man to a sophisticated M-100 piece of hardware?"

We Human Factors people would resent such an observation, and rightly so, but it may be worthwhile to examine its implications to review what we have accomplished and hope to achieve. For purposes of discussion, let me proceed for a few minutes with an analogy. May I compare and contrast the design and production problems, if you will, of the hardware component and the human component of the typical man-weapons system.

1. Both types of components must be designed in terms of the purposes and limitations of the man-machine system as a whole.
2. Both must be designed to perform the functions which are allocated to each in the overall system design.
3. Both must perform within the system with a degree of individual reliability that will result in acceptable reliability of the system as a whole.
4. Both must be capable of rapid and economical production.

Even to forestall your observation that pressing this analogy bespeaks a callous and dehumanizing point of view, I will not elaborate the obvious by listing all of the contrasts between these two kinds of components. I will only list a few which bear directly on my topic of "The Engineering of Training:"

1. The human component is a member, not only of the man-weapons system specified in his duty assignment, but also of a number of social systems within and outside the Army.
2. The human component changes with time as a result of experiences which occur within the occupational system of primary interest or in the course of his membership in other systems. These experiences may improve or degrade performance in the man-weapons system of interest.
3. The human component by no means realizes his full potential as a human being simply as a functioning component of a single man-machine system. It may be observed, however, that the more central or commanding a role the individual plays in a large system, the more nearly does he have opportunity to employ his entire range of abilities.

Having suggested these similarities and differences between the two types of man-machine components, let me carry the analogy further by discussing the problem of design and production of the human component for Army man-machine systems. Few men enter the Army with all the necessary knowledges and skills to assume immediately a role in an Army man-machine system. A human component needs to be "fabricated" from the raw material of recruit or officer candidate. The means for this fabrication or production is training.

Logically, the design of the component should precede the design of the production process, and component design considerations should be limited by the practical possibilities of the production process. Ideally, the designers of Army man-weapons systems should go about their work with the full knowledge of the potential capabilities and limitations of that sample of human beings from which the human components for the system will be produced. That this is not now the case, at least in as full a measure as we might desire, is due in part to our own inability, as human factors specialists, to provide this knowledge, as well, perhaps, as lack of awareness on the part of designers of what useful information is already available. Various efforts by all Army human factors agencies are contributing to an improvement of this matter, but to trace these developments would be beyond the scope of this paper.

So far, I have introduced the terms engineering and research, have compared and contrasted the human and hardware components of the man-weapons system, and have spoken of the difficulty in achieving simultaneous and equal consideration of design problems of hardware and human components. I wish now to outline a scheme, or series of steps, for the engineering process required in building a training program which will produce a specific human component for a particular man-weapon system. Of necessity, this schema has a dual purpose to design the human component and to design the training process by which the human component is produced. While the elements of this schema are not especially new or unique, their combination and specification in this form has been induced from HumRRO experience over the past several years.

Figure 1 represents, in diagramatic form, a sequence of activities which is required in the engineering of a training program. While the division of labor within these steps is somewhat arbitrary, I believe they include the essential things that have to be done. Each will be discussed in turn.

Analysis of the Military System from the Human Factors Point of View.

The military system, whether it is an existing infantry squad, a contemporary artillery battery, or a proposed weapon-system still on the drawing board, must be analyzed as the necessary starting point for a determination of the characteristics required of both the hardware and human components. The human factors aspect of the analysis is the basis for determining what the individual man will do, in each position, and with what equipment he will work. This analysis forms the basis for job specifications and functions allocation. It is at this system analysis step that it should be possible to determine the relative contributions to the performance of the human component which may be made by research in selection and classification and by what has traditionally been known as human engineering as well as what must be accomplished through training.

The balance of effort among these three kinds of human factors work can be determined during the system analysis. In the case of a particular system, and a certain available supply of manpower, the solution may involve much more effort along one of these three lines than the other two. Thus this system analysis from the human factors point of view is a responsibility which should be shared by all Human Factors Agencies. It is also in this step that attention is given to some of those characteristics mentioned earlier which are unique to the human component and result from his membership in several systems. For example, it would be determined whether or not the people involved in a particular system are expected to move about within the system from job to job or leave it for other jobs in other systems. Thus, career development has an important bearing on training. Also in this analysis, attention would be given to the general physical and social environment in which the system is to operate, since the characteristics of these environments have an important bearing on the continued reliability of performance of the human component. Doctrine of employment of the system would be considered as it forecasts extra-systemic influences on the human component.

Analysis of the particular job. Next, out of the analysis of the operational system, the particular job is studied to determine the inputs to the job from the rest of the system, and the outputs which are required from the job. Job analysis for training must be much more detailed and precise than that used for descriptions in personnel classification manuals. To support effective training programs it is necessary to analyze the tasks in stimulus-response terms to determine the forms of behaviors they require.

At this point in the developmental sequence, a division of labor is introduced. On the left-hand side of the figure are shown the steps involved in developing the curriculum of the training program itself, while the right-hand side pertains to the measurement of job proficiency. These efforts come together in the evaluation step at the bottom.

Specification of knowledges and skills. Within the parameters of required inputs to and the outputs from the job, the processes by which the individual makes these transformations are identified. Here the interest is to find out what kinds of knowledges and what sorts of skills the man has to possess in order to do his work. Here we attempt to "look inside the man," in a sense, to see, in psychological terms, what kinds of processes - like sensing, discriminating, remembering, deciding, and reacting - are required for him to function in the job. We must determine what must be done and with what accuracy and with what speed. We need also to find out what cues indicate that an action should be taken and what feed-back is available to tell the man how well the task was done. Social or inter-personal skills must also be considered when the job involves cross-cultural communication or crew coordination or leadership. It is especially important to determine here the minimum number of knowledges and skills which are required, lest time be wasted on training on irrelevant, nice-to-know information.

Determination of training objectives. From the knowledge and skill specification, and from an assessment of the probable content of the repertoires of persons to be trained, it is now possible to state in fairly precise terms the objectives of the training program as a whole. The goals may be limited to the specific job or they may contain elements furnishing preparation for other jobs later in the man's career. At this point, we consider the level of proficiency which the man is expected to have at the end of training, a matter which we will discuss in the step shown on the right-hand side of the figure. Here again we see the interaction of training research, selection research, and human factors engineering. If people can be selected who already have a large number of relevant skills, training time can be reduced. If the operation of the equipment can be simplified by modifications of dials, meters, and controls, training can be simplified. Furthermore, at this point, it is possible to decide about an optimum combination of school and on-the-job training, as well as the kinds of aids, such as manuals and check lists, which will be made available for use on the job.

Construction of the training program. This step involves the selection of specific subject matter to be used in the curriculum, the programming of instruction, and the special techniques which may be designed to motivate the trainee. Opportunities for practice may be provided in the form of training devices and simulators. The characteristics of such equipment may be more accurately specified at this point than is often the case when only the characteristics of the hardware are taken into consideration. Included in this "package of training" are achievement tests for each part of the program which provide a measure of the student's progress and are designed to keep up his motivation. These tests measure only the acquisition of knowledges and skills, and should not be confused with measures of the total job performance, which is accomplished by the proficiency test indicated on the right of the figure.

It is within this step that the most rapid advances are being made in the technology of instruction. Generalized principles of human learning are finding specific application in programming for automated instruction. In preparing material for presentation in teaching machines, scrambled books or other media of self instruction, programmers are discovering that the subject matter must be examined very carefully to be sure that each frame is meaningful and relevant to what the student is learning to do. The steps which are outlined in this diagram specify a method by which such precision of statement can be achieved.

Development of measures of job proficiency. Moving now to the right-hand side of the figure, we follow the line from the analysis of the job, which specified outputs or products of the job, down to the box labeled "Development of measures of job proficiency". In concept these are detailed and realistic, performance-type tests of the job as a whole, and they yield objective, numerical scores which measure both skill and knowledge. In so far as possible, the test situations simulates the inputs to the man as he would receive them from his position in the military system, yet isolates him from it in order to measure his individual output. In building these proficiency measures, we must seek military advice, especially as to the determination of acceptable standards of performance.

So far, we have been able to use only global judgments by military experts as to minimum standards of proficiency. As the technology develops, we hope to be able to derive, from the original system analysis in a mathematically elegant manner, the minimum proficiency required of each human component to provide acceptable system output. Also it is desirable, though not yet very feasible, to have this proficiency test yield a measure of reliability of performance over continuous operation within the system. This would probably require a complete system simulation rather than simulation of the output of a single job and would introduce several complications into the measurement of individual system output.

Evaluation of the training program. Finally, at the bottom of Figure 1, the effectiveness of the new program is evaluated by measuring the performance of the representative sample of soldiers trained under the new program. In some cases it may be a matter of comparing an old with a new training program toward the adoption of that one which yields higher proficiency and perhaps at less cost in time and money. In any event, it is a necessary step in determining the effectiveness of the entire training procedure which has been developed.

This combination of steps now serves as a useful guide in planning those research and development activities which we in HumRRO have come to call "Individual Curriculum Engineering". With the schema as a frame of reference, I would now like to discuss three topics.

1. The relation between research and engineering in training research and development.
2. The points at which this series of steps is most in need of improvement and elaboration.
3. The points in this schema at which all human factors agencies have a common interest.

When we grant that the principal business of those of us in training research and development is engineering, we face the very interesting question of the place of research in such an enterprise. The definition of research used earlier emphasizes the search for general principles. These general principles are useful because they relate to concepts which can be identified in many situations. By contrast, the accumulation of experience in a number of specific, individual curriculum engineering jobs raises the difficult question of the extent of possible generalization from specific findings to new problems. As we all know, the main difficulty lies in the fact that a great many variables are in concurrent operation in the engineering study so that the resultant is dependent upon a particular mix of these variables. In so far as we can reproduce the variables in a real Army training situation, we can forecast that the training program we develop will work in the field. The problem is, how can we judge whether the conditions which worked in one situation will work in another? Sometimes a common sense guess turns out to be correct, but we would like to have a more dependable means of moving from one engineering finding to another.

It appears that, for the immediate future, we must be satisfied to make the best use we can of isolated observations on the kinds of treatments which have worked in particular situations, sorting these out as best we can and placing them together in as similar context as possible. It is my belief that from sorting the isolated relationships we find in engineering studies, we will be able to identify certain areas in which more general relationships probably obtain. From this common sense type of sorting we hope to be able to pose hypotheses which can be tested under the rigorous conditions of research, and should be able to persue such research with some assurance that the variables so identified are important in practical situations and are worth the labor of controlled experimentation.

My second topic concerns how we go about improving the technology of training engineering - in the current instance, improving the state of the art in each of the seven steps. Our level of expertness differs for each step. I believe that the most precise technology exists for the building of proficiency tests because, in large measure, this is a matter of simulating the real operational situation. Limitations of equipment and terrain as well as time, are the chief obstacles. Also, with some ingenuity, objective ways of recording and measuring behavior can be invented. For the last step, experimental evaluation of the training, statistical techniques exist which are adequate, leaving only some interesting questions about the interpretation of differences in terms of statistical significance and practical utility.

The technology for the construction of the training program is by no means complete, but rapid advances are being made in this area. Much of the work being done in automated instruction is essentially of a technological nature, and a great many practical findings are coming out of the extensive engineering efforts in programming. Thus the technology of curriculum construction is making real progress. Some more basic research studies in progress in HumRRO and elsewhere having to do with fundamental questions as the absolute difficulty of a unit of learning are also adding to our knowledge.

The steps which are most in need of technological development are the early ones in the sequence: system analysis from the human factors point of view, analysis of the job, and specification of knowledges and skills.

I believe that it is in these areas that the various parts of the human factors program can be of most assistance to one another. This is my third topic. Let me elaborate on it. We have all been much concerned of late as to the methods of doing an analysis of a man-weapons system from the human factors point of view. Fortunately, a cooperative effort in this area has begun under the direction of the Human Factors Research Division, Office of the Chief of Research and Development, Department of the Army, in which selection and classification, human engineering, and training research people are working together. From such study we hope to learn a great deal about the kinds of "trade-offs" that can be effected between the ways of improving a system from the human factors point of view. We need to learn how to estimate costs in terms of selecting a certain sample of the manpower pool with special abilities, versus the costs of training men with less aptitude. Similarly, we need to learn how to estimate the production costs of various options in hardware design which options are taken to facilitate the manipulation and control by human beings of limited background and aptitude characteristics.

Perhaps the most important basis for such a system analysis is the precision with which a task and skill analysis can be done. These units of behavior determined by such an analysis, constitute the common denominator between all the human factors efforts. We need a great deal more study on how to define a unit of behavior and how to specify the cue-response relations within a given task or operation. This kind of study, the taxonomy of behavior, is fundamental to the work of all human factors agencies In so far as we can make progress in such study and to effectively divide our work, we will be in better position to share data. When we are able to name and classify, with a common understanding, all sorts of components of military performance, we will be able to specify indices of difficulty of training in human component behaviors, to select and classify with more precision, and to foresee the problems of adapting hardware components to facilitate fundamental kinds of behaviors.

In summary, this presentation began by citing various implications of the term engineering, and in discussing the engineering of human and hardware components. By elaborating a schema for the engineering of training I have attempted to specify things which training engineers must strive to learn through collation of engineering findings and fundamental research, and in addition, to point out, within this schema, points at which all human factors agencies within the Army may plan profitable interaction.

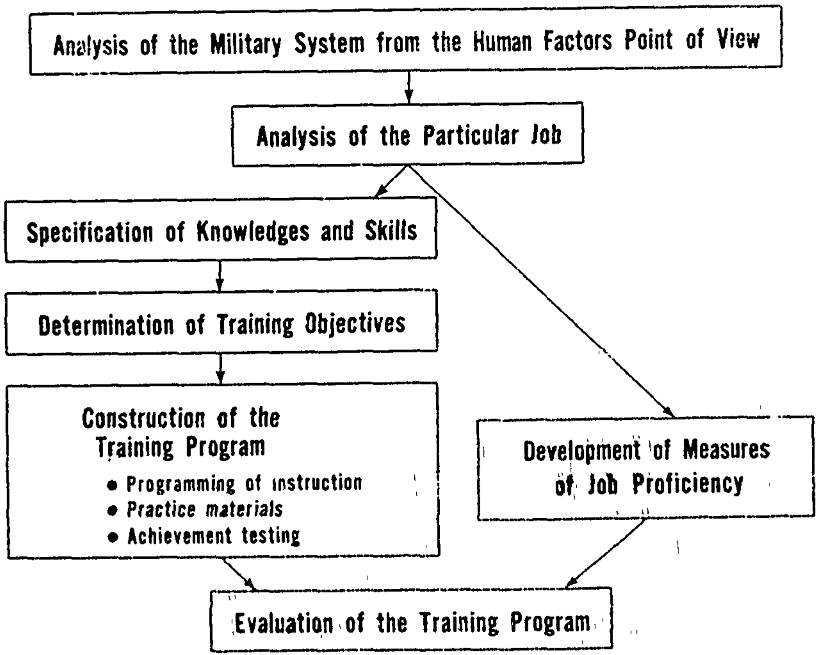

Figure I. Steps in the Development of Training

B. Computer Simulation in Human Factors Research by Lee W. Gregg, Carnegie Institute of Technology, Pittsburgh, Pennsylvania

One important part of any research effort is to find an appropriate model or way of conceptualizing the thing that is being investigated. In the physical sciences and engineering, progress in research can be linked very directly to the development of more powerful mathematical techniques. In human factors research many of our most powerful mathematical tools fail us—partly because of the nature of the complex interactions present in man-machine systems; partly because of the lack of a uniform dimensional structure for measuring man and machine performance. The purpose of this report is to relate some recent developments in computer technology to the problem of describing man-machine systems of the sort that human factors specialists might encounter.

Human factors problems arise in the design and development of man-machine systems in two ways. The first calls for an understanding of uniquely psychological aspects of human performance. Man, as one of several components of a larger system, is able to perform a variety of actions that depend on his perceptual or intellectual capacities. How best to specify precisely what the functions are so that function allocation—the division of effort between man and machine components—can be made appropriately is the source of innumerable specific questions. We have only partial answers to these questions even though much of experimental psychology, both individual and social, and the special interests of engineering psychology deal with the same set of questions.

A second souce of human factors problems comes about when we treat the human component of the system as a biological, rather than a psychological entity. Human tolerance to stress, adverse environmental conditions, or simply to work and effort determine the limits of performance of a human as an individual systems' component and, hence, the limits of whole-system performance. Here, the purely sensory and motor capabilities of man and his physiological reactions to trauma, in both brief and prolonged exposure, make up the problem areas.

Whether our research goals lead us to consider either psychological man or biological man, the focus for the solution of human factors problems is in finding a way to represent complex, interacting relationships involving human behavior and a changing environment. Usually, one part of the environment is composed of other units—other men or machines—so that the behavior of interest is that of the composite. The changes that occur do so as a function of time.

These facts lead us to the following statement of the requirements for understanding what a system is and how it works.

1. The model should be able to predict or generate "instantaneous" values of composite behavior during the time that the system is being studied.

2. The model should be able to show the relative contributions of component behaviors and their separate relationships to the composite behavior.

3. The model should provide a structure of sufficient generality that behavioral predictions from it are possible in a changed systems' environment and with changes in the systems components and their configuration.

Models of Systems.

Systems behave in time. This is, perhaps, the key aspect of system theory that imposes limitations on the choice of available models. If the system is simple enough and the behavior to be predicted by the model is well understood, it may be possible to write the differential equations that rigorously express changes in performance as a function of time. 'Well understood' behavior implies dimensionality in space, time, and mass units of conventional physical measurement.

There are a few ways in which we can cheat a little on our understanding of system's behavior, but apparently retain rigor in a mathematical model of the system. If changes in the system's components are slow enough, assuming a "steady-state" may make it possible to use constant coefficients and sets of linear equations from which response to time varying inputs can be predicted. Why is this cheating? Breaking the problem into a series of discrete stages is not cheating, but glossing over the mechanisms that lead to non-linearities is. Idealized models may be constructed where known functional properties of the system are ignored. Weather analysis and prediction today is moving into this stage of explanation. Of about seven known equations, only two or three actually enter into numerical prediction for idealized parcels of relatively high altitude air masses. In the extreme, focusing attention on input-output relationships that have been empirically obtained may make it possible to describe the transfer functions of a system. Through experimental analysis, useful results may be achieved, but these expressions, since they completely ignore the mechanisms by which behavior is produced, can scarcely be considered models of the systems.

The bulk of the stimulus-response relationships in the psychological literature represent "theory" in this form. These psychological laws, however, imply still another approach to modeling complex sustems. In contrast to the exact solutions of a completely deterministic model, probabilistic models invoke random variables to describe the expected values of effects produced by subunits.

Of course, it's entirely possible that some very basic physicological or psychological mechanisms can best be described in probabilistic terms. But, intuitively, the modeling of an artificially created system—one that is designed and developed to achieve specific goals—should be deterministic rather than probabilistic. After all, an evaluation is directed toward this particular system's performance, not the average performance of several systems alike in some respects, but different in others. This intuitive conception has clinical overtones. We want to know, in so far as is possible, how one particular unit behaves in contrast to a statement of the form that 60 per cent of the defined population will exhibit such behavior. All of our engineering training argues that system design should not incorporate unreliable components that perhaps will function as expected at a specified time, perhaps not. The involved and evolved, not-so-artificial human may exhibit behavior that is intuitively less deterministic. Yet, it appears that we too often are ready to plug in a random generator rather than attack the sources—some of them quite well established—of variability. The computer simulation models, it will be argued, provide a tool for understanding that should make it easier for us to incorporate deterministic mechanism more elaborate than ever before into our own thinking about complex systems.

Computer Simulation Models.

The new developments in computer technology have little to do with improved hardware. The important achievements emerge from innovations in the programming of computers. The invention of regional and symbolic addressing conventions and the development of translation facilities (pseudo codes and compilers) have increased the power and capabilities of the machines largely by making it possible for programmers to conceptualize ways of solving more and more difficult problems.

One basic idea, however, stands out. The computer simulation models of the sort we will be concerned with owe their existence to the simple fact that the symbolic manipulations carried out by the computer need not be numerical, arithmetic operations but can be any processes for which rules can be specified. The symbols need not be numbers. After all, the circuitry of the machine simply provides a format for representing numbers in the first place.

Non-numeric data units with structure and pattern can be defined and processes for modifying the structure, adding to it or eliminating elements from it, devised. Just as the machine can be made to store the number 10, by certain conventions, it can be made to remember that the color of an apple is red. The problem was to find convenient ways to do this and one solution was the creation of a class of "list" languages.

Information Processing Language-V (IPL-V) is the first of these languages to appear in published form for general use (Newell et al, 1961). The language prescribes a set of processes and the data term formats for creating larger data units that a single number. The list structures enable us to describe an object—any object. The red apple, for example, would have a name. Associated with the name is a description list where we could find that the value of the attribute "color of this object" is "red". If we wished to associate further information with the object, we might add another property to the description. The value of the attribute "edibility" for this red apple is "good to eat". Another apple with a different name might be a green apple and we might find by searching its description list that it is "not good to eat". With the information processing tools that IPL-V gives, we could represent the task of sorting all the apples in the machine into two piles—one for munching and the other for green apple pie.

The program that we might write to do this would be an exact description of a specific sequence of steps; an exact statement of the information processing indicating what tests are performed, the way that apples are "noticed", "discriminated", and, if we so chose, the way the apples are "picked up" and laid down in particular locations of the growing piles. The program could be a theory of perceptual-motor behavior as elaborate with respect to environmental circumstances and as detailed with respect to the sorters' actions as desired.

The early work with computer simulation models—the work out of which the IPL-V language grew—was that of Newell, Shaw, and Simon (1956, 1957, 1958a, 1958b, 1959). An overview of this work was given by Reitman (1959).

What follows is an attempt to show that certain human factors research problems are amenable to attack through the theoretical framework that the computer simulation models provide. Three problem areas will be discussed and the simulation techniques briefly described. The first example is one for which an operational computer simulation program now exists. The problem is one of human cognitive behavior in a problem solving task. It represents the purely "psychological man" aspect of human factors research. The second and third examples have not as yet been simulated; the "theories" have not been worked out in sufficient detail. These examples fall into the "biological man" class of human factors problems, although the second example, one of sensory-motor performance in a visual detection situation, is highly influenced by cognitive mechanisms usually associated with the higher mental processes. The third example has to do with human tolerance to deceleration—to crash forces resulting from light aircraft accidents. It is entirely concerned with biological man since the organism is a completely passive component, in the psychological sense if not in the physical sense.

Computer Simulation: Human Cognitive Function

F. V. Taylor expressed concern over the uneveness of productivity in engineering psychology that seemed to be a function of the kind of man-machine system that was under investigation. He noted that great progress had been made in the analysis of closed-loop control systems and went on to say

"Thus it seems to have happened that when the engineering psychologist needed a model for the man as an element in a tracking or control system, he found one ready made. But for the other roles which men play in systems, no equally fruitful models have been developed...What man does have to do, in addition to controlling, is to collect information, filter it, store it, evaluate it, and apply rules to it; in other words, he has to make decisions and think. And for these processes there are no adequate engineering models because we do not know enough about decision making and thinking to reduce them to mathematical logic.". (Taylor, 1960)

The ready-made model to which Taylor referred was, of course, servo-mechanism theory. The kinds of systems that seemed left out were the open-loop systems or those systems where the feedback is essentially discontinuous. And for the broad areas of human thought and decision-making, there was a theoretical void.

A small step toward filling this void is illustrated by the first example of a laboratory task for which parallels in actual system's control can be found. The Ss face a panel on which four two-position switches are mounted. Above the switches is a push-button and above the push-button is a light. Some combination of the switch positions—a setting—will permit the light to come on when the push-button switch is depressed. A sequence of different settings is used to establish a problem. In the abstract, these problems involve search and discovery. For sequences with certain repeating, systematic properties, the S must collect information, store it, evaluate it—all of the activities Taylor mentioned.

The computer simulation program is constructed by obtaining protocols of individual Ss performing the task, analyzing the response sequences in terms of the ways Ss represent the machine environment and apply previously acquired concepts in performing the task (Laughery and Gregg, 1961). A theory of human problem solving behavior is a collection of information processes and the data units on which these processes act arranged in the form of a computer program. A computer given the same problem sequence, the same "environment", and the program as input simulates the behavior of the human S by producing responses—switch settings generated according to the processing rules. The prediction is for an individual S, and the ultimate criterion is that every setting that S tries should be produced, in correct sequence, for the same reasons.

Tests of the model are made by comparing the trace of the computer on different problems and under changed conditions of presentation. We expect further that generality in the information processes will extend across different Ss with similar background and experience.

No comparisons with alternative models is possible because no other theories of human cognitive behavior exist that even approach the level of discourse implied by the simulation. However, certain statements can be made about the simulation model itself and its relevance to complex man-machine systems.

First, the model traces behavior over time. It does so for composite as well as for component behavior. The states of both the human operator and of the physical piece of laboratory equipment can be sampled throughout the simulation. "Instantaneous" values of variables are not reproduced, the computers are high speed digital machines. But one premise for which we have considerable evidence is that the human machine is not really continuous anyway. Any system's relevant behavioral variable, except time, can be obtained from the trace. Next, we note that the task is serial. What if we were certain that the phenomena underlying a particular piece of complex behavior were parallel in time? This is a difficult, but not insurmountable problem for simulation. Since the simulations do not pretend to be real time simulations, as long as discrete points in the system's flow diagram could be identified where parallel processes converge, perhaps providing several inputs to still another process, it should be possible to represent whole systems performance. In the same vein, paced in contrast to self-paced tasks require that nodes be defined where interruption or transfer of control occur. We have one such program that handles the learning of nonsense syllables presented as on a memory drum at a constant rate per syllable (Feigenbaum, 1961).

Computer Simulation Human Sensory and Perceptual Mechanisms.

Human operator performance in visual tasks is frequently of interest in human factors research. Many different kinds of machines provide visual displays that a human operator must monitor to detect targets, identify them, or interpret their significance. The research questions may have to do with changes in performance over time as in the vigilance tasks, with the complexity or structure of input stimuli, the spatial or temporal relationships between the inputs and the responses required, or simply the sensory limits as a function of conditions of viewing the display. When there are multiple display units, the perceptual phenomena become exceedingly complex (Karn and Gregg, 1961). Questions about time sharing and scanning, and the modification of these through experience with the task become critical.

For the simplest of visual tasks, detection of single targets in a relatively homogeneous field, enough is known that some alternative ways of modeling the behavior are available (Tanner and Swets, 1954, Swets, 1961; Mosier, C. L, 1940). None of these theories yields a moment-to-moment behavioral trace of perceptual performance. However, it is none the less possible to incorporate features of both of these alternatives into a single model for a rather particular case of visual detection.

Suppose that in a series of discrete presentations the target—stimulus to be detected—is presented randomly but with the constraint that in a block of presentations, the target occurs just half of the time. Next, suppose that we are able to manipulate the conditions of viewing so that visibility of the target ranges from zero to "perfect" visibility, and to avoid the parametric form of the equations, consider this change in visibility to be linear with respect to successive presentations in time. Thus, the observer would be required to report the presence or absence of the target as it becomes progressively easier to detect. However, the target would not always be present but would appear with a specified probability unknown to the observer at the outset. Drawing from classical psychophysical and test theory, we can propose that the probability of reporting that the target is present is equal to the probability of a "true" report of a target that has been presented plus errors that are a function of certain biasing mechanisms. The first is similar to the response bias of the Tanner and Swets model and is made a function of the rate of change in visibility. The second, thrown in for good measure, is an inertial bias that depends on the second derivative of visibility. The result is a familiar differential equation from which the theoretical probabilities of reporting the presence of the target when the target is in fact present (correct responses) and when the target is absent (errors of commission or false positives) can be derived. The linear, second-order equation is of the form.

$$L\,\ddot{p}_r + B\,\dot{p}_r + p_r = p_s$$

where: L is the inertial or lag coefficient; B is the responses bias coefficient; p_r is the probability of a "true" detection, and, p_s is the probability of target occurrence.

Beyond the fact that this model fits some data rather nicely, it is an interesting one to compare with computer simulation models for the same class of behavior. The model does predict, on a probability basis, the instantaneous values of the composite behavior. Since it represents a closed response system, the probabilities of the biased responses are clearly linked to the composite result. The model has some generality since it works over a range of input probabilities and, hopefully, will work when experimental operations are used to modify the initial values of the biasing coefficients.

A computer simulation model, starting with the same data, might contain the same basic mechanisms—a test process for "true" detection, a response bias process that is modified through information feedback that changes the value of an attribute in keeping with the recent changes in the stimulus, and another to represent the inertia in the response system. These processes, together with a response evocation mechanism and a test that compares Ss simulated response with the actual state of the stimulus on a given presentation, would be about all that is necessary to achieve the same results that the differential equation would give. In fact, the simulation model could be very little more than a model for computing the discrete values of the continuous mathematical expression.

Clearly, the simulation model must be prepared to offer more than a computational algorithm. Perhaps the quickest way to show where the two approaches split apart is by introducing just one additional complication to the experimental plan in which the observed responses are obtained. Let this complication be an independent information source that aperiodically "warns" the observer of imminent changes in the proportion of targets that will be presented in an ensuing time period, but does not always do so. The effect of this modification on the differential equation would be disasterous. No longer would the coefficient, L, be constant. There would be little hope for any reasonable solution except through determining the statistical properties of the auxiliary information source. On the other hand, it is possible to imagine the construction of the mechanisms by which the psychological set of the human operator is changed upon receiving the warning signal so that he "expects" the changes and is ready to cope with them. Further, we would expect rather marked changes in the way the observer attended to the ensuing series of targets and the ways that he tried, in particular, to determine the direction of the change and to estimate the probability of occurrence of the targets.

There are other possibilities having roughly the same consequences. Fatigue decrements (Gregg, 1961), learning effects (Karn and Gregg, 1961), a variety of fairly obvious psychological or physiological phenomena would be beyond the potential of the mathematical model, and yet, would be consistent with the proposed simulation. The point need not be labored. We all know how easy it is to write equations that can't be solved. The phenomena implicit in human behavior and complex machine systems quickly transcend our current mathematical tools.

Computer Simulation Crash Injuries in Lightplane Accidents.

The third example of a human factors research problem is a problem of describing the dynamics of an exceedingly complex event. The problem centers on the prediction of injuries to the human occupant of an aircraft subjected to the rapid decelerations of a crash.

One approach to the analysis of accidents is to define some variables: degree and kind of injury to the occupant; impact variables such as velocity and angle, other variables related to the terrain and structure of the aircraft. Then, either through controlled crash tests or field investigation of accidents, data can be obtained from which the relationships among the input variables and the injury variables are derived. Statistical analyses (Gregg and Pearson, 1961) show that seven or more types of input variables, or factors, are important in predicting just one gross output variable, degree of injury, and the prediction from field observations is not very good even then. Notice that this approach is very similar to the stimulus-response input-output, ideas discussed earlier. The multivariate prediction model can serve as an evaluation device to compare the results of different experiments where aircraft design and occupant tie-down links are varied. The statistical distributions of the variables are also of interest in their own right. But such an approach does not provide the detail that could lead to recommendations of design changes for engineers who might wish to build more crashworthy aircraft.

Well, back to the differential equations. Using data from a variety of studies of human tolerance to deceleration, it has been possible to conceptualize a mechanical model of the restraint system and the occupant, and with certain assumptions about stiffness and elasticity, to work through a mathematical model for computing forces in the spinal and transverse modes of application. One engineering firm offers us an analogue computer that will yield a physiological index as the output measure for any arbitrary deceleration input. The problem now becomes that of prescribing the input to the system at the point where the crash forces are applied. But what should these inputs be? What of the interaction of the transverse and spinal force vectors; and of the many kinds of injury that are caused independently of the restraint system properties? Each of the separate approaches has something to offer, but we still seek a more general picture, a more inclusive picture, of the behavior of the aircraft and its occupant during the crash.

The feasibility of a computer simulation of the crash dynamics rests in part on being able to define what we mean be "behavior" in information processing terms. The relevant behavior, we think, is the transmission of forces through the aircraft and occupant structures. The initial impact energy is dissipated in the progressive destruction or damage that ensues. The core of the simulation model is a process that takes as input information about the structural unit on which it acts and an energy vector applied to that unit. The process dissipates the absolute magnitude of the energy and transforms the vector for input to the next unit.

Identifying the "structural units" now becomes critical for developing the model. Engineering analyses of common makes and models of light aircraft are being made to determine major structural components. It is obvious that not every item that appears in a parts manual will qualify as a structural unit. It is less obvious that the independent engineerig studies will produce a small enough number of them to fit a modern computer. In any event, the initial attempts in programming a simulation model will follow simplified schematic diagrams that indicate the ways the units are linked.

At this point, we are still missing the information that is the most essential part of the simulation. How does the energy dissipation process "know" what to do? What are the rules for transforming energy? The consequences of energy absorption in the aircraft structure is damage. Consider the following, very crude example. Given an aircraft of a particular design, a hard landing may or may not lead to the collapse of the landing gear. If, however, the gear collapses, a series of alternatives are possible Among the alternatives are varying degrees of damage to the underside of the fusilage. Force transmitted through the major structural components must be associated with each alternative pattern and degree of damage. The data units of the computer program will specify, as attributes and values for each structural unit, alternative outcomes from which magnitude and direction of forces can be derived. The energy dissipation process applies a series of logical tests to accomplish its task.

Just as the simulations of cognitive behavior in humans was based on subject protocols and traces of ongoing behavior, the development of the crash dynamics program have objective data to draw upon. High-speed motion pictures and accelerometer traces obtained in the crash testing program sponsored by the U. S. Army Transportation Research Command will be the source of these data.

Conclusion

Perhaps the three examples are sufficient to show that computer simulation models are potentially useful conceptual schemes for the analysis of complex systems. The early successes of the technique in providing models of intelligent behavior, the broad span of human and machine activity that the simulation programs can encompass, the mere fact that human and machine behavior can live side by side within the context of one of these programs, all of these argue for the fruitfulness of the approach.

Over-riding the differences in the several examples is a particularly compelling idea. Models of complex systems should be as elaborate as they need to be to account for known mechanisms that play a part in producing behavior. This research strategy implies that our knowledge and understanding will increase faster if we broaden the scope of our explanatory efforts than if we narrowly pursue measurements of isolated fragments of behavior.

It is obvious that the expenditure of effort in writing the computer simulation programs is substantial. The existence of the technique does not guarantee fast or easy solutions to all of the problems of human factors research. It should also be clear that the issue is not that these information processing systems replace the creative efforts of the research worker. What the computer simulations do guarantee, however, is a means for elaborating our conceptualizations of behavioral phenomena and for testing the hypothesized processing mechanisms once they are conceived.

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APPENDICES

I. Roster of Conferees

II. Current Work Programs, Bibliographies and Biographical Directories of Professional Personnel of Human Engineering Activities of U. S. Army Agencies

1. U.S. Army Chemical Research and Development Laboratories
2. U.S. Army Engineer, Geodesy, Intelligence, and Mapping Research and Development Agency
3. U.S. Army Engineer Research and Development Laboratories
4. U.S. Army Human Engineering Laboratories and Former Ordnance Arsenals
5. U.S. Army Medical Service
6. U.S. Army Quartermaster Food and Container Institute for the Armed Forces
7. U.S. Army Quartermaster Research and Engineering Command
8. U.S. Army Quartermaster Research and Engineering Field Evaluation Agency
9. U.S. Army Signal Research and Development Laboratory
10. U.S. Army Transportation Research and Engineering Command
11. U.S. Army Board for Aviation Accident Research
12. U.S. Army Personnel Research Office
13. Human Resources Research Office

APPENDIX I
ROSTER OF CONFEREES

1. Mr. Billy A. Abbott
Bell Helicopter Company
Fort Worth, Texas

2. Mr. Jeff A. Abraham
Test Programs & Evaluation Dept.
U.S. Army Electronic Proving Ground
Fort Huachuca, Arizona

3. Mr Charles C Albrecht
American Optical Company
South Bridge, Massachusetts

4. Mr. Abraham Anson
Photogrammetry Division
U.S. Army Engineer Geodesy, Intelligence, and Mapping R&D Agency
Fort Belvoir, Virginia

5. Maj. J. Q. Arnette
Hq U.S. Army Combat Developments Command
Fort Belvoir, Virginia

6 Lt Col Byron D. Athan
U.S. Army Combat Developments Command
Fort Belvoir, Virginia

7. Lt Col John A. Bacon
U.S. Army CBR Combat Developments Agency
Fort McClellan, Alabama

8. Dr. Lynn E. Baker
Human Factors Research Division
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

9. Mr. Jacob L. Barber, Jr.
Human Factors Research Division
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

10. Mr. Edward R. Barron
Clothing & Organic Materials Division
Quartermaster Research and Engineering Command
Natick, Massachusetts

11. Co. George A. Barten
Office, Deputy Chief of Staff for Logistics
Department of the Army
Washington 25, D. C.

12. Maj David A. Beckner
Environmental Sciences Division
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

13. Mr. Fred P. Beguin
American Optical Company
Southbridge, Massachusetts

14. Lt Col Harry G Benion
Project Control Department
Army Participation Group
U.S. Naval Training Device Center
Port Washington, New York

15. Dr. Philip J. Bersh
U.S. Army Personnel Research Office
Washington 25, D. C.

16. Col William H. Birdsong
Special Subjects Department
U.S. Army Infantry School
Fort Benning, Georgia

17. Dr. Abraham H. Birnbaum
U.S. Army Personnel Research Office
Washington 25, D. C.

18. Mr. William V. Blevins
Directorate of Medical Research
U.S. Army Chemical R&D Laboratories
Army Chemical Center, Maryland

19. Mr. William J. Boardman
Clothing & Organic Materials Division
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

20. Mr. Joseph E. Boneta, Jr.
Electrical Department
U.S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

21. Mr. George E. Bonnell
U.S. Army CBR Engineering Group
Fort Detrick,
Frederick, Maryland

22. Col Millard G. Bowen, Jr.
Weapons Systems Evaluating Group
Office, Secretary of Defense
Washington 25, D. C.

23. Dr. Charles W. Bray
Smithsonian Institution
10th & Independence Avenue, S. W.
Washington, D. C.

24. Dr William B Bryant
Allied Research Association, Inc.
43 Leon Street
Boston, Massachusetts

25 Mr. Edward P Buckley
Engineering Psychology Laboratory
The Franklin Institute
Philadelphia 3, Pennsylvania

26 Maj James K. Bush
Directorate of Engineering
U S. Army Transportation Materiel Command
12th and Spruce Streets
St. Louis, Missouri

27. Capt Stanley L. Calvert
Ranger Department
U.S. Army Infantry School
Fort Benning, Georgia

28. Dr. Ruth Hoyt Cameron
Defense Research Board
Department of National Defense
Ottawa, Canada

29. Mr. William F. Campbell
International Business Machines Corp.
10301 Westlake Drive
Bethesda, Maryland

30 Maj James W. Cannon
2d Howitzer Bn, 10th Arty
Fort Benning, Georgia

31. Mr. Robert E. Carter
Human Engineer
Fairchild Stratos Corporation
Hagerstown, Maryland

32. Mr. Anthony E. Castelnovo
U.S. Army Personnel Research Office
Washington 25, D. C.

33. Maj Gen Chester W. Clark
Director of Army Research
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

34. Maj. Gerald E. Clausing
U.S. Army Cold Regions Research and Engineering Laboratory
Post Office Box 282
Hanover, New Hampshire

35. Col David Cooper
U.S. Continental Army Command
Fort Monroe, Virginia

36. Col John T. Corley
Assistant Division Commander
2d Infantry Division
Fort Benning, Georgia

37. Col J. G. Cornett
Chief of the Academic Staff
U.S. Army Infantry School
Fort Benning, Georgia

38. Mr. Douglas Y. Cornog
Research Information Center
National Bureau of Standards
U.S. Department of Commerce
Washington 25, D. C.

39. Mr. Robert L. Courtney
Army Missile Test Evaluation Directorate
White Sands Missile Range
New Mexico

40. Mr. Brian Crist
Engineering Psychology Laboratory
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

41. Mr. Edmund G. Cummings
U.S. Army Chemical Research and Development Laboratories
Army Chemical Center, Maryland

42 Lt Gen John P. Daley
Commanding General
U.S. Army Combat Developments Command
Fort Belvoir, Virginia

43 Lt Col William P. DeBrocke
Combat Materiel Division
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

44. Brig Gen Chester B. DeGavre
Deputy Chief of Staff for Personnel
Hq U.S. Continental Army Command
Fort Monroe, Virginia

45. Mr. Gino R. DeTogni
Human Factors Unit
Picatinny Arsenal
Dover, New Jersey

46. Lt Col Lester R. Dillion, Jr.
Director, Special Subjects Department
U.S. Army Infantry School
Fort Benning, Georgia

47. Capt Stephen P. Dittmann
Medical Equipment Development Laboratory
Fort Totten, New York

48. Mr. John E. Donlon
Technical Services Department
U.S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

49. Col James S. Douglas
Secretary
U.S. Army Infantry School
Fort Benning, Georgia

50. Dr. Jack W. Dunlap
Dunlap and Associates, Inc.
429 Atlantic Street
Stamford, Connecticut

51. Dr. E. Ralph Dusek
Engineering Psychology Laboratory
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

52. Dr. David L. Easley
Senior Scientist
U.S. Army Armor Human Research Unit
Fort Knox, Kentucky

53. Mr. Jan E. R. Eindhoven
Armed Forces Food & Container Institute
1819 W. Pershing Road
Chicago 9, Illinois

54. Mr. John R. Erickson
Systems Research Laboratory
U.S. Army Human Engineering Laboratories
Aberdeen Proving Ground, Maryland

55. Mr. Raoul A. Faralla
ATTN SIGRA/XC
U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

56. Mr. Stanley Finkelstein
Chrysler Corporation Missile Division
Warren, Michigan

57. Col William Fite
Office of The Adjutant General
U.S. Army Infantry Center
Fort Benning, Georgia

58. Mr. James Flanagan
Deputy Scientific Director for Engineering
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

59. Maj John L. Fletcher
U.S. Army Medical Research Laboratory
Fort Knox, Kentucky

60. Col N. Fooks (Ret)
U.S. Army Infantry Human Research Unit
Fort Benning, Georgia

61. Col Edward M. Foxworth
Quartermaster Section
U.S. Army Infantry Center
Fort Benning, Georgia

62. Dr. James W. Frick
Cornell Aeronautical Laboratory, Inc.
Combat Surveillance Project
1124 North Highland Street
Arlington 1, Virginia

63. Dr. Charles E. Fritz
Weapons Systems Evaluation Division
Institute for Defense Analyses
1825 Connecticut Avenue
Washington 9, D. C.

64. Lt Col Robert F. Galez
IG Section
U.S. Army Infantry Center
Fort Benning, Georgia

65. Col Mahlon E. Gates
151st Engineer Group (C)
Fort Benning, Georgia

66. Mr. David L. Gee
Military Department
U.S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

67. Maj Cyrus L. Gibbs
Director
Special Subjects
U.S. Army Infantry School
Fort Benning, Georgia

68. Dr. Aram Glorig
Director of Research
American Academy of Ophthalmology and Otolaryngology
327 South Alvardo
Los Angeles 57, California

69. Capt William C. Godwin
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

70. Mr. D. L Graham, Jr.
Engineering Requirements Coordination Office
Research and Development Directorate
U.S. Army Missile Command
Redstone Arsenal, Alabama

71. Dr. Lee W. Gregg
Carnegie Institute of Technology
Pittsburgh, Pennsylvania

72. 2d Lt Noel L. Griese
U.S. Army Infantry Center
Fort Benning, Georgia

73. Mr. Paul E. Griffith
ATTN. SIGRA/GDA
U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

74. Lt Col Joffre L. Gueymard
401 Lumpkin Road
Fort Benning, Georgia

75. 2d Lt Terry R. Gulledge
U.S. Army Infantry Center
Fort Benning, Georgia

76. Capt Wladimir Gulevich
Medical Equipment Development Laboratory
Fort Totten, New York

77. Mr. Frederick W. Haake
U.S. Army Electronics Research and Development Laboratory
Fort Monmouth, New Jersey

78. Lt Col William C. Hacker
Information Section
U.S. Army Infantry Center
Fort Benning, Georgia

79. Dr. Donald F. Haggard
Senior Scientist
U.S. Army Armor Human Research Unit
Fort Knox, Kentucky

80. Maj Joseph Hall
G-3 Section
U.S. Army Infantry Center
Fort Benning, Georgia

81. Col Robert Hall
Special Subjects
U.S. Army Infantry School
Fort Benning, Georgia

82. Col Curtis S. Hankins
Hq LAAC
Fort Benning, Georgia

83. Col Clifford P. Hannum
2d Battle Group, 9th Infantry
2d Infantry Division
Fort Benning, Georgia

84. Col Stanley L. Harding
Hq 2d Infantry Division Artillery
Fort Benning, Georgia

85 Dr. George Harker
U.S. Army Medical Research Laboratory
Fort Knox, Kentucky

86. Maj Gen Ben Harrell
Commanding General
U.S. Army Infantry Center
Fort Benning, Georgia

87. Mr. Richard L. Harrison
General Dynamics
Pomona, California

88. Lt Col William Hausman
U.S. Army Medical Research and Development Command
Office of The Surgeon General
Department of the Army
Washington 25, D. C.

89. Dr. Dean M. Havron
Human Sciences Research, Inc.
1408 N. Fillmore Street
Arlington, Virginia

90. Mr. G. Hawkes
Lockheed Aircraft Corporation
Marietta, Georgia

91. Mr. George Hayes
Lockheed Aircraft Corporation
Marietta, Georgia

92. Col Richard W. Healy
Coordinator Instruction
U.S. Army Infantry School
Fort Benning, Georgia

93. Dr. Howard W. Hembree
Scientific Director
U.S. Army Quartermaster Research and Engineering Field Evaluation Agency
Fort Lee, Virginia

94. Maj George R. Henderson
G-3 Section
U.S. Army Infantry Center
Fort Benning, Georgia

95. Mr. John R. Hennessy
ATTN. SIGRA/GDA
U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

96. Capt. James E. Hertzog
U.S. Army Aeromedical Research Unit
Fort Rucker, Alabama

97. Maj Gen R. A. Hewitt
Director, Military Personnel
Office, Deputy Chief of Staff for Personnel
Department of the Army
Washington 25, D. C.

98. Mr. Harold W. Howard
Applied Science Corporation
Post Office Box 632
Santa Paula, California

99. Col George E. Hudson
U.S. Army Infantry Board
Fort Benning, Georgia

100. Mr. Adolph H. Humphreys
Military Department
U.S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

101 Dr. William A. Hunt
Department of Psychology
Northwestern University
Evanston, Illinois

102. Mr. Harry O. Huss
U.S. Army CBR Engineering Group
Army Chemical Center, Maryland

103. Lt Col John F. Hyde
Office, Deputy Chief of Staff for Military Operations
Department of the Army
Washington 25, D. C.

104. Mr. Samuel E. Jackson
Directorate of Medical Research
U.S. Army Chemical Research and Development Laboratories
Army Chemical Center, Maryland

105. Maj Daniel L. Johnson
Quartermaster Section
U.S. Army Infantry Center
Fort Benning, Georgia

106. Mr. William A. Johnson
Rock Island Arsenal
Rock Island, Illinois

107. Dr. Wm. E. Kappauf, Jr.
Psychology Department
Gregory Hall
University of Illinois
Urbana, Illinois

108. Mr. A. C. Karr
Supervisory Psychologist
Frankford Arsenal
Philadelphia 37, Pennsylvania

109. Mr. Joseph Kaufman
Research and Development Directorate
U.S. Army Materiel Command
Washington 25, D. C.

110. Col H. Kelly (Ret)
U.S. Army Infantry Human Research Unit
Fort Benning, Georgia

111. Brig Gen John E. Kelly
Deputy Commanding General
U.S. Army Infantry Center
Fort Benning, Georgia

112. Mr. Elmer A. Kemp
Plant No. 2
General Motors Corporation
22220 Lakeland Avenue
Euclid 17, Ohio

113. Mr. Harold E. Kerber
Goodyear Aircraft Corporation
Akron, Ohio

114. Mr. Robert E. Kinch
Human Factors Engineer
Department 224
Western Electric Company, Inc.
Winston-Salem, North Carolina

115. Col J. M. King
Coordinator Instruction
U.S. Army Infantry School
Fort Benning, Georgia

116. Mr. Richard S. Kneisel
U.S. Army Chemical Corps School
Fort McClellan, Alabama

117. 1st Lt James E. Komer
Mechanical Department
U.S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

118. Dr. Karl D. Kryter
Bolt Beranek and Newman, Inc.
50 Moulton Street
Cambridge, Massachusetts

119. Dr. Martin Kurke
CORG
U.S. Army Combat Developments Command
Fort Belvoir, Virginia

120. Dr. Carl J. Lange
Director of Research
U.S. Army Infantry Human Research Unit
Fort Benning, Georgia

121. Mr. Harold R. LaPorte
Autonetics, A Division of North American Aviation, Inc.
Anaheim, California

122. Dr. Charles B. Lee
Research and Engineering Directorate
Army Tank Automotive Command
Center Line, Michigan

123. Maj Robert V. Lee
Plans Division
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

124. Dr. Samuel D. Leonard
Department of Psychology
University of South Florida
Tampa, Florida

125. Mr. H. D. Lerner
Applied Psychology Corporation
4113 Lee Highway
Arlington 7, Virginia

126. Mr. Alexander Levin
Chief, Research Office
Mechanical Engineering Division
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

127. Mr. Morris L. LeVitin
ATTN. SIGRA/NES
U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

128. Maj William W. Lewis, Jr.
Special Subjects Department
U S. Army Infantry School
Fort Benning, Georgia

129. Mr. Albert J. Lizza
Research and Development Division
Springfield Armory
Springfield 1, Massachusetts

130. Maj Donald O. Loomis
Behavioral Sciences Division
Office, Assistant for Bioastronautics
Hq Air Force Systems Command
Andrews Air Force Base, Maryland

131. Mr. Theodore G. Lorenzen, Jr.
U.S. Army Weapons Command
Rock Island, Illinois

132. Mr. Herman Madnick
Clothing and Organic Materials Division
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

133. Mr. Robert T. McCay
Dunlap and Associates, Inc.
429 Atlantic Street
Stamford, Connecticut

134. Lt Col Wallis E. McClain
Commanding Officer
2d Howitzer Battalion, 10th Artillery
Fort Benning, Georgia

135. Dr. William McClelland
Human Resources Research Office
The George Washington University
Post Office Box 3596
Washington 7, D. C.

136. Dr. Ernest J. McCormick
Occupational Research Center
Purdue University
LaFayette, Indiana

137. Lt Col W. McDermott
CBR Directorate
Office, Deputy Chief of Staff for Military Operations
Department of the Army
Washington [illegible], D. C.

138. Mr. John P. McDonough
Army Materials Research Agency
Watertown Arsenal
Watertown 72, Massachusetts

139. Col H. F. McFeely
Transportation Section
U.S. Army Infantry Center
Fort Benning, Georgia

140. Lt Col James D. McLanachan
U.S. Army Armor Combat Developments Agency
Fort Knox, Kentucky

141. Dr. William H. Melching
Department of Psychology
Texas Technological College
Lubbock, Texas

142. Mr. Joseph R. Melville
Bell Telephone Laboratories
Whippany, New Jersey

143. Mr. Harry J. Meyer
Standard and Systems Office
Office of Personnel Operations
Department of the Army
Washington 25, D. C.

144. Capt Patsy A. Milantoni
Dental Section
U.S. Army Infantry Center
Fort Benning, Georgia

145. Mr. Fred Mintz
Lockheed-California Company
Burbank, California

146. Col Stuart M. Mitchell
Dental Section
U.S. Army Infantry Center
Fort Benning, Georgia

147. Mr. Thomas Mongello
U.S. Naval Training Device Center
Port Washington, New York

148. Maj Don W. Moore
Hq U.S. Army Combat Developments Experimentation Center
Fort Ord, California

149. Mr. Irving B. Morgan
Office, Deputy Chief of Staff for Military Operations
Department of the Army
Washington 25, D. C.

150. Mr. Jack W. Mumford
Chance-Vaught Aircraft Corporation
Unit 53620
Dallas, Texas

151. Maj John D. Murphy
Classification and Standards Division
Office, Deputy Chief of Staff for Personnel
Department of the Army
Washington 25, D. C.

152. Mr. R. C. Navrin
Research Division
U.S. Army Materiel Command
Washington 25, D. C.

153. Dr. Thomas F. Nichols
Senior Scientist
U.S. Army Infantry Human Research Unit
Fort Benning, Georgia

154. Mr. George F. Nolan
President
Psychophysics Research Corporation
550 Fifth Avenue
New York 36, New York

155. Mr. William J. Nolan
U.S. Army Transportation Research Command
Fort Eustis, Virginia

156. Col Thaddeus M. Nosek
U.S. Army Combat Developments Command
Fort Belvoir, Virginia

157. Capt Francis O. Nugent
Communications Department
U.S. Army Infantry School
Fort Benning, Georgia

158. Mr. Paul D. Oakley
Diamond Ordnance Fuze Laboratories
Washington 25, D. C.

159. Mr. Robert E. O'Brien
President
Bio-dynamics, Inc.
1 Main Street
Cambridge, Massachusetts

160. Pfc E-3 James T. O'Connor
Building 23
Frankford Arsenal
Philadelphia 37, Pennsylvania

161. Dr. Harry Older
President
The Matrix Corporation
507 18th Street, South
Arlington 2, Virginia

162. Col Albro L. Parsons, Jr.
Command and Staff Department
U.S. Army Infantry School
Fort Benning, Georgia

163. Col Michael Paulick
Air Mobility Department
U.S. Army Infantry School
Fort Benning, Georgia

164. Maj George E. Peck
U.S. Army Personnel Research Office
Washington 25, D. C.

165. Mr. Henry M. Fernmi
The Armour Research Foundation
10 W. 31st Street
Chicago, Illinois

166. Mr. Harry D. Poole
Defense Research Staff
British Embassy
Washington, D. C.

167. Mr. Theodore R. Powers
Research Associate
U.S. Army Infantry Human Research Unit
Fort Benning, Georgia

168. Lt Col James H. Proctor
U.S. Army Representative
Hq Air Force Systems Command
Andrews Air Force Base, Maryland

169. Mr. John D. Reed
Research Office
U.S. Army Combat Developments Experimentation Center
Fort Ord, California

170. Maj Alexander M. Reid
Deputy Director
Clothing and Equipment Physiological Research Establishment
c/o Royal Aircraft Establishment
Farnsborough, Hants.
England

171. Brig Gen Royal Reynolds, Jr.
Assistant Commandant
U.S. Army Infantry School
Fort Benning, Georgia

172. Mr. Richard C. Robinson
Research Analysis Corporation
6935 Arlington Road
Washington 14, D. C.

173. Mr. John J. Romba
U.S. Army Human Engineering Laboratories
Aberdeen Proving Ground, Maryland

174. Dr. Paul G. Ronco
Institute for Psychological Research
North Hall
Tufts University
Medford 55, Massachusetts

175. Col Thomas B Ross
Operations
U.S. Army Infantry School
Fort Benning, Georgia

176 Dr. George E. Rowland
President
Rowland and Company
Post Office Box 61
Haddonfield, New Jersey

177. Dr. Joseph N. Ruocco
Grumman Aircraft Engineering Corporation
Huntington, New York

178. Dr. Jesse C. Rupe
U.S. Army Air Defense Human Research Unit
Fort Bliss, Texas

179 Mr. James E Russell
Research Analysis Corporation
6935 Arlington Road
Washington 14, D. C.

180. Col Edward N. Rydalch
Weapons Systems Evaluation Group
Office, Secretary of Defense
Washington 25, D. C.

181. Col S. E. Sacerdote
Command and Staff Department
U.S. Army Infantry School
Fort Benning, Georgia

182. Mr. Jerrell L. Sanders
Chief, Methods Engineering Branch
U.S. Army Quartermaster Research and Engineering Field Evaluation Agency
Fort Lee, Virginia

183. Mr. Sidney Sandler
U.S. Army Electronics Research and Development Laboratory
Wanamassa, New Jersey

184. Dr. Ezra V. Saul
Human Factors Unit
Picatinny Arsenal
Dover, New Jersey

185. Maj Paul Schultz
Office of the Provost Marshal
U.S. Army Infantry Center
Fort Benning, Georgia

186. Mr. Erminio O. Settembre
ATTN SIGRA/PSC
U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

187. Lt Col Luther L. Sexton
U.S. Army Combat Developments Command
Fort Belvoir, Virginia

188. Capt Robert L. Shaffer
U.S. Army Missile Command
Redstone Arsenal, Alabama

189. 1st Lt Edward J. Shanahan, Jr.
G-3 Section
U.S. Army Infantry Center
Fort Benning, Georgia

190. Lt Col Norman I. Shapiro
Command and Staff Department
U.S. Army Infantry School
Fort Benning, Georgia

191. Col Granville A. Sharpe
U.S. Army Institute of Advanced Studies
Carlisle Barracks, Pennsylvania

192. Dr. Carroll L. Shartle
Office of Science
Director of Research and Engineering
Office of the Secretary of Defense
Washington 25, D. C.

193. Col Walter D. Short
Chairman of the Defense Committee
U.S. Army Infantry School
Fort Benning, Georgia

194. Dr. Arthur I. Siegel
Applied Psychological Services
114 North Wayne Avenue
Wayne, Pennsylvania

195. Dr. Paul A. Siple
Scientific Advisor
Army Research Office
3045 Columbia Pike
Arlington 4, Virginia

196. Col Braxton E. Small
Signal Section
U.S. Army Infantry Center
Fort Benning, Georgia

197. Capt Ernest C. Snyder
Special Subjects Department
U.S. Army Infantry School
Fort Benning, Georgia

198. Dr. Philip I. Sperling
U.S. Army Medical Research and Development Command
Office of the Surgeon General
Department of the Army
Washington 25, D. C.

199. Mr. Emil Spezia
Human Factors Section
U.S. Army Board for Aviation Accident Research
Fort Rucker, Alabama

200. Lt Col Harold G. Stacy
Hq Combat Service Support Group
Fort Lee, Virginia

201. Dr. Alfred H. Stanton
The McLean Hospital
Belmont 79, Massachusetts

202. Mr. Francis W. Stengle
U.S. Army Chemical Research and Development Laboratories
Army Chemical Center, Maryland

203. Mr. Gilbert L. Stewart
Department of Nonresident Instruction
U.S. Army Infantry School
Fort Benning, Georgia

204. Mr. Richard Stewart
Allied Research Association, Inc.
43 Leon Street
Boston, Massachusetts

205. Col Hubert E. Strange
Communication Department
U.S. Army Infantry School
Fort Benning, Georgia

206. Col William M. Summers
U.S. Army Infantry Board
Fort Benning, Georgia

207. Maj Thomas H. Tackaberry
Human Factors Research Division
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

208. Capt Joseph T. Tambe
Engineering Psychology Laboratory
Pioneering Research Division
U.S. Army Quartermaster Research and Engineering Command
Natick, Massachusetts

209. Mr. Albert L. Taylor
U.S. Army Engineer Maintenance Center
Columbus, Ohio

210. Col Walter B. Todd
Martin Army Hospital
Fort Benning, Georgia

211. Dr. Martin A. Tolcott
Dunlap and Associates, Inc.
429 Atlantic Street
Stamford, Connecticut

212. Dr. G. C. Tolhurst
Human Engineering Branch, Code 455
Office of Naval Research
Washington 25, D. C.

213. Mr. James P. Torre, Jr.
Systems Research Laboratory
U.S. Army Human Engineering Laboratories
Aberdeen Proving Ground, Maryland

214. Mr. John L. Van Arkel
CBR Agency
Army Chemical Center, Maryland

215. Col Kenneth W. Wallace
U.S. Army Combat Developments Command
Fort Belvoir, Virginia

216. Mr. Harold L. Walpole
Douglas Aircraft Company, Inc.
Long Beach, California

217. Dr. Joseph S. Ward
Research Scientist
U.S. Army Infantry Human Research Unit
Fort Benning, Georgia

218. Lt Col Herman Webel, Jr.
Special Subjects Department
U.S. Army Infantry School
Fort Benning, Georgia

219. Dr. John D. Weisz
Director
U.S. Army Human Engineering Laboratories
Aberdeen Proving Ground, Maryland

220. Maj Edward C. West
Infantry Combat Developments Agency
U.S. Army Infantry Center
Fort Benning, Georgia

221. Dr. W. L. Williams, Jr.
Executive Officer
Human Resources Research Office
The George Washington University
Post Office Box 3596
Washington 7, D. C.

222. Maj Joseph O. Wintersteen
Research Programs Office
Office, Chief of Research and Development
Department of the Army
Washington 25, D. C.

223. Dr. C. L. Wood
Human Factors Unit
Heavy Military Electronics Department
General Electric Company
Syracuse, New York

224. Lt Col Douglas G. Younger
Hq U.S. Army Combined Arms Group
Fort Leavenworth, Kansas

225. Mr. Peter Zakanycz
U.S. Army Electronic Research and Development Laboratory
Fort Monmouth, New Jersey

226. Mr. Charles A. Zelaites
ATTN: SIGRA/GD
U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

227. Brig Gen John G. Zierdt
Deputy Director
Research and Development
U.S. Army Materiel Command
Washington 25, D. C.

APPENDIX II

CURRENT WORK PROGRAMS, BIBLIOGRAPHIES AND BIOGRAPHICAL DIRECTORIES OF PROFESSIONAL PERSONNEL OF HUMAN ENGINEERING ACTIVITIES OF U.S. ARMY AGENCIES.

1. U.S. ARMY CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES, ARMY CHEMICAL CENTER, MARYLAND

A. CURRENT WORK PROGRAM

1. a. The human factors work program at USA Chemical Research and Development Laboratories is carried out largely by the Directorate of Medical Research, under the following projects.

4008-02-024	Medical and Biological Aspects of Chemical Agents
4080-01-005	Chemical Defense Research
4099-02-002	Wound Ballistics, and
4X99-26-001	Basic Research in the Life Sciences.

b. Work Recently Completed.

(1) CRDL participated in a field study of the changes in estimated casualty experience resulting when chemical and biological weapons, with the necessary CBR protective equipment, were introduced into the play of various tactical infantry problems Other participants in the study were the USA Chemical Corps Field Requirements Agency and the USA Chemical Corps Biological Laboratories.

Project	Experimenters	Date Started	Estimated Completion
PROJECT SAMPLES	G.B. Coe F.N. Craig E.G. Cummings C.R. Phillips	Mar 1962	Completed

Results have been reported in a classified report.

(2) The Antiflash Mask M19 is a gained item of the Chemical Corps, formerly withdrawn from issue. The design has recently been undergoing modifications intended to improve the mask's protective qualities in its intended use .e., to protect the faces of 3.5" rocket-launcher crewmen from flash and firing debris incidental to firing, a particular hazard in cold weather). A design prototype, the M19 (improved) mask, was submitted for human factors evaluation prior to entry into final engineering tests.

Project	Experimenters	Started	Completion
Human factors evaluation of Rocket Launcher Anti-flash Mask, M19 (Improved)	S.E. Jackson E.R. Clovis	Oct 1961	Completed

The mask proved to have several grave design defects from the human factors point of view. Most of the defects involved impaired visual functions, a crucial family of abilities for the rocket-launcher gunner. Other defects involved fogging/frosting of eyelenses and the absolute incompatibility with use of the left eye in sighting. Recommendations for minimizing or correcting the major sources of human factors conflict in the design were submitted along with the findings. Included were photographs of a rouch mock-up of a mask modified according to the recommendations.

c. Present Status

No human factors engineering studies are in progress at this time.

In non-engineering human factors work, the most active field is human pharmacology, especially psychopharmacology. In a continuing program of human testing and experimental studies, the qualitative and quantitative natures of man's responses to candidate chemical agents and potential therapeutic drugs are being elucidated. At present the incapacitating agent-type of candidate (together with possible antidotes) is receiving major emphasis. One major concern is methodological in nature. Briefly, it is How important is each change, chemically induced in man, to combat effectiveness?

B. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

CLOVIS, ERNEST R., Major, MSC. Research Psychologist, PhD, University of Pittsburgh, 1952 Methodology of Assessment.

CRAIG, FRANCIS N., Chief, Applied Physiology Branch, PhD, Harvard University, 1937. Respiratory and Environmental Physiology.

CUMMINGS, EDMUND G., Research Physiologist, PhD, North Carolina State College, 1955. Respiratory and Environmental Physiology.

FIDDLEMAN, PAUL B., First Lieutenant, MSC. Research Psychologist, PhD, University of North Carolina, 1961. Psychopharmacology.

KETCHUM, JAMES S, Captain, MC. Research Psychiatrist, M.D., Cornell University Medical College, 1956. Experimental Psychiatry, operant psychology, information theory.

McCLURE, CLAUDE - JR., Major, MC. Chief, Human Investigations Branch; M.D., Bowman Gray School of Medicine, Wake Forest College, 1950, PhD, University of North Carolina, 1960. Neurosurgery and biochemistry.

SHINKMAN, PAUL G., First Lieutenant, MSC. Research Psychologist, PhD, University of Michigan, 1962. Comparative Psychology.

STEARNS, EDWARD R., Captain, MSC. Acting Chief, Psychology and Human Factors Engineering Branch, PhD, University of California, 1960. Experimental Psychology.

STRONG, M. JEROME, Captain, MC. Anesthesiologist, M.D., Boston University School of Medicine, 1956. Anesthesiology, pharmacology.

GOODMAN, EPHRAIM P., SP/5, Clinical Psychology Specialist/Research (915.24) MA, State University of Iowa, 1958. Tests and measurement.

MELTZER, DONALD, Second Lieutenant, MSC. Graduate Student Trainee, MS, University of Pittsburgh, 1960. Operant Psychology.

MERKLER, NORMAN L., Research Psychologist, AM, George Washington University, 1957. Operant Psychology.

BARHOUM, JOHN A., Pvt., Clinical Psychology Specialist/Research (915.14) AB, Loyola University of Los Angeles, 1960. Tests and measurement.

HERTZLER, DAVID R., SP/4, Clinical Psychology Specialist/Research (915.14) AB, Gettysburg College, 1960. Experimental Psychology.

JACKSON, SAMUEL E., Research Psychologist. BS, University of Louisville, 1956. Experimental Psychology.

KYSOR, KRAGG P., SP/4, Clinical Psychology Specialist/Research (915.14) AB, Boston University, 1960 Tests and measurement.

C. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

(1) In-house Studies:

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Semi-Annual Progress Report covering the period 2 October 1961 to 2 April 1962, Contract DA18-108-CML-6644, "Aircrew performance decrement resulting from ingestion of a selected incapacitating agent" (U). North American Aviation, Inc., Downey, California, April 1962.

2. U.S. ARMY ENGINEER, GEODESY, INTELLIGENCE, AND MAPPING RESEARCH AND DEVELOPMENT AGENCY, FORT BELVOIR, VIRGINIA

A. CURRENT WORK PROGRAM

1. Equipment Evaluation

Title	Experimenter(s)	Date Started	Estimated Completion
a. Automatic Mosaicker	A. Anson	March 60	August 62

Components have been delivered and accepted. As the result of studies in the Engineering Test phase, the size and design of the operating knobs have been changed. Tests of room illumination have led to a maximum safe-light illumination without affecting photographic processes. Operator selection of film images has been solved by the invention of a collimating mark reflector on the positioning printer. The fumes of an alcohol and ammonia mixture used in an integral procedure were removed with the installation of an exhaust hose with an exterior exhaust fan Machine mounted instruction cards printed in white on red were changed to white on black for easier reading. The floor height of the easel frame was raised to 23 1/2 inches for operator comfort.

2. Supporting Research: None

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE PREVIOUS ANNUAL CONFERENCE (Not Previously Reported)

None

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

None

3 U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES, FORT BELVOIR, VIRGINIA

A CURRENT WORK PROGRAM

1. Equipment Evaluation

	Title	Experimenter(s)	Date Started	Estimated Completion
a	Mobile, Floating Assualt Bridge/ Ferry	J.F. Christian	April 62	May 62

A human factors review was made near the end of the engineering design stage and recommendations submitted for consideration.

b.	15,000 BTU Heater	J.F. Christian	March 62	March 62

A human factors review was made of the prototype heater. The front panel was redesigned to permit safer operation.

c	Armored Vehicle Launched Bridge/M60	J.F. Christian	June 61	June 62

A configuration design of the crew compartment to satisfy human factors and engineering requirements was created for consideration in any future major design of the AVLB/M60.

d.	Long Range Survey System, GIMRADA	J.F. Christian	June 62	June 62

At the request of GIMRADA a human factors review was made of the prototype components and recommendation was made for current and future changes

e.	Binoculars,	H.G. Johnson	June 58	1965

Working to vision relationships of wearer under conditions of apparent eye point from true eye point, limitations of depth of focus and stereo vision effects when using night vision binoculars incorporating image tubes. In addition to visual performance, comfort, weight, and balance factors for wearer under prolonged usage under field conditions must be also considered.

f. (1)	Small Starlight Scope	R. Uhier	1962	1964
(2)	Unit Commanders Observation Telescope	H.G. Johnson	1962	1964
(3)	Night Observation Device	J. Updegraff	1962	1964
(4)	Passive Sight for Crew Serviced Weapons	J. Updegraff	1962	1964

Night Vision aids for individual soldier required for observation and sighting of weapons Visual performance of resolution, brightness, contrast, magnification, field of view, and eye relief are considered. These devices use image intensifier tubes together with objectives and occular lenses to provide direct vision capability at night. Viewers must be operated under arctic conditions, as well as, temperature and tropical.

g.	Image intensifier for Helicopter Night Operators	J. Parton	1962	1967

Night vision aid for helicopter night operation including pilot operation and observer viewing. Presentation must be such that pilot can use night vision presentation, see his instruments, and use unaided vision where possible. Visual presentation must present magnified view for distant objects but maintain perspective of height and orientation. Both direct view and remote view night vision systems are being studied.

h. Sound Reduction in High-Speed Prime Movers and Elect. cal Machinery	T.D. Cooper	1 June 61	Initial Phase Comp.

The sound pressure levels being encountered in modern high speed prime movers and electrical machinery exceed damage risk criterion for human ear. This study covered an investigation to establish criterion for a 4-hour operating cycle and design of sound reduction system in the Primary Power Station for the Pershing Missile.

i. Universal Engineer Tractor (Crawler)	W.H. Leathers	June 60	1964

A full scale mock-up of the armored cab and controls of the tractor was constructed, a study was made of control placement and operation, adequacy of space, and vision. Changes were made to vehicle design based on this study prior to fabrication of the vehicle.

j. Load Bank Generator Alternator Tester	T.W. Smith	June 60	June 63

A human factors study was made on the engineering prototype model. Re-arrangement of controls, circuitry and meters resulted in increased operator safety and ease of operation.

k. Crane, Rough, Terrain 20-Ton	J.K. Knaell	Jan 60	Jul 62

The crane was modified to enhance safety and provide for ease of daily lubrication. Larger cab and access doors were provided to improve ease of maintenance on upper works. Presently machine is being service tested which includes evaluation of above described modifications.

l. Universal Engineer Tractor (Rubber-Tired)	S.F. Williams	Nov 60	Nov 63

Modifications were made in the equipment in accordance with recommendations made during ease of maintenance review. Changes are being made to the operators compartment to increase comfort during cold weather operation. Additional changes to the item will be made as a result of human factors engineering studies to be conducted during service tests.

m. 25-Ton Engineer Equipment Transporter	H.B. Bennett	1957	1964

A contract has been awarded for a new gooseneck to make the 25-ton Equipment Transporter compatible with the new 830M Caterpillar Tractor. Human Factors consideration have dictated several changes which will be incorporated in the new gooseneck. Hydraulic cylinder with which to manipulate the gooseneck when detached from the transporter will be provided. All controls for raising, lowering, and manipulating the gooseneck during connecting and disconnecting operations will be relocated so that the operator can see the gooseneck and the point of separation of the gooseneck from the transporter.

n Metascope	A.E. Dilliard	Jan 62	Dec 62

A coupling of the functional design approach of value analysis and the man-machine concept of human factors was made in an effort to reduce cost, complexity and maintenance time, and to increase operational efficiency in the end-use environment. Design change recommendations are being formulated.

o. Ion Exhange Unit	Richard Gainey	1 Jul 62	30 Jan 64

Evaluate instrument locations, working areas, and hazardous chemical requirement from human factors standpoint.

p.	Foam Generator 750 U.S., gpm cap. liquid throughout, gasoline engine driven, two wheel trailer mounted, 300 U.S. gal. foam liquid storage tank	J.Malcolm	21 Jun 62 (modification contract date)	30 Jun 63

The foam generator, trailer mounted, is a functional component of petroleum fuel depots as prescribed in TM 5-302 "Construction in the Theatre of Operations" dated October 1958, capable of being used in mobile or semifixed configurations for fuel storage fire protection. Engineering/Service tests are scheduled FY63 to determine troop operational compatibility, and manpower requirements in the mobile and semifixed configurations of use. Human factors are being evaluated also in terms of operating controls for the foam generating unit.

q	Antivehicular Mine	H.C. Smith	1960	1961

Item was evaluated from the standpoint of operator convenience, fatigue, and safety, considering operator position, standing, sitting and walking Also considered were ease of communication with the driver, night operation, location of personnel and combat gear, and necessity for recording data.

2. Support Research

Title	Experimenter(s)	Date Started	Estimated Completion
Anthropometric Survey of the Dynamic Dimensions of the Soldier	USAQMR&EC	Apr 62	Jun 63
User Review of Camouflage for the Individual Combat Soldier in the Field	Adolph H. Humphreys & David L. Gee in Supp. U.S.A. Inf. Bd.	Apr 1962	Dec 62
Redesign of Engine & Battery Enclosure of Airborne Crane	D.W. Youmans	Jun 62	Dec 62

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(Not Previously Reported)

Humphreys, Adolph H. and Gee, David L., "Experimental Design for User Review of Camouflage for the individual Soldier in the Field." Revised 6 April 1962, U.S. Army Research and Development Laboratories, Fort Belvoir, Virginia.

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Christian, John F., "Ergonomics — Palliative or Definitive?", Ergonomics, Volume 5, Number 1, January 1962.

Christian, John F., "Human Factors Evaluation of the Crew Compartment of the Armored Vehicle, Launched Bridge, M-60". Unnumbered, December 1961, U.S. Army Research and Development Laboratories, Fort Belvoir, Virginia.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

None

4. U.S. ARMY HUMAN ENGINEERING LABORATORIES, ABERDEEN PROVING GROUND, MARYLAND AND FORMER ORDNANCE CORPS ARSENALS

A. CURRENT WORK PROGRAM

1. Systems Research

The Systems Research Laboratory, with seven (7) branches, is the laboratories agency for the conduct of applied research studies and the application of human factors engineering data to material in the RDT&E cycle. Whereas in the past the Systems Research Laboratory has been confined in its efforts to Ordnance material, excepting limited work for Transportation and Engineer Corps, this laboratory will be responsible in the future for all materiel developed within Army Materiel Command.

Project	Branch	Date Started	Estimated Completion
a. Carrier, Cargo, 1/2-ton Tracked, Articulated XM571	Mobility Br.	Dec 1961	Continuing

The effort on this program is to provide consultation to the prime contractor through Ordnance Tank-Automotive Command. During FY 62 effort was directed towards a detailed design review of the driver's station, the squad area, maintenance, and litter carrying capability of the carrier. This project will continue through FY 63 with the additional task of supporting recommendations through the monitoring of developmental and environmental tests.

b. Carrier, Universal, Four-Man Cab, XM547-548	Mobility Br.	Dec 1961	Continuing

During FY 62 project personnel have reviewed contractors mock ups and pilot vehicles. Reports have been made to OTAC, resulting in modifications in the driver's station and accessibility for organizational maintenance. Continuation of this program through 63 is dependent upon the acceptability of the contractors' overall program.

c. Armored Squad Carrier Concept	Mobility Br.	Feb 1961	Continuing

The original work conducted during FY 61 on the establishment of the total combat task requirements provided the basis for the design and development of a full scale mock-up of the personnel carrier. During FY 62, the mock-up was completed, and detailed studies on seating, confinement, and stowage were conducted. During FY 63 evaluations of this mock-up with a full crew will be conducted for various confinement periods and compared with results obtained from the M-113 confinement studies.

d. Development and Testing of Seats for Armored Tracked Vehicles	Mobility Br.	June 1962	Continuing

This project was undertaken as a detailed attempt to overcome the deficiencies in seating for tank personnel which had been revealed in prior evaluations of such vehicles as the M48, M60, etc. Two separate areas are under consideration. The first is a new concept of a seat for the tank commander's position which will permit the commander to rapidly and efficiently translate his seat height to accommodate his many functions which range from commander control to radio and fire control operations. For this purpose a concept has been built and demonstrated to both OTAC and CONARC personnel. Detailed fabrication of an operational seat unit is underway and will be installed in a M60 tank for final evaluation. The second area under consideration is the general seat requirements for drivers, gunners, and support personnel of self-propelled howitzers and tanks. The basic problem under consideration is the design of seats which will permit adequate support and comfort in tanks and for the self-propelled howitzer as an additional restraining device to permit personnel to safely ride on such vehicles. Assembly of the combat seats is in progress and final testing will be accomplished during FY 63.

e. Truck, Cargo 1-1/4 Ton, XM561	Mobility Br.	July 1962	Continuing

Project	Branch	Date Started	Estimated Completion

During FY 62 OTAC personnel drew up the technical requirements for a development program on the subject vehicle. The Human Engineering Laboratories prime role during this phase was to develop a "Manual of Standard Practices for Human Factors in Military Vehicle Design", TM 21-61, specifically for the purpose of including this in the design as part of the package in the request for bids from industrial contractors. In addition, project personnel were included on the Evaluation Committee for selecting the final contractor for development of this vehicle. This development program will continue through FY 65 with the Human Engineering Laboratories providing consultative services to both OTAC and the prime contractor in addition to continuing studies on an as requested basis.

f. SHILLELAGH Sub-System	Mobility Br.	Sep 1959	Continuing

This is a continuing in-house program. During FY 62 the Human Engineering Laboratories provided consultative monitoring and coordinating services on the many human factors aspects of the SHILLELAGH Sub-System. Primary effort was related to the development of the conceptualized operational procedures of the SHILLELAGH in conjunction with its integration into the ARVT. During FY 63 emphasis will probably be directed toward looking at the capability of SHILLELAGH to be employed in a ground mount role. In this instance the guidance and control components will be especially critical.

g. Ground Effects Machines—Air Cushion Vehicles	Mobility Br.	May 1962	Continuing

In conjunction with the Mobility Command, project personnel are actively engaged in determining the control parameters of a Genaric air cushion vehicle. The initial effort is largely confined to gathering and analyzing control information from various sources. Based on the analyses, several studies of control parameters will be investigated, using a simplified GEM, with a view toward the development of control specifications and in as great detail as possible. These specifications will be used to guide the development of a tactical ground effects machine vehicle.

h. A/RVT Armored Reconnaissance Vehicle, Tracked, XM551	Mobility Br.	Feb 1960	Continuing

During FY 62 project personnel continued to support OTAC and its prime contractor in the solution and application of human factors engineering to the design of the A/RVT. The major FY 62 accomplishments were (1) solution of the firing shock problem evidenced during the firing of the conventional weapon by a redesign of the gunner's brow pad, (2) preparation of a human factors design standard for incorporation in the basic contract between OTAC and the prime contractor, (3) detailed review of final mock-up and pilot #1 with specific design recommendations, and (4) preparation of the human factors test requirements be conducted within the engineering test plan. The work effort for 63 will be directed toward detailed evaluation of pilot vehicles and investigations of deficiency of spotting round techniques for the conventional weapon, mechanical vision problems, workspace allocations, and ammunition handling.

i. SPIW, Special Purpose Infantry Weapon	Weapons Br.	May 1961	Continuing

During FY 62 a series of studies were performed to evaluate different SPIW concepts and to establish relationships between system parameters such as weight, centers of gravity, impulse and accuracy. Resultant data is being evaluated and will be included as a part of the technical requirements for a development program. Work on this project will continue through the complete development program.

j. 105-mm Howitzer, XM102-104	Weapons Br.	Oct 1960	Continuing

During FY 62 detailed consultation has been provided to the developing agency in the areas of workspace layout, task analysis, emplacement and loading problems, and a general fire control problem. Human factors design studies have been completed for the environmental cover for this weapon and its crew and for seat designs with safety harness to permit the efficient transportation of personnel. Studies have been initiated to evaluate

Project	Branch	Date Started	Estimated Completion

the direct fire capability using a spotting rifle and to evaluate the requirements for hearing protection during firing of the weapon. Evaluation of prototype hardware is planned for FY 63

k Heavy Assault Weapon (TOW)	Weapons Br.	Nov 1961	Continuing

During FY 62 the Human Engineering Laboratories were requested to participate in a program designed to determine the feasibility of the TOW concept. Within this feasibility program the Human Engineering Laboratories were given responsibility for developing the feasibility of tracking mounts and establishing those criteria to optimize human tracking for this weapon. The current feasibility study has been extended to include the operational hazards as well as the operational requirements for the system.

l HU1B/SS-11 Helicopter Armament	Weapons Br.	July 1961	Continuing

This program was designed to evaluate the gunner's task with respect to helicopter dynamic optical sights and missile controls in order to provide human factors criteria for optimum installation. During FY 62 the primary effort has consisted of the preparation of test methodology to establish the criterion information without the necessity of flying helicopters and expending missiles. In addition, a complete evaluation of the SS-11 operator's control units and workspace layouts were performed. This program is extended to continue through FY 63.

m. 81mm and 4.2 Mortars	Weapons Br.	Aug 1960	Continuing

During FY 62 the evaluation of the 4.2 Mortar was completed and an outline of applicable human engineering data compiled. This, in conjunction with a mortar portability study, resulted in recommendations which provide substantial improvements for the 4.2 Mortar. A preliminary investigation of the Mortar Platoon has been completed in which the overall accuracy was recorded during a series of platoon missions. Current and future effort will consist of monitoring new material developments, evaluation of new concepts with respect to the military characteristics, and the study of fire control equipment and procedures in a continuing effort to reduce human errors.

n. Medium Assault Weapon	Weapons	July 1962	Continuing

This is a new project within the Human Engineering Laboratories and is primarily concerned with evaluating concepts to determine the feasibility for development of a new Medium Assault Weapon. The Human Engineering Laboratories responsibilities are to provide the human factors criteria in the areas of accuracy, firing hazards, and operational compatibility for the MAW System.

o. Limited Warfare	Weapons	July 1962	Continuing

The purpose of this task within the Human Engineering Laboratories is to develop realistic human factors criteria to use as a base for design and evaluation of limited warfare materiel. The orientation of this project is to establish categories of human factors criteria, particularly to limited warfare operations. This background will be the foundation for the application of human engineering to the concept, design, and evaluation of weapons and equipment being designed for limited war usage.

p. Mauler	Missile Br.	May 1960	Continuing

The FY 63 program for human factors engineering of the Mauler System will be a continuation of the work performed during FY 61. During FY 61 the program was primarily oriented towards isolating and defining the potential human factors problem areas which required detailed design solutions. During FY 63 project personnel will monitor the operational and acoustic tests to be conducted at Aberdeen Proving Ground.

q. NIKE ZEUS	Missile Br.	Sept 1961	Continuing

During FY 62 project personnel performed a human factors evaluation of the near tactical components of the Zeus system to determine those areas of human factors

Project	Branch	Date Started	Estimated Completion

deficiencies which require solution prior to release for final production. A report on the initial phase has been prepared and distributed to AOMC. The second phase to be conducted in FY 63 will be a more detailed evaluation of the as yet non-tactical components to insure that their design will be compatible with the currently existing tactical equipment.

r. Pershing	Missile Br.	Oct 1958	Continuing

During FY 62 the Human Engineering Laboratories have continued to support the Pershing R&D Office in addition to starting on a human factors program for the Industrial Division. This phase shifting between R&D and Industrial will insure the continuity of human factors designs throughout production of the system. The industrial program consists of detailed review of Pershing Memoranda to insure consistency with previous R&D designs and decisions. The primary FY 62 Pershing R&D effort was directed toward finalization of count-down procedures, noise hazards evaluation, communication requirements, and establishment of human factors test requirements for the final weapon system test program.

s. Missile B	Missile Br.	Sept 1962	Continuing

This project is scheduled to begin during the first quarter of FY 63. Consultation has been continuing with Missile B project personnel as an attempt to specify the detailed human factors requirements in support of the Missile B program.

t. NIKE-HERCULES	Missile Br.	Dec 1961	Continuing

During the third quarter FY 62, Human Engineering Laboratories provided consultation services to AOMC and their civilian prime contractors on the human factors problems which required solution for the development of the ATBM missile. Consultation services will be continued through FY 63 on an "as required" basis.

u. SERGEANT	Missile Br.	Jan 1958	Continuing

During FY 62 studies were conducted to determine estimates of computer operation reliability, in terms of freedom from human error, and speech intelligibility levels which can be expected during tactical operation of the SERGEANT firing set. Recommendations were made on the basis of an analysis of the data which could significantly and practically improve the operator's performance. The extreme temperature tests of the SERGEANT at Eglin AFB climatic chamber were monitored and studies of the critical sub-systems were made to determine whether extreme weather conditions, including wind and rain, could be expected to induce a decrement in the physical or mental performance level of the crew.

v. ML-1 and ML-1A Mobile Low Reactor Prototype	Missile Br.	Sept 1961	Continuing

During FY 62 project personnel conducted a detailed evaluation of the ML-1 control cab to determine its operability and effectiveness as the central control for plant functioning. A control cab mock-up was fabricated to aid in the investigation. A report containing all of the deficiencies and recommendations of this phase was published as TM 8-62. The FY 63 effort will be directed toward (1) establishing a recommended design for a ML-1A control cab and, (2) investigating the power conversion skid to evaluate the equipment and tasks associated with maintaining the equipment and preparing the skid for operation. This work is being done for the U. S. Army Corps of Engineers.

w. Mobile High Power Reactor MH1A	Missile Br.	July 1962	Continuing

The Corps of Engineers have requested the Human Engineering Laboratories to undertake a human factors evaluation of the Mobile High Power Reactor, MH1A. Project personnel will evaluate the general MH1A plant design, operations, and equipment. It is anticipated that a mock-up of the proposed control console will be fabricated to provide for incorporating and illustrating recommendations for the most efficient human factors engineering design.

2. Supporting Research

The Supporting Research Laboratory conducts basic and applied human factors research. This research is oriented to define and capitalize on the capabilities and limitations of Army equipment operators under a wide variety of operational and environmental conditions.

Three branches, Fire Control, Applied Psychophysiology, and Environmental, conduct a program of investigation which includes the following current tasks:

Project	Branch	Date Started	Estimated Completion
a. Army Aircraft Armament	Fire Control Br.	Jan 1961	Continuing

This task is to establish baselines for (1) probability of detection of military ground targets, (2) the types of ground targets most likely to be detected, (3) the accuracy with which the slant range to such targets may be estimated and (4) evaluating mechanical optical, or electronic aids for both ground target detection and range estimation. To investigate the problems of nap-of-the-earth navigation and aircraft vulnerability. One ground target detection study and one range estimation study have been completed and the results published. It is anticipated that most effort will be concentrated this fiscal year on problems of low level navigation and aircraft vulnerability.

b. Aerial Television Sensor and Remote Monitor	Fire Control Br.	March 1961	Continuing

This task was initiated to determine operator limitations and acceptable display degredations for detection, acquisition and closing course tracking of ground targets by way of a remote display from an aerial television camera. One pilot study of perceptual acuity has been conducted and a literature survey and review of similar investigations have been completed.

c. Television Use in Remote Ground Vehicle Control	Fire Control Br.	July 1962	Continuing

The purpose of this task is to determine the ability of a man to (1) remotely maneuver a vehicle over various types of terrain using television as his visual contact and (2) identify various target types while under way. While awaiting maneuverable wheeled vehicles adaption, studies of range estimation from stationary television cameras are currently being conducted and the effects of camera speed on target detection will be investigated utilizing a television camera mounted on a remotely controlled railroad cart.

d Telescopic Rifle Sight Magnification	Fire Control Br.	April 1962	Continuing

The effects of sight magnification from 2 5x to 8x will be evaluated under conditions of normal and stress time intervals. A pilot study using Army riflemen of "Marksman, Sharpshooter and Expert" classification has been conducted for magnifications of 2.5x, 4x, 6x and 8x under both stress conditions.

e. Vigilance	App. Psy.	June 1959	Continuing

This task is being conducted as a multi-phase in-house research program. Current emphasis is on the effects of feedback upon monitoring performance It has been demonstrated that feedback (knowledge of results) can eliminate performance decrement. Feedback in the form of mild electric shock was found to be no more effective than auditory feedback in the initial monitoring session. Studies during FY 1963 will be concerned with the possible differential transfer effects of punishing and non-punishing feedback.

f. Design of a Picture Language To Identify Vehicle Controls	App. Psy.	July 1961	Thru FY 64

This task was initiated to develop a non-verbal system of labelling wheeled vehicle controls, enabling foreign personnel (e.g., of the NATO group) to operate equipment with a minimum of training. A tentative set of picture symbols has been constructed,

Project	Branch	Date Started	Estimated Completion

and is now being evaluated. Effort during FY 63 will be directed at final evaluations and extensions of the symbol set to all dials, meters, guages and warning lights.

g. Physical Force Problems	App. Psy.	Aug 1962	Continuing

The purpose of this program is to determine the energy cost of selected physical tasks and the effects of such energy cost upon the fulfillment of primary and secondary job requirements. This will include studies of rotary work and load carrying. With respect to rotary work, such variable as torque, handcrank dimensions, and placement of cranks will be investigated. The load carrying capability studies will emphasize the design features of containers.

h. Check-Reading Displays	App. Psy.	June 1962	Nov 1962

The efficiency of various check reading displays will be evaluated under conditions of (1) brief exposure and (2) prolonged monitoring.

i. Auditory Localization of Combat Sounds	App. Psy.	July 1962	Continuing

The purpose of this program is to determine those characteristics of selected battlefield sounds that contribute to auditory localization. A comparison of battlefield sound localization and localization of pure tones will be made. Testing will be performed with and without combat headgear. The data will be used for two purposes: (1) as an aid to the development of techniques in object identification and (2) as an aid to the design of weapons with minimal or maximal sound "signatures".

j. Optical Magnification Loss of Perceived Depth	App. Psy.	Sept 1961	Nov 1962

The purpose of this study is to quantify the reduction of perceived depth under conditions of optical magnification. A varipower telescope has been fabricated to specifications. Data obtained will provide information relevant to the use of optics for ranging purposes.

k. Headlight Placement on Track-Laying Vehicles	App. Psy.	June 1962	Oct 1962

The task was initiated to evaluate the feasibility of mounting headlights to the sides or aft of the driver. Two phases of work are involved. First, criteria for headlight evaluation will be selected, or, if unavailable in the literature, developed. Second, these criteria will be used to evaluate the feasibility of several proposed mounting locations.

l. Detection of Figures in Whiteout Conditions	App. Psy.	Sept 1961	June 1963

The purpose is to explore the perceptual consequences of a uniform visual field (ganzfeld) under controlled laboratory conditions. The uniform field occurs in the arctic and occasionally to pilots. In both cases severe visual deficiencies result, such as myopia and loss of depth. The studies will include investigations of the effects of colored fields and intermittent lighting upon the detection of figures in the ganzfeld.

m. Operation SWAMP FOX II	Env. Br.	Aug 1962	During FY 63

The purpose of this program is to obtain quantitative data on the effects of a tropical environment upon men operating military equipment. The program has four (4) major objectives 1) measurement of heat stress experienced by men performing regular military duties, i.e., operating vehicles of interest to the Army; (2) measurement of total thermal balance of men in selected tropical environmental situations, (3) assessment of the effects of a hot wet environment upon the performance of men confined to track-laying vehicles for prolonged time periods, (4) a human factors survey of selected vehicles of interest to the Army with emphasis on tropical employment. These data will be obtained during Operation SWAMP FOX II in Panama during the summer-fall of 1962.

	Project	Branch	Date Started	Estimated Completion
n	Effects of Noise Exposure on Auditory Acuity in the Rhesus Monkey	Env. Br.	Aug 1955	Continuing

The eventual goal of this program is to provide data needed for the development of human damage-risk criteria for impulse noise exposure. The current effort includes the establishment of quantitative relations between auditory threshold shifts and selected noise parameters, using the Rhesus monkey as the experimental subject. Among the noise parameters being investigated are sound pressure level, number of impulses, and impulse rate/unit time. A reliable and efficient method for obtaining audiograms for the Rhesus monkey has been developed. A group of animals is being trained and will be tested during FY 63.

o.	Effect of Extreme Temperature Upon Performance	Env. Br.	July 1962	July 1963

The purpose of this program is to evaluate the effects of thermal gain or loss upon combat efficiency. An extensive literature survey is being conducted into the areas of (1) the effects of temperature extremes and (2) the criteria of human performance relevant to combat performance. Based upon the data obtained, studies of efficiency will be carried out under high and/or low temperatures.

p	Evaluation of a Developmental Armored Squad Carrier	Env. Br	April 1962	Late FY 1964

This task has been divided into two phases (1) development of an interior layout for future armored personnel carriers, based upon available dimensions for such future vehicles: (2) Empirical comparison of the proposed interior with existing vehicles with respect to such factors as loading and unloading time, ingress and egress time, and effects of prolonged confinement upon crew performance. The findings of the HEL program "Individual Capabilities and Limitations of Personnel Operating in Armored Vehicles" (FY 61-62) were applied to the design of the proposed interior layout, and a static mock-up has been built Evaluations of the design will continue throughout FY 63 and 64.

q.	Small Arms Effectiveness from a Mobile Firing Platform	Env. Br.	Oct 1962	Continuing

This is an outgrowth of HEL task "Evaluation of a Developmental Armored Squad Carrier". The purpose of this task is to evaluate the ability of individual riflement to acquire and hit targets while firing from a moving platform, e.g., while riding in a squad carrier. The effects of terrain, speed of vehicle, and firing position upon rifle accuracy will be investigated. In addition, accuracy will be evaluated as a function of selected weapon characteristics.

r.	Exploratory Study: "Psychweap"	Wpns. Br.	July 1962	Continuing

This is a new task in which research was initiated in July 1962 This is a classified project.

PICATINNY ARSENAL, DOVER, NEW JERSEY

1. Project Development

a. Currently active projects and experimenters are

(1) Nike Zeus Missile System:	M. H. Weasner J. Kostakis
(2) Pershing Missile System:	J. Kostakis
(3) Sergeant Missile System	M. H. Weasner
(4) Missile B:	G. R. DeTogni

Project	Branch	Date Started	Estimated Completion
(5) Projectile, atomic, 155mm:		J. Kostakis	
(6) Engineer Nuclear Demolition		G. R. DeTogni	
(7) Line Charge Design		J. Kostakis	

b. Human Factors Specialists are working members of "design teams" throughout all phases of materiel research and development carried out by Picatinny Arsenal. Analytical and emperical methods results in detailed Human Factors evaluations and recommendations for consideration and implementation by Project Managers, are used in the following areas

(1) Weapon system analysis
(2) Personnel sub-system analysis
(3) Operating and procedural manual development
(4) Component sub-system analysis
(5) Check out and maintenance requirements
(6) Packaging and handling design
(7) Stockpile to target sequence analysis
(8) Extreme environmental effects

2. Consultation Activities

A substantial portion of time is devoted to consulting with design personnel on matters of optimal equipment design, psychological, biological or anthropometric data requirements, or disseminating Human Factors information. Examples of current projects in this area and their scope are:

	Experimenters
a. Anti-tank and anti-personnel mines	P. S. Strauss
(1) detection factors (2) identification factors (3) recovery techniques (4) Arming and safing problems	
b. Packaging and handling problems	M. H. Weasner J. Kostakis
(1) handle and latch design (2) size, weight, handling characteristics	
c. Tripwire Systems	P. S. Strauss G. R. DeTogni
(1) force consideration (2) detection factors	
d. Target acquistion under flare illumination	P. S. Strauss G. R. DeTogni
(1) candlepower requirements (2) camouflage and terrain factors (3) personnel acquisition capability	

3. Monitoring Activities

A small amount of time is also spent in monitoring human factors activities which are or could become relevant to Picatinny's research and development mission. Some of these projects are:

a. Bionics Research	P. S. Strauss
b. Programmed Instructional Devices	M. H. Weasner
c. TV Target Acquisition	P. S. Strauss
d. Material Handling Research	J. Kostakis

Project	Branch	Date Started	Estimated Completion

4. Special Projects

The Concepts and Applications Laboratory of Picatinny Arsenal is conducting an operations research analysis of the Army's Explosive Ordnance Disposal (EOD) operations, including the forecasting of 1965-1970 requirements. Human Factors Specialists serve the study team as follows.

a. P. S. Strauss	Study Coordinator
b. G. R. DeTogni	Organization and Mission Analysis
c M. H. Weasner	Training and Testing Analysis
d. J Kostakis	Equipment Requirements

FRANKFORD ARSENAL, PHILADELPHIA, PENNSYLVANIA

Project	Branch	Date Started	Estimated Completion
a. Psychological Warfare Ammunition Program	J. T. O'Connor E. J. McGuigan	June 1961	Indefinite

This project involves the human engineering of a family of weapon systems. Security considerations preclude the discussion of the program except in general terms. The problems involved include the evaluation of weapon and ammunition with regard to: (1) Detection Factors, (2) Anthropometrics, (3) Maintenance, (4) Safety, and (5) Overall weapon capability.

b. Tank Tracking	A. C. Karr	Nov 1957	Continuous

The electronic tank-tracking system is used in conjunction with mock-ups of new anti-tank weapon systems to obtain human engineering data to be used as design criteria. It may also be used in connection with tracking problems other than those directly connected with tanks. Experiments to study control parameters for the Heavy Anti-tank Weapon System - XM-89 have been completed using this equipment. Other studies dealing with general control design problems will be conducted in the future.

c. Fire Control Consultation Services	Staff	Sep 1959	Continuous

Separate funds have been set aside by the Fire Control Division for human engineering consultation services that will not require more than 2 man weeks of effort. Where more effort is required, a separate project is to be set up for it. These funds permit project engineers to request the Human Factors Engineering Branch to look into their projects and determine how much human engineering is required, outline a complete program to be followed, and provide assistance in obtaining human engineering data through literature searches and experimentation.

d. Main Battle Tank	A. C. Karr	June 1960	June 1963

The purpose of this project is to provide human engineering services for the fire control of the Main Battle Tank. The work of the Human Factors Engineering Branch is concerned primarily with monitoring contractor efforts and coordinating the work of the Human Engineering Laboratories, Frankford Arsenal, and the contractors. Certain problems in the use of television will also be investigated.

e. Electro-Visual Equipment.	R. F. Kelly	June 1958	June 1962

This system offers the possibility of night-time operations through the use of electro-visual equipment. Problems requiring human engineering attention concern surveillance, target detection, weapon laying, control-display relationships, communication links, and so forth.

At a later stage both static and dynamic field tests under combat-like conditions will be conducted.

Project	Branch	Date Started	Estimated Completion

WATERVLIET ARSENAL, WATERVLIET, N. Y.

a. 105mm Pivot Chamber Howitzer Concept and Experimental Design
b. 155mm Pivot Chamber Howitzer Concept for XM62 Weapon System
c Muzzle Blast Studies on 105mm Howitzer XM103, 155mm Howitzer T255 Series, and 155mm Howitzer T258 Series
d. 81mm Mortar XM93 Concept
e. 107mm Mortar XM95 Concept
f. 4 2 Mortar T201, Portability and Mount Studies
g. 4.2 Mortar M30, Portability and Target Acquisition Studies
h. British 81mm Mortar L1A1 Comparison with American Standard M29
i. Blast and Noise Studies, Bore Evacuation Studies, and Control Panel Design on 152mm Gun Launcher XM81 for Shillelagh Weapon System
j. Rapid Fire Weapon Concept
k. Field Evaluation of Vigilante Weapon System

U. S. ARMY MISSILE COMMAND, REDSTONE ARSENAL, ALABAMA

Contractor

a. Advanced Visual Information Display (AVID) — McDonnell HEL

A human factors evaluation of the AVID technique was conducted. Considerations investigated with regard to this anti-aircraft defense system display study were effect of display hardware on decision time reduction, effect of display simplification on decision making, comparison of alphanumeric and symbolic displays, integr. ion of geographic information on operational displays and its effect on the equipment operator. Among parameters experimentally investigated were the influence of the number of tracks displayed, duration of data presentation, information content, and the effect of color on predicted situation display. This effort has been concluded with preparation of a final report.

b. DX-43, DX-44 Simulators — Nord-Aviation

A brief human factors evlauation of the DX-43 and DX-44 (wire guided missile) simulators was conducted. Critical aspects of these simulators, assessed in classroom and field environments, were such considerations as pertinence of task practice, miss measurement technique., utilization in job environment, ease of utilization, economy of use, equipment layout, and operating and instruction procedures.

Contractor

c. MAULER — Convair

Among completed and current experimentation efforts designed to provide operator-associated information for the design of the MAULER System are: video displays studies, assessment of vibration effect on operator functions, habilitability and noise evaluations, and data pick-off device studies. Future human factors studies will investigate saturation level of the operator, seating, on vehicle equipment, console proposed for fire unit, capability of operator to handle air defense problem in face of each type of predicted ECM, sector control capabilities of the human operator, lighting, and operator performance under all environmental and situation variables on which MAULER operation is predicted. Preparation of Task and Skill Analysis is in process.

d. MISSILE B — (AOMC)

A brief technical and management plan has been prepared to assure the inclusion of human factors engineering in the development of the MISSILE B Weapon System from the earliest point in the program. Overall human engineering inclusion requirements, identification of critical areas, and delineation of features already planned to reduce or eliminate potential operational difficulties experienced in previous systems, formed the technical human engineering overview. Plans for coordination, evaluation, and design assistance activities were established; human engineering design criteria were selected.

Project	Branch	Date Started	Estimated Completion

Contractor

e. Multisystem Test Equipment — RCA

Human factors engineering analyses, providing data for human engineering application during equipment design phases, were performed. Such design application data as operation environment, performance, system profiles, functions analyses, sequence analyses, etc., were provided. Design inputs, based on these analyses and on system human engineering criteria, have been integrated into preliminary designs of workspaces, panelware, repair equipment, procedures, and other areas where the human operator will be a critical factor in the efficiency of electronic, hydraulic/pneumatic, and repair unit operation. Human engineering design criteria were prepared and supplementary criteria were selected for MTE human factors engineering design application.

f. NIKE HERCULES ATBM — BTL, HEL

Current human engineering activities include panel layout studies, control and indicator evaluations, and assessment of human engineering aspects involved in transition from a permanent to mobile system operation.

g NIKE ZEUS — BTL, DAC, HEL

Continuing human engineering efforts have been applied by the contractor, during R&D, to the design of NIKE ZEUS equipment, particularly in radar, computer, and other ground equipment areas. The current reporting period has seen the initiation of an intense human engineering evaluation performed by HEL for AOMC. To date, the following areas have been exposed to human engineering assessment· ZEUS Defense Center including acquisition radar transmitter and receiver, and power plant; computer equipment including operation and maintenance; ambient environmental influences including noise, rotation, and radiation, development of special weapon and adaption kit; and system consistency. A human engineering evaluation of the missile itself has been initiated. Other areas to be studied from the human engineering standpoint are ground guidance equipment, missile assembly procedure, missile loading and launching procedures. A human engineering assessment of equipment, its operation and its procedural aspects will take place at Kwajelein.

h. PERSHING — Martin-Orlando, HEL

Representative PERSHING Human Engineering studies conducted during this reporting period, in addition to major human factors efforts in design preparation of documentation, specification reviews, consultation, etc., were as follows. Evaluation of crane loading techniques and operating time, evaluation of warhead assembly stand and container, assessment of containers, missile air vanes, warhead davit, Erector-launcher and warhead vehicles, and Communications Central during road testing, Erector-Launcher crewman transportability studies, evaluation of Power Station and Power Station Equivalent including Air Cycle Equipment acoustical tests and measurements of sound-attenuated Power Station near field noise, FMTX cable storage study; physiological and psychological measurements during high-low temperature tests, blackout operations study (pilot study), studies of human engineering aspects of three azimuth laying systems; Noise measurements of Systems Test Station and Components Test Station, ground networks color coding study, evaluation of simplicity, completeness, procedural logic, handbook and skill requirements for malfunction isolation in the Programmer-Test Station, Systems Test Station and Components Test Station.

i. SERGEANT — Sperry-Utah, HEL

During the current reporting period, the SERGEANT Weapon System's data input provisions were experimentally evaluated. This study was designed and conducted to ascertain the degree of reliability, in terms of freedom from operator error, that can be expected during the initial data insertion by the Firing Set operator. Also performed was a human engineering evaluation of SERGEANT Weapon System operational aspects when subjected to extreme temperatures in the Eglin AFB Climatic Laboratories.

Project	Branch	Date Started	Estimated Completion
j. SHILLELAGH Missile Subsystem		Aeronutronics HEL	

A preliminary study on gunner training and tracking ability was completed. Assessment of possible glare and retinal effects of missile tracking flare observation was performed. Noise measurements were taken and are being evaluated.

k. ADVANCED PROJECTS (AOMC)

Human Factors Engineering development and management plans have been prepared for advanced projects. These studies outline critical human engineering areas to receive priority, selection of design criteria, management plan for coordination and design assistance, and inclusion of positive engineering features of current systems into proposed systems. Other activities in the advanced projects area (such as FABMDS) consisted of proposal and feasibility evaluations from the human engineering standpoint. Research projects receiving human engineering inputs or research projects pertaining to human factors research are typified by Out-of-Line-of-Sight studies and the Effects of Stress on Performance studies which are currently being initiated.

U. S. ARMY TANK-AUTOMOTIVE CENTER, DETROIT, MICHIGAN

a. Human Engineering Studies on M60E1 Tank, Responsible Agencies. Aberdeen Proving Ground, HEL and Chrysler Mopar.
b. Human Engineering. Studies on the XM571, Articulated Vehicle, Cargo Carrier. Responsible Agencies: Aberdeen Proving Ground, HEL and Canadair Limited.
c. Human Engineering Studies on AR/AAV. Responsible Agencies: Aberdeen Proving Ground, HEL and COTP (Cleveland).
d. Human Engineering support for XM561, 1-1/4 Ton truck series. Responsible Agency: Aberdeen Proving Ground, HEL.

ROCK ISLAND ARSENAL, ROCK ISLAND, ILLINOIS

a. Human engineering of Auxiliary Propelled 155mm Howitzer Carriage, XM123, Howitzer, Light Towed.
b. 105mm XM102 and 115mm Boosted Rocket Launcher, XM70.

ORDNANCE WEAPONS COMMAND, ROCK ISLAND, ILLINOIS

a. Howitzer, 105mm Towed, XM102
b. Launcher, 115mm, XM70
c. Special Purpose Individual Weapon (SPIW)

Studies associated with the above-listed projects have been made by in-house personnel, contractors, and the Human Engineering Laboratory. The Command function is to monitor and coordinate the studies, to review technical reports, and to assist the member arsenals in their Human Factors Program.

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5. U. S. ARMY MEDICAL SERVICE

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND, OFFICE OF THE SURGEON GENERAL, WASHINGTON 25, D. C.

A. CURRENT WORK PROGRAM

1. Military Psychophysiological Studies
   (Project No. 6X95-25-001)

Task 01 - Vision and Perception in Relation to Performance

Task	Experimenter(s)	Date Started	Estimated Completion
a. Studies of Stereoscopic Vision	Eugene R. Wist George S. Harker U. S. AMRL Ft. Knox, Kentucky	March 56	Continuing

A combination optical-electronic device has been constructed for generating the Pulfrich effect stereoscopically. This apparatus makes possible direct control of the intensity of light in each eye as well as the contrast ratio of illumination of the pendulum bob to its background.

Three pilot studies have been performed with this apparatus in order to refine it and to determine the range of absolute light intensities and contrast ratios significant in the production of the Pulfrich effect. Two further preliminary investigations have been performed to investigate the effect of interocular absolute intensity differences, contrast ratio differences, and simultaneous contrast on the Pulfrich effect. Results suggest that absolute intensity differences are more important than contract differences. However, the results also suggest that the effect can be induced by simultaneous contrast differences between the eyes. A subsequent study concerned the effect of interocular sensitivity differences on the Pulfrich effect.

Instrumentation has been completed for the purpose of investigating the classic assumption that only impulses arriving simultaneously at the cortex from the two eyes fuse to produce stereopsis. Essentially, this appartus involves the coupling of a Roush flash generator with a stereoptometer. It is now possible to delay the arrival at the cortex of impulses from a glow modular tube from one eye with respect to the other by from 1 to 300 (plus) milliseconds. Preliminary data suggest that simultaneously arriving impulses at the cortex may not be a necessary condition for stereopsis. The apparatus is so designed that in addition to interocular delays, the effect on stereopsis of pulse intensity, duration and repetition rate can be investigated.

A study on the effect of base magnification on perceived absolute size and distance; a study on the interaction of voluntary and rotational nystagmus, as well as a bibliography on voluntary nystagmus have been completed.

b. Studies in Perceived Radial Slope	George S. Harker U. S. AMRL Ft. Knox, Kentucky	1 Jan 59	Continuing

Cyclorotation measures in response to a single-line stimulus have been studied by four techniques of measurement to permit comparison of the methods of measurement. Sophisticated and naive observers were used to permit, in addition, an evaluation of the experience variable.

c. Perceptual and Physiological Aspects of Uniform Visual Stimulation	W. Cohen Univ. of Buffalo	June 1957	February 62

A study of electroencephalographic patterns under conditions of uniform stimulation of the entire visual field has been completed. The laboratory condition of "homogeneous ganzfeld" simulated the meteorological state of "white-out." During prolonged stimulation, a temporary stoppage of visual experience occurred and alpha waves returned. The task was conducted under Contract No. DA-49-007-MD-866. The Final Report has not yet been received.

Task	Experimenter(s)	Date Started	Estimated Completion
a. Effects of Noise on Performance and Hearing	John L. Fletcher Michel Loeb U. S. AMRL Ft. Knox, Kentucky	August 54	Continuing

An investigation of the reliability of temporary threshold shift and contralateral threshold shift induced by loud monaural stimulation was completed The reliabilities for contralateral threshold shifts obtained ranged from very low to moderate, and the reliabilities for temporary threshold shifts ranged from moderate to moderately high. Magnitudes were such as to explain the lack of significant relationship between different indices of acoustic reflex action (e.g., reduction in each type of shift) previously observed. In another investigation performed jointly with the U.S.N. Air Materiel Center Air Crew Equipment Laboratory, there was an attempt to determine relationships between psychophysical and manometric measures of acoustic reflex action. The expected relationships were not found, though some unexpected relationships seemed to be present in the data.

Data have been reviewed which suggest that the method of temporary threshold shift reduction may be superior to the free field threshold shift method for the evaluation of ear protective devices.

Task	Experimenter(s)	Date Started	Estimated Completion
b. Effect of Overstimulation and Internal Factors on the Function of the Inner Ear	M. Lawrence Univ. of Michigan	May 55	June 64

The cochleas of guinea pigs were injected with a high potassium, low-sodium solution to produce greatly increased intracochlear pressure. The cochlear AC potentials were recorded simultaneously and found to decrease according to the pressure applied. Four layers of the basilar membrane and two of Reissner's membrane were examined electromicroscopically. They appeared to serve as a selectively diffusing membrane in support of a radial direction for the major path of endolymph flow.

Studies of the inner ear response to increasingly higher tones showed that even in the absence of the middle ear, the inner ear produces a "clamp" in the AC response of the cochlea. The appearance of this response on a cathode ray oscilloscope is identical to that produced by the middle ear muscles. The effect is related to the overloading process of the inner ear in response to high level sounds. These studies are being conducted under Contract No. DA-49-007-MD-634.

Task	Experimenter(s)	Date Started	Estimated Completion
c. Measurement of Noises of U. S. Army Weapons	K. D. Kryter Bolt Beranek and Newman, Inc. Cambridge, Mass.	July 58	July 63

Instrumentation has been completed to simulate the impulse noises of certain U. S. Army weapons. Subjects were exposed to pulses at a repetition rate of 1, 5, 10, 20, 40, and 80 per second for durations varying from 5 to 80 seconds. Rise time of the pulses was 0.5 millisecond; duration 1 millisecond, with a peak sound pressure level of 168 db re 0.0002 microbar The temporary threshold shifts obtained were highly variable from one subject to another (5 S's); the maximum loss was around 5000 cps; the most severe losses were caused by pulse repetition rates of 1 pulse per second and the least at 5 and 10 pulses per second, the longer the exposure, the greater was the temporary threshold shift. This study is being conducted under Contract No. DA-49-007-MD-985.

Task	Experimenter(s)	Date Started	Estimated Completion
d Neural Mechanisms for Responses of Middle Ear Muscles	W. D. Neff Bolt Beranek and Newman, Inc. Cambridge, Mass.	January 62	December 62

This study was initiated only recently. No reports are yet available. The study is being conducted under Contract No. DA-49-193-MD-2230. The information to be gathered will serve in making differential diagnoses in hearing disorders; in surgical procedures of the ear and in the utilization of the "acoustic reflex" for protection of hearing.

Task 03 Improvement of Control and Coordination in Performance

Task	Experimenter(s)	Date Started	Estimated Completion
a. Studies in Biomechanics and Fatigue	Lee S. Caldwell U. S. AMRL Ft. Knox, Kentucky	July 56	Continuing

Work on the effects of body stabilization on the strength of manual control forces has shown that the shoulder stabilization afforded by the backrest may vary the strength of arm extension by as much as 50%, and that the footrest position may vary the strength of arm flexion as much as 25%. Work is continuing on the study of the load-endurance relationship with special emphasis upon the relationship between body measurements and both strength and endurance. A preliminary analysis of the data reveals that strength and endurance are unrelated when the load is proportional to the subjects' strength. Also, the load-endurance relationship is apparently unchanged by variation in the mechanical advantage of the anatomical lever systems. Static and dynamic work tasks with high measurement reliability have been developed for the study of factors influencing physical fatigue and recovery. These techniques have been used in studies on the effects of pharmacological agents on human performance and fatigue.

Task	Experimenter(s)	Date Started	Estimated Completion
c. Studies in Driving-Skill Fatigue	Marvin J. Herbert U. S. AMRL Ft. Knox, Kentucky	July 56	Continuing

A battery of vehicle driving performance measures has been designed and evaluated. Test-retest reliability of selected measures obtained from the nine tests in the battery range from .47 to .78. Estimates of validity were made by correlating "post-task" test results with hours of fatigue driving prior to the test; Pearson product-moment correlations from .18 to .38 were obtained. Test performances of 524 subjects from three studies are being analyzed by the centroid method to identify basic skill factors. In one of the three studies, scores from a number of psychomotor tests, a small driving simulator, and two personality inventories were included as reference tests to aid in factor identification. Preliminary tables of rotation indicate the presence of two motor and two perceptual factors, a strength factor and a personality factor.

Task	Experimenter(s)	Date Started	Estimated Completion
c. Certain Physiological Correlates of Psycho-motor Functioning	R. B. Malmo McGill University	June 55	July 63

Three investigations were conducted. In the first, divided set in a tracking task produced a highly significant increase in tracking error scores, but this difference in performance was not accompanied by any reliable changes in the physiological measures. That this absence of differences in the physiological measures was not due to their insensitivity was demonstrated by five other comparisons with the same subjects (e.g., single versus double tracking with muscular exertion controlled) in which highly significant differences were obtained between physiological measures. From these results it appears reasonable to conclude that purely cognitive factors of set and attention were evidently capable of impairing performance, independently of activation (or arousal).

In a second investigation cognitive factors were further explored employing a paced auditory serial addition task. Effects over longer (minutes) and briefer (seconds) temporal intervals were studied. While the main analysis of the longer intervals showed that the EEG and autonomic changes were highly concordant when level of activation was shifted, there was a suggestion of EEG change accompanying reminiscence that was not reflected in the autonomic measures. The main finding for the short-term study of EEG alpha and beta in this experiment was that both showed few effects attributable to what might be called the more cognitive aspects of performance (e.g., those aspects of performance reflected in the error analysis), but showed great sensitivity to motor aspects of performance (e.g., motor response and preparation for motor response). It seems likely that this finding has important implications for the "psychological refractory period" in motor response, and follow-up studies are being planned to pursue this problem further.

In a third investigation, with brain stimulation as unconditioned stimulus an intracranially elicited autonomic response was conditioned to an exteroceptive stimulus. Heart rate slowing produced by stimulation in "rewarding" areas of the brain was conditioned to a tone in a group of 20 rats. These studies are being conducted under Contract No. DA-49-007-MD-626.

d. Retention of Tracking Skills	A. W. Melton Univ. of Michigan	January 59	September 62

No recent progress report is available. This study is expected to terminate in the fall of 1962, after which a Final Report will be available. The study has been conducted under Contract No. DA-49-007-MD-1020.

Task 04 - Motion and Balance in Relation to Performance

Task	Experimenter(s)	Date Started	Estimated Completion
a. Studies on Effects of Air Transport on Performance	J. Y. Gillenwater A. Jewett U. S. AMRL Ft Knox, Kentucky	February 62	March 62

To evaluate the effects of a prolonged flight on the performance of airborne troops, a medical study team consisting of a medical officer, a psychologist, and three enlisted men evaluated the condition of the troops prior to departure, while en route and after arrival at destination. Each soldier was given a tag on which hourly entries were recorded. In summary, there was no problem with airsickness since the flight was relatively smooth; the airborne troops were somewhat fatigued midway of the flight, but after a good night's sleep, they were in excellent physical and mental condition; the soldier's reported that meals during flight could have been improved, the toilet facilities at the refueling stops were considered inadequate at several places; although most of the troops complained of boredom due to insufficient activities at the stops, on arrival they were considered by their officers and NCO's to have been immediately ready for combat had the situation demanded.

Task 05 - Special Sensory Functions in Relation to Performance

Task	Experimenter(s)	Date Started	Estimated Completion
a. Studies of Thermal Experience	W. W. Dawson U. S. AMRL Ft. Knox, Kentucky	January 62	Continuing

To investigate the temperature sensing capacity of the trigeminal nerve endings in the human cornea and certain facial areas, stimulation equipment for radiant warming of the cornea is being assembled and tested. The pilot study which will describe thresholds for radiant corneal damage is well underway. Early data indicate the "permanent damage" (opacity) threshold at an energy between 250 and 300 calories total input per square centimeter. The use of lasers for controlled radiant warming has been considered. Presently available units are either deficient in output energy or too erratic for controlled use. Preliminary data indicate that the threshold for "permanent damage" of the cat cornea is considerably higher than anticipated from the available literature.

b. Neural Correlates of Thermal Sensations	D. R. Kenshalo	December 55	August 61

The thermal threshold varies as a function of skin temperature, sex of the subject and time of day of the measurement, but apparently is not affected by subject age, oral temperature, or changes in the menstrual cycle. It is suggested that cutaneous sensations are mediated in the following manner. Fibers ending in the skin are generally sensitive to movement, either in relation to their surrounding tissue or upon themselves. This accounts adequately for tactile sensitivity. Other fibers, also sensitive to movement, terminate among smooth muscle of the cutaneous vascular system. Smooth muscle acts as a thermo-mechanical transducer, changing thermal energy to mechanical movement. Fibers ending in the cutaneous vascular system respond, through thermally induced movement of the muscle elements, to temperature changes. Tests of the sensitivity of free nerve endings of the cornea of the eye show that they can be stimulated directly by changes in thermal energy, but are not of sufficient sensitivity to account for thermal sensitivity in other regions of the body, nor does such corneal thermal stimulation give rise to thermal sensation. The study was conducted under Contract No. DA-49-007-MD-683. A Final Report has been received and is available from ASTIA. (ASTIA No. AD-267-909)

Task 06 - Integration of Complex Functions in Performance

Task	Experimenter(s)	Date Started	Estimated Completion
a. Studies in Learning	I. Behar J. N. Cronholm T. C. Cadwallader U. S. AMRL Ft. Knox, Kentucky	August 57	Continuing

It has been demonstrated that the formation of learning sets in sooty man ~beys (Cerocebus fuliginosus) progresses at the same rate as for rhesus monkeys and displays similar characteristics. An analysis of the differential effects of reward and nonreward on the acquisition of the discrimination learning set indicated that the approach response to the positive cues is learned as a monotonic function of practice, while this is not true for the avoidance response to the negative cues. Studies of form perception, one with rhesus and the other with mangabey monkeys, are in process of analysis. Basically, an attempt was made to determine the physical stimulus characteristics that influence pattern discriminability. The design and construction of apparatus has been undertaken for a comparative study of visual acuity.

In another study, our electronic gate has been developed which permits the precise timing of the duration of electric shock received by an animal, making possible an objective and accurate differentiation between an avoidance response and an escape response. A recently completed experiment showed that resistance to extinction of a conditioned avoidance response is greatly increased by extending the maximum duration of the conditioned stimulus in extinction. Preliminary analysis of another avoidance conditioning experiment indicates that the usual conception of the distribution of practice, i.e., that spaced practice facilitates learning more than does massed practice, may not apply in a presumably anxiety-arousing situation. Work is continuing to perfect a suitable method for evaluating the effects of neural damage on emotional behavior.

Task	Experimenter(s)	Date Started	Estimated Completion
b. Context Effects in Psychophysical Judgments	W. E. Kappauf Univ. of Illinois	July 57	September 60

This study showed the biases occurring in making judgments which are attributable to the context in which the judgment is made. There are wide individual differences in the magnitude of the effect, in the rate at which it develops and in the nature of its decay function. The study was conducted under Contract No. DA-49-007-MD-877. The Final Report has not yet been received.

Task	Experimenter(s)	Date Started	Estimated Completion
c. Extreme Environment and Complex Performance	A. J. Riopelle Yerkes Laboratories Orange Park, Fla.	February 60	June 62

This study was to have determined the nature and degree of auditory impairment following acoustic insult and other stresses on the animal. Tests for discrimination and other complex performance tests were devised but the contract study was terminated prior to the animals being placed in an extreme noise environment. A Final Report has been received and is available from ASTIA. The study was conducted under Contract No. DA-49-193-MD-2095.

2 Basic Research in Psychological and Social Sciences (Project No. 6X99-28-001)

Task	Experimenter(s)	Date Started	Estimated Completion
a. Psychophysiology of Vision	D. B. Lindsley U.C.L.A.	May 56	August 63

Studies have continued on the perceptual blanking phenomenon to determine the temporal aspects of visual perception. This study is being conducted under Contract No. DA-49-007-MD-722.

b. Spectral Sensitivities for Small Retinal Areas — J. Krauskopf, Rutgers Univ. — September 60 August 62

Studies utilizing the stabilized image technique have yielded results bearing on the nature of the fundamental color response systems of the human retina. Color experiences for tiny spots of monochromatic light are not necessarily the same as the stimulus. This is explicable only in terms of imperfect instrumentation for producing stable images or in terms of the size of the receptor area being stimulated in the retina. Measurement of retinal images has been made with a photoelectric ophthalmoscope to provide information on the fidelity of the image forming mechanism. This study has been conducted under Contract No. DA-49-193-MD-2128. A Final Report will be available in the fall of 1962.

c. Traumatic Origins of Permanent Hearing Loss — I. Behar, M. Loeb, J. N. Cronholm, A. Jewett, U. S. AMRL, Ft. Knox, Kentucky — January 61 Continuing

To assess the relation of temporary to permanent hearing loss as a function of the characteristics of the noise stimulus - (Continuous type or impulse-type), a study has been initiated to evaluate the effects of duration, intensity, and mode of exposure on audiometric performance of rhesus monkeys. Pre-exposure audiograms have been obtained in one subject using a modification of the Blough-Bekesy technique for self-determined thresholds. Two additional subjects are undergoing training.

d. Vestibular Function in Man and Animals — G. H. Crampton, U. S. AMRL, Ft. Knox, Kentucky — July 56 Continuing

A major project, employing 60 cats, evaluated the importance of vision in the nystagmus habituation process. It was found that, although vision is a prominent determiner of eye movement during rotation, that repeated rotary trials with vision has no effect whatsoever on the nystagmic reflex if later tested in darkness. Work is continuing on the effects of linear acceleration on the nystagmic response of man. Data collected so far indicate that with tilts of the gravitational resultant up to 16°, no change can be detected in the ocular nystagmus as compared to nystagmus recorded in the absence of linear acceleration. A new study is designed to determine if habituation to one level of acceleration is effective in reducing the nystagmic response to accelerations of higher and lower magnitudes. Development is continuing on a method for implanting micro-electrodes in the vestibular ganglion of the cat. All of the current studies are oriented toward elucidating man's accustomization to unusual acceleration environments.

One new rotary device was installed during this last year and has been in steady operation. A second device is scheduled for delivery and installation during the fall of 1962.

e. Audition and Auditory Perception — M. Loeb, J. L. Fletcher, U. S. AMRL, Ft. Knox, Kentucky — August 54 Continuing

Two studies of factors influencing the intensive difference limen were completed. In one it was found that when "doubtful" judgments are precluded but "equal" ones are not, limens for modulation are somewhat smaller than those for discrepancies between signals, and limens are smaller for greater intensities and (generally) more comparison cycles. On a second experiment (performed jointly with personnel at the University of Louisville) it was found that the superiority of detection for modulation signals is enhanced under vigilance conditions and that the effective limen tends to increase with time on task.

A seminar on middle ear function was held at the laboratory on 6-7 May 1962. Among the participants were, Dr. Charles Blevins, Dr. R. Fleer, Capt. John L. Fletcher, Dr. Odell W. Henson, Dr. Ira J. Hirsh, Dr. Merle Lawrence, Dr. Michel Loeb, Mr. Emanuel Mendelson, Dr. J. R. Mundie, Dr. W. D. Neff, Dr. Scott N. Reger, Dr. F. Blair Simmons, Dr. W. Dixon Ward, Dr. Howard Weiss, Dr. Jozef Zwislocki.

f.	Studies in Psychopharmacology	W. O. Evans G. H. Crampton U. S. AMRL Ft. Knox, Kentucky	July 61	Continuing

The effects of psychotropic drugs on human attention and temporal experience have been studied Techniques, using animals, have been developed for the screening and behavioral analysis of analgesic and psychotropic drugs and reported in USAMRL Reports No. 476, 494, 480. The synergistic potentiation of opiate induced analgesia by "Alpha" adrenergic stimulants and "Beta" adrenergic blockers has been studied and their potential military utility reviewed. Continuing studies of d-amphetamine on vestibular function have shown that in clinical doses, the drug has only a small enhancement effect (as measured by nystagmus) in man.

g.	Effects of Noise on Man	K. D. Kryter Bolt Beranek and Newman, Inc.	February 62	January 63

This is to be a review of all the scientific literature of the past decade concerning the effects of noise on man. The study was initiated only recently. No reports are available. The study is being conducted under Contract No. DA-49-193-MD-2235.

h.	Communication by Electrical Stimulation of the Skin	Emerson Foulke Univ. of Louisville	November 61	October 63

Studies at U. S. AMRL, Fort Knox, Kentucky had already demonstrated the potential use of a one way communication system by means of the skin acting as a sensor for electrical stimuli. Research is now on-going to determine the most practical parameters. The study is being conducted under Grant No. 62-G49.

i.	Psychological Influences on Gastro-intestinal Activity	R. Russell Indiana Univ.	September 59	August 62

This study is concerned with a systematic search for psychological and pharmacological factors which may control gastro-intestinal movements. The electrophysiological characteristics of gastro-intestinal motility are being studied as are those environmental conditions, bodily states or drugs which generate changes in gastro-intestinal activity This study is being conducted under Contract No. DA-49-193-MD-2063

j.	Localization of Sound in Depth	I. Hirsh J. L. Fletcher Central Institute for the Deaf St. Louis, Mo.	January 60	December 60

The intensity of sound is an important factor in the judgment of distance from the source, but under conditions where sound intensity cannot be used as a cue, sufficient cues other than intensity provide relatively reliable localization judgments. The study was conducted under Contract No. DA-49-193-MD-2088. A Final Report is available from ASTIA (ASTIA No. AD-252-818)

k.	Effects of Practice on Sensory Discrimination	R. Bixler M. Loeb Univ. of Louisville	August 59	July 61

To refine the precision of audiometric tests, this experiment was designed to explore the nature of the practice effect for low sound frequencies where individuals might be learning to distinguish between a low frequency signal and a low frequency broad-band background of "physiological noise" in the ear. When a 50 db white noise was introduced to mask the physiological noise, the practice effect producible at 125 cps and 1000 cps was absent. When a narrow-band high frequency noise (3000-3200 cps) was introduced, a learning effect for the 3000 cps threshold was not induced. This study was conducted under Contract No. DA-49-193-MD-2041. A Final Report is available from ASTIA.

l Perceptual Evaluation of Sensory Information	J. R. Binford Univ. of Louisville	September 61 August 63	

Vigilance is being studied by collecting data on the effect of rise time and discrimination difficulty of auditory stimuli on detectability. Vigilance will also be related to the changing probabilities of target occurrence Other studies, supporting research at the U. S. AMRL, Fort Knox, Kentucky include experiments comparing auditory and cutaneous reaction time, and the relationship between forces exerted and their durations by a seated man with arm held at various distances and angles.

m Irradiation and Visual Function	W. W. Dawson U. S. AMRL Ft. Knox, Kentucky	January 62	Continuing

Research has been initiated to provide a basis for greater understanding of normal photochemical events in the eye to yield methods for decreasing the onset time of scotopic vision and enhancement of its maximum sensitivity, and to enable the recommendation of protective measures for the reduction of visual deterioration and "noise" when high background radiation levels are present. All major apparatus for the biochemical and electrophysiological phases of the research has been secured. Installation and repair of existing x-ray equipment has been completed. Radiological survey of the installation indicates that x-ray scatter into the external work area is less than 0.1 mr/hr., within the specified safety limits of the Atomic Energy Commission. Successful extraction of photopigment (rhodopsin) has been made from the retinas of frogs. Stockpiling of this extract is underway in anticipation of bioassay for sulfhydril activity during irradiation. The device for titration has been completed and functions accurately in titrations of glutathione, a known sulfhydril bearing compound. Final construction of the visual stimulator required for the electrophysiological studies is underway. Titration of rhodopsin sulfhydril groups during illumination has been accomplished following the techniques of Wald and indicates that the biochemical procedure is adequate for the research.

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U. S. Army Medical Research Laboratory, Fort Knox, Kentucky

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WIST, EUGENE R., 1/Lt., MSC, Research Psychologist; Ph.D., University of Missouri, 1960. Vision.

6. U. S. ARMY QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES, CHICAGO, ILL.

A. CURRENT WORK PROGRAM

1. Nature and Control of Attitude Toward and Preference for QMC Materiel

Title	Experimenter	Date Started	Estimated Completion
a. Increasing preferences by exploiting non-functional characteristics	J. Eindhoven	Mar 1962	Sep 1962

Investigation of the effects on soldiers' attitudes and preference of information printed on packaging, estimation of soldiers' bias against foods bearing Army labels as compared to those with commercial labels, manipulation of information variables to improve food preferences.

b. Analysis of mastication sounds	B. Drake (Visiting Scientist)	Sep 1961	Sep 1962

Techniques are being developed for recroding and analyzing chewing sounds for various foodstuff and for relating these data to other objective and sensory characteristics of food.

c. Attitude change through cognitive pressures	P. Zimbardo (Grant)	June 1962	Jun 1963

Attitude change theories are being developed and tested for effectiveness in military situations. Variables to be considered include (a) the timing of presentation of indoctrination programs, and (b) types and degrees of positive and negative pressures exerted upon the target population.

d. Application of programmed instruction theory and techniques to attitude change	J. Kamen	May 1962	May 1963

Methods of programmed instruction are being tested and revised for the purpose of improving the attitude of soldiers to new rations and ration components. These methods are also being compared to more conventional techniques.

e. Sensory evaluation for quality control of products	D. Peryam	Jan 1952	Continuing

Development of methods of measurement and establishment of standards of palatability and flavor for procurement of foods; growing emphasis is upon newly developed and unusual foods.

f. Complex taste interactions	J. Kamen	Apr 1962	Jul 1963

A systematic investigation is underway of the effects of combinations of two taste stimuli upon the perceived intensity of a third; all four primary taste qualities are being studied in a series of four experiments.

g. National surveys of soldiers' food preferences	J. Kamen	Sep 1962	May 1963

A survey is being planned to obtain soldiers' perferences for foods recently introduced into the Master Menu and to determine shifts in preferences for certain foods over the past seven years.

h.	Effect of military operations in the tropics on soldiers' attitudes toward QM materiel	Under contract	Sep 1962	Sep 1964

Investigation of the effect of interaction between soldiers' attitudes and environmental factors in tropical situations upon the acceptability of foods, clothing, and items of personal equipment.

i.	Structure and content of mass communication	J. Kamen	Sep 1962	Sep 1963

Investigate the organization and the nature of the content of scripts intended to change attitudes toward QM materiel.

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EINDHOVEN, JAN E.; Chief, Sensory Testing Laboratory, Food Acceptance Branch; M.A., University of Hawaii, 1949; Consumer preferences, taste and odor research; Member, American Psychological Association.

KAMEN, JOSEPH M., Dr., Acting Chief, Research and Evaluation Section, Food Acceptance Branch; Ph.D. University of Illinois, 1955; Psychophysics of taste and odor, monotony, attitude change, product acceptance, Member, American Psychological Association, Sigma Xi, Psychonomic Society, American Marketing Association.

McCOY, JOHN L., Research Psychologist, Food Acceptance Branch; M.A.; University of Chicago, 1962, Communications, small group dynamics, attitude measurement; Member, American Sociological Association, American Academy of Political and Social Science.

PERYAM, DAVID R., Dr., Chief, Food Acceptance Branch, Ph.D., Illinois Institute of Technology, 1961, Sensory test methods for foods, taste perception, attitudes and preferences, Member, American Psychological Association, Institute of Food Technologists, American Marketing Association.

7. U.S. ARMY QUARTERMASTER RESEARCH AND ENGINEERING COMMAND, NATICK, MASS.

A. CURRENT WORK PROGRAM

1. Human Engineering and Compatibility of QMC Items

Title	Experimenter	Date Started	Estimated Completion
a. Human engineering compatibility studies of QMC developmental items and equipment of other Technical Services	J. McGinnis	Jan 1959	Continuing

Identification and analysis of incompatibilities involving the use of QMC items in man-machine systems are being applied for further refinement of precision and efficiency.

b. Preparation of handbook of human engineering information for guidance of QMC engineers and designers	J. Kobrick	Aug 1960	Continuing

Relevant human engineering guidance information pertinent to QMC problems is periodically published to assist QMC designers and those of the other Technical Services.

c. Human factors guidance, consultation and research in support of materials handling equipment development	B. Crist	Jan 1959	Continuing

Human factors guidance in the design and development of rough terrain forklift vehicles is provided as required. Emphasis has recently been placed on the prototype Sandpiper and Portageur vehicles.

d. Investigation of sensorimotor responses critical to performance of military tasks and the effects of environment and QMC items on such responses	R. Dusek J. Lockhart E. Youngling	Jan 1962	Continuing

Research is conducted in sensorimotor areas of general application to problems of design of QMC items. Particular emphasis is placed at present on environmental effects upon basic response complexes previously isolated by factor analysis techniques.

e. Evaluations, assistance and guidance in support of new QMC clothing and equipment development programs	J. Kobrick J. McGinnis R. White	Jul 1960	Continuing

Evaluations, assistance and guidance in support of item development are furnished as requested.

f. Research on headgear system variables related to verbal communication, attenuation of hazardous noise, comfort and crash protection	B. Crist	Jul 1959	Continuing

Human engineering research is conducted to obtain guidance information for improvement of protective headgear, particularly for combat vehicle crewmen and aviators.

Title	Experimenter	Date Started	Estimated Completion
g. Study of personal clothing and equipment requirements of the equipped combat soldier performing specific types of duties	J. Tambe	Jan 1962	Jul 1965

Human engineering studies are conducted to determine the effectiveness of QMC items in use in the field and the effect of such equipment on the effectiveness. Emphasis is placed at present on the effects of tropic conditions upon soldier effectiveness, as contrasted to similar effects produced by temperate conditions.

h. Analysis of human factors problems associated with newly developed equipment and tactics	J. Senna K. Guthrie	Jan 1962	Continuing

Research is conducted on new techniques and devices to provide increased effectiveness to existing procedures and tactics, such as the current program to provide armor protection to Army operators of light aircraft.

i. Human engineering study of aerial equipment delivery systems	J. Kobrick R. White	Jul 1962	Jul 1964

Human engineering guidance and supporting research is provided to development programs for aerial delivery equipment, especially for personnel delivery. Present attention is directed toward design and development of personnel delivery pods and safety devices for parachutists.

2. Anthropometry

a. Collection and analysis of anthropometric data concerning the functional characteristics of military populations	R. White	Jan 1958	Continuing

Range of body size, range of movement, spatial dimensions and other functional characteristics of military populations are being determined to provide anthropometric criteria and guidance for the design and development of military clothing and other equipment.

b. Anthropometric design and sizing guidance	R. White	Jul 1948	Continuing

Design guidance and human engineering considerations are furnished as requested in support of development programs for military clothing and equipment. Tariffs are developed for the procurement of new or modified items.

c. Anthropometry of friendly populations	R. White	Jul 1962	Continuing

There is an increasing requirement for anthropometric data on the populations of friendly countries to whom we may supply military aid. Data have been collected from several NATO countries and are being analyzed. Similar data are being collected for other populations.

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BASILIO, KENNETH C., Research Psychologist, M.A., Boston University, 1959, Physiological and sensory psychology.

BURSE, RICHARD L.; Biologist; B.S., Massachusetts Institute of Technology, 1958, AMT, Harvard University, 1962, Physiological psychology, biophysics; Member, National Science Teachers Association, Society of American Military Engineers.

CRIST, BRIAN, Engineering Psychologist, M.A., Boston University, 1957; Engineering psychology, apparatus design, Member, American Psychological Association, New England Psychological Association, American Association for the Advancement of Science, Acoustical Society of America, Armed Forces-NRC Committee on Hearing and Bioacoustics.

DUSEK, E. RALPH, Dr.; Head, Engineering Psychology Laboratory, Ph.D., State University of Iowa, 1951; Human engineering, psychomotor performance, experimental design, Member, American Psychological Association, Psychonomic Society, American Association for the Advancement of Science, Sigma Xi, Army Human Factors Engineering Committee, New England Psychological Association, Eastern Psychological Association, Midwestern Psychological Association, Armed Forces-NRC Committee on Hearing and Bioacoustics, Armed Forces-NRC Committee on Vision.

FICKS, FILMORE L., Captain, QMC, Research Psychologist; M.S., Pennsylvania State University, 1952, Human engineering, equipment design, Member, American Psychological Association.

GODWIN, WILLIAM C., Captain, QMC; Mathematician; M.S., Georgia Institute of Technology, 1962; Experimental design, mathematics.

GUTHRIE, KENNETH E., 2/Lt., QMC; Mathematician; B.A., New Mexico State University, 1960; Statistics, human engineering.

KOBRICK, JOHN L., Dr., Project Leader; Ph.D., Pennsylvania State University, 1953, Engineering psychology, experimental design sensorimotor performance; Member, American Psychological Association, Eastern Psychological Association, Sigma Xi, Armed Forces-NRC Committee on Vision.

LOCKHART, JOHN M., Research Psychologist; M.S., University of Wisconsin, 1961; Learning, physiological and sensory psychology, statistics; Member, Psi Chi.

McGINNIS, JOHN M., Dr.; Project Leader; Ph.D., Yale University, 1929, Human factors in systems design, psychophysiology, attitude measurement; Fellow, American Psychological Association, American Association for the Advancement of Science, Diplomate in Industrial Psychology.

SENNA, JOZEF F., Captain, QMC, Project Leader, M.A., Ohio State University, 1959, Human factors in systems operations, engineering psychology.

STEMBRIDGE, GEORGE E., 2/Lt., QMC, Ph.D., University of Maryland, 1962, System operations in tropics.

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TERRELL, ROBERT M., Third, Pvt., Electrical Engineer, B.S., Stevens Institute of Technology, 1959, Apparatus design, electronics.

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YOUNGLING, EDWARD W., Research Psychologist, M.S., University of Massachusetts, 1962, Engineering Psychology, effects of climatic variables on psychological processes.

ZIMMERER, THEODORE, Pfc., Mechanical Engineer, B.S., Rutgers University, 1959, Apparatus design, mechanical engineering.

8. U.S. ARMY QUARTERMASTER RESEARCH AND ENGINEERING FIELD EVALUATION AGENCY, FORT LEE, VA.

A. CURRENT WORK PROGRAM

1. Field studies of Quartermaster Items

	Title	Experimenter	Date Started	Estimated Completion
a.	Variations in relative preference ratings obtained under field vs garrison conditions	T. Burt	Jun 1961	Continuing

Data are being collected to determine whether the measurement of acceptability of operational rations made under garrison conditions can be used to predict acceptance in the field

	Title	Experimenter	Date Started	Estimated Completion
b	Development of a unified theory methodology for sensory testing and preference measurement	J. Sanders (Grant)	Jan 1961	Aug 1962

The objectives of this study are: (1) to formulate a completely general sampling theory for the method of paired comparisons, (2) to prepare a computer program for a solution to the method of successive categories and (3) to write a complete review of scaling methodology in the Thurstonian system of scaling with appropriate examples.

	Title	Experimenter	Date Started	Estimated Completion
c.	Development of quantitative measure of combat effectiveness for the evaluation of QM equipment	J. Sanders (Contract)	Jun 1962	Continuing

An important aspect of the evaluation of new chemical-biological warfare protective systems will be to determine the effect they have on the operational efficiency of the infantry soldier. This research, being conducted under contract, will develop and validate objective procedures for measuring the relevant aspects of combat effectiveness. The techniques developed will then be incorporated in the field evaluations of prototype items as they are developed.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

ASKEW, ROBERT L., Industrial Engineer, Methods Engineering Branch, B.S., 1956; Industrial engineering.

HEMBREE, HOWARD W., Dr., Scientific Director; Ph.D., 1956; Human factors.

SANDERS, JERRELL L., Supervisory Technologist, Methods Engineering Branch, B.S., 1962; Field test methodology.

9. U.S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY FORT MONMOUTH, NEW JERSEY

A. CURRENT WORK PROGRAMS

1. Internal

As part of the product review and value analysis function of the Applications Engineering Branch, human factors engineering reviews were made of approximately twenty Signal components, equipments and/or systems.

As part of the Applications Engineering Branch research effort in human factors engineering, two studies were made, resulting in a report on the "Human Factors Engineering Considerations of the Infantry Radar MLV-2a", and the initiation of an experimental study of the relationship between object/image ratio and speed and accuracy of target identification by unaided operators.

Human factors engineering consultation service was provided to USASRDL scientists and engineers on a variety of equipments and systems. Representative equipments and systems are Balloon Launching and Inflation Device, Trip Wire Device, Central Office, Telephone Electronic AN/TTC-12 (XC-2), and the Squad Radio Set.

Effort is continuing within Systems Techniques Branch in the areas of imagery and display interpretation techniques, "real-time" interpretation, combining of multi-sensory information, and the comparison of electronic and optical display methods.

	Project	Experimenter	Date Started	Estimated Completion
a.	Human Factors of Imagery Interpretation Techniques	D.L. Huebner	Jan 61	Continuing

The objective of this program is to experimentally determine valid, quantitative data that are applicable to the development of advanced techniques and man-machine systems for the interpretation of imagery from photo, radar and infrared sensors. A pilot experimental study of performance at high rates of interpretation has been conducted, and suggested performance measures presented A report is in the draft stage. A series of meetings have been initiated to coordinate Army-wide efforts in Human Factors in Imagery Interpretation. An initial meeting in April 1962 included representatives of Project Michigan, HumRRO, USAPRO and USAEPG.

2. External

	Project Title	Firm	Date Started	Estimated Completion
a.	Study of Human Information Handling Rates	Applied Psychological Services	16 June 61	15 June 1963

This study developed a facility for the evaluation of displays developed by USASRDL scientists and engineers. The facility enables measurement of the capacity of a display to transfer information to an operator, and the effectiveness of the operator in acting on the transferred information.

	Project Title	Firm	Date Started	Estimated Completion
b	Human Engineering Studies of Signal Corps Systems and Equipments	Dunlap and Associates, Inc.	1955	continuing

The purpose of this work is to provide service in specialized areas of human factors engineering to USASRDL engineers and scientists engaged on particular projects. Current projects are: The UNICOM Subscriber Subsystem, Study of Auditory Signal Characteristics for Doppler Ground Surveillance Radar Systems, Human Factors Design and Systems Study for a Second Generation Lightweight, Handheld Radar Set, Human Factors Engineering Study of the Visual Airborne Target Locator System AN/UVS-1, Human Factors Engineering Review of Radio Set AN/GRC-106, Environmental Conditions in Signal Corps Enclosures.

	Project Title	Firm	Date Started	Estimated Completion
c.	Study of the Human Factors Aspects of Reliability	Ford/Aeronutronic	1 July 62	30 June 63

This study is concerned with feasibility of quantification of the human factors aspects of reliability, and the possible application of quantified reliability theory to the development of Signal Corps equipments and systems.

B BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Huebner, D.L., Time and Error in Human Recognition of Arabic and Binary-coded Decimals, USASRDL. Technical Report 2250, January 1962

Applied Psychology Corporation

Final Report on Contract Nr. DA-36-039-SC-78328, DA Project Nr 3-99-00-110, "Human Factors Ratings in Design of Signal Corps Systems."

Applied Psychological Service

First, Second, Third, and Fourth Quarterly Progress Reports on Contract Nr DA-039 SC-87230, Project Nr 3A99 01 001, "Information Transfer in Display - Control Systems."

"I. Survey and Variables Included in a Proposed Display Evaluative Index."

"II. Exponent Determination and First Applications of a Display Evaluative Index."

"III. Further Applications, Reliability, and Validity of a Display Evaluative Index."

"IV. Summary Review of the DEI Technique."

Dunlap and Associates, Inc

The following human factors engineering studies in support of specific USASRDL projects were completed under Contract Nr DA 36-039-SC-78921.

"Design Parameters for the AN/PPS-6 Radar System"

"Dwell Time, Noise and Target Type, An Experimental Study of Aural Detection of Radar Targets"

"Guide to the Coding of Controls"

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

Applications Engineering Branch

Griffith, Paul E., Chief, Applications Engineering Branch; B.A. Carleton College 1929, Communications. Member, Acoustical Society of America, Sigma Xi, Senior Member, IRE.

Hennessy, John R., Chief, Human Factors Engineering Section, M.A. New York University, 1949, Mathematics Education, Member, Human Factors Society.

Reinhart, Alfred G., Electronic Engineer (General), Human Factors Engineering Section, National Radio Institute, 1930.

Systems Techniques Branch

Huebner, Daniel L., Research Psychologist; M.A. The New School for Social Research, 1955, Perception and Learning, Member, APA, EPA, IRE.

10. U.S. ARMY TRANSPORTATION RESEARCH COMMAND, FORT EUSTIS, VIRGINIA

A. CURRENT WORK PROGRAM

1. Program includes the continual review of a limited number of the items of the Transportation Corps equipment during the period that these items are being conceived, designed and developed. This summary review has to do with the design and recommended method of operation of this equipment from the viewpoint of human use. This type of review usually includes one or more of three approved approaches:

a. Laboratory test which normally involves simulated use of an item.

b. Field test, usually performed when an item is in an advanced stage of development.

c Provide advisory service on the application of known human factors engineering principles to the equipment designers.

2. Supporting Research

Project	Experimenter(s)	Date Started	Estimated Completion
a. Aviation Crash Injury Research	F. P. McCourt W. J. Nolan TRECOM Flight Safety Foundation, Inc.	Sept 59	Continuing

The program objective is to eliminate or greatly reduce those factors which cause or contribute to injury and death of personnel involved in survivable type Army aircraft accidents. Through a contract with the Flight Safety Foundation, Inc., New York, New York, research is conducted in fields related to Army Aviation Safety, with particular emphasis placed on crash injury and crashworthiness programs. Accident investigations, statistical analysis, training, and human factors areas comprise much of the work requirements specified in the contract; however, the majority of the effort expended this year has been in the form of experimental research. This research has consisted of dynamic crash tests of fully instrumented Army-type helicopters and the fabrication of an experimental fire suppression and inerting system for radial engines. Two remote controlled crash tests are planned for FY-63 which will incorporate both Crash Injury and Crash Fire instrumentation. Data from these tests, when validated by, and correlated with, data to be derived from future experiments, will provide valuable information upon which to base recommendations for changes to applicable Military Specifications and aircraft and component design.

Project	Experimenter(s)	Date Started	Estimated Completion
b. Vehicle Vulnerability and Crew Protection	E. V. Merritt TRECOM D. W. Mowrer BRL Capt. J. F. Senna QMRECOM	Feb 59	Continuing

The program objective is to determine the degree of vulnerability of Army aircraft and the optimum degree of protection which can be provided for air crews through the combination of personnel armor and aircraft armor.

The work dealing with protection of Army aircraft crews from small arms fire continues. A protection concept was formulated and systems designed for several specific aircraft. The system varies in weight and configuration dependent on the degree of protection desired (full or partial coverage) and the range at which protection is afforded. Studies related to air crew protection are being conducted as follows

(1) Visibility Restriction Study: To determine the effects of reduced visibility occasioned by installation of protective system on pilot performance.

(2) Effects of Altitude and Speed on Air Observer Performance: To determine the optimum altitude and speed for detecting and identifying ground targets, this will in turn permit a higher degree of accuracy in identifying the threat in terms of specific weapons. The vulnerability of the aircraft may then be determined in relation to the threat and tradeoffs made as required.

The personnel protection concept as formulated for Army aircraft has been applied to shallow draft boats, and studies are currently being directed to application of the concept to other ground vehicles.

c. Gust Acceleration Simulator Study	Martin R. Copp Robert L. Brugh TRECOM North American Aviation, Inc.	1 July 62	1 May 63

The objective of the program is to study the effect of variations in gust acceleration frequency and amplitude upon the performance of the crew of an aircraft operating in a low altitude, high subsonic speed environment. The simulation of the vertical motion due to turbulence will be accomplished by the movement of human subjects in a flight simulator which permits vertical motion to be controlled. Realistic tasks will be assigned to the crew (pilot and observer) and from the results of the study the degree of performance degradation which may be tolerated in a sustained turbulence environment will be determined.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

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(2) Contract Studies

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KOPP, MARTIN R., Aerospace Engineer, Aeromechanics Division, Aviation Directorate, BS in Aeronautical Engineering, New York University, 1946.

MCCOURT, FRANCIS PATRICK, Aviation Requirements Technical Advisor, Technical Directorate.

MERRITT, ELMER VERNON, Armament & Vulnerability Branch, Design & Performance Division, Aviation Directorate.

NOLAN, WILLIAM JOSEPH, Research Analysis Division, Aviation Directorate.

REED, JERRY LEE, 2/Lt, TC, Armament & Vulnerability Branch, Design & Performance Division, Aviation Directorate. BS in Aeronautical Engineering, The Agricultural & Mechanical College of Texas, 1960.

11. U.S. ARMY BOARD FOR AVIATION ACCIDENT RESEARCH, FORT RUCKER, ALABAMA

A. WORK PROGRAM

1. Program includes on-site investigation of Army aircraft accidents and continual review and analysis of accident investigation reports. The purpose of this program is to learn about the human component of accident prevention since people plus hardware equal accidents. Inherently the accomplishment of this objective encompasses the broad spectrum of human factors indicated by the following areas:

a. Physiological - physical stress in flight; fatigue; sensory organs, vertigo and illusions; physical fitness, injury causation and prevention, autopsies

b. Psychological - man-machine relationship, experience and knowledge, psychomotor skills and errors, attention and errors of attention, perception and errors of perception, judgment and errors of judgment, training and selection.

2. The data gathered in the cited areas are for the primary purpose of enhancing the mission capability of Army aviation. The data are used widely, including the earliest stages of the life cycle of new aircraft, the modification of existing aircraft and as a source of feed-back of training and operational programs. In addition the data are used in the preparation of reports, presentations, and justification for new or revisions to existing specifications and/or regulations. Some of the specific accomplishments of the past year are:

a. Equipment Evaluation

1. HU-1B&D Model Specifications
2. HU-1B Safety of Flight Inspection
3. HU-1E Contractor Technical Compliance Conference
4. HU-1D Design Engineering Inspection
5. LCH Mockup Inspection
6. LOH Plan of Test
7. AC-1 Contractor Technical Compliance Conference
8. AC-1 Model Specification Review Conference
9. Army Aircraft Crewman's Helmet
10. Martin Baker MO-1 Ejection Seat

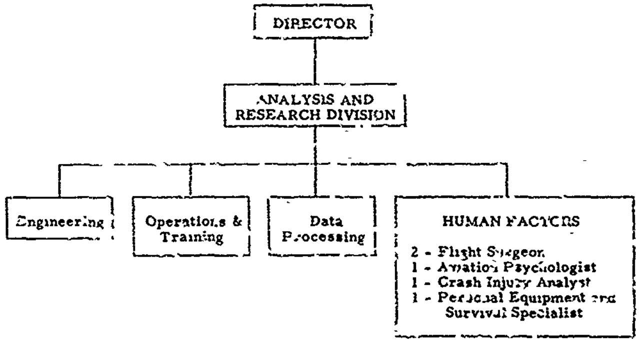
b. Reports

1. HU-1 Seat Failures
2. Physiological Factors in Army Aircraft Accident Causation
3. Army Aviation Crewman Helmet Experience
4. A Comparison of Army Rotary and Fixed Wing Fire Accident Experience
5. Army Fixed Wing Accidents Involving Fire
6. Role of Pilot Factors in Army Helicopter Accidents
7. Role of Pilot Factors in Army Fixed Wing Aircraft Accidents

c. Presentations

1. "Parameters of Head Injuries," Army Aircrewman's Helmet Task Group, QMC, Research and Engineering Command, Nat[illegible], Massachusetts
2. "Helicopter vs Fixed Wing Crash Injuries - [illegible]my Experience, 33rd Annual Scientific Meeting of Aerospace Medical [illegible]ation, Atlantic City, New Jersey
3. "Accident Prevention Through Reduction of Human Error," Aviation Safety Seminar, Fort Campbell, Kentucky
4. "Level and Priority of Protective Requirements," Office of Surgeon General, Washington, D. C.
5. "Summary of Army Aircraft Accident Experience Since 1958," Joint Committee on Aviation Pathology, Toronto, Canada
6. "Army Experience with Crash Injuries and Protective Equipment," Symposium on Biomechanics of Head Injury & Body Restraint, Naval Materiel Center, Philadelphia, Pennsylvania
7. "Helicopter Accidents Involving Fire," Aviation Committee-National Fire Prevention Committee, Detroit, Michigan

B. ORGANIZATION - The human factors effort is closely coordinated with the other functions of the Analysis and Research Division in order to cover the spectrum of human factors as a source of causation in aircraft accidents.



12. U.S. ARMY PERSONNEL RESEARCH OFFICE

a. CURRENT WORK PROGRAM

1. The U. S. Army Personnel Research Office (APRO) carries out RDT and E funded Project 0J95-60-001 to undertake studies and research in the fields of selection, classification, management, and utilization as approved by the Chief of Research and Development.

a. To carry out appropriate studies and research in selection and classification, APRO develops psychological, psychometric, and mathematical models through which the best candidates for successful training or job assignment are identified from a large applicant pool, and optimum match of men to jobs is accomplished when a large pool of applicants must be distributed to training or job assignments.

b. Research in personnel management is conducted to improve manpower management systems. Emphasis is placed on problems amenable to a research approach generally involving the use of scientific experimentation and construction of mathematical models. Such research takes into account manpower flow and requirements, communication channels, information flow, formal organizational structure, and individual differences as they affect the performance of the system.

c. Research in personnel utilization involves the development and application of human factors knowledge and techniques to the improvement of Army man-machine systems for the promotion of more efficient individual and unit performance on the job. Personnel utilization research takes into account needed balance between man and machine capabilities, psychological and behavioral limits of working demands, and factors in work environment, including unusual as well as typical conditions of the job.

2. The current work program (FY 63) consists of 13 research tasks carried out by four research laboratories:

a. The Military Selection Research Laboratory conducts human factors research with particular emphasis on development of techniques for selecting and classifying enlisted personnel of the U. S. Army.

(1) INPUT QUALITY TASK (Methods for Improving Enlisted Input Quality). Research information on operational screening problems, technical information and methods for improving future forms of input tests, methods for estimating mental abilities of the civilian pool available for service, development and implementation of AFQT and auxiliary instruments.

(2) NEW CLASSIFICATION TECHNIQUES (New Techniques for Enlisted Classification). Periodic introduction of new and improved instruments into the ACB, development of measures predicting what men will do in training and on the job in relation to what they can do, identification of personal and situational factors leading to changes of career intention, development of measures of physical proficiency relevant to Army jobs.

(3) CIVILIAN RESEARCH CONSULTATION (Consultative Assistance on Civilian Personnel Research). Application of previous civilian and military personnel research to current civilian personnel problems, evaluation of proposals for new research on civilian personnel problems.

b. The Combat Systems Research Laboratory focuses its research effort on analysis and solution of human factors problems (other than training or human engineering problems) in present and future man-machine systems, as related to direct combat effectiveness. Particular attention is paid to the combat capability of individuals and of small groups together with their equipment, performing under psychological and environmental hazards.

(4) FIGHTING VEHICLES (Identification and Measurement of Psychological Factors Related to Operation of Fighting Vehicles). Human factors knowledge concerning optimal composition and organization of personnel within an armored tactical system.

(5) FUTURE COMBAT (Personnel Planning and Utilization in Combat Organizations). Estimating of total Army personnel requirements, including determination of personnel requirements arising from new weapons systems, probable critical areas of personnel shortage and overage, and improved selection, classification, and utilization through use of computers.

(6) MONITOR PERFORMANCE (Dependable Performance in Monitor Jobs). Improvement of work methods and selection techniques for a broad spectrum of critical U. S. Army monitoring jobs having a vigilance component, and improved utilization of personnel for the Army Security Agency.

c. The Support Systems Research Laboratory focuses its research effort on analysis and solution of human factors problems (other than training or human engineering problems) in present and future man-machine systems, as related to combat support activities (technical services type systems, e.g., combat surveillance, image interpretation, electronics). Particular attention is paid to enhancing the capability of individuals in small groups, their work methods, and their overall effectiveness in the system situation.

(7) IMAGE INTERPRETATION (Psychological Factors in Image Interpretation). Performance standards and selection tests for image interpreters, improved techniques for image interpretation, information as to optimal limits of sustained work and time demands and as to the photo qualities which influence accuracy, completeness and timeliness of interpreter performance.

(8) IMAGE SYSTEMS (Image Systems Integration). Approaches that maximize group interpreter productivity in typical missions, improved means of requesting information from interpreters and of communicating the information extracted by interpreters, information establishing the utility and human factors requirements for real-time image systems, and determination of human factors problems and difficulties likely to arise in new image systems when used in tactical operations.

(9) ELECTRONICS (Selection and Utilization of Electronics Personnel). Improved assignment of electronics personnel through differential identification of aptitude for MOS of high and low levels of complexity, improved general level of on-job performance, improved utilization of human abilities in complex man-machine systems by specification of effective individual and group work methods and techniques, and objective performance measures for the evaluation of system and sub-system effectiveness.

d. The Behavioral Evaluation Research Laboratory specializes in human factors research required for the identification and utilization of special Army personnel—officers, NCO's, fighting personnel, special warfare personnel—upon whom critical psychological and physical demands are made.

(10) OFFICER PREDICTION (Prediction of Effective Officer Performance). Maximum utilization of available officer talent in the Army of the future through definition of the specific demands of each type job assignment, recognition of aptitudes and characteristics related to competent performance in specific jobs, and improved criteria for the selection or early identification of potential officers.

(11) CADET LEADERS (Psychological Measures for Use in Primary Officer Selection and Evaluation Programs). Increased quality and career motivation of USMA, ROTC, and OCS graduates through the use of improved selection and evlauation measures of cadets and officer candidates.

(12) NCO LEADERS (Selection of NCO Leaders). Screening techniques to identify upon entrance into the Army those persons with greatest likelihood of developing NCO abilities and screening techniques to use with an EM after he has accumulated sufficient experience and training, to be used in conjunction with other evidence to identify those persons most likely to become good combat NCO's.

(13) COMBAT SELECTION (Army Classification Tests for Combat Selection). Development of improved personality measures for use in identifying more effective personnel for combat MOS, use of rating instruments to increase substantially the effectiveness of selecting combat personnel, and techniques to select an increasing number of successful candidates for Ranger and Special Forces training.

3. A fifth laboratory, the Statistical Research and Analysis Laboratory, provides statistical consultative and planning support and data processing and analysis services for the research activities of the other laboratories.

4. The Combat Systems and Support Systems Research Laboratories are particularly concerned with man-machine and hence lead to considerable close interaction with human engineering laboratories.

5. The complete APRO program is of interest to personnel engaged in human factors engineering activities and is available upon request from the U. S. Army Personnel Research Office, Washington 25, D. C.

B. REPRESENTATIVE TECHNICAL RESEARCH PUBLICATIONS

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Boldt, Robert F. A Multivariate Function useful in Personnel Management Models. Paper presented at First Army Operation Research Symposium, Duke University, Durham, North Carolina. March 1962.

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Kotula, L. J. Evaluation of Personality Test Forms used in the Army Reenlistment Research Program. Paper presented at the annual convention of the American Psychological Association, St. Louis, Missouri. September 1962.

Orleans, I. D. and Birnbaum, A. H. Validation of a Selection Battery for Army Civilian Supervisors. Paper presented at the annual convention of the American Psychological Association, New York City, New York. September 1961.

Sadacca, Robert. Development of New Techniques for use In Image Interpretation Systems. Report - Seventh Annual Army Human Factors Engineering Conference 3-6 October 1961, 221, 1961.

Zeidner, Joseph. Requirements for Research on Psychological Factors in Image Interpretation. National Academy of Sciences, National Research Council, 158, 1962.

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C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL--Organizational mailing address is U. S. Army Personnel Research Office, Washington 25, D. C.

ANDERSON, ALAN A., Research Psychologist (PMandE); MA, American University, 1958, Psychology

ANDREWS, ROBERT S., Research Psychologist (General); MS, William and Mary College, 1958, Psychology; Assoc APA, SEPA, AAAS, Va. Acad of Science

BAYROFF, ABRAM G., Task Leader; PhD, University of North Carolina, 1931, Psychology, Fellow APA, EPA, DCPA, AAAS, SEPA, Sigma Xi, So. Society for Philosophy and Psychology

HERKHOUSE, RUDOLPH G., Task Leader, BS, Ohio State University, 1940, Psychology (all work toward PhD completed except dissertation - American University), Member APA, Psychometric Society, Psi Chi

BIGELOW, GEORGE F., Intelligence Operations Specialist; AB, Howard, 1938, English, American Society of Photography

BIRNBAUM, ABRAHAM H., Task Leader; PhD, New York University, 1957, Psychology; Member APA, EPA DCPA

BERSH, PHILIP J., Chief Research Laboratory; PhD, Columbia University, 1949, Psychology; Fellow APA, AAAS, Sigma Xi, Psychonomic Society

BOLDT, ROBERT F., Task Leader; PhD, Princeton University, 1962, Psychometrics; Member APA, EPA, American Stat. Assoc., Psychometric Society, Sigma Xi

BROGDEN, HUBERT E., Chief Scientist, PhD, University of Illinois, 1939, Psychology, Fellow APA, DCPA, Sigma Chi, Psychometric Society

BROWN, EMMA E., Research Psychologist, MA, University of Colorado, 1927, Languages, Member APA, Psi Chi, DCPA

BURKE, LAVERNE K., Research Psychologist (PMandE), MA, Ohio State University, 1935, Psychology (all course requirements and language examinations completed toward PhD, American University, Statistics), Member APA, EPA, DCPA, Psychometric Society, American Stat. Assoc.

CASTELNOVO, ANTHONY E., Research Psychologist, MS, Kent State University, 1950, Psychology

CORY, BERTHA H., Assistant Chief, Statistical Research and Analysis Laboratory, MA, University of Rochester, 1941, Psychology, Member APA, DCPA, EPA, American Stat. Assoc;. Psychometric Society, Sigma Xi, Phi Beta Kappa

DENTON, BARNETT, Research Psychologist, MA, Syracuse University, 1960, Psychology, AAPA

DOBBINS, DELANEY A., Task Leader, PhD, Louisiana State University, 1959, Psychology, Member APA, La. Psych. Assoc, Phi Kappa Phi

DRUCKER, ARTHUR J., Staff Assistant, PhD, Purdue University, 1949, Psychology, Fellow APA, DCPA, EPA, Internation Assoc. Applied Psychology

DUBUISSON, ADRIAN U., Research Psychologist; MS, University of Auburn, 1955, Psychology

FRANKFELDT, ELI, Research Psychologist, MS, City College, New York, 1938, Psychology, Member APA, EPA

FUCHS, E. MUND F., Chief, Research Laboratory; MS, Fordham University, 1942, Psychology; DCPA, Fellow APA, American Catholic Psych. Assoc., Md. Psych. Assoc., Psychometric Society, AAAS

GIBSON, WILFRED A., Chief Statistical Research and Consultation Unit, PhD, University of Chicago, 1951, Psychometrics; Fellow APA, American Stat. Assoc., Psychonomic Society, Psychometric Society

GORDON, LEONARD V., Chief, Research Laboratory; PhD, Ohio State University, 1950, Psychology; Fellow APA, International Association Applied Psychology, Psychometric Society, WPA

HAGGERTY, HELEN R., Research Psychologist, PhD, Teachers College, New York, 1938, Education; Member APA, AAAS Nat. Society for Study of Educ.; American Educ. Rsch. Assoc.

HAMMER, CHARLES H., Research Psychologist (General); PhD, Purdue University, 1958, Industrial Psychology; Member APA, DCPA, MPA, Sigma Xi

HARDY, GUTHRIE D., Research Psychologist, BA, Cornell University, 1959, Psychology

HEERMANN, EMIL F., Research Psychologist (PMandE); PhD, Ohio State University, 1959, Psychology and Statistics; Member APA, Md. Psych. Assoc.

HELME, WILLIAM H., Task Leader, PhD, New School for Social Research, 1959, Psychology, Member APA, EPA

HENDERSON, DAGMY, Systems Analyst, MA, Syracuse University, 1956, Psychology; A-AAA, EPA, DCPA

HILLIGOSS, RICHARD E., Research Psychologist; MA, George Washington University, 1960, Psychological Measurement, Member APA, Psi Chi

HOUSTON, THOMAS J., Research Psychologist (General), MS, Howard University, 1947, Psychology

JOHNSON, CECIL D., Chief, Statistical Research and Analysis Laboratory, MA, George Washington University, 1951, Psychology, Member APA, Psi Chi, Psychometric Society

KAGERER, RUDOLPH L., Research Psychologist MA, Purdue University, 1958, Psychology, Sigma Xi

KAPLAN, HARRY, Research Psychologist (PMandE), MA, George Washington University, 1952, Psychology; Member APA, EPA, DCPA, AAAS, Psychometric Society

KATZ, AARON, Research Psychologist, MS, City College, New York, 1947, Psychology; Member APA, EPA

KLIEGER, WALTER A., Chief, Machine Statistical Analysis Unit, MA, George Washington University, 1952, Psychology; Member APA, EPA, DCPA

KOTULA, LEO J., Research Psychologist (PMandE), Phd, University of Pittsburgh, 1951, Psychology, Member APA, Sigma Xi, Pittsburgh Psych. Assoc.

MARTINEK, HAROLD, Research Psychologist (General), MS, Iowa State College, 1954, Psychology; Member APA

MEDLAND, FRANCIS F., Task Leader; MA, University of Chicago, 1948, Psychometrics; Member APA, Sigma Xi

MORTON, MARY A., Research Psychologist; MA, Howard University, 1933, Education; MS, Howard University, 1934, Psychology, Member APA, DCPA

ORLANS, JEROME L., Research Psychologist; MA, Teachers College, Columbia University, 1950, Psychology (all work toward PhD completed except dissertation - George Washington University), Guidance; Member APA, DCPA, EPA

OLSON, MARJORIE A., Research Psychologist, Phd, University of Minnesota, 1949, Psychology; Member APA

ORLEANS, ISSAK D., Research Psychologist, MA, City College, New York, 1940, Education (course requirements for PhD completed, Teachers College, Columbia University, Social Psychology); Member APA, Society for Study of Social Issues, American Society for Quality Control

RINGEL, SEYMOUR, Task Leader, MA, Brooklyn College, 1952, Psychology, Member APA, SEPA, DCPA

ROOT, ROBERT T., Research Psychologist, PhD, University of Maryland, 1962, Psychology; Member APA, Psi Chi

SACHS, SIDNEY A., SandE Mathematical Statistician, MA, University of Illinois, 1960, Statistics; American Inst. Industrial Engineers

SADACCA, ROBERT, Task Leader, PhD, Princeton University, 1962, Psychometrics; Psychometric Society, Human Factors Society, Americal Photogrammetry Society

SARGENT, BRYAN B., Research Psychologist (PMandE); BIE, Georgia Institute of Technology, 1956, General Psychology (all work toward PhD completed, presently writing dissertation, University of Tennessee); American Inst. Industrial Engineers; AAPA, Psychometric Society

SCHWARTZ, ALFRED L, Operations Research Analyst, MS, University of Chicago, 1948, Geography; American Assoc. of Geographers, American Society of Photogrammetry

SEELEY, LEONARD C., Research Psychologist; MA, American University, 1958, Psychology Member APA

SIEGMANN, PHILIP J., Research Psychologist, PhD, Ohio State University, 1955, Psychology; Member APA, Photogrammetry Society

SKORDAHL, DONALD M., Research Psychologist, MA, University of Minnesota, 1958, Psychology

STERNBERG, JACK J., Task Leader; MA, Syracuse University, 1950, Psychology and Statistics; Psi Chi

STICHMAN, EUGENE P., Research Psychologist, AB, Dartmouth College, 1957, Psychology, AAAS

STUBBS, JOEL R., Analytical Statistician, MS, Purdue University, 1958, Industrial Psychology; MPA

THOMAS, JAMES A., Research Psychologist, MA, Ohio State University, 1949, Psychology, AAPA, Psychometric Society

TIEDEMANN, JOHN G., Research Psychologist (General), PhD, American University, 1961, Psychology, Member APA, Psi Chi

TRACEY, ERNEST A., Research Psychologist; MA, American University, 1962, Psychology, Society Study Social Issues

UHLANER, JULIUS E., Director, Research Laboratories, PhD, New York University, 1947, Psychology; DCPA, Fellow APA, EPA, SEPA, Society for Adv. of Mgt., Society for Pers. Admin., Psychometric Society, Iowa Acad. of Science, AF-NRC Vision Com., NRC-Highway Rsch. Bd., RDB Panels and Committees

VICINO, FRANK L., Research Psychologist; MS, University of Maryland, 1962, Psychology, Psi Chi

WATERS, CARRIE J., Research Psychologist; PhD, Ohio State University, 1959, Psychology; Member APA

WATERS, LAWRENCE K., Research Psychologist; PhD, Ohio State University, 1958 Psychology; Member APA, Psychometric Society

WEINBERG, SOLOMON A., Research Psychologist; PhD, Ohio State University, 1953, Educational Psychology; Member APA, DCPA

WILLEMIN, LOUIS P. JR., Task Leader; MPA, University of Pennsylvania, 1955, Statistics, Psychometric Society

WISKOFF, MARTIN F., Research Psychologist; MA, University of Maryland, 1958; Industrial Psychology, AAPA, EPA, DCPA, Psi Chi

ZEIDNER, JOSEPH, Chief, Research Laboratory, PhD, Catholic University of America, 1954, Psychology; Member APA, DCPA, NRC-Bio-Astronautics Committee

13. HUMAN RESOURCES RESEARCH OFFICE, The George Washington University, Washington, D. C.

A. CURRENT WORK PROGRAM*

The HumRRO Work Program is concerned with human factors research in training, motivation, morale, leadership, and man-weapons system analysis. Research aimed at solving practical military problems is carried on by six research groups: the Training Methods Division in Washington and the Armor, Leadership, Infantry, Air Defense, and Aviation Human Research Units, located at military installations across the country. There is also a staff in Washington D. C. which is engaged in a project in the area of Special Warfare. In addition, the HumRRO basic research program is being monitored in the Director's Office Each research group provides a Techni Advisory Service to assist the Army in planning implementation of research results and meet other Army requests. Exploratory Studies aimed at identifying human factors problems likely to arise in future military operations are also being conducted by the research groups.

Following is the list of Tasks, and Task objectives, grouped by functional areas, for Fiscal Year 1963:

Functional Area 1: Equipment Maintenance

JOBTRAIN - Development of an Integrated Training and On-the-Job Support System for Electronics Repairman Personnel

Objective: To develop an integrated training and on-the-job support system for Signal Corps electronics repairmen in their first enlistment.

FORECAST - Development of a Method of Forecasting Training Demands Imposed by New Electronic Weapon Systems

Objective: To develop improved methods for forecasting the content of effective and economical training programs for the operation and maintenance of new electronic weapon systems.

MAINTRAIN - Maintenance Proficiency and Its Relation to Trainging Procedures for Guided Missile Personnel

Objective To provide a basis for the improvement of maintenance training of air defense guided missile personnel by development of general and comprehensive principles appropriate for the guidance of such training.

VE-TRAIN - Methods for Improving Training for Automotive Maintenance

Objective: To develop a new course for the training of vehicle mechanics, and to prepare generalized guidance for improving training in other automotive maintenance courses.

Functional Area 2: Equipment Operation

LIFT - Army Aviation Helicopter Pilot Training

Objective To develop more efficient and more effective training methods for Army helicopter pilot training.

INTACT - Integrated Contact/Instrument Training

Objective To improve Army flight training through the application of the integrated contact/instrument training concept. Specific research goals include (1) developing relatively objective, analytic, fixed wing flight proficiency measures, and (2) developing and evaluating a fixed wing, integrated contact/instrument training concept.

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*A copy of the complete Work Program for FY 1963 is available on request to the Director, Human Resources Research Office, Post Office Box 3596, Washington 7, D. C

LOWENTRY - Methods for Improving Navigation Training for Low Level Flight
Objective. To improve navigation techniques for low level flight and to develop training methods to teach these skills to aviator personnel.

HELFIRE - Methods for Improving Aerial Gunnery From the Helicopter
Objective To develop instructional techniques for improving performance in aerial gunnery from the armed helicopter.

VIGIL - Methods and Techniques for Improving Performance of Air Defense Missile Operator Personnel
Objective. To develop a basis for improvements in (1) procedures for performing air defense missile operator jobs, (2) methods and courses of training for these duties, and (3) tests of job proficiency and knowledge.

ARGUS - Analysis of Nuclear Safety Requirements
Objective: To provide an objective basis for evaluation of current nuclear safety requirements and procedures and to improve operational, inspection, and selection techniques where required.

Functional Area 3: Individual Combat Skills

RIFLEMAN - Improvement of the Combat Proficiency of the Light Weapons Infantryman
Objective: To improve the combat proficiency of the light weapons infantryman by conducting research in the area of Advanced Individual Training (AIT) for this soldier.

SWINGSHIFT - Techniques and Training Methods for Improving Individual and Squad Infantry Performance in Operations During Limited Visibility
Objective. To increase the individual soldier's effectiveness in infantry operations during limited visibility by development of improved operating techniques and training methods.

OBSERVE - Improved Methods for Training Aerial Surveillance Personnel
Objective. To develop improved methods for training aerial observers. The research will (1) determine the requirements to be placed on aerial observers under modern tactical concepts, (2) determine the critical skills prerequisite to meeting these requirements and develop the means for measuring these skills, and (3) develop and evaluate improved methods for training aerial observers.

RECON - Training Methods and Techniques for Improving Combat Readiness of the Armored Cavalry Platoon
Objective To develop training program guidance, instructional aids, and techniques to improve the over-all proficiency of the Armored Cavalry Platoon.

Functional Area 4: Team Combat Skills

TRAINCREW - Methods for Improving Tank Crew Performance
Objective: To provide Armor with improved techniques for tank crew training by the evaluation of the present system and the development of improved methods.

RAID - Methods for Improving the Effectiveness of Small Groups Under Stress
Objective: To develop and test principles of group structure and operation, in order to provide guides for improving the effectiveness of small groups operating under stressful (decrement-producing) conditions.

UNIFECT - Development of Procedures for Increasing the Effectiveness of Small Infantry-Type Units
Objective: To study training procedures utilizing task-related experiences to increase group esprit and improve team functioning of small infantry-type units.

Functional Area 5 Leadership

NCO - Training of Potential Noncommissioned Officers
Objective: To improve the caliber of noncommissioned officer performance in the Army through curricula and techniques designed to develop noncommissioned officers as early as possible in their Army careers.

OFFTRAIN - Studies in Leadership and Leadership Training

Objective. To improve leadership training by the development of training procedures and materials based on study of the leadership process in platoon-sized units.

LEAD - Development of Training for Improving the Combat Skills of Leaders in Small Infantry Units

Objective: To improve officer training in the critical skills required for effective combat leadership in small infantry units.

Functional Area 6: Decision Making

SPANOCON - Human Factors Influencing Span of Control Within Military Organizations

Objective: To explore factors related to improved methods for training platoon and higher unit commanders to control their units under present and future concepts of military organization.

RESOLVE - Development of War Game Training Procedures

Objective. To develop methods and techniques for constructing and conducting training war games to simulate the decision-making environment of field grade officers during battle.

SAMOFF - Analysis of Job and Training Requirements for Air Defense Missile Officers

Objective: To analyze the duties performed by Air Defense missile officers and to improve school courses and on-the-job training given these officers.

COMSTAFF - Officer Performance in Air Defense Systems

Objective: To increase the effectiveness of Army officer performance in the operation, maintenance, and development of air defense systems.

PIONEER - Decision Making (Basic Research)

Objective. Two Subtasks will be conducted in this area directed toward (1) developing a model of decision making, and (2) determining the role, in individual problem solving, of situational and motivational variables on the development of ideas and the treatment of problem contingencies.

Functional Area 7: Motivation and Stress

FIGHTER - Factors Related to Effectiveness and Ineffectiveness of Individuals in Combat

Objective To develop a systematic understanding of stress as a factor in human performance, with the long-range objective of application of results to improving combat effectiveness.

QUIZ - Psychological Techniques for Facilitating and Countering Interrogative Processes

Objective. To add to the practical knowledge of techniques of interrogation and exploitation of the individual, and of the means of counteracting these techniques, by discovering psychological principles and methods of manipulating behavior.

PIONEER - Motivation and Stress (Basic Research)

Objective: To study the fundamental aspects of social isolation and sensory deprivation and their effects on performance.

Functional Area 8: Remote Area Operations and Language

SPECIAL - Training in Special Warfare, Counter-Insurgency and Related Missions

Objective. To increase the capabilities of Army personnel to perform Special Warfare, counter-insurgency and related unconventional missions through improved training and operational procedures.

CONTACT - Feasibility of Training for Faster Acquisition of Perishable Tactical Information From Non-English-Speaking Prisoners of War.

Objective To develop methods for training troops in the acquisition of highly perishable tactical information from non-English-speaking prisoners in the combat zone. A course based on such methods would be intended for selected combat personnel whose work would complement rather than substitute for the efforts of the experienced and highly trained linguist-interrogator.

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8 What HumRRO is Doing, September 1962

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A Provisional Core Curriculum for Infantry Night Operations Training: Conceptualization and Proposed Content, by Gilbert L. Neal, U.S. Army Infantry Human Research Unit, Fort Benning, Georgia, December 1960 (Task SWING-SHIFT I).

74 A Survey of Problems in the Tactical Training of Armor Units (U), by Robert A. Baker, December 1961 (CONFIDENTIAL, Modified Handling Authorized (Task UNIT I).

75 Survey of Operational Flying Activities of Rotary Wing Aviators, by Norman W. Heimstra, Nicholas B. Louis, and Maj. Arnold R. Young, April 1962 (Task LIFT III).

76 Survey of Operational Flying Activities of Fixed Wing Aviators, by Norman W. Heimstra, Nicholas B. Louis, and Maj. Arnold R. Young, April 1962 (Task LIFT III).

77 Improving Flight Proficiency Evaluation in Army Helicopter Pilot Training, by George D. Greer, Jr., Wayne D. Smith, and Capt. Jimmy L. Hatfield, May 1962 (Task LIFT II).

78 An Evaluation of Flash Localization Performance With the Fire Control System of the M48 Tank, by Alfred J. Kraemer, June 1962 (Task ARMORNITE X).

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Research Memoranda

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A Provisional Core Curriculum for Infantry Night Operations Training: Conceptualization and Proposed Content, by Gilbert L. Neal, U.S. Army Infantry Human Research Unit, Fort Benning, Georgia, December 1960 (Task SWING-SHIFT I).

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C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL DIRECTLY CONCERNED WITH RESEARCH ACTIVITIES*

Name	Title	Degree	Year	University	Primary Field
Office of the Director, HumRRO, Washington, D. C.					
Braly, E.	Sr. Scientist	PhD	55	Univ. of Texas	English
Cogan, E.	Sr. Staff Sci.	PhD	51	Univ. of Calif.	Psychology
Crawford, M. P.	Director, HumRRO	PhD	35	Columbia Univ.	Psychology
Goffard, S. J.	Sr. Staff Sci.	PhD	49	Univ. of Minn.	Psychology
Hayes, J.	Res. Assistant	MS	59	Purdue Univ.	Sociology
Heyl, A.	Sr. Staff Sci.	MA	47	Univ. of Texas	Mathematics
Kraemer, A.	Sr. Staff Sci.	PhD	56	Vanderbilt Univ.	Psychology
McClelland, W.	Deputy Director	PhD	48	Univ. of Minn.	Psychology
Osanka, F.	Res. Associate	AM	61	No. Ill. Univ.	Soc-Anthro.
Stewart, E.	Res. Scientist	PhD	56	Univ. of Texas	Psychology
Vallance, T.	Deputy Director	PhD	50	Syracuse Univ.	Psychology
Williams, W.	Sr. Scientist	PhD	55	Univ. of Tenn.	Indus. Psych.
Windle, C.	Sr. Scientist	PhD	52	Columbia Univ.	Psychology
Training Methods Division, Washington, D. C.					
Bloxom, M.	Res. Assistant	MA	56	Ohio State Univ.	Psychology
Brown, G.	Sr. Scientist	PhD	52	New York Univ.	Psychology
Buchanan, R.	Res. Associate	MS	60	Univ. of N. C.	Psychology
Butler, P.	Res. Associate	MA	57	Univ. of S. C.	Psychology
Clark, J.	Res. Associate	MA	61	Univ. of Kentucky	Psychology
Fink, C. D.	Res. Scientist	PhD	58	Univ. of Colo.	Psychology
Froehlich, D.	Res. Scientist	PhD	61	Univ. of Ill.	Psychology
Garvey, K.	Res. Scientist	PhD	58	Univ. of Texas	Linguistics
Gebhard, R.	Res. Scientist	MA	58	Univ. of Minn.	Psychology
Hoehn, A.	Director of Resch.	PhD	51	Univ. of Ill.	Educ. Psych.
Kamenske, G.	Res. Associate	MA	55	Mich. St. Univ.	Indus. Psych.
MacCaslin, E.	Sr. Scientist	PhD	53	Univ. of Texas	Psychology
McClure, A.	Res. Associate	MA	51	Univ. of Penn.	Psychology
McCrary, J.	Res. Scientist	PhD	61	Brown Univ.	Psychology
McKnight, J.	Sr. Scientist	PhD	57	Univ. of Minn.	Psychology
Montague, W.	Res. Scientist	MA	52	Geo. Wash. Univ.	Psychology
Rasmussen, E.	Technician	--	--	---	Electronics
Rayner, J.	Res. Assistant	--	--	---	Psychology
Rocklyn, E.	Sr. Scientist	PhD	56	Univ. of Pitt.	Psychology
Seidel, R.	Res. Scientist	PhD	57	Univ. of Penna.	Psychology
Shriver, E.	Sr. Staff Sci.	PhD	53	Univ. of Pitt.	Psychology
Trexler, R.	Sr. Technician	AB	55	Wash. & Jeff. Coll.	Elec. Engnr.
Vineberg, R.	Sr. Staff Sci.	PhD	52	New York Univ.	Psychology
U. S. Army Armor Human Research Unit, Fort Knox, Kentucky					
Baker, R.	Sr. Staff Sci.	PhD	52	Stanford Univ.	Psychology
Cannon, L. D.	Res. Scientist	PhD	59	Purdue Univ.	Clin. Psych.
Cook, J.	Sr. Technician	--	--	---	Mil. Ops-Armor
Drucker, E.	Res. Associate	MA	58	Univ. of Kentucky	Psychology
Easley, D.	Sr. Scientist	PhD	56	Vanderbilt Univ.	Psychology
Haggard, D.	Sr. Scientist	PhD	56	St. Univ. of Iowa	Psychology
Miller, A.	Res. Scientist	PhD	61	Univ. of N. C.	Psychology
Olson, H.	Sr. Scientist	MS	59	N. C. St. Univ.	Psychology
Osborn, W.	Res. Associate	MS	59	Purdue Univ.	Indus. Psych.
Pickett, J.	Res. Assistant	MS	61	Purdue Univ.	Exper. Psych.
Schwartz, S.	Sr. Scientist	BA	33	Long Island Univ.	German
Sheldon, R.	Res. Scientist	PhD	61	St. Univ. of Iowa	Psychology
Smith, J. P.	Sr. Scientist	PhD	54	Ohio State Univ.	Education
Willard, N.	Director of Resch.	PhD	54	Univ. of Minn.	Psychology
Wolff, P.	Res. Scientist	PhD	59	Univ. of Houston	Psychology

*This roster does not include specialist professional personnel primarily engaged in technical or logistical support of research

Name	Title	Degree	Year	University	Primary Field
U. S. Army Leadership Human Research Unit, Presidio of Monterey, California					
Berkun, M.	Sr. Scientist	PhD	56	Yale Univ.	Psychology
Bialek, H.	Sr. Scientist	PhD	57	Claremont Col.	Psychology
Burdick, H.	Res. Scientist	PhD	57	Univ. of Mich.	Sociology
Caylor, J.	Res. Scientist	PhD	56	Univ. of Mich.	Soc. Psych.
Gay, G.	Sr. Technician	--	--	---	Device Engnr.
Hood, J.	Res. Associate	PhD	61	Ohio State Univ.	Psychology
Hood, P.	Sr. Staff Sci.	PhD	53	Ohio State Univ.	Psychology
Kern, R.	Sr. Scientist	PhD	53	St. Univ. of Iowa	Clin. Psych.
McFann, H.	Director of Resch.	PhD	52	St. Univ. of Iowa	Psychology
Murphy, D.	Sr. Scientist	PhD	53	St. Univ. of Iowa	Psychology
Myers, T.	Sr. Scientist	PhD	52	St. Univ. of Iowa	Psychology
Sebree, E.	Sr. Technician	BS	19	West Point	Engineering
Showel, M.	Sr. Scientist	PhD	52	Wash. State Univ.	Sociology
Smith, S.	Res. Scientist	PhD	59	U. of Rochester	Psychology
Snyder, R.	Sr. Scientist	PhD	52	MIT	Psychology
Taylor, E.	Sr. Scientist	PhD	54	St. Univ. of Iowa	Psychology
Taylor, J.	Sr. Staff Sci.	PhD	53	St. Univ. of Iowa	Psychology
Viljoen, B.	Technician	--	--	---	Device Engnr.
Walker, J.	Res. Scientist	PhD	61	Univ. of Wash.	Psychology
Wheeler, L.	Res. Associate	BA	59	Stanford Univ.	Psychology
Yagi, K.	Res. Associate	MS	58	Univ. of Utah	Psychology
U. S. Army Infantry Human Research Unit, Fort Benning, Georgia					
Brown, F.	Res. Associate	BS	56	Clarion Teach. Col.	Education
Brown, R.	Res. Scientist	PhD	60	S. Ill. Univ.	Psychology
Felton, E.	Res. Associate	MS	57	Univ. of Georgia	Psychology
Fooks, N.	Sr. Technician	BS	27	West Point	Engineering
George, C.	Res. Scientist	MA	53	Univ. of Ariz.	Psychology
Harris, L.	Technician	--	--	---	Device Engnr.
Jacobs, T. O.	Sr. Scientist	PhD	56	Univ. of Pitt.	Psychology
Kelly, H.	Sr. Technician	--	--	---	Mil. Ops.-Inf.
Lange, C.	Director of Resch.	PhD	51	Univ. of Pitt.	Psychology
McCrystal, T.	Res. Scientist	MA	59	Univ. of Ky.	Exper. Psych.
Nichols, T.	Sr. Scientist	PhD	55	Univ. of Calif.	Psychology
Olmstead, J.	Sr. Scientist	PhD	56	Univ. of Texas	Soc. Psych.
Powers, T.	Res. Associate	MA	56	Univ. of Kentucky	Exper. Psych.
Ward, J.	Res. Scientist	PhD	62	Tulane Univ.	Psychology
U. S. Army Air Defense Human Research Unit, Fort Bliss, Texas					
Ammerman, H.	Res. Scientist	PhD	60	Purdue Univ.	Psychology
Baldwin, R.	Sr. Staff Sci.	PhD	54	Univ. of Iowa	Psychology
Bergum, R.	Res. Scientist	PhD	58	Northwestern Univ.	Psychology
Burrell, W.	Technician	BS	40	Kansas State Col.	Mech. Engr.
Coleman, E.	Res. Scientist	PhD	61	Johns Hopkins U.	Psychology
Cox, J.	Sr. Scientist	PhD	54	Univ. of Texas	Educ. Psych.
Christenson, H.	Res. Assoc.	MS	60	Univ. of Utah	Educ. Psych.
Collettie, J.	Sr. Scientist	PhD	61	Tulane Univ.	Psychology
Harris, J.	Res. Associate	BSC	54	U. of Louisville	Bus. Admin.
Haverland, E.	Sr. Scientist	PhD	54	Univ. of Ill.	Psychology
Lehr, D.	Res. Assistant	BA	59	Mich. State Univ.	Psychology
Melching, W.	Sr. Scientist	PhD	53	U.C.L.A.	Psychology
Norred, W.	Res. Assistant	--	--	---	Elec. Engr.
Napper, H.	Technician	--	--	---	Elec. Engr.
Rogers, J.	Sr. Scientist	PhD	56	Emory Univ.	Psychology
Rupe, J.	Sr. Scientist	PhD	50	Purdue Univ.	Indus. Psych.
Severns, J.	Res. Assistant	--	--	---	Elec. Engr.
Smith, R. G.	Director of Resch.	PhD	50	Univ. of Ill.	Psychology
Solem, A.	Sr. Technician	BS	27	West Point	Engineering

Name	Title	Degree	Year	University	Primary Field
Thorne, H. W.	Sr Technician	--	--	---	Device Engr.
Whitmore, P.	Res. Scientist	PhD	56	Univ. of Tenn	Psychology
Wright, A. D.	Res Associate	MS	59	Ft. Hays Kans.	Exper. Psych.

U. S. Army Aviation Human Research Unit, Fort Rucker, Alabama

Name	Title	Degree	Year	University	Primary Field
Blohm, J.	Technician	--	--	---	Mil. Ops.-Avn.
Boney, W.	Res. Assistant	BA	61	Furman College	Psychology
Boyd, W.	Res. Associate	MS	61	N. C. State Col.	Indus. Psych.
Colgan, C.	Res. Scientist	PhD	54	Univ. of Fla.	Psychology
Dawkins, P.	Sr. Scientist	PhD	57	Univ. of Texas	Psychology
Duffy, J.	Res. Associate	MA	53	Univ. of Fla.	Psychology
Edmonds, E.	Res Assistant	MS	61	Auburn Univ.	Psychology
Jolley, O.	Sr. Technician	--	--	---	Mil. Ops.-Avn.
Lyons, J. D.	Director of Resch.	PhD	53	Univ. of Ill.	Psychology
Prophet, W.	Sr. Scientist	PhD	58	Univ. of Fla.	Sociology
Schulz, R.	Res. Associate	MA	58	Mich. State Univ.	Psychology
Thomas, F.	Sr. Staff Sci.	PhD	53	Cornell Univ.	Psychology
Waller, T. G.	Res. Assistant	MS	61	Miss. So. Coll.	Psychology
Wright, R.	Res. Scientist	PhD	62	Purdue Univ.	Exper. Psych.

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