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A STUDY OF THE PSYCHOLOGICAL (AND ASSOCIATED PHYSIOLOGICAL) FACTORS TO BE CONSIDERED WHEN CONSTRUCTING FIELD FORTIFICATIONS

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(6) A STUDY OF THE PSYCHOLOGICAL (AND ASSOCIATED PHYSIOLOGICAL) FACTORS TO BE CONSIDERED WHEN CONSTRUCTING FIELD FORTIFICATIONS

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FOREWORD

The Fort Hood Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI), by assessing the human performance aspects of man/weapon systems evaluations in field situations, provides support to Headquarters, TCATA (TRADOC Combined Arms Test Activity, formerly called MASSTER--Modern Army Selected Systems Test Evaluation & Review). A war using modern weapons systems is likely to be both intense and short; U.S. man/weapons systems must be effective enough, immediately, to offset greater numbers of an enemy. Cost-effective procurement of improved and/or new combat systems requires testing that includes evaluation in operational settings similar to those in which the systems would be used, with troops representative of those who would be using the systems in combat. The doctrine, tactics, and training packages associated with the systems being evaluated must themselves also be tested and refined as necessary.

The present report presents an analysis and synthesis of the literature dealing with requirements for constructing field fortifications for a mid- or high-intensity conflict and with the psychological and physiological factors to be considered in such construction. A hypothetical scenario presents an example of the use of field fortifications in the future, and suggestions are made for future research as well as practical suggestions for planners.

ARI research in this area is conducted as an in-house effort augmented by contracts with organizations with unique capabilities for human factors research. The present research was done jointly by personnel from the ARI Fort Hood Field Office and the Human Resources Research Organization (HumRRO), under contract DAHC 19-75-C-0025, and is responsive to the special requirements of TCATA and the objectives of RDTE Project 2Q763731A775, "Human Performance in Field Assessment," FY 1976 and 1977 Work Programs.

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Technical Director

A STUDY OF PSYCHOLOGICAL (AND ASSOCIATED PHYSIOLOGICAL) FACTORS TO BE CONSIDERED WHEN CONSTRUCTING FIELD FORTIFICATIONS

BRIEF

Requirement:

Both the accuracy and lethality as well as the variety of weapons in the arsenals of today's major powers has increased greatly during the past quarter century. Improved vehicles, obtained in increasing numbers, have greatly increased mobility. As a result, new tactics have been developed, and the wars of the future are not expected to be like those of the past. Therefore, the requirements for field fortifications for the future may be expected to be quite different than in the past. For example, it is expected that field fortifications in the future will have to be both deeper underground and less open to provide protection against both heavier conventional weapons and the possible use of unconventional weapons.

Several new concepts for field fortifications have been studied by the Army. However, little or no consideration was given to human factors aspects in these studies. Exactly what will be required to enable the American soldier of today to adapt to life in a fortification and remain effective is not known. Therefore, a requirement exists to determine what human factors must be considered before final selection of any fortification designs is made.

The primary objective was:

> To compile a list of human factors requirements that must be considered in the construction of field fortifications in the future to ensure a psychologically supportive environment that will enable the occupants to perform effectively both during and following occupancy.

Procedure:

A literature survey of previous related work appeared to be an obvious first and major step in this research. Literature dealing with psychological or human factors aspects of field fortifications was found to be virtually nonexistent. However, literature dealing with the psychological effects of a number of other environments on human performance was available from a variety of sources. Most of these documents dealt in some form with the concept of "habitability," and habitability was chosen as the central concept around which to structure the research.

Habitability, being a function of the total environment, is affected by the structural characteristics of an enclosure. In the case of field fortifications, structural characteristics are determined to a significant extent by the type of threat they must protect against. Therefore, literature and other information available on the anticipated threat environment and design concepts to counter various threats was also reviewed.

The information available was integrated in order to compile a list of factors that must be considered in the design of field fortifications, and to make recommendations for further research.

Principal Findings:

An analysis of the information available revealed the following:

- The most likely field fortifications to be employed in the foreseeable future are the prefabricated or modularized types.

- The most important factors related to physical well being are those concerned with nutrition, liquid intake, ventilation, temperature, and work/rest cycles,

- The most important factors related to psychological well being are those concerned with space availability/utilization and leadership/management.

- The most fruitful areas for future research in human factors aspects of field fortifications are:

  1. Human engineering the use of space;
  2. Systems or techniques for provisioning/reprovisioning;
  3. Leadership/management of shelter living.

Utilization of Findings:

The list of factors compiled will serve to highlight the need for considering human factors requirements in the design of field fortifications to developers. It will also provide them with indications of the types of problems most likely to occur, and suggest possible means of minimizing the effects. Finally, this effort provides the Army with information to enable authorities to focus future research and training in field fortifications on the real needs.

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CHAPTER 1

INTRODUCTION

United States (US) military forces have employed both deliberate and hasty field fortifications to varying degrees in every major conflict in their history. The nature of these fortifications, of course, has changed over time in order to provide improved protection against increasingly sophisticated threats.

For example, during World War I (WWI), extensive trench systems were employed by both adversaries as a means of protection against the primary threat of massed attacks by large groups of infantry and from extensive artillery bombardment. During World War II (WWII), the use of the trench was largely outmoded by the use of armored vehicle attacks, more accurate and more lethal artillery, and a well-developed capability for aerial strafing and bombardment. The much publicized "foxhole" became the common mode of individual protection. Deliberate fortifications, typically constructed of sandbags and timbers, were also used extensively in both the European and Pacific theaters. The much publicized concrete and steel fortifications of the Maginot and Siegfried lines saw virtually no use.

A wide variety of fortifications, including trenches in some locations, were employed in Korea, with the cessation of hostilities seeing the construction of strategically-located concrete and steel bunkers along the border. Finally, during the recent low-intensity Vietnam conflict, the US forces made only limited use of deliberate fortifications due to the lack of conventional fronts. Even hasty fortifications, such as the foxhole, saw minimal usage. Instead, natural cover was generally sought for protection. Only a few relatively permanent positions, such as air defense sites and base camps, were fortified to any great extent.

In determining requirements for field fortifications for future wars, one must consider the total threat environment in which they will be employed. If a relatively unsophisticated enemy and a low-intensity or mid-intensity conflict with conventional fronts is foreseen, revolutionary changes in fortification designs would not be expected. New methods of construction and probably some new materials would be employed. However, extensive use of sandbags and timber (where available), employed in much the same manner as in the past, would be expected.

If any enemy with sophisticated weapons and large resources is foreseen, new and different types of field fortifications appear to be called for. The actual types required depend upon the type of conflict visualized. However, regardless of how the conduct of a future war is visualized, it must be noted that the fortifications employed by US forces in our most recent conflicts were not designed to protect against the weapons found in the arsenals of today's modern military establishments. Both the accuracy and lethality of conventional weapons has greatly increased since the Korean conflict.[1] The enemy in Vietnam did not have the types of weapons to provide a real test for US-built fortifications. Therefore, against a sophisticated enemy, even if a war with conventional weapons and conventional fronts is foreseen, new types of fortifications may be required due to vastly improved weapons systems.

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[1]TRADOC Bulletin 8. *Modern Weapons on the Modern Battlefield*, Department of the Army, US Army Training and Doctrine Command, Fort Monroe, Virginia.

In any future conflict where non-conventional weapons may be employed, fortifications must not only be designed to survive near-misses by large caliber conventional weapons, they must also provide protection against harassment by chemical and biological agents and afford some measure of protection against radiation hazards in the event that tactical nuclear weapons are employed. In addition, because of the lingering hazards posed by the use of non-conventional weapons, fortifications must also be designed for extended occupancy.

This report will critically examine the requirements for field fortifications designed to protect friendly forces from a sophisticated enemy employing both conventional and non-conventional weapons. This effort will focus on the "psychological and associated physiological factors" which need to be considered in the design and construction of field fortifications. However, architectural and structural factors cannot be completely ignored, as they obviously place limitations on the habitability of the fortification. For example, authorities agree that a fortification designed for protection in a Chemical, Biological, and Radiological (CBR) environment will undoubtedly have to be deeper underground than in the past in order to provide the necessary protection. Unfortunately, the minimum requirements for making such a fortification habitable for long periods of confinement while maintaining the combat readiness of the troops who are confined have not been determined. It is the objective of this research effort to compile a list of factors that affect habitability and, therefore, which must be considered in the design of field fortifications in the future. More specifically, the objectives of this research effort are:

1. To determine the need for and feasibility of employing various types of field fortifications in full scale mid-intensity or high-intensity conflicts during the next decade,

2. To compile a list of factors that must be considered in the construction of field fortifications to ensure a minimal acceptable level of habitability,

3. To provide recommendations for immediate implementation by the Army and for future research in the area of field fortifications.

The remainder of this report is divided into three chapters. Chapter 2 further defines the problem and presents a review of the literature. Some discussion of the threat and fortification design has been included, but the major emphasis is on factors which affect human habitation. Chapter 3 provides a summary of the major considerations and implications resulting from the review of previous research, and presents conclusions. Chapter 4 attempts to look into the future, and discusses promising directions for future work in the area of field fortifications.

CHAPTER 2

REVIEW OF THE LITERATURE

Factors to be Considered When Constructing Field Fortifications

Field fortifications employed in any conflict must be designed to protect the soldier from both physical and psychological hazards. The physical hazard is defined primarily by the threat posed by the enemy. The psychological hazard is, of course, directly related to the physical hazard. Confidence in the notion that the shelter will provide protection from enemy action is a very important psychological factor. However, there are other factors involved than the mere preservation of life. For purposes of this report, the concept of *habitability* will be invoked as a general term to encompass these factors. Ledbetter,[1] in a review of the literature on cold regions habitability, discusses the meaning of the term. At one point he describes habitability "... as the union of architectural and engineering aspects of a habitat with its operational and managerial aspects." He further examines definitions as employed by others, and defines habitability as:

> The qualities of an environment for habitation (design, management and operations) that influence the degree of physical and emotional well-being of the principal inhabitant and his dependents, which in turn influences the performance of all occupants in conducting their assigned and assumed tasks.

While Ledbetter did not have field fortifications in mind in arriving at this definition, it is still quite appropriate. If the term *factor* is

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[1]C. Ledbetter. *Cold Regions Habitability - A Selected Bibliography*, Special Report 211, US Army Cold Regions Research and Engineering, Hanover, New Hampshire, September 1974.

substituted for the words "The qualities of an environment," the meaning of the term *factor* as used in this report begins to emerge. The factors that must be considered in the construction of field fortifications are those qualities of the environment that will influence the performance of US forces both during and after habitation.

Although this report is primarily concerned with habitability from the psychological standpoint, issues in habitability cannot be considered in a vacuum. There are factors inherent in a battlefield situation over which the psychologist has no control. The threat posed by the enemy is one such, and an all important factor. The threat determines the type of protection that must be afforded, and thereby places limitations on the structural designs that can be employed. The human factors psychologist, being expert in neither military intelligence nor engineering, must accept the testimony of experts on these matters, and plan to work within some set of inevitable limitations. However, this does not mean that the psychologist cannot challenge the engineer to modify designs to improve habitability so long as protection from the threat is not degraded. It simply means that the psychologist cannot exercise complete control over the physical environment.

Realizing the implications of the threat for field fortification design, a review of the literature concerning the threat was undertaken. However, details concerning specific types, numbers, and capabilities of weapons in the arsenals of potential enemies were not sought. Rather, more general literature concerning the types and geographical locations of possible conflicts and general classes of threat weapons was examined. This literature, it seemed, would bear more directly on the need for and feasibility of employing various types of field fortifications. This brief overview of the threat comprises the first major section of this chapter.

The second major section of this chapter is devoted to a review of previous work on field fortifications. While considerable detail vital to engineers who might be planning to duplicate a particular design is presented in several of the documents, it will not be reported here. This review was conducted only to obtain some general notions about the current thinking of engineers with regards to protective construction concepts that would bear on psychological and physiological habitability.

The third and fourth major sections of this review are concerned with habitability. The first deals with the physical environment, the second with the psychological environment. These sections provide considerably more detail concerning the works reviewed than the previous sections.

The Threat

It is naturally not possible to predict when, if ever, or where US forces might next become engaged in warfare. However, it is possible to make some reasoned assumptions concerning the types and locations of conflicts that might required US troops to employ fairly extensive systems of field fortifications. US military doctrine, as outlined in current documents such as Field Manual (FM) 17-50,[2] Training Circular (TC) 7-24,[3]

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[2]FM 17-50. *Attack Helicopter Operations* (Draft), Department of the Army, US Army Armor School, October 1975.

[3]TC 7-24. *Antiarmor Tactics and Techniques*, Department of the Army, US Army Infantry School, 30 September 1975.

and TRADOC Bulletin 1 (U).[4] suggests that Soviet/Warsaw Pact forces constitute the primary threat for US forces. Furthermore, the presence of and close proximity of US/NATO and Soviet/Warsaw Pact forces in central Europe makes conflict in this geographical area more likely than other places. Therefore, the threat that will be considered in this report will be the threat posed by the Warsaw Pact nations in central Europe.

The possibility of conflict in other geographical areas certainly cannot be ruled out. US forces have been rather heavily engaged in Korea and Vietnam in the past. However, further limited engagements of this type do not now appear to be a major threat to US survival. Nor is the political climate such that US forces are likely to be committed to such conflicts in the near future. Furthermore, even though enemy forces might be Soviet-equipped and employ Soviet-inspired tactics, they are unlikely to possess the new and sophisticated weaponry that would call for a revolution in field fortification designs. Therefore, the only threat of real consequence so far as field fortification redesign is concerned appears to be the threat in central Europe.

Much of the information concerning the threat in Europe is classified. In this brief overview only a few unclassified sources will be cited. However, it should be pointed out that the classified literature deals largely with highly specific data on foreign-made equipment and/or US capabilities to counter such equipment rather than overall strategic concepts. Therefore, it is possible to make some generalizations concerning the type or types of conflict that might occur in central Europe without

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[4] TRADOC Bulletin 1 (U). *Range and Lethality of U.S. and Soviet Anti-Armor Weapons*, Department of the Army, US Army Training and Doctrine Command, 30 September 1975.

resorting to this material. First of all, opinion is divided on the type of war that is likely to be fought in the European theater. One camp presupposes that it will be impossible for NATO troops to hold on the current border. They foresee a war in which frontline troops fight a delaying action, while defensive positions are prepared somewhere in a rear area. This defensive line would take maximal advantage of natural barriers, such as rivers and mountains, and fortifications would make maximal use of terrain features and natural camouflage. These positions would be far enough to the rear to strain the enemy's logistical system, and strong enough to hold until reinforcements could arrive. Therefore, a more or less stable FEBA would result. The exact length of time that the stable front would be maintained is open to question. However, it would last until one side or the other was able to mass a sufficient force to break the stalemate. Deliberate and extensive fortifications would be constructed along this holding line. Troops would eat, sleep, and fight from these fortifications.

A second camp foresees a war with no well-defined FEBA. This camp also sees an initial retreat. Like the other camp, as the US and other NATO countries reinforce the friendly troops, and as the enemy strains his logistical system, a near equilibrium of forces is foreseen. However, rather than stable defense lines, fast moving penetration by armored mechanized units supported by extensive air mobile operations would be the order of battle. In other words, attacks and counterattacks in limited areas and for limited objectives would be the mode of operations for both sides. In such a case, there would be no well-defined FEBA, rather, the war would consist of a series of far-flung though extensive skirmishes. In this type of war, there would be neither time nor need for anything but hasty and expedient field fortifications.

Both sides have made several assumptions concerning a war in Europe.[5,6,7] Both Soviet and US writers assume that the war will be massive in scale. Both assume that megaton nuclear weapons will not be employed. The Soviets assume that tactical nuclear weapons will be employed, while the US only assumes that they might be employed.

Of particular interest in this research area relative to the threat is Soviet doctrine concerning the attack of fortified positions. A prepared defensive position can be attacked from a "situation of direct attack with the enemy or from a situation of movement."[8] A hastily occupied defensive position is usually attacked from a situation of movement. In any case, destruction of the position takes priority over protection of personnel. Direct contact is almost always employed when Soviet forces have been in a position opposite the enemy for long periods of time. Water barriers, unless especially formidable, are seen by the Soviets as presenting few problems. The Soviets assume underwater crossings during daylight hours.[9]

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[5] *The Concept for the 1970-1980 Field Army*. US Army Combat Developments Command, Fort Belvoir, Virginia, August 1973.

[6] V. Sokolovskii. *Soviet Military Strategy* (translation and analytical introduction, annotation, and supplementary material by H. Dinerstein, L. Goure, and T. Wolfe, The Rand Corporation), Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

[7] *Command and Combat Doctrine of Soviet Ground Forces*. Army Memorandum No. 10, Army Service Regulation No. 171/1 (translated from German, translation of Soviet document), July 1963.

[8] *Ibid.*

[9] A. Rimarev and V. Chernov. "Negotiating Water Barriers," *Voyenna Teknika*, 1973, 3 (translated from Bulgarian).

Although the type of war that might be conducted in central Europe is still open to question, one thing seems apparent. Soviet, and Soviet-trained and equipped forces, will fight an "all out" war, with the preservation of human life being secondary to the attainment of military objectives. The implications of this threat for the employment of field fortifications by US forces will be discussed further in Chapters 3 and 4. For the present, let it suffice to say that deliberate field fortifications, if constructed at all, should be designed for protection against heavy conventional weapons, harassment by chemical and biological agents, fallout from tactical nuclear weapons, and direct assault by enemy ground forces.

Previous Research on Field Fortifications and Related Topics

The US has never had an extensive centrally coordinated research effort on field fortifications. However, engineering design and protective aspects have been examined in a number of both civil defense and military studies.[10,11,12,13,14,15,16,17,18] Unfortunately, this lack of coordination

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[10] G. Christy. *Expedient Shelters Survey*, Defense Civil Preparedness Agency, Washington, D.C., July 1973.

[11] B. Hoot, et al. *Evaluation of Field Fortifications*, Technical Report N-74-5, Engineer Waterways Experiment Station, Weapons Effects Laboratory, Vicksburg, Mississippi, August 1974.

[12] T. Kennedy. *In-structure Motion Studies for Shallow Buried Protective Facilities, Phase IIb*, Technical Report N-71-1, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, February 1971.

[13] T. Kennedy, B. Hoot, J. Ball, and P. Rieck. *Expedient Field Fortifications for Use Against Nuclear Weapons*, Final Report, Technical Report N-74-7, US Army Engineer Waterways Experiment Station, Weapons Effects Laboratory, Vicksburg, Mississippi, September 1975.

[14]M. Hanley. *MASSTER Field Fortifications Program, Part I, Test Report (Tactical Protective Structures, Subtests I and II, Short Title: Field Fort)*, Test Report No. FM 207, HQ MASSTER, Fort Hood, Texas, 14 June 1974.

[15]N. Davis. *Protection Afforded by Field Fortifications Against Nuclear Weapons* (U), Report 1557-TR, US Army Engineer Research and Development Laboratories, Corps of Engineers, Fort Belvoir, Virginia, December 1958.

[16]*Protective Construction for Combat Positions/Bases.* Final Report, United States Marine Corps, 31 October 1972.

[17]*Internal Marine Corps Project Directive 90-70-1: Protective Construction for Combat Positions/Bases.* Final Report, Phase I (14 April - 15 October 1970), United States Marine Corps.

[18]R. Corrigan. *Prefabricated Bunker Shells*, Final Report, Marine Corps Development and Education Command, Quantico, Virginia, 22 November 1974.

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has led to both some overlap and some serious deficiencies (or omissions) in the types of protective shelters studied as well as other problems attendant to habitation.

Virtually all of the previous research on fortifications or shelters has been concerned with the physical protection of the occupants. Studies concerned with the effects of confinement and/or isolation and other psychological constructs have been oriented toward life in space or in the extremely cold arctic and antarctic regions. Studies of fallout shelter occupancy, such as those conducted by HRB-Singer[19,20] and the University of Georgia,[21] have addressed some of the psychological problems.

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[19]C. Newmiller, P. Francis, and R. Cooper. *Psychological Factors Related to Tolerance of Confinement*, HRB-75111-3F, HRB-Singer, Inc., November 1967.

[20]G. Wright and N. Fenstermacher. *The Psychological Environment of Protective Shelters*, HRB-75111-2F-SUMM, HRB-Singer, Inc., July 1966.

[21]J. Hammes and R. Osborne. *Shelter Occupancy Studies at the University of Georgia, 1962-1963*, Civil Defense Research Psychological Laboratories, University of Georgia, Athens, December 1963.

However, the stresses faced by shelter occupants are not nearly as great as those faced by soldiers in field fortifications. Nevertheless, these studies cannot be considered irrelevant as the problems that they indicate should not only exist in field fortifications, but should be magnified.

Previous work at MASSTER[22] tested several concepts for prefabricated bunkers. MASSTER personnel also tested protective concepts for foxholes. In general, none of the bunkers tested were considered to be completely satisfactory. However, the British Field Shelter, Mark II, was evaluated as showing the most military potential of the structures evaluated. The US foxhole cover was preferred over the British and Canadian. The Marine Corps tested three types of portable prefabricated bunkers.[23] Two of these were among those also tested by MASSTER. The Marine Corps concluded that none of the bunkers met the Stated Operational Requirements (SOR). In fact, the designers of one shelter tested in this study were apparently so concerned with the structural integrity of the shelter that they failed to provide fighting ports, even though the requirement for these openings was specified in the SOR document.

Headquarters, MACV (Military Assistance Command, Vietnam),[24] conducted an analysis of enemy fortifications at Khe Sahn. The enemy bunkers, constructed of locally available materials and well camouflaged, held up extremely well against US artillery and aerial bombing. For all practical

[22] M. Manley, *op. cit.*, 1974.

[23] R. Corrigan, *op. cit.*, 1974.

[24] *Analysis of Enemy Positions at the Khe Sahn and Evaluation of the Effectiveness of Weapon Systems Against Enemy Fortifications.* Vietnam Lessons Learned No. 69, Headquarters, US Military Assistance Command, Vietnam (MACV), 10 September 1968.

purposes, the bunkers were destroyed only by direct hits. The majority of the bunkers were quite small, having a floor design of approximately four by six feet with an entrance at one end in line with the short axis of the bunkers. Bunker tops were virtually at ground level, and consisted of a layer of logs and a layer of rocks topped by an earth fill. It is believed that the living bunkers were used by two to four men, so by American standards would probably be considered crowded. However, their small size was very likely a factor in their effectiveness. It is believed that the positions were abandoned only because of the extremely heavy artillery fire and aerial bombardments. In the design of future living bunkers, the discomfort resulting from the small size must be weighed against the protection it affords.

The most extensive studies of field fortifications conducted in recent years have been reported by the US Army Engineer Waterways Experiment Station in Vicksburg, Mississippi.[25,26,27] Investigators at the Experiment Station have studied a wide variety of protective shelters. They present some excellent discussions of the necessary characteristics of protective shelters as well as data on the results of actual tests on representative types. They typically present considerable detail on construction, and on the basis of tests conducted, make recommendations for particular types of structures. Presentation of the architectural details is beyond the scope of this review. However, some general statements

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[25] B. Hoot, et al., *op. cit.*, 1974.

[26] T. Kennedy, *op. cit.*, 1971.

[27] T. Kennedy, B. Hoot, J. Ball, and P. Rieck, *op. cit.*, 1975.

summarizing the results are in order. Overall, the best protection seems to be afforded by shelters which top off at ground level or at only slightly above and which provide an overhead cover of three to five feet of earth fill. Fighting holes should be small and only slightly above ground level. Entrance should be through a vertical shaft connected with the bunker by a tunnel.

With reference to foxhole construction, Davis[28] suggests that further work needs to be done on the round foxhole. Preliminary indications are that the round foxhole resists blasts better than the square or rectangular foxhole.

It is both interesting and puzzling to note that the work on tactical protective shelters to date has been concerned almost exclusively with protection from blasts and blast fragments, thermal radiation, and ionizing radiation, or the maintenance of a habitable internal environment (i.e., protection from biological agents, toxic substances, and heat and cold). No attention or even mention has been given to requirements for other aspects of life support, such as food preparation and sanitation. Further, no consideration is given to space requirements for life-support activities, including sleep. These latter activities are crucial in maintaining personnel in fighting trim. The only data on these latter aspects come from Civil Defense studies which will be discussed later. These studies can provide a starting point for further study. However, management of life support and other activities in a fallout shelter are quite different than those to be expected in a living/fighting bunker. Fallout shelters are typically considerably larger and are expected to contain

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[28] N. Davis, *op. cit.*, 1958.

people of all ages and both sexes. The only major activities are those concerned with life support and the maintenance of order. Personnel in a tactical protective shelter will likely be all male, must engage in a wide variety of activities, and will be under a constant stress of the threat of new attacks by a variety of weapons. Furthermore, they may be called upon to leave the protection of the shelter and engage in other activities with virtually no notice. Therefore, requirements for life support in a bunker in future wars will necessarily be somewhat different from those in the fallout shelter.

In summary, work on life-support systems for protective shelters for battlefield use appears to be nil.

Habitability of Field Fortifications

The Physical Environment

The soldier in a tactical protective structure on a battlefield of the future will be exposed to a number of physical hazards. While the primary purpose of this review is to examine the psychological hazards, they cannot be totally separated from the physical hazards. The soldier must be confident that the shelter provided will protect him from enemy fire and provide him with a habitable environment. Each of the major physical hazards facing the soldier in a tactical protective shelter will be discussed briefly below.

Overpressure. Explosions, whether from nuclear or conventional weapons, create pressure waves. Sprenger[29] cites evidence that even in a

[29] T. Sprenger. *Survival on the Nuclear Battlefield,* Student Essay, US Army War College, Carlisle Army Barracks, Pennsylvania, September 1974.

thermo-nuclear battle, 85 percent of the casualties are expected to result from mechanical and thermal effects with only 15 percent from ionizing radiation. Overpressure resulting from blasts most commonly causes lung hemorrhage, eardrum rupture, and air bubbles in the bloodstream. The damage done by pressure waves is a function of both the peak pressure and the rise time. The more rapid the rise time, the greater the danger to human beings. With a very rapid rise time, an overpressure of five psi will probably cause eardrum rupture. With slower rise times (e.g., 10 milliseconds), a peak overpressure of 40 to 50 psi is necessary to produce eardrum rupture in a majority of cases. Regardless of rise time, casualties will occur if the peak overpressure reaches 75 psi or more.[30] The rise time of pressure waves from conventional explosives is typically much sharper than for nuclear explosions. Therefore, considerably greater overpressure resulting from a nuclear explosion is required to inflict the same degree of injury as a smaller conventional explosion. Department of the Army Pamphlet (DA PAM) 39-3[31] states that overpressure from a small explosion of as little as five psi may well displace an adult man standing erect at a distance of 21 feet. Unfortunately, personnel have little opportunity to seek protection even from eardrum damage unless they receive early warning. For example, the pressure wave from a one megaton blast travels approximately one mile in four seconds. The pressure wave resulting from nearby conventional explosions would reach the shelter in fractions of a second.

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[30] T. Kennedy, B. Hoot, J. Ball., and P. Rieck, *op. cit.*, 1975.

[31] DA PAM 39-3. *Nuclear Weapons*, Department of the Army, Deputy Chief of Staff for Operations, 2 April 1962, pp 559-560.

Care must be taken in designing shelters as the overpressure inside a poorly designed shelter can actually peak higher than the external overpressure. This phenomenon has been observed in tunnels dug into the side of foxholes. Internal pressure in one study was 2.6 times that of the external pressure.[32] Magnification is almost certain to occur at the end of a cavity if the entry to the cavity is larger than the cross section of the far side.

Blast fragments. Fragments, either from the explosive itself or from debris picked up by the pressure wave, can reach velocities more than sufficient to cause casualties. However, protecting personnel from blast fragments is easy to achieve through proper construction. First of all, if the entryway is a vertifical shaft so that the top is horizontal to ground level, most blast fragments will pass directly across the entry and not enter the shelter. Even if the entryway must be constructed perpendicular to and above ground level, an "L" shaped passageway between the entry and the main shelter will all but eliminate blast fragment damage. Fragments entering the passageway will become embedded in the opposite wall, but are unlikely to "turn the corner" with sufficient velocity to inflict casualties. Obviously, protection from blast fragments can be easily achieved if sufficient time is available for the construction of the shelter.

Heat stress. Duke, Findikyan, and Sells[33] conducted an exhaustive review of the literature on heat stress in 1967. They found great consistency in the literature surveyed. Performance on almost all tasks

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[32] N. Davis, *op. cit.*, 1958.

[33] M. Duke, N. Findikyan, and S. Sells. *Stress Reviews. II: Thermal Stress-Heat*, Technical Report No. 11, Institute of Behavioral Research, Texas Christian University, Fort Worth, May 1967.

diminished after temperatures reached 90°F. An exception was reaction time, which was unaffected by considerably higher ambient temperatures. Results on vigilance performance were somewhat contradictory. Some investigators found that mild heat stress actually improved vigilance performance. Others found the opposite. Simple and well-practiced tasks were the last to be affected by heat stress. Unfortunately, in most of the earlier studies, temperature was the only variable considered. It is not possible to assess the effects of humidity and air movement (or the lack thereof) on these results. Later investigations did use the concept of "Effective Temperature" (ET). ET is a function of both the Wet Bulb Temperature (WBT) and the Dry Bulb Temperature (DBT) and is defined as $ET = 0.4\ (WBT + DBT) + 15$. An ET of 75°F is comfortable, an ET of 80°F results in some distress, an ET of 85°F brings great distress, and an ET of above 86°F results in casualties. Kennedy, et al.,[34] make some interesting observations concerning ET. They point out that WBT will approach DBT after a period of time in a poorly ventilated shelter due to respiration and perspiration on the part of confined personnel. Also, the heat generated by personnel will typically exceed any cooling effect resulting from absorption by the shelter's cover and walls. Therefore, both WBT and DBT will rise with time and approach body temperature. In a warm climate, temperatures will exceed 80°F in a matter of hours in a crowded shelter. Heat stress and the attendant decreases in performance will result. As a result, ventilation must be planned for shelters constructed in areas where ambient external temperatures are high. A minimum of 15 cubic feet per occupant is recommended if external temperatures exceed 80°F.

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[34] T. Kennedy, B. Hoot, J. Ball, and P. Rieck, *op. cit.*, 1975.

While ET is a more useful measure in predicting heat stress than actual temperature, it does not take into account the effect of air movement. Suarez[35] employed another index called the Wet Bulb Globe Temperature (WBGT). WBGT is defined as: *WBGT = .1 DBT + .7 WBT + .2 BGT, where BGT stand for Black Globe Temperature, a measure of radiation.* Thus far, this index has seen little use, but if widely accepted, should be a better measure of the internal environment of protective shelters than either ET or actual temperature.

Cold stress. Research on cold stress, like that on heat stress, has produced relatively consistent findings. Findikyan, Duke, and Sells[36] drew this conclusion from a review of the literature on cold stress in 1966. Though the human body has a fairly sensitive thermal regulatory system, it functions effectively only within a fairly limited temperature range. The lower limits of temperature at which the human can survive without protection has not been exactly determined. However, it is probably in the vicinity of 60°F. The human can, of course, withstand short exposure to much lower temperatures without ill effects. Cold injury results from prolonged exposure, and is most typically found in the extremeties which expose the largest exposed surfaces. Findikyan, et al., report that MacFarlane[37] listed three types of cold injury: chilblains,

[35] J. Suarez. *Methodology Investigation of Armored Fighting Vehicle Compartment Temperatures, M60 Tank,* USAPG Report 203, US Army Yuma Proving Ground, Arizona, November 1974.

[36] N. Findikyan, M. Duke, and S. Sells. *Stress Reviews. I: Thermal Stress-Cold,* Technical Report No. 8, Institute of Behavioral Research, Texas Christian University, Fort Worth, July 1966.

[37] W. MacFarlane. "General Physiological Mechanisms of Acclimatization," in S. Tromp (ed.), *Medical Biometerology,* New York: Elsevier Publishing Company, 1963, pp 372-417.

wet-cold syndromes, and frostbite. Chilblains is a relatively mild form of tissue damage; poor circulation resulting from cold produces local itching and swelling -- generally at the extremeties. Wet-cold syndromes result from prolonged (several days) of exposure to temperatures of 53°F or less. The so called "trenchfoot" is the best known example of this type of injury. The feet become red and swollen. Blood vessels are damaged and nerve injury is frequent. Frostbite results from prolonged exposure to temperature below 32°F. In most extreme cases, internal freezing takes place. Warming of the injured tissue causes considerable pain, and tissue rupture and swelling are observed. Damage to liver, kidneys, and adrenals may also be noted.

Although winter temperatures in central Europe can be extremely low, cold injuries should not be expected to be a major problem in protective shelters. The most likely effects of cold will be on those activities requiring fine tactual discriminations or tasks requiring fine manual dexterity.[38] Even performance on these types of tasks may not be greatly affected if the hands need to be exposed for only short periods of time. It has also been found that exposures of two or three hours reduce hand strength by 20 to 30 percent. Hence, time-consuming tasks which require considerable strength that cannot be accomplished wearing gloves will be affected in extreme cold.

Little has been done on the effects of cold on mental performance. However, Findikyan, Duke, and Sells report an unpublished study by Torrance which indicated that verbal recall was seriously affected by exposure to cold.

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[38] N. Findikyan, M. Duke, and S. Sells, *op. cit.*, 1966.

With the assumption that personnel will have adequate protective clothing, cold is not seen as a major factor affecting performance. Air movement, which contributes significantly to discomfort during cold weather, should not be a factor in an enclosed shelter. Furthermore, heat generated by both human activity and various items of hardware should keep the internal temperature above that of the external environment. Cold, then, may be more of a psychological than a physical hazard.

Radiation. Radiation is not a hazard when only conventional explosives are employed. With thermo-nuclear weapons, two types of radiation present potential hazards to the soldier on the battlefield. Kennedy, et al.,[39] discuss radiation hazards in considerable detail. The following paragraphs present a summary of their presentation in this area.

Thermal radiation, a major hazard with large thermo-nuclear weapons, is not a major hazard to protected troops if only tactical nuclear weapons are employed. Although internal temperatures may reach as high as 300°F, the period of intense heat is so short-lived that it is unlikely to seriously affect personnel. Exposed flammable materials; for example, wood buttressing at the entrance, might be charred. However, any actual flames will be extinguished by the following blast winds. Therefore, fire hazard is very small.

Nuclear radiation poses a much greater hazard. Neutron and gamma radiation can reach lethal levels even with 10 kt tactical weapons. Tactical protective shelters, therefore, must be designed to protect personnel from radiation hazards. The level of protection required, however,

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[39] T. Kennedy, B. Hoot, J. Ball, and P. Rieck, *op. cit.*, 1975.

is far less than that desired for civilian fallout shelters. Civilian shelters are intended to protect individuals from dosages at levels likely to result in genetic damage. This level of protection cannot be afforded on the battlefield. In general, it is recommended that shelters be designed so that initial radiation dosage level is no greater than 150 rems. At this level of radiation the vast majority of personnel will probably survive. Some nausea and/or vomiting may occur the first day, but a latent period of 10 days to two weeks will follow during which no physiological symptoms will occur. Personnel will be able to emerge from the shelter after radiation subsides and carry on the battle for several days.

The radiation protection afforded by the shelter must be commensurate with the blast protection it affords. For example, if a shelter is designed to withstand overpressures of 50 psi, it must protect personnel from radiation from weapons detonated at a distance which will produce a 50 psi overpressure. In other words, the better the design level, in terms of blast protection, the greater must be the protection against initial radiation. Shelters have been designed to protect personnel from both radiation and blast effects where overpressure reaches 100 psi. These designs will be studied carefully before any research on their overall habitability is undertaken.

Noise. Noise is considered to be an occupational hazard for soldiers. Protective shelters, if properly constructed, should provide some protection against noise. However, poorly constructed shelters may actually amplify noise in the same manner in which they amplify pressure waves from blasts. Other than taking care to assure that mechanical amplification does not take place, designing shelters for noise reduction is probably not cost effective in terms of either time or materials. Providing individual protection should be both simpler and more effective.

Steady-state noise should not be a problem in protective shelters. Impulse noise is likely to be a problem everywhere in the battle area, including protective shelters. Impulse noise is defined as a noise in which there is a 20 dB drop in less than 500 milliseconds after the onset and which is not followed by a new pressure wave in less than 500 milliseconds.[40] The maximum acceptable noise level for impulse or impact noise depends upon both the positive pressure rise time and the duration of the positive pressure envelope. Human Engineering Lab Standard (HEL Std) S-63b[41] specifies 160 dB as the absolute limit under any conditions.

A publication of the General Radio Corporation[42] states that the Occupational Safety and Health Administration (OSHA) lists 140 dB as the maximum allowable impulse noise level. They further indicate that the maximum acceptable level is a function of the number of impacts per day. For example, 140 dB is acceptable if the number of impacts per day is only 100. However, if 10,000 impacts per day is anticipated, 120 dB is the maximum acceptable level. Noise levels inside fighting bunkers will undoubtedly exceed 140 dB and probably 160 dB if weapons larger than 5.56mm are fired. Therefore, individuals must wear protective devices

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[40] [Conference on] Noise Evaluation and Control, Temple Texas, 1975, presented by Texas A&M University, Occupational Health and Safety Institute.

[41] J. Weitz. *Maximum Noise Level for Army Materiel Command Equipment*, HEL Std S-63b, US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, June 1965.

[42] *Guidelines for Measuring OSHA Noise*. B&K Instruments, Inc., Cleveland, Ohio, 1975.

in order to prevent hearing damage. Earplugs and earmuffs which reduce the effective level from 20 to 30 dB are readily available. Therefore, if noise levels do not exceed 160 dB, these devices should prove adequate. However, measurements of noise levels inside of proposed designs for fighting bunkers should be made to ensure that personnel are adequately protected.

Protective devices are more likely to interfere with communications than with other types of activities. Intermittent impulse noise also poses a psychological hazard, and is very likely to interfere with sleep. These hazards will be discussed in greater detail in a later section.

Toxic substances. Noxious fumes from the firing of ammunition might be a problem in fighting bunkers, although no reports on this subject have been found. The primary dangers in living shelters come from either a lack of oxygen or an accumulation of carbon dioxide. Carbon monoxide could also reach dangerous levels if any organic materials are combusted in the shelter. Kennedy, et al.,[43] provide the following information concerning toxicity. The oxygen concentration of normal air is approximately 20 percent. The content can drop to as low as 17 percent with no apparent ill effects on man. Unless a shelter is overcrowded or has exceedingly poor ventilation, personnel should be able to survive for a considerable period of time without loss of adequate oxygen concentration. Carbon dioxide, however, poses a different kind of problem. A concentration of 0.4 percent is normal. Concentrations as high as 4.0 or 5.0 percent can be endured without ill effect for a matter of hours. However, concentrations in excess of 5.0 percent are dangerous

[43] T. Kennedy, B. Hoot, J. Ball, and P. Rieck, *op. cit.*, 1975.

over a period of days. Relatively low intake of fresh air (24 cubic feet/hour/occupant) is required to maintain satisfactory oxygen concentration for sedentary personnel). On the other hand, a fresh air intake of 180 cubic feet/hour/occupant is required to maintain carbon dioxide levels at 0.5 percent or less. Of course, carbon dioxide production among personnel in a shelter during an air or artillery attack is likely to be considerably above that of "sedentary" personnel. Therefore, ventilation rates above 180 cubic feet/hour/occupant must be planned for if shelters are to be inhabited over a matter of days.

Carbon monoxide, though dangerous in very small concentrations, should not be a problem in protective shelters so long as no fossil fuels or other organic substances are burned in the shelter. The human machine is very efficient and produces only negligible quantities of carbon monoxide. If ventilation is adequate no problem should occur, even if efficiently designed heaters are used within the shelter. However, if the shelter must be sealed, even for very short periods of time, great care must be taken to prevent the accumulation of carbon monoxide. Tobacco smoking must be prohibited. Cigar smoking is especially dangerous as cigars generate approximately 20 times as much carbon monoxide as cigarettes.

As can be seen from the above discussion, some means of ventilating shelters which must be inhabited over long periods of time must be one of the design characteristics. If adequate ventilation cannot be achieved by the inclusion of a sufficient number of openings, then some means of forced air ventilation will be required. Kennedy, <u>et al</u>.,[44] describe two forced-air ventilating systems which are comparatively simple and

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[44] *Ibid.*

inexpensive to construct, and are man-operated. These are the Kearny air pump and the hand-operated bellows. The Kearney air pump is somewhat simpler to construct and can deliver approximately 1000 cubic feet of air per hour. The bellows must be shop-constructed, but is capable of delivering up to 3000 cubic feet per hour. The bellows would probably be adequate for a shelter designed for up to 15 men if physical activity were kept to a minimum. Therefore, the most cost-effective means of ventilating a shelter will depend on what is deemed to be the optimum occupancy based on other factors.

Biological agent hazards. Protection from biological agents in shelters or bunkers that have forced-air ventilating systems can be provided fairly simply and at a fairly reasonable cost.[45] The Edgewood Arsenal particulate filter has a 99.97 percent efficiency in removing particles of 0.3 microns or larger in size. The major problem involved in the use of such a filter lies in the installation. The filter naturally must be sealed into the air intake opening. A four-man filter unit which produces 12 cubic feet/minute is also available in the Army inventory.[46] Although this unit was designed for use in a vehicle and requires an external power source of 24 volts, it is conceivable that it could be adapted for use in a protective shelter.

While the employment of biological agents is seldom mentioned in the literature on the threat, it would be foolhardy to assume that they would

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[45] J. Petty and W. Brooks. *Cost Estimates for Providing Biological Agent Protection to Fallout Shelters*, Director of Engineering and Industrial Services, Edgewood Arsenal, Maryland, October 1964.

[46] J. Lunn and W. McIntyre. *Surveillance/Environmental Tests of Filter Unit, Gas Particulate, Four Man, Twelve CFM, N8A3*, Desert Test Center, Fort Douglas, Utah, October 1972.

never be used. Therefore, shelter design must make provision for the use of equipment for protection from biological agents.

Chemical agent hazards. No literature was located specific to the protection of shelter inhabitants against chemical agents. The particulate filters will remove large molecules, such as Diocytalphthalate (DOP). Protection from gaseous substances must be achieved by the use of the individual gas mask. Since no discussion on this subject was found, it must be assumed that the individual mask is expected to be the protective device employed in protective shelters.

Life-support systems. No literature was located concerning the type of life-support systems that might be employed in protective shelters. All of the literature found thus far has been concerned with the protection of occupants from physical hazards. Certainly, it men are to be confined for periods of days, provisions for supplying the shelters with uncontaminated food and water and for the disposal of waste must be made. Since, during periods of confinement, it is assumed that delivery of supplies would be extremely dangerous at best, the shelters must be equipped with provisions at the time they are completed. Planning along these lines appears to be lacking. However, further search of the literature will be instituted.

At the present time, the availability of life-support provisions in the inventory is not known. Until such is determined, speculation on the adequacy of life support in protective shelters does not seem warranted.

The Psychological Environment

There is a considerable body of literature dealing with the effects of confinement and isolation on small groups. Much of the earlier work along these lines was sponsored by the US Air Force. Their interest lay in the performance of air crews on extended missions. Roby[47] studied crew composition and compatability as a factor in performance. More recently, Hartman and his associates[48] have examined stress effects of extended C-5A missions on crewmen. The US Navy has long been active in the study of groups in isolation. Earlier work was oriented toward the selection and training of submarine crewmen. More recently, their interest lay in the study of groups of aquanauts and in personnel isolated during the winter in arctic and antarctic climates.[49,50,51] The National Aeronautics and Space Administration (NASA)[52,53] has sponsored an extensive program on the anticipated effects of confinement and isolation in

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[47] T. Roby. *Sociometric Index Measures as Predictors of Medium-Bomber Crew Performance*, AFPTRC Research Report TN-56, Lackland AFB, Texas, April 1956.

[48] B. Hartman, H. Hale, D. Harris, and J. Sanford. "Psychobiologic Aspects of Double-Crew Long-Duration Missions in C-5 Aircraft," *Aerospace Medicine*, 1974, 45(10), 1149-1154.

[49] E. Gunderson and P. Nelson. "Criterion Measures for Extremely Isolated Groups," *Personnel Psychology*, 1966, 19, 67-80.

[50] R. Doll and E. Gunderson. "The Relative Importance of Selected Behavioral Characteristics of Group Members in an Extreme Environment," *Journal of Psychology*, 1970, 75, 231-237.

[51] R. Helmreich. *Evaluation of Environments: Behavioral Observations in an Undersea Habitat*, Social Psychology Laboratory, Department of Psychology, University of Texas, Austin, August 1971.

[52] S. Sells and R. Trego. *Normative Studies of Personality Measures Related to Adaptation Under Conditions of Long Duration, Isolation, and Confinement, Final Report, Part I. Personal Characteristics for Successful Adaptation*, IBR Technical Report 73-17, Institute of Behavioral Research, Texas Christian University, Fort Worth, July 1973.

[53] S. Sells (chairman). *APA Symposium on Factors Affecting Team Performance in Isolated Environments, September 5, 1967*, Institute of Behavioral Research, Texas Christian University, Fort Worth, July 1968.

long duration space flights. Among the variables most commonly studied are confinement, social isolation, interpersonal compatability, work-rest cycles, and group size.

Although interesting, most of this work is of marginal relevance at best in this research effort, as it is oriented toward long-term confinement such as in space flight, winter in arctic or antarctic regions, and extended submarine duty. Confinement in a field fortification is, at most, not likely to be more than a matter of days. In addition, opportunities for selection in the situations described are much better than in the field army. Space travelers, especially, are an extremely select and well-trained group. Aquanauts are also very carefully selected and trained, and are also essentially volunteers for the specific kinds of missions they perform. Personnel wintering over in arctic and antarctic regions are a mixture of many types, including civilian scientists. Military personnel on these missions may be less carefully selected than for aquatic or space missions, but are largely restricted to personnel of a small group possessing skills necessary for the accomplishment of the mission. Hence, neither the mixture of personnel, the types of dangers faced, nor the length of confinement can be said to resemble the situation likely to occur in the field fortification.

Submariners are the group that probably resembles most closely the personnel in the field army. However, they are all volunteers, and know when they enter the service that they will be subject to long periods of crowding and confinement under the water. Also, creature comforts such as adequate and well-prepared food, adequate sanitation, changes of clothes, and a reasonably habitable physical environment are givens, except in extreme emergencies. Therefore, the relevance of much of this large body of literature is open to serious question. However, some aspects of these works are directly relevant, and will be treated in this section.

The ultimate purpose of the field fortification is to provide US soldiers with a supportive environment that will enable them to conduct battle operations efficiently, both during confinement and upon exiting. From a slightly different point of view, the fortification must minimize the stresses placed on the individual soldier. The potential hazards or physiological stresses were discussed in the previous section. However, many of these stressors have psychological components. For example, the hazards from blast fragments or overpressure from explosions are physiological in nature. Nevertheless, fear of impending physical harm is a psychological hazard. This fear can exist even when the real danger is very minimal. In other words, it is the perception of the threat that is critical. While this has been known intuitively for some time, it has only been recently that experimental work was undertaken to demonstrate the point. Wherry[54,55] developed the Anticipatory Physical Threat Stress (APTS) Model. Wherry's model states that performance on any task is affected as a function of "(a) the perceived proximity (closeness of the unpleasant event, (b) the perceived unpleasantness of the event if it occurs, and (c) the perceived probability that the unpleasant event will

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[54] P. Curran and R. Wherry. "Measure of Susceptibility to Psychological Stress," *Aerospace Medicine*, October 1975, 36, 929-933.

[55] R. Wherry and P. Curran. *A Study of Some Determiners of Psychological Stress*, US Naval School of Aviation Medicine, Pensacola, Florida, July 1965.

occur." For a stressor to be truly stressful; it must meet all three criteria. For example, if the soldier believes that an attack is certain, that it will happen momentarily, and that he will be seriously injured or killed if the attack does occur, his perception of the situation will result in near intolerable stress. However, if the soldier feels he is certain to survive attack unharmed, it matters little if he assumes that it is certain and will occur in the very near future. This perception will result in very little stress. The usefulness of this model in the current research is obvious. The soldier must have confidence in the protective capabilities of the shelter. This is the only element in the model which can be controlled to any degree within the Army's resources. Serious consideration must be given to the most efficient and cost-effective means of developing individual soldier confidence in the types of field fortifications developed.

Unfortunately, the earlier literature on stress is badly fragmented and disorganized.[56] The later literature is more systematic, but as discussed earlier, deals largely with stress factors or marginal relevance to the problem at hand. In fact, stress research of the type most relevant to the battle situation was all but halted in about 1960 due to ethical considerations. HumRRO work in Work Unit FIGHTER[57] was severely criticized, and was terminated before being brought to fruition. As a result, there are still many gaps in our understanding of stress, and the

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[56] R. Lazarus, J. Deese, and S. Osler. "The Effects of Psychological Stress Upon Performance," *Psychological Bulletin*, July 1952, 49(4), Part I.

[57] M. Berkun, H. Bialek, R. Kern, and K. Yagi. "Experimental Studies of Psychological Stress in Man," *Psychological Monographs*, October 1962, 76(15).

literature, taken as a whole, is still difficult to organize. The organization finally chosen for this review is but one of several that were considered. Five of the subsections deal with various kinds of stresses, one section deals specifically with stress effects on performance, one with stressors that have been used in experimental research, one with management and leadership considerations in confinement and isolation, one with means of measuring stress, and the final section deals with research problems as they apply to the area of field fortifications.

Stresses

Battle stress. Literature dealing with casualties due solely to battlefield stresses in the United States stems from the Civil War. The Surgeon General of the Union Army recognized a condition which afflicted the minds of soldiers, making them incapable of performing their duties, although no evidence of physical injury existed. The Surgeon General termed this affliction *nostalgia*.[58] A total of 5213 cases were reported during the first year of the war with nearly twice as many during the second year of the war. Since that time, psychiatric casualties have been termed as afflicted with *shell-shock, battle fatigue, war neuroses*, and simply as neuropsychiatric casualties. The fact that such casualties can become a serious problem is substantiated by data from World War II. During a two-year period between January 1943 and December 1945, there were 409,887 neuropsychiatric patients admitted to Army hospitals overseas alone. The highest rate was 101 per thousand soldiers per year in

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[58] P. Bourne. "Psychological Aspects of Combat," in H. Abram (ed.), *Psychological Aspects of Stress*, Springfield, Illinois: John C. Thomas, 1970, pp 70-85.

the First US Army. Interestingly enough, psychiatric casualties were only 37 per thousand men per year in Korea, and 12 per thousand men per year in Vietnam. Reasons for these differences can only be speculated upon, but several factors are deserving of consideration. World War II was the most lengthy and intense of our three most recent armed conflicts. Vineberg,[59] in a fairly thorough review of literature on neuropsychiatric casualties during World War II and the Korean War, noted that neuropsychiatric casualties increased as battle-related casualties increased. He further noted that neuropsychiatric casualties also appeared to be a function of both the intensity and the duration of the conflict. Of particular importance to this research was the finding that static situations tended to lead to high casualties. Static situations were defined as those where there is little or no possibility of taking action, as when "pinned down" by artillery fire or when held in place for tactical reasons. Apparently, the ability to retaliate, even though many battle casualties may be produced, tends to reduce psychiatric casualties. On the basis of this previous evidence, it might be assumed that soldiers holding for periods of days in field fortifications would be highly prone to neuropsychiatric breakdown. In reviewing work on battle stress, Carlock and Bucklin[60] conclude that combat fear is virtually universal. However, they also point out that fear is augmented in situations involving helplessness, hopelessness, or idleness in the face of threat of

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[59] R. Vineberg. *Human Factors in Tactical Nuclear Combat*, HumRRO Technical Report 65-2, Human Resources Research Organization, Alexandria, Virginia, April 1965.

[60] J. Carlock and B. Bucklin. *Human Factors in Mine Warfare: An Overview of Visual Detection and Stress (Part II, Stress)*, prepared for presentation at the TTCT Panel 0-1 Work Group, Mine Warfare Study Group Seminar, October 1971.

of life. Mild fear, it is believed, typically tends to increase effort and probably efficiency. On the other hand, acute fear usually leads to subjective stress feelings, depression, fatigue, and other ill-suited reactions. Fear of battle is accepted by the Army as normal. Fear need not bring about total disorganization, but *panic* ("a prolonged avoidance behavior on the part of a group with elements of irrational and excited behaviors") can result when men are fatigued, undernourished, in actual danger, and lose faith in their leaders. This latter opinion is worth attention for several reasons. It suggests that strong and effective leadership (discussed in a later section) is essential. Leadership can minimize fatigue by ensuring equitable distribution of duty functions and optimized work-rest cycles. Undernourishment, or rather a means of combating it, mentioned specifically by Garlock and Bucklin,[61] does not seem to be dealt with at all in the literature. In fact, as mentioned before, life-support systems seem to have been almost totally ignored by previous investigators.

Bourne[62] acknowledges that aerial and artillery bombardments, which characterized battle in World War II, were a much smaller factor during the Korean War, and a very minor factor during the Vietnam War. This undoubtedly tended to reduce neuropsychiatric casualties. However, Bourne suggests several other factors which may have been responsible for the comparatively low incidence in Vietnam. First of all, he suggests the one-year tour, broken with an R&R (Rest and Recreation), as the primary factor. Better mail service and the possibility of telephone

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[61] *Ibid.*

[62] P. Bourne, *op. cit.*, 1970.

service, at least in certain areas kept home-ties much stronger. The "finite duration" of the individual war was presumed to be a stronger influence than either the "buddy system" employed in Korea, or the strong unit identification presumed to maintain morale during World War II. Unfortunately, the "guaranteed" tour is not likely to be possible in a European conflict. Therefore, consideration should be given to the development of some means of enhancing morale in a field fortification. To some degree, this is a function to management/leadership, and will be discussed later.

Confinement and isolation. Smith, et al.,[63] in 1963, and Sells and Rawls[64] in 1969 published surveys of the literature on confinement and isolation. While these surveys were oriented more toward long-term isolation, several generalizations seem important toward life in a field fortification. Leadership can become a problem as "status-leveling" is very likely to occur. Lack of privacy makes virtually all of the leader's activities open to inspection, making it difficult to maintain social distance, and thereby, the absolute authority needed at times. Therefore, even in field fortifications, some attention should be paid to requirements for privacy, activities to strengthen normal superior-subordinate relationships, and other activities to prevent the close scrutiny of

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[63] S. Smith, R. Farrell, and B. Gonzales. *The Performance of Small Groups in Isolation and Confinement: A Brief Annotated Bibliography*, The Boeing Company, 1963.

[64] S. Sells and J. Rawls. *Effects of Isolation on Man's Performance*, USI 20, Bioengineering and Cabin Ecology, Science and Technology Series, American Astronautical Society, Tarzana, California, 1969.

individuals -- especially leaders. Monotony and boredom can become pervasive problems, again emphasizing the need for leadership and the requirement for productive activities. As feelings of hopelessness and helplessness develop, frustration is frequently tranferred to focus on other groups or higher command. While this focus may tend to prevent breakdown in the same manner that retaliation against an enemy prevents breakdown, it could result in future problems when the personnel emerge from the shelter. Loss of faith in or anger with higher command is not conducive to effective battlefield operations.

One of the most interesting results of the recent literature on confinement and isolation has been the recognition of confinement, aside from any physical danger, as a potent stressor. This has been demonstrated almost universally in laboratory-type studies by the fact that large numbers of subjects, although volunteers for the studies, have defected prior to the end of the confinement period.[65,66,67,68,69,70]

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[65] I. Altman and W. Haythorn. "The Effects of Social Isolation and Group Composition on Performance," *Human Relations*, 1967, 20 (4), 313-339.

[66] J. Hammes, and R. Osborne, *op. cit.*, 1963.

[67] T. Myers, D. Murphy, S. Smith, and S. Goffard. *Experimental Studies of Sensory Deprivation and Social Isolation*, HumRRO Technical Report 66-8, Human Resources Research Organization, Alexandria, Virginia, June 1967.

[68] J. Zubek, L. Bayer, and J. Shephard. "Relative Effects of Prolonged Social Isolation and Confinement: Behavioral and EEF Changes, *Journal of Abnormal Psychology*, 1970, 75(5), 625-631.

[69] J. Zubek, L. Bayer, S. Milstein, and J. Shephard. "Behavioral and Physiological Changes During Prolonged Immobilization Plus Perceptual Deprivation," *Journal of Abnormal Psychology*, 1969, 74(2), 230-236.

[70] M. Zuckerman, H. Persky, K. Link, and G. Basu. "Experimental and Subject Factors Determining Responses to Sensory Deprivation, Social Isolation, and Confinement," *Journal of Abnormal Psychology*, 1968, 73(3), 183-194.

The more confining the environment, the sooner were defections noted. For example, when subjects were deprived sensorially and placed in recumbent positions, 13 of 30 subjects quit on the first day, and only 12 finished the week of isolation.[71] The notion that confinement rather than social isolation was the important variable was shown by Zubek, Bayer, and Shephard.[72] They compared a socially isolated as well as confined group, a confined but not socially group, and an ambulatory control group. The two confined groups did not differ from each other, but both differed from the ambulatory control group. Zuckerman, et al.,[73] attempted to dissect results obtained with sensory deprivation and isolation studies in terms of the contributions of sensory restriction, social isolation, confinement, set, and to some degree, subjects. They concluded that "the stress effects of confinement are rather massive and are found even when Ss are neither sensorially nor socially isolated." Life in a field fortification will almost certainly seem to be confining. Unfortunately, the literature does not propose any techniques for making confinement seem less confining. Social isolation does not seem to be a problem as shelters will undoubtedly be designed for numbers of people. However, the fact that confinement alone appears to be extremely stressful presents a research challenge. Means of training personnel to endure confinement or the development of activities to reduce the stressful effects of confinement should be a part of the overall field fortifications research program.

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71 J. Zubek, L. Bayer, S. Milstein, and J. Shephard, *op. cit.*, 1969.

72 J. Zubek, L. Bayer, and J. Shephard, *op. cit.*, 1970.

73 H. Zuckerman, H. Persky, K. Link, and G. Basu, *op. cit.*, 1968.

Hardship stresses. Soldiers living in field fortifications will almost certainly face a number of hardships. Obviously, home-like facilities cannot be provided. Overall resources must necessarily be limited, so the question is: how well can soldiers adapt to the hardships imposed, notwithstanding battle stresses. Data on the quality and effects of life-support systems under varying conditions from previous conflicts is notably lacking. The only data of real relevance discovered pertained to the occupancy of fallout shelters by civilian personnel.[74,75] A whole series of studies was conducted at the University of Georgia. Extrapolation of these results to field fortifications is tenuous for several reasons. However, the conditions studied are probably nearer to those that will be faced by the soldier in a field fortification than any other identified. Personnel were restricted to approximately eight square feet per person, one-and-one-half quarts of water per day for drinking, no washing or shaving facilities, restricted caloric intake (1000 calories per day or less), limited recreational materials, one change of clothes, and a proposed two-week occupancy. Defections varied from two out of 30 to eight out of 30, with defections tending to decrease with each succeeding study -- probably because of improvements in shelter management. Subjects tended to survive with no apparent physiological or psychological performance decrements. Weight loss was observed in virtually all subjects, but in general half the weight loss was recovered during the first week outside the shelter. A number of psychological, physiological,

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[74] J. Hammes. *Shelter Occupancy Studies at the University of Georgia (Summary of Final Report)*, University of Georgia Psychological Laboratories and Office of Civil Defense, Athens, 31 December 1963.

[75] J. Hammes and R. Osborne, *op. cit.*, 1963.

coordination, and strength tests were employed in an effort to determine performance decrements. The lack of decrements observed indicates that confinement alone should not affect performance in battle after exiting. However, it should be noted that the confinement and physical deprivations were the only stressors involved in these studies. Physical danger was not a factor at all. Social isolation was certainly not a factor as 30 persons of both sexes covering a wide range of ages were the occupants. Nevertheless, these studies to indicate the ability of the human being to survive under deprived conditions with little loss in capability -- certainly a fact to be considered in the design of cost-effective field fortifications and their life-support systems.

Crowding stress. A whole new area of research opened up following Calhoun's 1962 article in *Scientific American*.[76] Calhoun's work suggested that increasing population density resulted in greater social disorganization and a variety of maladaptive, if not abnormal, behaviors among individuals within the society. In a recent review of the literature concerning crowding, Stokols[77] pointed to a modern trend to consider "crowding" as a subjective variable, with "density" being the primary underlying physical variable. The two are correlated, but not identical. Emphasis has been placed upon non-spatial factors which interact with density to promote the subjective experience of crowding. The feeling of crowding then is really a stress reaction to a total situation of which population density is only one element. For an individual to feel crowded,

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[76] J. Calhoun. "Population Density and Social Pathology," *Scientific American*, 1962, 206, 139-148.

[77] D. Stokols. "The Relation Between Micro and Microcrowding Phenomena: Some Implications for Environmental Research and Design," *Man-Environment Systems*, 1973, 3(3), 139.

some form of disruption in his normal social relationships with those in his immediate area must occur. For example, an individual may feel less crowded at a New Year's Eve party than in his working environment, as office staff increases, although the population density at the former may still be several times as great in the latter.

The notion of disruption in the individual's immediate surround is suggestive of the concept of Personal Space (PS). Evans[78] summarized over 130 publications dealing with PS. He indicates that a large number of hypotheses (e.g., people who are friends will interact at closer distances than strangers) have been generally, although far from universally, supported by the literature. A hypothesis of greater import to this research states that hostile or stressful environments tend to increase Interpersonal Distances (IPD) between subjects -- indicating a greater need for PS. This hypothesis too has been supported by a majority of the literature on the subject. For example, Stokols,[79] citing some of his own work,[80] observed that the perception of crowding in a small area was greater among subjects playing a game competitively than when playing under a cooperative set. These findings suggest that while the stress involved may increase PS needs among men in field fortifications, their common goals, and the fact that they are likely to be familiar with each other, should decrease these needs.

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[78] G. Evans. "Personal Space: Research, Review, and Bibliography," *Man-Environment Systems*, July 1974, 3(4), 203.

[79] D. Stokols, *op. cit.*, 1973.

[80] D. Stokols, M. Rall, B. Pinner, and J. Schopler. "Physical, Social and Personal Determinants of the Perception of Crowding," *Environment and Behavior* (in press).

Evans[81] mentions briefly work on another concept, that of "territory," which is related to PS and crowding. PS can be distinguished from territory in that territory is geographically bounded, while PS surrounds the individual, regardless of his geographical location. Territory is typically defended by aggression, while PS is typically defended by withdrawal. Territorial behavior in humans is typically confined to areas with longstanding associations and emotional attachments, such as the home. However, under the stresses imposed by confinement, territorial behavior in unfamiliar surrounds has been observed, even in relatively short-term experimental studies by Zuckerman, et al.[82] The potential for the development of territorial behavior in a field fortification, especially with regard to routine functions, such as sleeping and eating, is certainly there. However, it can probably be prevented through proper management. Space allocation by function, rather than by individual or group, should discourage the development of territorial behavior.

Exactly how much space or what conditions are required to preclude crowding stress is not known. Subjective statements indicate that personal compatibility, necessity, and personal hygiene are all important factors in determining requirements for PS.[83] Fallout shelter studies indicated no ill-effects or serious problems occurred when only some eight to ten square feet (including storage space) per person could be pro-

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[81] G. Evans, *op. cit.*, 1973.

[82] M. Zuckerman, H. Persky, K. Link, and G. Basu, *op. cit.*, 1968.

[83] J. Rawls, R. Trego, and C. McGaffet. *Personal Space and Its Effect Upon Performance of Three Psychomotor Tasks Under Three Degrees of Closeness*, IBR Report No. 69-6 (NASA Technical Report No. 10), Institute of Behavioral Research, Texas Christian University, Fort Worth, April 1969.

vided.[84,85] A Canadian study aimed at design requirements for living conditions in a snow-bound vehicle set minimum requirements at 90 cubic feet per occupant.[86] This study also acknowledged the need for privacy in stipulating a requirement for a curtain in front of the commode. This latter mentioned study contains a number of suggestions on optimizing the use of space and weight for the convenience of inhabitants. While no data on the subject have been located, it seems reasonable to assume that convenient and efficient use of available space would help alleviate feelings of crowding. This document is also interesting for another reason. It is the only document thus far identified that pays any more than lip service to the details of requirements for life-support systems, and especially as they related to available space and weight.

While the literature suggests situations and circumstances under which crowding, territorial behavior, and PS problems may develop, it offers many fewer suggestions for prevention or cure. Stokols[87] cites evidence that exposure to high density situations and familiarity with the total environment will enable individuals to restructure their personal environment and reduce crowding stress. Withdrawal is the normal means of alleviating stress resulting from seemingly intolerable density. Since

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[84] J. Hammes, *op. cit.*, 1963.

[85] J. Hammes and R. Osborne, *op. cit.*, 1963.

[86] D. Beevis and C. McCann. *Human Engineering Aspects of a Small Self-Contained Mobile Shelter System*, Behavioral Sciences Division, Defence and Civil Institute of Environmental Medicine (DCIEM), Downsview, Ontario, Canada, July 1972.

[87] D. Stokols, *op. cit.*, 1973.

this will not be possible in a field fortification, crowding stress must be reduced by other means. Stokols suggests enhancing the attractiveness of one's activities, or the adoption of other cognitive and perceptual modes of managing the total environment. Again, exposure and practice would seem important. Perhaps the primary lesson to be learned from the literature in this field is that previous exposure (which can be easily translated as training) should be employed to help individuals develop coping behavior. The amount and composition of such training should be the subject of future research.

Fatigue stress. Many writers will argue that fatigue as normally experienced in a battle zone is more a result of stress than a stressor itself. They can point to the literature on extended operations where decrements in performance of military tasks are rarely found, even after periods of up to 48 hours.[88,89,90,91] While this argument is somewhat of an overstatement of a point of view, there is certainly evidence that fatigue has psychological as well as physiological origins. However,

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[88] L. Ainsworth and H. Bishop. *The Effects of a 48-Hour Period of Sustained Field Activity on Tank Crew Performance*, HumRRO Technical Report 71-16, Human Resources Research Organization, Alexandria, Virginia, July 1971.

[89] J. Banks, J. Sternberg, J. Farrell, C. Debow, and W. Dalhamer. *Effects of Continuous Military Operations on Selected Military Tasks*, Technical Report 1166, US Army Behavioral and Systems Research Laboratory (BESRL), Arlington, Virginia, December 1970.

[90] D. Cannon, E. Drucker, and T. Kessler. *Summary of Literature Review on Extended Operations*, HumRRO Consulting Report, Human Resources Research Organization, Alexandria, Virginia, December 1964.

[91] R. Doll and E. Gunderson, *op. cit.*, 1970.

regardless of origin, once fatigue exists, it becomes itself a stressor. Hartman, _et al._,[92] have demonstrated stress-induced fatigue in a study of aviators on 66-hour missions. They found that subjective fatigue increased during the mission then recovered toward the end of the mission. The validity of the self-reports was demonstrated by the fact that oral temperature correlated very highly with the subjective statements.

Fatigue, regardless of origin, can be best both prevented and cured through optimization of work-rest cycles and nutritional intake. There has been considerable effort put into the investigation of work-rest cycles. Chiles, Alluisi, and Adams[93] summarized eight years of work on the optimization of work-rest cycles for astronauts. The most recent general review of the literature on the effects of sleep loss, work-rest schedules, and recovery on human performance was reported in December 1974 by Woodward and Nelson.[94] These authors point out that the results obtained in the literature are not entirely consistent. However, they attribute a considerable portion of the inconsistency to the lack of a standard taxonomy for classifying jobs or tasks, and lack of a standard system for quantifying human performance. Nevertheless, they felt they could make some generalizations concerning the effects of sleep loss and

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[92] B. Hartman, H. Hale, D. Harris, and J. Sanford, *op. cit.*, 1974.

[93] W. Chiles, E. Alluisi, and O. Adams. "Work Schedules and Performance During Confinement," *Human Factors*, 1968, 10, 143-196.

[94] D. Woodward and P. Nelson. *A User Oriented Review of the Literature on the Effects of Sleep Loss, Work-Rest Schedules and Recovery on Performance*, Office of Naval Research, Biological and Medical Sciences Division, Arlington, Virginia, December 1974.

the optimization of work-rest cycles. Sleep loss appears to be most likely to affect performance on uninteresting and monotonous tasks, tasks that require continuous attention on the part of the operator, performances where several tasks must be performed on a time-shared basis, and tasks that are relatively unlearned prior to performance. Since little control can be exerted over the type of tasks that must be performed inside field fortifications, the primary lesson from this review concerns the potential decrement in performance on new or incompletely learned tasks. Obviously, critical tasks should be overlearned so that sleep loss will have minimal effects on their performance.

With relation to work-rest cycles, the literature indicates that regular duty-rest cycles produce the most efficient performance. Changes in shift normally disrupted performance for a considerable period of time. Therefore, once duty cycles have been established, they should undoubtedly be maintained whenever possible. Work on the length of duty and rest periods indicates that rest periods of less than four hours have little effect on performance over a few days period. However, personnel on two-hour rest periods suffer greater impairment from longer periods of forced sleep loss (e.g., 24 hours) than those on longer rest cycles. Work-rest cycles of four on and four off or eight on and eight off can be sustained for several weeks without any noticeable effects on performance. However, in stressful situations, longer periods of rest are typically required. For example, Hartman[95] found that aviators on stressful extended missions required more sleep both during and after the

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[95]B. Hartman. "Field Study of Transport Air Crew Work Load and Rest," *Aerospace Medicine*, August 1971, 42(8), 817-821.

mission than while on regular duty. Therefore, shifts of eight on and eight off or 12 on and 12 off would probably be the best choices under the conditions anticipated in a field fortification.

Performance Effects

Lazarus, *et al.*,[96] published one of the earlier reviews of the effects of psychological stress upon performance. Despite the early publication date, much of what the authors concluded is still considered valid. They point out that stress is considered to be a secondary concept, dependent upon the relationship between motivation and the situation in which the motivated behavior appears. This, they feel, is largely responsible for the inconsistent results obtained in laboratory studies of stress. For example, if an experimenter is attempting to induce stress through failure, an individual who is not threatened by failure in that particular situation will not evidence stress. A different individual, who has ego-involvement with the task demanded by the situation, may be severely threatened by the possibility of failure, and exhibit a variety of behaviors which can be interpreted as stress reactions. They further point out that a highly motivated individual, although feeling no subjective stress, may change his attack upon a problem when his previous approach is unsuccessful. The change in behavior could be interpreted by the experimenter as a stress reaction, whereas in reality, it simply represents an attempt on the part of the subject to find a workable solution to the problem at hand. These individual differences make it extremely difficult to predict individual performance in any given situation. However,

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[96] R. Lazarus, J. Deese, and S. Osler, *op. cit.*, 1952.

group comparisons may still be valid. The majority of individuals may well be stressed by a particular situation, although it may be impossible to predict in advance which individuals will be stressed.

The authors point out other reasons for inconsistencies in the literature. One of the important reasons is that it is difficult to specify exactly what performance means. For example, studies are reported in which subjects under presumed time stress in working arithmetic problems increased the number of items attempted, but had higher error rates. The performance measure, total number of items correct, differed little from pre-stress performance. Nevertheless, performance was obviously affected. It is further pointed out that the types of stressors employed have varied considerably, the performances studied have been equally varied, and subjects have ranged from children through adults of both sexes. Despite the fact that the interactions between tasks, subjects, and stressors has not been systematically investigated, the authors feel that some generalizations about the experimental findings can be made. Their general conclusions concerning the effects of stress on performance were: (1) tasks involving reasoning or thinking suffered a decrement; (2) tasks incompletely learned were more affected than those completely learned; (3) mild stress may improve performance; and (4) stress generally degrades psychomotor performance.

Again, the necessity for thorough training and overlearning of critical tasks to be performed in a highly stressful situation was emphasized.

Asher, et al.[97] studied the effects of stress on speaking and listening abilities. The stressor was the superposition of a second task upon a listening/speaking task. Their finding was that the more difficult the task which was used as a stressor, the more performance in both the stressor task and the listening/speaking task was affected. Since communications between personnel in a fortification and higher authority will be both necessary and frequent, the effects of stress on communications tasks must be considered. It would seem, on the basis of this research, that the individual involved in communications must give his undivided attention to that task for maximally effective performance.

In a highly relevant study, Lidberg and Seeman[98] studied the effects of confinement on the ability of young soldiers to shoot the service pistol. The publication opens with the statement: "In modern war a situation often arises in which soldiers have to be confined for a long time in shelters then perform various defense operations immediately on leaving the shelter." Twenty-seven healthy draftees were the subjects for the study, and were confined for 52 hours in a Civil Defense shelter. No decrements in mean performance upon exiting were observed. Soldiers who appeared to be most affected by the confinement during the experiment performed as well as others upon exiting. Although the relevance of this work to the current effort is questionable, the stresses involved were considerably less than might be expected in a battlefield situation. The

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[97] J. Asher, L. Doty, T. Hanley, and M. Steer. *A Study of the Effects of Stress on Speaking and Listening Abilities,* Purdue University and Naval Training Devices Center, February 1957.

[98] L. Lidberg and K. Seeman. *Psychomotor Performance Before and After Confinement in a Shelter,* Laboratory for Clinical Stress Research, Departments of Medicine and Psychiatry, Karolinska Institute, Stockholm, Sweden, November 1969.

confinement did not involve the threat of loss of life. Also, temperature was maintained at 81°F with a relative humidity of 80 percent. While these figures are higher than those anticipated for real comfort, they are also below those reputed to cause heat stress. Adequate food, water, and means of disposing of waste were provided. Apparently, the soldier had no in-shelter duties to perform, so the only stressors in the situation were the confinement -- which was not excessive in length and, possibly, crowding, as only eight square feet of space per person were allotted.

Almost all of the work dealing with the effects of stress has been concerned with relative short-term stresses. The exception to this may be the work done on battle fatigue discussed earlier. However, even this work has been more concerned with the immediate rather than the long-term correlates of breakdown. The effects of prolonged and constant stress have received minimal attention from behavioral scientists. Nevertheless, even mild but consistent stress is known to take its toil on the human organism. Ulcers, hypertension, increased blood pressure, and heart disease are cited by Levi[99] as concomitants of long-term stresses. While these long-term results are perhaps more relevant to considerations of personnel rotation than to field fortifications, cumulative effects do need to be considered. The effects of stressful confinement on fresh troops may be considerable less than on troops who have been in battle for a considerable period of time. Unfortunately, no literature directly relevant to this problem has been identified.

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[99] L. Levi. *Society, Stress and Disease: A Popular Synopsis of Some Papers Read at a Symposium on Various Medical and Social Implications of the Relationship Between Man and His Environment,* Departments of Medicine and Psychiatry, Karolinska Institute, Stockholm, Sweden.

During long-term confinement in a field fortification, a third to a half of the inhabitants are likely to be in the rest cycle. In case of an attack or other emergency, the services of all personnel may be required. Rising to activity from a state of sound sleep can be extremely stressful. Langdon and Hartman[100] found appreciable decrements in performance of air crew personnel immediately after awakening. Progressive recovery took approximately 10 minutes. Later work indicated that more than 10 minutes may be necessary for full recovery if the task to be performed is a highly skilled one.[101] An enemy will undoubtedly attempt to make use of artillery and air attacks as instruments of psychological warfare and may well feign infantry attacks in order to keep friendly forces on guard and in a state of fatigue. If and when a massive attack does occur, friendly troops will be forced to make an all-out effort to repel the offensive. It is apparent that troops who must be roused during a rest cycle should be assigned very simple duties. This will require careful planning on the part of the leadership to ensure minimal decrement in total group performance.

Experimental Stressors

Lazarus, *et al.*,[102] in their 1952 review of the literature state that experimental attempts to induce stress have fallen largely into two general classes: (a) stress induced through threat of failure, and (b) stress induced by the task itself. Although the tasks involved may vary

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[100] D. Langdon and B. Hartman. *Performance Upon Sudden Awakening*, SAM-TR-62-17, School of Aviation Medicine, November 1961.

[101] Personal communication from B. Hartman, 1975.

[102] R. Lazarus, J. Deese, and S. Osler, *op. cit.*, 1952.

considerably, studies using threat of failure tend to be much alike. No matter what performance is required or how well the subject is actually doing, the subject is always told that his level of performance is well below the experimenter's expectancy. If the subject is motivated to do well, the threat to his ego can be very stressful. A wide variety of task characteristics have been employed in studies where stress has been induced by the task itself. Situational variables such as poor illumination, distracting noise levels, and malfunctioning equipment have all been employed. Tasks involving information overload and fatigue have perhaps been even more common. Of course, many of the situations employed in stress experimentation involve tasks capable of producing stresses of both classes. For example, threat of failure could be easily employed to produce additional stress in subjects already working in a task involving information overload. However, as pointed out earlier, none of the situations employed is inherently stressful unless the subjects are well motivated. Furthermore, the stresses produced by these types of tasks are not necessarily representative of the stresses produced by exposure to combat, catastrophe, or other situations involving fear of death or mutilation.[103]

It is interesting that Lazrus and his coworkers did not mention the use of physical threat as a stressor. The use of mild electric shock in the psychological laboratory was certainly not uncommon. The reason may be that electric shock was typically thought of a "reinforcer" rather than as a stressor. Nevertheless, even the notion of electric shock is

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[103] M. Berkun, H. Bialek, R. Kern, and K. Yagi, *op. cit.*, 1962.

stressing as can be attested to by an psychologist who has attempted to obtain subjects for experiments involving electric shock. Of course, the use of a threat of genuine physical harm as a stressor has always been considered unethical by some. Still others, when placing subjects in situations where the likelihood of physical harm appeared to be high, felt the subjects did not react as though actually threatened. They felt that subject denied, psychologically, that the experimenter would deliberately expose them to any real danger. Therefore, knowing that they were part of an experiment, they had little genuine fear. Berkun and his colleagues[104] termed this latter reaction as *cognitive defense*, and felt that this defense must be denied the subject in some manner for an experimental situation to be truly stressful. They developed a series of situations which they felt produced stresses similar to those that might be found in battle. They titled this type of stress produced as *cognitive stress*. In each situation "the stage is set which has the one essential element whereby the subject 'figures out' that he is in trouble." Each situation is developed in a manner so that the perceived threat is not seen by the subject as an intentional part of the situation. For example, he is led to believe that through some mistake or accident that he has actually been placed in an impact area for an artillery practice. A series of nearby but safely located explosions add to the illusion. The subject is in no actual danger, but perceives a threat which is both unintended and beyond his control. The HumRRO researchers felt that the experimental situations they contrived did produce a genuine physical threat stress. However, because the ethics involved in placing subjects in such situations

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[104] *Ibid.*

were seriously questioned, little actual experimental use was made of the situations. In fact, ethical considerations were responsible for the virtual termination of stress research in this country around 1960.

At the present time, the type of stressors available to the experimenter appear to be extremely limited. The doctrine of "informed consent" mandates that the subjects be volunteers and be fully informed of the purposes of the experiments and the procedures to be employed. Thus, the use of stressful situations will make it difficult to obtain volunteer subjects. Even if the subjects are obtained, they are unlikely to be representative of the entire population, rendering the results of questionable value. About the only stressors which can be safely employed at the present time are those which occur naturally and are an acceptable part of a life or job situation. For example, it is not considered unethical to study the stressful effects of a 60 plus hour air crew mission, as the accomplishment of such missions is considered to be a regular part of the air crewman's job. The problems involved in placing men in stressful situations for experimental purposes will be discussed in greater detail in a later section.

Management/Leadership Considerations

All of the studies concerned with the management or leadership of isolated groups have been oriented toward either space travelers, persons "wintering over" or personnel in fallout shelters. Work by Hammes and Osborne[105] has already been cited. In these University of Georgia studies of fallout shelter occupancy, there was a trend toward fewer and fewer

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[105] J. Hammes and R. Osborne, *op. cit.*, 1963.

defectors in each succeeding study. In fact, considering the relative hardships and the two-week length of confinement, the number of defectors seems relatively small when compared to other studies with much shorter periods of confinement. In the worst case, only eight out of 30 occupants defected. The maintenance of an apparently high state of morale can probably be attributed, at least in part, to effective management. As the series of studies progressed, means of handling previous problems or irritations were effected. For example, waste disposal procedures were modified to minimize offensive odors. Sleeping arrangements were made by the managers to minimize territorial behavior and prevent interpersonal conflict and petty jealousies. Activities such as sing-songs and story-telling hours and other forms of entertainment involving virtually no resources were scheduled to prevent boredom and prevent the onset of perceived states of general depression. In general, in each succeeding study, the shelter manager exercised greater control over both personnel and resources. This assumption of greater leadership is believed to be responsible for the increasing success experienced through the series of studies.

While the types of activities and some of the purposes of a field fortification are quite different than those of a fallout shelter, the two situations resemble each other in that both are confining and both are capable of providing only limited resources. Certainly, it could be expected that some of the functions of leadership in both would be the same. The management of work-rest cycles, the management of internal space, the distribution of resources, the management of waste disposal, and the planning of activities are all potential functions of the leader-manager of a field fortification. At the present time, the Army does not provide training in these functions at either the NCO or the junior officer levels. It would seem that one topic for research should involve a study, similar to the University of Georgia study, to determine exactly what the leader functions are in a field fortification, to describe them in detail, and to develop a training program for those likely to be assigned the leader/manager's role.

Cantrell, et al.,[106] in their literature survey on long-term air crew effectiveness, arrived at many of the same conclusions as Hammes and Osborne. They also point out other factors with which a manager must deal that were not included in the fallout shelter studies. The manager must also take necessary steps to reduce CBR hazards, ensure ventilation, and possibly deal with the ill or injured. Although it seems strange for investigators concerned with air crews, these authors point out that insects and even some kinds of vegetation could be a problem for groups in isolation. Insects that either produce painful bites or carry disease could certainly be a problem in a field fortification. Other factors discussed by Cantrell and his associates, such as temperature, humidity, pressure, noise, radiation, and gaseous contaminants have been discussed elsewhere. This study, in addition to emphasizing the breadth and necessity of the manager/leader's job, also stresses the value of experience. Their investigation concluded that the confidence gained through experience not only increases overall efficiency, but significantly reduces stress.

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[106] G. Cantrell, R. Trimble, and B. Hartman. *Long-term Air Crew Effectiveness (A Literature Survey)*, Aeromedical Review 1-71.

Day,[107,108] in two publications, takes a somewhat novel and historical approach to an examination of leadership and management functions in isolated groups. He likened the extended missions of space travelers to those of the sailing navy. Both situations involve stress, isolation, confinement, limited availability of resources, and the necessity for discipline and teamwork to ensure survival. Day suggests that the combination of these conditions requires both special codes of conduct for the participants and different authority structures. Day points out that both custom and law in the sailing navy developed over a long period of time. Early evolution took place aboard smaller vessels which spent less time at sea and remained much closer to land. Originally, sailing vessels were only the tools of commerce. However, with the development of the cannon, they became instruments of war. Because of differences in missions, different sets of laws and customs for the maritime and naval fleets developed before the end of the sailing era around 1900. While authority structure, custom, and duty functions in the navy developed over centuries, the cost, comparative rarity, and danger of space flight prohibits a comparable evolution. The entire personnel and leadership/management system must be developed through a combination of logic and earth-bound experimentation, and in a matter of years rather than centuries. While Day's concern was with space flight, much of what he says

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[107] R. Day. *Social Structure and Group Behavior in Extended Duration Space Missions*, Technical Report No. 3, Institute of Behavioral Research, Texas Christian University, Fort Worth, August 1970.

[108] R. Day. *Authority in the Sailing Navy*, Technical Report No. 3, Institute of Behavioral Research, Texas Christian University, Fort Worth, August 1967.

is relevant to the field fortification. The development of a system for life in field fortifications should not wait to be evolved on the battlefield. Such could be too costly in terms of casualties, territory, and resources.

The studies cited in this section, as well as others which have touched on management/leadership functions, all point to similar research needs. The leader's duties and authority must be well defined and made known to all, and a training program for the leader/manager must be established to give him the experience required to maintain his own as well as his men's confidence.

Measurement of Stress

Like so many psychological concepts, *stress* tends to defy definition. Kennedy[109] attempted to improve on an earlier definition by defining stress as "... an insult received by the organism which results in a departure from homeostasis."[110] Kennedy further states that by "insult," he means a negative, adverse, or nonadaptive stimulus. Unfortunately, the term *homeostasis*, at least as regards a large segment of human behavior, is equally difficult to define. Because of problems in defining stress, many investigators have preferred to infer stress on the basis of performance decrements occurring in particular stimulus situations. In other words, stress is defined as anything which produces a decrement in performance. This approach to defining stress may be adequate for some situations but is far from satisfactory in others. Suppose, for example, the experi-

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[109] R. Kennedy. *Two Procedures for Applied and Experimental Studies of Stress*, US Army Aeromedical Research Laboratory and Naval Aerospace Medical Institute, February 1970.

[110] The definition proposed by Kennedy was adopted from an earlier work by Hans Selye.

menter assesses decrements in performance on Tasks A and B after subjecting his subjects to some presumed stressor. He finds a decrement in Task A, but none in Task B. Had he measured performance only on Task A, he would conclude that the subjects were stressed. Had he measured performance only on Task B, he would have concluded that his experimental situation was not stressful. Lazarus and his coworkers[111] noted such inconsistencies in the literature on stress. While such an operational definition of stress is appealing, it is also obviously lacking in that one cannot assess the effects of stress on performance while defining stress in terms of performance.

A purely psychological means of assessing the degree of stress produced by a given set of circumstances is the self-report. Kerle and Bialek[112] devised a simple instrument called the Subjective Stress Scale (SSS). The scale was based on the Thurstone scaling technique commonly applied to attitudinal measurement. The scale detected significant affective changes in those situations which were judged stressful by the experimenters and had been used in a number of studies. Because of its ease of administration and accepted validity, it has been used by a number of other investigators. At worst, the scale has face validity.

A scale designed specifically to measure the effects of isolation was devised by Myers, Murphy, and Terry.[113] This instrument contains

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[111] R. Lazarus, J. Deese, and S. Osler, *op. cit.*, 1952.

[112] R. Kerle and H. Bialek. *The Construction, Validation and Application of a Subjective Stress Scale*, Staff Memorandum, US Army Leadership, Human Research Unit, 21 February 1958.

[113] T. Myers, D. Murphy, and D. Terry. *The Role of Expectancy in Subjects' Responses to Sustained Sensory Deprivation*, paper presented at the meeting of the American Psychological Association, St. Louis, September 1962.

242 items and produces 23 scale scores, scales being based on as few as three items or as many as 29. Originally known as the "Retrospective Questionnaire," the instrument was later known as the "Myers Post-Isolation Questionnaire." It too has seen considerable use by other investigators. The primary drawback to this questionnaire is its length, as it places a considerable burden on individuals with limited reading skills.

A third type of self-report employed to assess subjective stress is the adjective checklist. Myers, Murphy, Smith, and Goffard[114] developed a 114-item checklist for use in studies of sensory deprivation and social isolation. The adjectives referred to feeling states of the individual. Each was categorized by the subject as applying to him "not at all," "somewhat slightly," or "mostly or generally."

A similar checklist has also been developed by Nowlis.[115,116] All of these checklists purport to measure mood, with Nowlis actually titling his instrument the Mood Adjective Checklist (MACL).

It is beyond the scope of this review to describe each of the above cited instruments in detail. It seems sufficient to state that they were all designed to measure affective states under conditions of stress, and have all seen previous use in the studies of confinement and social isolation. Any or all should prove useful in assessing the effects of

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[114]T. Myers, D. Murphy, S. Smith, and S. Goffard, *op. cit.*, 1967.

[115]V. Nowlis and H. Nowlis. "The Description and Analysis of Mood," *Annals of New York Academy of Science*, 1956, <u>65</u>, 345-355.

[116]V. Nowlis. "Research With the Mood Adjective Check List," in S. Tompkins and E. Izard (eds.), *Affect, Cognition, and Personality*, New York: Springer, 1965, pp 352-389.

arious field fortification configurations, internal leadership prac-
.ces, taks to be performed, and life-support systems in any experimental ork on field fortifications.

A third approach to the measurement of stress has been physiological. .s a very simple technique, Hartman[117] found that oral temperature cor-'elated very highly with subjective reports of stress. Other investi-;ators have favored more complicated but, presumably more reliable, measures. Miller[118] reviewed work on the secretion of 17-Hydroxycortico-steroids (17-OHCS) as a biological index of response to stress, and concluded that it was an excellent technique. The polygraph, better known as the "lie-detector," is also a frequently employed device for measuring physiological response to stress. Those favoring the physio-logical approach to stress measurement feel that it is less subject to faking than the subjective measures. However, the cost of this approach far exceeds that of the others.

Interestingly, Berkun, et al.,[119] as early as 1958 suggested a combination of all three types of indices to determine the validity of a presumed stressor. Validating subjective reports through the use of physiological indices is certainly desirable if resources permit. However, the requirement for a performance decrement seems questionable. If one were merely trying to prove that a particular stimulus situation was stressful, then certainly the additional evidence from performance data

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[117] B. Hartman, H. Hale, D. Harris, and J. Sanford, *op. cit.*, 1974.

[118] R. Miller. "Secretion of 17-Hydroxycorticosteroids (17 OHCS) in Military Aviators as an Index of Response to Stress: A Review," *Aerospace Medicine*, 1968, 39, 498-501.

[119] M. Berkun, H. Bialek, R. Kern, and K. Yagi, *op. cit.*, 1962.

would add to the weight of the argument. However, in most studies of psychological stress, performance is the dependent variable. That is, the experimenter is interested in how stress affects various kinds of performance. In such an instance, it makes no sense to *require* a performance decrement. To do so would be requiring the experimental variable to behave in a certain manner rather than simply investigating the behavior of the experimental variable under the stimulus conditions imposed.

Research Considerations

The discussions in this section will center around three areas: (a) general problems and considerations involved in field research, (b) protection of human subjects in experimentation, and (c) specific research techniques applicable to field fortifications research. While some literature will be cited, much of the discussion will be based on the cumulative experience of the authors and other HumRRO scientists who have devoted a considerable portion of their professional life to field experimentation. Unfortunately, the bulk of the documentation on lessons learned by HumRRO scientists is available only in bits and pieces in in-house memoranda and, therefore, cannot be cited.

General considerations. Recently, an entire issue of *Human Factors* was devoted to the subject of field testing. Two of the articles, those by Finley, et al.,[120] and Johnson and Baker,[121] are particularly relevant to this present effort. Finley and his coworkers were concerned primarily

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[120] D. Finley, R. Webster, and A. Swain. "Reduction of Human Errors in Field Test Programs," *Human Factors*, 1974, 16(3), 215-222.

[121] E. Johnson and J. Baker. "Field Testing: The Delicate Compromise," *Human Factors*, 1974, 16(3), 203-214.

with the reduction of errors by test personnel and test support personnel. They point out that the majority of field tests are conducted solely to test hardware systems, and tests of the man-machine interface are secondary and are seldom considered in the initial planning stages. They point out that human factors scientists are seldom called in during the design phases of a test, severely restricting the human factors work that can be accomplished. In their study of test situations, they derived a list of the most common types or reasons for errors. These were: (1) faulty coordination among test groups, (2) disregard of written procedures and checklists, (3) boredom and distraction, (4) late assignment of inexperienced personnel to test duties, (5) failure to make adequate second-party checks, and (6) unrealistic and rushed test schedules. They point out that unrealistic scheduling further results in additional failure in communication, insufficient time to prepare and check procedures, failure to make proper records, and a disregard of the consequences of blind adherence to printed schedules.

Johnson and Baker make many of the same points expressed by Finley and his coworkers. However, they make some further observations worthy of mention. They point out that the problems or questions which originate from the sponsor are frequently dependent upon the stage of development of a system as well as the particular perspective of the sponsor/user group. They further point out that basic system requirements are typically stated very imprecisely, that assumptions concerning equipment operation have a tendency to be "placed in concrete" regardless of their actual utility, and that criteria of successful equipment performance are rarely well defined.

A final observation by Johnson and Baker is worthy of more than simple mention. They recognize the problems of motivation and attitude with test subjects who are levied into the test situation without regard for their desires. Test subjects or participants are almost universally selected in one of two ways. One means is to levy an entire unit to support the test. This frequently results in undesired and indefinite term TDY (Temporary Duty) assignments to remote and uninteresting areas. Many of the personnel levied have neither interests in nor aptitude for the duties to which they are assigned. Commanders rarely relish such assignments as training schedules are disrupted and unit readiness is reduced through lack of practice of essential skills and teamwork functions for the unit's primary mission. The typical result is malassignment of at least some of the unit's personnel and generally poor troop motivation. The chief advantage of the total unit assignment procedure is that it is easier to maintain discipline because the men continue to work under the same NCOs and officers. However, this total unit approach to personnel assignment is normally superior to the other means -- that of levying several units for a given number of personnel each. More frequently than not, commanders send those men whom they feel they can do best without. The hardships associated with probable TDY are the same, but discipline is typically a greater problem as personnel feel that the assignment outside their own unit will have little effect on their futures. Also, NCOs and officers, not knowing the men individually, and possibly unhappy with their own assignments, tend to be less effective during the early stages of the test. Therefore, although both of the typically employed assignment procedures have drawbacks, the assignment of units as a whole should be preferred.

Morale and motivation problems could probably be alleviated to a great extent if test planners and test directors fully appreciated the effects that lack of motivation can have on test results. Unfortunately, those in authority tend to become so involved in budgets and schedules that little attention is paid to personnel on whose efforts the outcome of the test depends. HumRRO experience has shown that judicious application of the Hawthorne effect can greatly improve morale. If the test participants feel that the test directorate is making every possible effort on their behalf, morale is less likely to decline. Carefuly explanation of the purposes of the test and many of the seemingly meaningless activities associated with it (in words chosen so that the test participants can understand) has also proven very useful in enhancing motivation. Elimination of make-work activities, provision of recreational opportunities, assignment of personnel by aptitude and interest, and assignment of compatible personnel to duties requiring close proximity or cooperation all pay dividends in personnel satisfaction.

While it may seem that the subject of motivation has been belabored at this point, it is felt that this all too important factor is all but ignored in the vast majority of field tests. Unless completely automated, no system can perform any better than those who operate it. Therefore, poorly motivated operators do not provide for a fair system test. However, lest the wrong impression be left, the selection of "super" operators is not being recommended. The selection of test personnel whose capabilities are far above those of personnel likely to operate the system in the field will result in an overestimation of total system capability. Personnel involved in tests should be representative of those who will man the system in the field. The point being stressed is, that without motivation, test personnel will not perform in the same way as men in the field and, therefore, erroneous conclusions are likely to be drawn from the test results.

A point covered in some detail in both of the articles cited is that human factors specialists seldom enter the picture until system development is well underway. Cases in point are readily available even in the meager literature on field fortifications. The only human considerations involved in design studies are man's biological frailties. He is considered only in terms of his ability to withstand overpressures, heat, cold, CBR agents, or other agents of violence. As mentioned before, one designer apparently became so obsessed with structural characteristics he neglected to make provision for fighting ports, although these were specified in the requirements document.[122] Nowhere in the literature located was the psychological habitability of field fortification structures even considered. One might even wonder if the designers intended for them to be inhabited, as no consideration was given to the storage or provision of even minimum essentials such as food, water, and bedding.

While human factors specialists may deplore the current situation regarding their lack of input into design, it is a fact of life that must be accepted while working for change. They should realize that a part of their job is to salvage as much as possible of a system that may have been ill designed for human use. A part of this aspect of the job is to recommend modifications which can feasibly be incorporated in later versions of the system, and which improve the system from the standpoint of

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[122] R. Corrigan, *op. cit.*, 1974.

personnel employing it. In this manner the human factors specialist will influence the design of future systems and the cumulative impact of his efforts will be greater with each succeeding generation of similar systems.

The last topic of a general nature which will be discussed, and one which was virtually ignored by both Findley, et al., and Johnson and Baker, is that of the training of test participants. Human factors specialists are typically on board sufficiently in advance of the initiation of training to have a major impact. Not infrequently, lip service is given to requirements to test the training packages for both operator and maintenance personnel in conjunction with the major hardware tests. However, these "training packages" are frequently given short shrift. Manuals, if available at all, are usually in draft form and replete with inconsistencies and errors. Simulators and even simpler training aids are unlikely to be available. In the case of new equipments, instructor personnel will probably be employees of the developer. The level of the instruction may well be beyond the capabilities of the students to absorb, and may be overly focused on design rather than operational considerations. If the instruction is not properly geared and paced, the trainees will lose interest, lose motivation, and emerge from the course poorly equipped for their duties during the test. The human factors specialist can do much to keep the course on the proper track by assessing the previous knowledge and learning capabilities of the would-be student input. From this knowledge he can work to see that the instruction is pitched at the reading and listening level of the students. He can also work toward the elimination of "nice-to-know" but job-wise irrelevant material from the program, and for the institution of performance-oriented rather than lecture-oriented instruction. While he should not be expected to be totally successful in these efforts, experience has shown that an insistent expert in the field of training is more likely to have an influence on the development of training programs than he is on engineers charged with equipment design.

Experimentation with human subjects. Concern for the rights of human subjects involved in experimentation has been steadily growing since the early 1950s. As previously mentioned, the ethics of placing subjects in stressful situations without their prior knowledge led to the virtual termination of stress research of the type performed by HumRRO during the decade of the 50s. This concern is probably only a part of a more encompassing concern for human rights which began to mushroom after World War II. This movement, especially where minority groups were concerned, received considerable attention from the news media. It has also led to considerable legislation and a volume of challenges to existing laws. While less in the limelight, a number of groups also challenged traditional approaches to experimentation with human subjects. In the past, psychologists frequently "fooled" subjects concerning the actual purposes of the experiment. Indeed, such procedure was standard if it was felt that informing the subject of the true nature of the experiment would affect the results. However, this practice was challenged even in the most harmless of experimental situations. These challenges to the ethics of experimentation as frequently practiced led to the development of some guidelines by the Department of Health, Education and Welfare (DHEW)[123,124]

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123 *The Institutional Guide to DHEW Policy on Protection of Human Subjects.* US Department of Health, Education and Welfare, Washington, D.C., December 1,, 1971.

124 "Protection of Human Subjects." *Federal Register,* May 30, 1974, 39(105), Part II, 18914-18920, US Department of Health, Education and Welfare.

to ensure protection of human subjects. Any institution or individual receiving funds from DHEW must adhere to these guidelines. Essentially, these guidelines set forth the doctrine of "informed consent." They state that a subject must be informed fully of the purposes of the experiment, the procedures to be followed, and freely consent to participation. Even with this oversimplified interpretation of the guidelines, it is obvious that the types of stress research or stressors which can be employed are severely limited. If the subject is informed that he will be placed under stress, the proposed stressor may well cease to function as a stressor. The use of threat of failure becomes highly questionable, and the use of situations such as those devised by Berkun, et al.,[125] are definitely not permissible.

The US Army has developed guidelines recently which are similar to those adopted by DHEW. These are set forth in Army Regulation (AR) 70-25.[126] The American Psychological Association (APA) first published guidelines for experimentation on human subjects in 1963. These were revised in both 1965 and 1972.[127] Another APA publication, dated in 1973, is one of the most comprehensive guides on the subject available today.[128] Anyone who believes that a psychologist's conduct of experimentation falls outside the principles outlined in the policy can refer the matter to the APA Ethics Committee. If the Committee determines the violation to be willful and/or flagrant, they can recommend expulsion from the association

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[125] M. Berkun, H. Bialek, R. Kern, and K, Yagi, *op. cit.*, 1962.

[126] AR 70-25. *Use of Volunteers as Subjects of Research,* Department of the Army, Washington, D.C., 31 July 1974.

[127] "Ethical Standards of Psychologists." *American Psychologist,* January 1963.

[128] *Ethical Principles in the Conduct of Research With Human Participants.* American Psychological Association, 1973.

to the Board of Directors. In addition, the psychologist or the institution he represents might be subject to a civil suit for damages by the subject(s).

As a result of these developments, most organizations conducting research with human subjects have developed internal policies to ensure proper protection of subjects' rights. HumRRO management has long been aware of the problems inherent in human experimentation, and has issued guidance to the research staff at frequent intervals over the years. Guidelines for implementing the DHEW guidelines were first issued in July 1972. A more formal policy statement was issued in April 1974,[129] and a review committee was established in November 1974.[130] This committee is charged with the responsibility of ensuring that all HumRRO research efforts comply with the guidelines of the sponsoring agency.

Although the US Army has policy guidelines, experimentation in the military setting must be recognized as different from that in the civilian setting for which the DHEW guidelines were developed. At least at the present, all persons in the military are volunteers for their jobs, and by their very nature, most military jobs are hazardous. In the past, it has not been considered unethical to ask a man to perform those duties which are essential to the conduct of his job, even though some hazard is involved. Air crewmen are required to fly their missions, even under hazardous conditions, as these missions are considered to be a regular part of the air crewmen's job. Artillerymen are required to fire their

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[129] *HumRRO Policy Statement Concerning the Protection of Human Subjects.* Office of the President, Human Resources Research Organization (HumRRO), Alexandria, Virginia, April 15, 1974.

[130] *Implementing Guidelines for a General Institutional Assurance on Research Involving Human Subjects.* Office of the President, Human Resources Research Organization (HumRRO), Alexandria, Virginia, November 13, 1974.

weapons, even though an eventual hearing deficit can be expected. Of course, there are limits. Historically, even during wartime, volunteers were requested for unusually hazardous missions. So far as research is concerned, if the situation and the performances required are a normal part of the soldier's job, and every attempt is made to minimize unnecessary hazards, questions of ethics should not arise. The problem is one of determining what is "normal" or "routine." If the notion that the soldier assigned to the European theater can realistically expect to spend considerable periods of time in a field fortification in the event of hostilities, then requiring soldiers to do so for either research or training purposes cannot be considered unethical. However, an official statement by competent authority, realistically justified, will probably be necessary as confinement under hardship conditions is considered to be both psychologically and physiologically stressful.

The ethics problem could be solved by asking for volunteer subjects. However, volunteers are not likely to be representative of the soldier population as a whole. Men who feel that the stresses might become intolerable simply would not volunteer. Obviously, a representative group is necessary if valid conclusions are to be drawn in this type of field research.

Applicable research techniques. A complete program of research in this area would be designed to determine: (a) what kinds of psychological and social problems develop during habitation of a field fortification, (b) how various performances are affected upon exiting, (c) how environmental and architectural factors affect behavior both during and after habitation, and (d) what practices and procedures should be established to minimize any adverse effects of habitation. The findings would impact on the design of future facilities, management practices, adequacy of proposed provisioning concepts, and training for habitation and post-habitation activities. Since so much of the effect of the in-shelter experience would be personal and subjective in nature, subjective evaluations of the effects of the experience would be appropriate. Several means of assessing subjective stress have already been discussed. Some of these should be employed in exactly the form in which they were used in the past. This would provide some opportunity to compare the stressful effects of field fortification habitation with other types of stressors employed in the past. Other of the instruments might be adapted to reflect more accurately the field fortification environment. For example, some of the questionnaires employed by HRB-Singer[131] to assess individual perceptions of annoyances and problems could be easily modified for the different environments. Final decisions concerning the types of specific instruments that should be employed should not be made until final decisions are made concerning such things as the type of structure to be employed, the kind and amount of provisions to be stocked, the total period of confinement, and the kinds of tasks to be performed after leaving the shelter.

While the value of self-reports in this type of research cannot be denied, neither can they be considered as totally satisfactory for all purposes. The inaccuracies, even in the reporting of facts by untrained observers, are well known. It is essential that a means for the collection of systematic observational data on human behavior during habitation be

[131] G. Wright and W. Hambacher. *Psycho-Social Problems of Shelter Occupancy*, HRB-Singer, Inc., Scenic Park, State College, Pennsylvania, July 1965.

developed. The technique must be both subjective and reliable, and in situations such as the habitation of a field fortification, must operate continuously. The most suitable technique for this purpose thus far identified is one employed by Helmreich and his associates.[132,133] To employ this technique, a list of the various behaviors which might be engaged in for the particular setting is developed. Each of these is further subdivided into specifics. For example, the category of recreational activities could be subdivided into solitary card playing, group card playing, singing, reading, conversing, etc. Observations of each individual involved is made at regular intervals. In the TEKTITE program, observations were recorded every six months. In this manner, a fairly detailed account of each man's behavior during the entire period of observation was made possible. All observations were made through the use of closed circuit TV to prevent any disruption of activities by the observers. Although Helmreich apparently did not do so, it would be possible to tape all activities in case any questions concerning behavior arose at a later time. Data obtained in this form can be easily analyzed by computer. Changes in an individual's social interaction patterns, sleep patterns, eating habits, time spent in various activities, and general activity level could all be indicative of changes in adjustment to the situation. It is recommended that this type of observation be employed, if possible, in any field fortification habitation studies conducted in the future.

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[132] R. Helmreich, *op. cit.*, 1971.

[133] R. Helmreich, J. LeFan, and R. Mach. *Human Reactions to Psychological Stress*, Technical Report No. 13, Behavior Observer's Manual, Project TEKTITE II, Department of Psychology, University of Texas, Austin, March 1971.

The effects of the field fortification habitation experience upon performance at exit must also be determined. However, until these performances which might be considered critical have been selected by competent authority, a discussion of techniques of performance measurement would be presumptuous.

CHAPTER 3

STATUS, IMPLICATIONS, AND CONCLUSIONS

At the present time, there appears to be little high-level interest in the area of field fortifications. The TRADOC Field Fortifications Task Force, chaired by the Infantry School, has been disbanded. The US Army Engineer School is the proponent agency for FM 5-15, *Field Fortifications*. However, so far as is known, the only change currently planned for this 1972 publication concerns the frontal parapet emplacement. This planned change is based on the results of a MASSTER test directed by the TRADOC Task Force.[1] The Weapons Effects Laboratory of the US Army Engineer Waterways Experiment Station has conducted most of the actual structural testing of design concepts. While this group has proposed designs to the Office of the Chief of Engineers (OCE), their primary mission in this area is the development of criteria for acceptability and field evaluation of design concepts.[2]

At the present time, only three new projects on field fortifications could be identified by the authors. These include: (a) further studies of designs similar to the British Field Shelter Mark II, previously evaluated by MASSTER, (b) a contractor effort in the evaluation and redesign of the Airtransportable Assault Bunker, also previously evaluated by MASSTER, and (c) a Tactical Protective Structures Study. This latter study is examining user requirements, needs for new materials, costs, and

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[1]E. Green. *MASSTER Field Fortifications Program, Part I, Test Report (Frontal Parapet Evaluation, Subtest III)*, Test Report No. FM 207, HQ MASSTER, Fort Hood, Texas, 14 August 1974.

[2]Personal communications from G. Carre and D. Coltharp, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, March 1976.

the potential usage of off-the-shelf items. None of these studies promises any startling new developments.

Further indication of a lack of current interest in field fortifications comes from data on times devoted to training. For example, in April 1976, only four hours of the Programs of Instruction (POI) in each of the four Enlisted Noncommissioned Officer Advanced Courses (ENCOA) at the US Army Engineer School were devoted to field fortifications. Of this, two-and-one-half hours were in the classroom and one-and-one-half hours were designated for practical exercise. In the Engineering Officer Basic Course (45-C-20), a total of seven hours were devoted to field fortifications. Of these, 2.2 were in the classroom, 0.8 were allowed for a demonstration, and 4.0 were designated as practical exercise.[3] It is unlikely that this limited exposure could make students proficient in the construction or emplacement of the various types of fortifications.

At the present time, it is apparent that neither the development of new technology in field fortifications nor instruction on field fortifications is enjoying a high priority within the TRADOC community. Human factors considerations, although recognized by engineers, have seldom found their way into official documentation.[4]

The seeming lack of interest in field fortifications may be due, at least in part, to the projected threat environment during the next decade. If other conflicts develop which are similar in nature to that of Vietnam,

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[3] Personal communication from US Army Engineer School, Fort Belvoir, Virginia, April 1976.

[4] Scientists from HumRRO Division No. 4, Fort Benning, Georgia, provided Technical Advisory Services to engineers at the US Army Engineer Waterways Experiment Station during the fall of 1967. However, HumRRO documentation of this effort is only found in in-house memoranda, and not generally available to the scientific community as a whole.

the requirement for fortifications could again be expected to be minimal. Also, the types of fortifications employed in the past should be expected to be adequate against an enemy lacking heavy conventional weapons, modern aircraft, and a CBR capability.

If US forces face an enemy with sophisticated weapons, it is all but certain that the conflict will be in central Europe against Warsaw Pact nations. These enemy forces are expected to employ all the tactical weapons they have available and if deliberate field fortifications were employed, they would have to be designed for protection against both heavy conventional weapons and CBR agents. However, for both technological and political reasons, it appears unlikely that extensive deliberate field fortifications would be employed in a European conflict. The major reasons for this conclusion are:

a. A more fluid battlefield situation is foreseen than in the past. There are two reasons for this. First of all, mobility on both sides has and will likely continue to increase. Airmobile units will be capable of deploying concentrated forces anywhere in a large area in a matter of minutes and withdrawing with equal rapidity. Mechanized infantry and armor units can cover miles in a matter of hours. Therefore, fortifications and protective shelters are anticipated to be relatively useless in most situations, with the exception of situations involving a point or small area defense. Secondly, it is expected the enemy will begin his offensive with limited objectives, due to the fact that an attempt to crush the NATO powers would involve too high a risk of an all out nuclear holocaust. Therefore, it is anticipated that he will make a limited number of strong offensive thrusts in the direction of his selected objectives. Once his offensive begins, friendly forces are not expected to have either the time or the engineer equipment to prepare extensive fortification systems.

b. For political reasons, US forces have not and probably will not build a system of fortifications in Europe before an actual conflict. The reasons most frequently cited are:

1. Friendly nations are afraid of offending potential aggressors by building fortifications or preparing defensive lines. Such action, they fear, would be interpreted, at best, as a breach of faith, and, at worst, as outright hostility.

2. Civilian populations in "front" of a defensive line or outside fortified areas would undoubtedly become very disturbed at the realization that they would likely be abandoned to the aggressor in case of conflict.

Therefore, even if it is assumed that some of the enemy's objectives are known, it is unlikely that positions along the most likely avenues of approach will be fortified. Fortifications immediately surrounding the objective, if constructed in advance of an attack, would not be classified as "field" fortifications. Rather, they would undoubtedly be constructed of concrete and steel and intended for permanent occupancy even prior to an attack.

In summary, it can be said that present conceptions of future hostilities in a European environment indicate little need for "field" fortifications. Fortifications, particularly those designed for extended living and protection against attack by heavy conventional as well as tactical non-conventional weapons, are unlikely to be employed in conflicts in the foreseeable future. Rather, the type of fortification seen as necessary is one that can be employed in a conflict characterized by mobility. That is, it must be capable of being emplaced quickly without undue strain on either personnel or equipment resources. It must be capable of being moved (or destroyed) rapidly, again without undue resource requirements. Finally, it must offer a good measure of protection against a variety of weapons. Prefabricated or modularized fortifications appear to satisfy many of these requirements. Therefore, it appears that any further work in the area of field fortifications should address problems associated with prefabricated transportable or modularized fortifications, which are envisioned as the battlefield shelters of the future. A further look at the employment of these types of shelters, and behavioral research that should be conducted concerning them, will be presented in Chapter 4.

Although first priority must be placed on examining requirements for the rapidly emplaceable prefabricated fortification, the possibility does exist that stabilized fronts requiring different types of fortifications may come to exist in central Europe. Therefore, requirements for live-in fortifications for protection against a sophisticated threat cannot be completely ignored. Furthermore, many of the requirements for battlefield shelters will be the same, regardless of the length of occupancy by a given individual(s) or the primary activity conducted in the shelter. Therefore, requirements for habitability must be examined for applicability to any and all fortification designs.

The remainder of this chapter is devoted to a summary of habitability requirements and a brief discussion of their applicability to different types of field fortifications. The authors cannot assume credit for the derivation of any of the specifics in the list. However, so far as is known, this effort is the only attempt to compile and synthesize all of the known requirements for habitability of a field fortification. In some cases, the discussion goes beyond the data available simply because no data were available. For example, a gas analysis of the air in an emplaced and occupied transportable bunker has apparently never been conducted in an effort to determine when carbon dioxide reaches dangerous levels and/or oxygen is depleted to dangerous levels. However, it is obvious, based upon the cubic volume of these types of shelters, that without ventilation, the volume of air could not support life for long. Therefore, the authors have attempted to "extrapolate" the data and hypothesize some limitations. Whenever this is done, however, it is clearly indicated as such.

The major factors considered essential to the preservation of the psychological and physiological health of the inhabitants are:

a. Space Requirements: A minimum of 10 square feet and 85-90 cubic feet per inhabitant, exclusive of storage space for major equipment items, is considered essential for a live-in shelter. Less actual personnel space can be tolerated if the shelter serves only as a work area. The space requirements for a work area, of course, will vary with the type of work to be accomplished.

b. Nutritional Requirements: An intake of 700 calories per day appears to be sufficient to maintain life and health for sedentary personnel of average stature in a near optimum environment (70°F, ET). Personnel existing on this basic diet in fallout shelter studies lost weight, but suffered no decrements in mental or physical performance, even after two weeks of confinement. However, data were not obtained concerning performance on tasks requiring endurance. Such tasks might be expected to be adversely affected. Certainly a higher level of intake should be planned for. Nevertheless, a 700 caloric ration in emergency situations should prove adequate to maintain basic health in an otherwise comfortable environment. If hard physical labor must be performed during an occupancy of several days, intake of as much as 3000 calories per day may be required to prevent undue weight loss and weakness. Also, if temperatures are below 50°F, additional nutrients should be planned for. Finally, if personnel are to be confined for more than 72 hours, vitamin supplements, especially ascorbic acid, should be provided if fresh fruits and vegetables are not available.

c. Liquid Requirements: Civil Defense authorities originally planned on the provision of one quart of water per day per inhabitant for essentially sedentary personnel in fallout shelters. However, studies have shown that serious dehydration will occur over a period of time with this quantity. Current estimates indicate a minimum daily requirement of slightly more than two quarts for sedentary adult males in a near optimum environment. Requirements increase significantly at temperatures above 80°F, ET, or when strenuous physical activity is required. At ETs above 90°F, even sedentary personnel may consume over two gallons per day.[5] As can be seen, provisioning shelters for long-term occupancy with water supplies for drinking alone could present problems in terms of logistics and storage space. However, previous studies have shown that

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[5] F. Rohles, R. Nevins, and P. McNall. *Human Physiological Responses to Shelter Environment*, Report No. 2, Institute for Environmental Research, Kansas State University, Manhattan, February 1967.

psychological well-being can be greatly enhanced if sufficient water for shaving, brushing teeth, and sponge bathing can be provided. Therefore, it appears that an absolute minimum of three liters per day per occupant should be planned for a live-in shelter even in near optimum conditions. Of course, water supplies for shelters dedicated to specific work activities need be provided only for drinking purposes. For normal activities, such as operating a command post, two liters per occupant per 12-hour shift should meet minimum requirements in near optimum conditions.

d. Ventilation Requirements: A minimum of 180 cubic feet per hour per inhabitant is required to keep carbon dioxide concentration at safe levels for sedentary personnel. Up to four times this amount may be required if personnel are engaged in continuous strenuous activities. In addition, in a toxic environment, either air pumps with filters or individual masks would have to be worn. Ventilation could easily become a problem in a prefabricated bunker as cross-ventilation is difficult to provide. Most of the prefabricated structures examined so far have been designed to be placed in an excavation and covered with three to five feet of earth fill. Only one opening, an entrance/exit, is provided, and this is typically below ground level to help prevent entrance of blast fragments. Thus, even on windy days, internal air circulation will be minimal. If the entrance is closed for protection, virtually no circulation can be expected. Since these shelters are designed to be as lightweight as possible for transportability, they typically contain less than 1000 cubic feet. No gas analysis data were found which document the rates that oxygen becomes depleted and carbon dioxide concentration increases in this type of shelter. However, if such a shelter were occupied by four men on a relatively windless day, it is hypothesized that a hazardous situation could develop in four to five hours. Certainly, this aspect of habitability needs to be thoroughly investigated before these types of shelters are accepted for use. The use of fossil fuel heaters and tobacco smoking in this environment should also be investigated. Burning of organic matter not only depletes oxygen and produces carbon dioxide, it also produces deadly carbon monoxide. Ventilation requirements for the use of tobacco and combustion heaters in a shelter must be investigated before their use can be permitted.

e. Temperature Requirements: Either extreme heat or extreme cold can be expected to affect performance on a number of different tasks. In general, performance decrements in virtually all except simple well-practiced tasks can be expected at temperatures above 90°F (ET). Tasks requiring considerable physical effort <u>may</u> produce casualties at ETs above 80°F, and can be <u>expected</u> to produce casualties at temperatures above 85°F (ET). Therefore, during very warm weather, activity must be restricted. Also, ventilation becomes extremely important, as body heat generated by activity (and from any equipment employed) must be dissipated in order to keep temperatures as low as possible.

The ideal temperature for normal activities is generally regarded as being between 70°F and 75°F (ET). If hard physical labor is to be performed, temperatures ranging between 60°-65°F (ET) should be quite comfortable and help reduce casualties from heat prostration. At temperatures below 50°F (ET), tasks requiring finger dexterity over a period of time will likely be adversely affected. However, with proper clothing, occupants should suffer no ill-effects. In fact, if properly dressed, soldiers should be able to perform most activities at temperatures down to 20°-25°F with little decrement. Finger dexterity will be adversely affected in a matter of minutes when gloves cannot be worn. Also, some means of preventing water supplies from freezing and for warming food will be a virtual necessity. Again, ventilation must be closely watched if other than electrical heaters are employed. At temperatures below 20°F, virtually all tasks are likely to be adversely affected; if for no other reason, the bulk of the clothing required will restrict movement.

f. Duty Cycle Requirements: Work/rest schedules in a shelter environment have never been investigated. However, the general literature indicates that the minimum rest period should be at least four hours. With shorter rest periods, the ability to sustain performance is generally impaired. However, there appears to be no reason why either an 8/16 or a 12/12 cycle should not be employed. The American soldier normally works on such cycles, so a smaller period of adjustment should be required. Also, once the "shifts" have been established, personnel should remain on the same shift as changing shifts will require some two weeks of adjustment time. Worker efficiency in industry is undoubtedly reduced by constantly changing personnel shifts. However, this is necessary to allow workers time off during normal business hours and to be with their families who are on regular daytime schedules. During wartime, soldiers will probably care little about which shift they work.

The interaction between work/rest schedules and feelings of isolation, confinement, and crowding have not been studied. In a working fortification, that is, one dedicated to a particular activity, duty personnel will change with each shift. Off-duty personnel will have an opportunity to rest and change their surroundings. Therefore, these factors may not be problems. However, in a living/fighting shelter, where troops may be continuously confined for days at a time, these interactions may become problems and need to be investigated.

g. Leadership/Management Requirements: No special leadership or management requirements appear to be needed for a work activity shelter. It is assumed that these shelters will be manned on a shift basis, that some peripheral personnel may enter or exit at various times, and that they will be closed up only during a period of attack. Furthermore, the primary occupants will have well-defined duties in connection with the dedicated purpose of the fortification. Personnel should not feel isolated due to the presence of others, and feelings of confinement and crowding will last for only the specified time of the shift. Therefore, except perhaps for some periods of sustained or extended operations, the typical psychological stresses associated with confinement and crowding should be minimal. Leaders may have to deal with battle-induced stresses, but should not be confronted with management problems, such as space utilization, resource allocation, time allocation and boredom.

The problems associated with leadership/management of a living/fighting fortification in which personnel may be continuously confined for extended periods has not been investigated. The only relevant research has been concerned with occupancy of fallout shelters. In these studies, it was found that authoritarian leadership which assumed total control of all resources, space and activity produced the best results in terms of morale. It can be assumed that the stresses facing occupants of a field fortification will be much greater than those facing occupants of a civilian fallout shelter. Therefore, even stronger leadership and resource management is likely to be needed in a battlefield fortification. US forces have no program for training leaders for this job. In fact, there are no guidelines for leaders, no list of necessary provisions, no designed storage space in fortification designs that have been tested, no provision for waste elimination, and no provision for reprovisioning. Obviously, if it is assumed that living/fighting fortifications will be occupied continuously for extended periods, considerable additional research in a number of areas will be needed. At the present time, too little is known about resource and management requirements of a fortification to hazard a guess as to specifics.

CHAPTER 4

THE FIELD FORTIFICATION OF THE FUTURE

A Hypothetical Conflict

The time is October 1, 1982. The enemy offensive is now a month old and several strongholds have been established in the Eastern Sector of the Federal Republic of Germany. The V US Corps has been successful in containing the enemy's penetration in their sector and has restricted his offensive operation to limited objective attacks to secure dominant terrain or to disrupt civilian activities. The V Corps Commander has just received word that a strong motorized column left Einheim about an hour ago heading south. Intelligence reports that *PT-76* tanks and *BRDM-2* scout vehicles are well in front and to the sides of the main force which is headed by at least two battalions of *T-62* tanks. Aerial photos revealing *BTR-50PK* and *BTR-60PK* personnel carriers to indicate that the force is, at least, one motorized rifle regiment. Various other vehicles, both SP and towed, have been spotted, including 180mm and 220mm howitzers and *ZSU-23-4*, *SA-6* and *SA-9* air defense systems, indicating the possibility of a multi-regiment effort. It is believed that the objective of the task force is to capture and either remove, if possible, or destroy the steel working equipment in the industrial city of Dreiheim. The city is well defended against air attack and is readily approachable on the ground from the north only. The defense of the city has a high priority, but the V Corps Commander cannot shift significant forces until the enemy's overall intentions are revealed. Consequently, the V US Corps Commander decides that his best plan is to put a mobile force as far forward as possible to delay and disrupt the enemy's movement. If the enemy's advance can be held to 10-15 km per day, he will either have to withdraw or have to reinforce.

The US task force must be capable of causing the delay in the enemy's movement. It will be amply supported by mobile Stinger teams, Chaparral air defense missile systems and the FRG Flakpanzer air defense gun to minimize the possibility of resupply by air. Roland systems already in the area will be moved into range. These defenses should prove virtually impenetrable by air as neither side has air superiority.

The 313th Separate Infantry Brigade (Mech) under the command of COL Belton N. Killeen is tasked with the critical mission. COL Killeen decides to engage the enemy with a small force at Zweiheim. The Flusse River at Zweiheim is at flood stage and the enemy can probably be delayed at the crossing, hopefully, for 18 to 24 hours. The 1st Squadron (Air Cav) 216th Cavalry Regiment is placed under Operational Control (OPCON), and is quickly deployed to contact the enemy force. COL Killeen begins planning for a main defensive effort in an area 30 km south of Dreiheim where the enemy will have to traverse some rugged terrain to reach the plateau on the south side of the Verwerfung fault lines. He gathers his battalion commanders and sketches out the situation on a map (see Figure 1).

After the conference, COL Killeen and his staff survey the area by helicopter. The distance from the valley to the edge of the plateau is about 25 km air distance, and represents a rise of approximately 300 meters in elevation. The battalion commanders make final decisions on deployment, and locations are picked for transportable shelters to serve

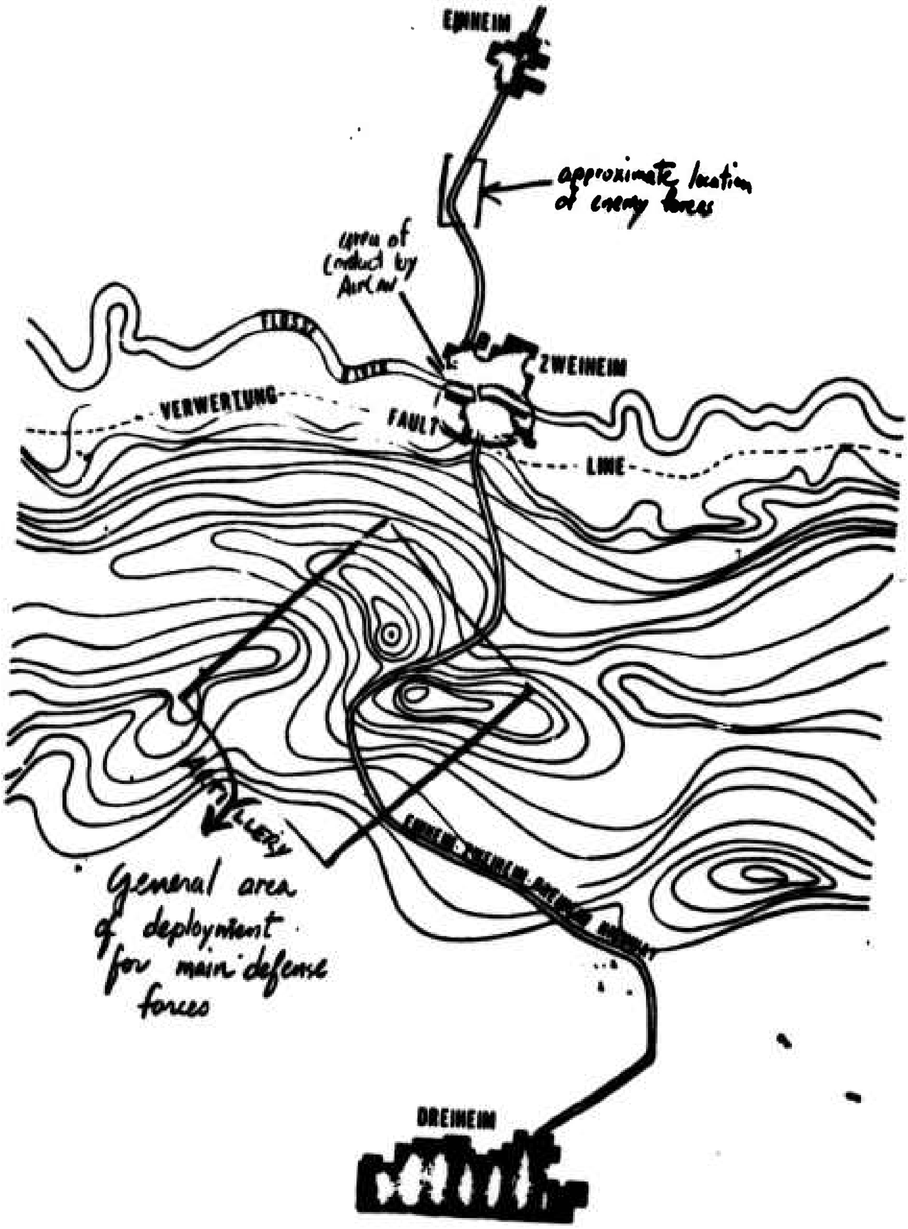

Figure 1. COL Killeen's map.

as command posts, operations centers, first-aid stations, fighting bunkers, communications centers, and small equipment maintenance shops. COL Killeen's Command Post (CP) is dug in near the top of the rise some five kilometers west of the only area where the enemy will be able to traverse the terrain coming up from the valley. Only a short distance from the valley floor, and one kilometer west of the traversible area, a Universal Engineer Tractor (UET) prepares an excavation for a Battalion Tactical Operations Center (BTOC). The preassembled BTOC structure is flown in by a CH-48 and placed in the excavation. In order to prevent the entryway from being blocked during backfilling, two rows of sandbags are set to form a passageway from the entry to ground above. The walls are reinforced by locally cut timbers. Backfilling is largely accomplished by the UET. However, the final filling around the entry is accomplished by hand tools to minimize the likelihood of collapsing the sandbag and timber walls.

The BTOC, constructed of corrugated aluminum, weighs nearly 2300 pounds, but contains all the equipment necessary to conduct battalion operations. The equipment is quickly set in place, and because the use of space has been carefully studied and planned for, it seems quite "roomy."

Dr. (MAJ) Cove, Commander, 18th Medical Company (49th Med), carefully examined an area on the western slope of a hill near the edge of the plateau and about eight kilometers west of the route the enemy would have to follow. This site had been selected earlier for the emergency medical facility. The area could be easily reached by rubber tired vehicles from the plateau as well as the areas just below the top. There was also a flat area suitable for a helipad within 100 meters of where he stood. Trucks containing the unassembled elements of the facility were quickly called in. The facility was to be constructed from a specific layout of modules from the Modified Modular Combat Protection System (MMCPS). A squad of engineers quickly leveled an area of the gentle slope while another squad unloaded the elements of the structure and began to assemble the modules. The basic elements of a module consist of panels, spacers, adjustable supports, and roof beams. The panels and spacers are made of fiberglass reinforced with steel rods. The supports and roof beams are made of steel. A single basic module, when completed, is approximately 60 cm tall, 120 cm wide, and 28 cm thick. The modules are designed to be stacked, so walls of several heights can be constructed. When walls are completed and emplaced, they are filled with earth, usually from inside the shelter. When all the walls are in place, steel roof beams are laid across the top, and supports are fitted under to help sustain the weight. Next, notched beams are laid perpendicular to the first set. Finally, aluminum panels approximately 120x240 cm are laid on the roof beams. When the structure is completed, sandbags are placed five deep over the roof. Another set of 4'x8' panels are laid on top of these sandbags, and another five-deep layer of sandbags is placed on top. The structure is now ready for extended occupancy, and is capable of surviving in a conventional environment (see Figure 2).

Long before the final sandbags were placed on the roof of his facility, MAJ Cove and his men were busy on the inside. The floor had been flattened and filled with loose sand from the nearby creek bed to

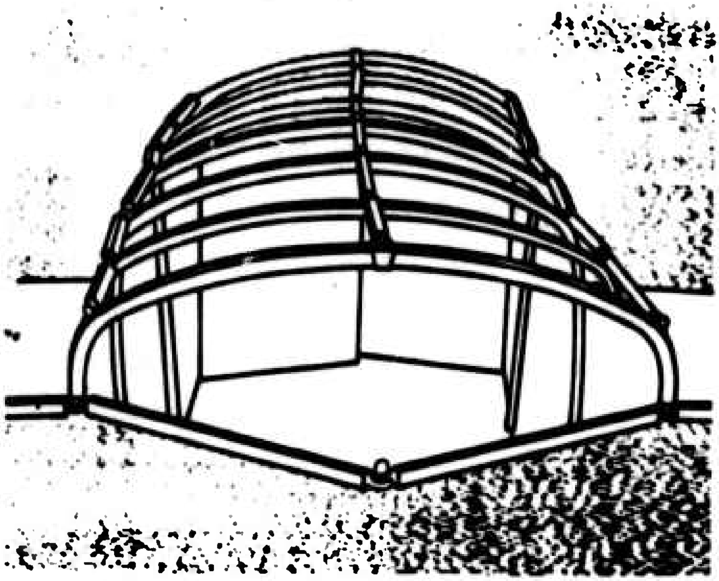

Figure 2. Modified modular combat protection system shelter.

a depth of slightly more than one inch. Interlocking plywood floor panels had been worked into the sand for stability. The floor failed to meet the walls completely, a design feature that permitted some error in placements of the wall panels. The floor panels were marked with special codes on top. This was done for two reasons. One was to ensure that the floor panels were correctly placed, the other was to ensure that all equipment would be placed in exactly the proper location in the shelter. Previously, human factors scientists had worked with medical personnel to determine the optimum shelter configuration and equipment layout for an emergency medical facility of the type required for this kind of conflict. Work space required for each major function was determined, the amount and type of equipment and supplies was determined, and storage containers were designed to hold the equipment and place it in easy reach of personnel involved. All labels on drawers and doors were properly sized to ensure readability and minimize error. Illumination requirements were computed for each function, and light fixtures were placed to ensure adequate lighting for all areas while minimizing power requirements. Furthermore, placement of lighting fixtures was predetermined to ensure that work space would not be shadowed. Traffic flow was considered in the location of work areas, and those requiring the heaviest traffic were placed near the entrance. Once MAJ Cove had his equipment in and properly placed, he would be ready to handle casualties in a highly efficient manner. The road would be improved to provide more rapid transportation for both incoming casualties and stabilized casualties being evacuated to hospital facilities in the rear area.

Nearer the expected point of contact, land mines were being laid. Artillery units were digging in at the edge of the plateau. Smaller sections of the MMCPS were being assembled to form revetments around the pieces. At vantage points above the valleys traversible by vehicles, small teams of men were preparing positions from which to fire the TOW and the Dragon. These were set by forming a V-shaped revetment of two 4'x4' modules of the MMCPS. The bottom of each panel was set about six inches into the ground, and the points of the "Vs" were aimed in the direction of expected approach. Earth from behind each revetment was packed in front, and foliage was cut to camouflage the positions.

Along a ridge overlooking one of the valleys with a gentle slope towards the plateau, a UET operator had provided an excavation for an air transportable assault bunker. When the hole was ready, a "flying crane" brought in the bunker and placed it in the hole. The UET had moved the earth from the excavation in towards the bunker before departing to excavate another site. Personnel with hand tools were finishing arranging of the earth around the bunker, and using much of the remaining earth from the excavation to fill sandbags.

The assault bunker was a new model. It resembled the earlier models in that the dimensions at the base were smaller than at the top to facilitate extraction by helicopter. However, this is where the resemblance ended. Instead of being constructed of plywood, it was constructed largely of aluminum, and weighed considerably less than the 1800 pound plywood version. It differed in other respects also. The roof was slightly rounded to better distribute the stresses from an overhead impact. Also, the bunker was not completely buried. About two feet of the wall facing the line of probable approach was exposed, and two fighting ports suitable for firing a rifle or an M60 machinegun provided a view of the valley below. A steel plate the length of the bunker was hinged to the roof, and the bottom of the plate was lowered into a small trench dug by hand tools, and earth was packed around it. The steel plate, which had fighting ports matching those in the bunker, lay at an angle of about 15 degrees to the vertical. This was designed so that blast fragments striking the plate would be directed upwards. Sandbags were placed on top of the bunker, and in front of the steel plate where they would not interfere with sighting or firing through the ports. Finally, armor cloth was hung where it could be dropped in front of the firing ports. Although the bunker was not ready for occupancy, the sergeant in charge checked to be sure the four steel rings used to lift the bunker were exposed.

Boxes of prepackaged supplies were unloaded from a truck, and the three men who were to occupy the bunker opened the boxes and began to arrange the supplies inside the bunker. There was sufficient food and water for 48 hours for three men. There was also two foam pads and blankets, a small disposable propane cook stove, disposable aluminum and plastic utensils, communications equipment, a waste disposal kit, and ammunition. In 10 minutes, the fortification was ready for the attack.

At other locations, other types of fortifications were being prepared. Soldiers were digging individual foxholes, but they were round instead of rectangular. Slightly to the rear, some shelters modeled after the British Field Shelter Mark II, were being emplaced. Although this shelter does not offer as much protection as some of the others, it is well thought of by commanders for several reasons. First of all, it is light and easily transportable -- the components consisting of metal pickets, spacers, and arches, with flexible revetting material for cover. Secondly, it can be assembled and emplaced without engineer support, if necessary, in only 24 man hours on the average. Finally, it can be emplaced in a variety of configurations suitable for use as aid stations, company CPs, rest areas, and storage areas.

Construction of the steel framework for a company CP is very simple and requires no tools. A picket is attached to each end of each arch by simply fitting a male connector on the arch into a female connector on the picket. These selections are placed approximately 18 inches apart in an excavation prepared by a backhoe. Three spacers are employed to attach the tops of the arches to each other. This is accomplished by fitting holes in the spacers over male connector rods on the top of each arch. The steel arches top off at slightly more than a foot below ground level. Flexible revetting material is placed over the top, and is held in place by sandbags and earth fill. As earth is piled on the top, a smooth mound is formed. A few small bushes are "planted" on the top. From any distance, the CP is virtually undetectable. Figure 3 show a partially constructed shelter.

Although the CP prepared differs little from the original British version in concept of construction, it differs in one way that makes it far more acceptable to its occupants. Twice as many roof arches are employed as in earlier versions. While this adds little to the shelter's protective capacity, it greatly reduces the sag in the revetting material

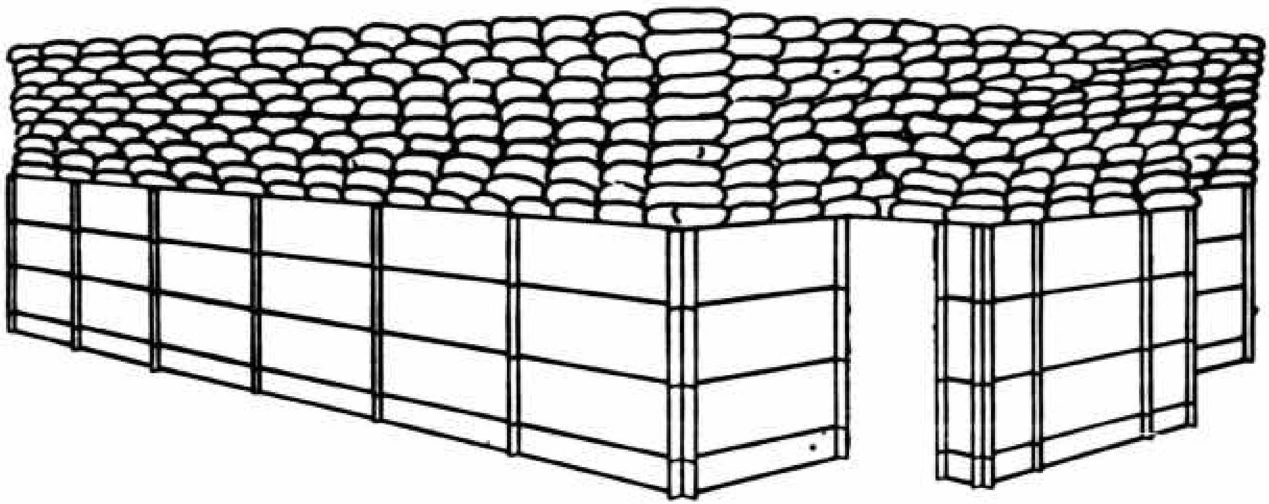

Figure 3. Modified British field shelter under construction.

After the shelter is covered with earth. This reduces feelings of claustrophobia, resulting in better job performance.

Areas in several locations are cleared and leveled sufficiently to permit helicopter landings, supplies and troops are trucked in, and the defenses are ready.

Hopefully, situations as describe above will never need to become realities. However, US forces cannot afford to be unprepared. Versions of the shelter/fortifications described above have been among those tested previously, and found to have sufficient potential for further consideration. Furthermore, they would very likely be employed in situations such as the one described -- where time and manpower were very limited, and where the conflict was expected to be of short duration and in a limited geographical area. Assuming that the attack would be repulsed and the territory held, most of the material could be reclaimed and used again.

Evaluations of prefabricated shelter designs in past studies have been based primarily on: (a) simplicity and ease of construction and emplacement, (b) protection afforded to occupants, (c) transportability -- in terms of both weight and volume, and (d) reusability. Very little consideration has been given to the effectiveness of design in terms of its intended uses. The BTOC mentioned earlier was designed specifically to accept the TOE of the Battalion Operations Center. Also, the various configurations of the British Field Shelter Mark II were designed for specific purposes. However, so far as is known, the adequacy of the configurations, in terms of US Army operations concepts and US personnel and equipment, has been only superficially examined. In brief, little has been done to ensure that intended functions can be carried out efficiently in the shelters that have been fabricated. Some human factors research that should lead to improved utilization of field fortifications is described in the succeeding section.

Priorities For Research

It would appear that the greatest contribution human factors scientists can make to the field fortifications effort at the present time is to "human engineer" the fortifications which hold the most promise from other standpoints. Human factors personnel should look at problems associated with the construction or assembly of each type to ensure that standards for reach, human lifting capacity, etc., are not exceeded, and that instructions for assembly are clear and concise. However, the main contributions the human factors specialist can make lie in the areas of space utilization and provisioning. Some of the aspects that should be investigated are discussed briefly below.

Space utilization. Except for the BTOC, virtually no thought has been given to questions concerning the locations of personnel and various equipments in shelters when employed for a particular purpose or function. These aspects should be examined to ensure that: (a) work spaces will accommodate men for the 5th through the 95th percentiles in size, (b) all necessary equipment and supplies are accessible to personnel without undue movement or effort that would interfere with combat operations, (c) duty positions are located to minimize interference due to noise, lighting, or physical movement, and (d) traffic flow in and out is efficient and does not interefere with duty performance.

In some types of shelters for some purposes, space utilization may not pose any problems. For example, storage bunkers and rest areas, or bunkers emplaced primarily for troop protection during attack, should require little, if any, study. However, communications centers, brigade or division CPs, and aid stations are highly complex activity centers and the US Army can ill afford anything short of maximally efficient operations. Some notions about how proper use of space might be ensured were related in the description of the medical aid facility presented earlier. However, the actual layout for optimum space utilization for such a facility is not known. Communications centers are an extremely vital cog in military operations. Timely receipt and transmission of information can make the difference between winning and losing a battle. Care must be taken to ensure that interference between operators is minimized. Interference can result from speech or other noise, lighting, or physical movement. The flow of messages to and from the operators by and for persons not directly in the nets must be handled smoothly and without confusion. The optimum arrangements for various types of equipments have not been studied.

While the human factors specialist can undoubtedly do much to ensure optimum utilization of space in current designs of prefabricated bunkers, he should not necessarily assume that the designs thus far tested are the only and final configurations. It is possible that slight modifications which would have only negligible effects on weights, assembly and emplacement, and protective capacity might greatly enhance functionality. Therefore, he should not neglect his obligation to suggest basic changes in design.

Provisioning. For purposes of this report, the term *provisions* encompasses all the stocks, supplies, and equipments required to perform the functions of a particular facility for some predetermined length of time. Provisions not only include foodstuffs and liquids for drinking, but could include cooking and heating equipment, furniture, weapons, ammunition, CBR protective gear, communications equipment, bedding, spare parts, tools, waste disposal kits and medical supplies, as well as the specialized equipment required to carry out the particular function for which the fortification was intended.

Virtually no consideration has been given to provisioning shelters or to storage of provisions within a shelter. Several questions concerning the most efficient means of provisioning need to be answered. For example, one of the major questions is:

> Should "kits" containing all necessities be prepackaged for each of the major combinations of shelters/functions?

Certainly, prepackaging would ensure that all necessities were on hand when a package arrived. It would also make delivery much simpler. However, some items such as individual CBR gear perhaps should be excluded. If the individual is responsible for his own personal gear, a fit will be ensured, and defective equipment would be discovered in advance and replaced.

Assuming that kits are deemed to be the most efficient means of provisioning, questions concerning packaging arise. For example:

> Should food and liquid be packaged as a daily supply for the expected number of occupants, or, should a daily package for each occupant be prepared?

Naturally, the fewer the number of packages required, the less opportunity there will be for error and the simpler will be delivery. However, some versatility would obviously be lost. Incrementing or decreasing personnel complements as might be necessary would result in either shortages or overages if a supply based on the expected number of occupants is prepackaged.

A number of other questions also arise, such as, "What foods should be included -- 'C' rations, or other?" "How much liquid should be supplied?" "Should separate packages be prepared for different seasons, due to different intake levels?" "Should different kinds of supplies be packaged separately, e.g., food kits, ammunition kits, waste disposal kits, etc., or should a series of standard packages be prepared from which a bunker leader can select exactly what he needs?"

If research on human factors problems in field fortifications is judged to have sufficient priority to be continued, it appears that work on space utilization and provisioning are the most promising areas to expend the effort.

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