Chapter 6

HEALTH HAZARD ASSESSMENTS

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INTRODUCTION

Although military duty is inherently hazardous, soldiers in combat should not be placed at a disadvantage or at unusual risk because their hardware is deficient or information is lacking regarding the health hazards associated with their equipment.[1] Neither should soldiers be exposed unnecessarily to health hazards during training, even though the training must be realistic to achieve a high degree of operational readiness. Therefore, the Army Medical Department's (AMEDD's) mission—to conserve the fighting strength—must include reducing the risks to soldiers' health that are posed by their own materiel (military equipment, weapons, clothing, and training devices). AMEDD must ensure that soldiers do not suffer serious adverse health effects as a result of operating their materiel systems, and that the equipment itself does not prevent them from performing at maximum efficiency.

By 1983, Department of Defense (DoD) Directive 5000.1, *Major Systems Acquisitions*, had instructed all uniformed services to consider health hazard assessment as an integral part of their materiel acquisition process, and Army Regulation (AR) 40-10, which formally established the U.S. Army Health Hazard Assessment (HHA) Program, was published in October of that year.[2,3] When properly executed and integrated into the army's Materiel Acquisition Decision Process (MADP), the HHA Program not only prevents injuries and job-related illnesses, but it also enhances the soldier's ability to accomplish his or her mission. For example, excess carbon monoxide reduces visual acuity (see Chapter 8, Conserving Vision, and Chapter 11, Carbon Monoxide). By eliminating or reducing carbon monoxide to its lowest acceptable level, the HHA Program prevents the soldier's performance from being degraded. There are no formalized, mandatory civilian programs for assessing the potential health hazards of equipment during the research and development stages.

Rationale

The HHA process applies biomedical knowledge and principles to document and quantitatively determine the risks that the materiel itself poses to the health and effectiveness of the personnel who test, use, or maintain U.S. Army equipment. The primary objective of the HHA Program is to identify, assess, and eliminate or control health hazards associated with weapons systems during the early stages of development and acquisition. Specifically, the program objectives are to identify and evaluate the health hazards caused by materiel to

- preserve and protect the soldier from such health hazards,
- reduce soldier performance decrement and enhance system effectiveness,
- reduce the need for retrofitting system designs,
- enhance readiness by reducing health hazards that cause training or operational restrictions (eg, reducing carbon monoxide to an acceptable level so that more rounds can be fired), and
- save money by eliminating or reducing occupational injury and illness compensations attributable to health hazards from the use of army materiel.[3]

This evaluation of hazard severity and hazard probability provides decision makers with (*a*) a formal estimate of the health risks associated with military hardware as it proceeds through the acquisition process, (*b*) a summary and discussion of potential and real health hazard issues, and (*c*) recommendations for methods of controlling, mitigating, reducing, or eliminating hazards.[3]

Militarily unique settings offer the preventive medicine team unusual and complex challenges. For example, tank or aviation crews can be exposed to simultaneous stresses—such as acoustical energy, chemical substances, temperature extremes, and whole-body vibration—each of which can produce several different adverse health effects.[4] All occupational health professionals within the military must deal effectively with the traditional hazards of an installation's industrial setting and the unique hazards of the military; and all military physicians must be competent to diagnose, manage, and report the adverse health effects associated with testing, using, and maintaining military equipment.

During the late 1970s and early 1980s, the army leadership as well as AMEDD and the materiel developers recognized the need for a medical review of new or improved equipment. This resulted from an increased awareness that *soldier performance decrements* (short-term, materiel-induced conditions that prevent a soldier from performing at maximum effi-

Fig. 6-1. The M198 155-mm Towed Howitzer. The M198 is a helicopter-transportable 155-mm medium towed howitzer. It has a conventional split-trail carriage and uses a hydropneumatic recoil mechanism. The maximum rate of fire is 4 rounds per minute for the first 3 minutes and 2 rounds per minute sustained. It is capable of firing a 96-pound rocket-assisted projectile to a range of 30 km.

Fig. 6-2. The Multiple Launch Rocket System (MLRS). The MLRS is a free-flight artillery rocket system that improves the conventional, indirect-fire capability of the field army. It consists of a 12-round launcher mounted on a mobile, tracked vehicle. The MLRS is capable of launching rockets, with varying types of warheads, either one at a time or in rapid ripples, to ranges beyond 30 km.

Fig. 6-3. The Bradley Fighting Vehicle (BFV). The BFV is named for the late General of the Army Omar N. Bradley. Two versions, the M2 Infantry Fighting Vehicle (IFV) and the M3 Cavalry Fighting Vehicle (CFV), are externally indistinguishable and have the same armament and automotive performance. The major difference between the M2 and M3 is the arrangement of the crew compartment and internal storage. The armament includes the M242 25-mm chain gun, M240 7.62-mm coaxial machine gun, and a TOW (tube-launched, optically-tracked, wire-guided) antitank missile launcher.

Fig. 6-4. The Stinger Manportable Antiaircraft Missile. The Stinger was developed by the army to provide individual combat soldiers with effective air defense in forward combat areas. It is so popular that it is integrated into the active inventories of all four armed services. Three variants are in operational inventories: the basic Stinger, Stinger-POST (passive optical seeker technique), and Stinger-RMP (reprogrammable microprocessor).

ciency) and adverse health effects were associated with the use of field equipment and were defining the limits of technology for new systems. Systems that were developed during this time, which could have benefited from very early AMEDD HHA input during the MADP, include the M198 155-mm howitzer (Figure 6-1), the Multiple Launch Rocket System (MLRS, Figure 6-2), the Bradley Fighting Vehicle (BFV, Figure 6-3), and the Stinger Manportable Antiaircraft Missile (Figure 6-4).

Soldiers who fired the M198 experienced chest-wall pain and blood-tinged sputum. These are signs of *primary blast injury*, which occurred when the weapon was fired.

> *Blast injury* is a general term that refers to the biophysical and pathophysiological events and the clinical syndromes that occur when a living body is exposed to blast of any origin. Blast-wave physical properties, the complexity of the waveform, and the number of blast repetitions determine the potential for *primary blast injury*.[5(p242)]

In this instance, blast injury was controlled by restricting the number of rounds (blast repetitions) fired each day by each member of the howitzer crew.

Hydrogen chloride is a combustion product of ammonium perchlorate–based propellant used in the MLRS missile. The MLRS crew members experienced temporary eye and respiratory irritation when hydrogen chloride gas entered the crew compartment during missile launch. The hydrogen chloride levels outside the crew compartment are also high enough to incapacitate unprotected personnel. An early medical review would probably have recommended the use of an alternate, safe propellant. Initially, crew members inside the crew compartment were required to wear their protective masks until modifications were made to improve the compartment seals and overpressure system.

Several shortcomings were found in the design of the BFV. The high, steady-state (continuous) noise levels were similar to those found in its predecessor. Such high noise levels are typical of armored tracked vehicles, and are characteristic of the existing design of their suspension and drive system. Hearing loss among crew members and passengers is controlled by double hearing protection (the Combat Vehicle Crewmember [CVC] DH-132 helmet and army-approved ear plugs) and limiting the time each day that personnel can occupy the vehicle. However, double hearing protection adversely affects speech intelligibility among crew members talking on the vehicle's intercom system, and between the crew and external communications stations. Another shortcoming of the BFV is that the

heater in the crew compartment is unable to provide adequate heat while operating at the vehicle's minimum design temperature, and low temperatures within the crew compartment adversely affect the crew's ability to operate the vehicle. Testing found the heater to be unsatisfactory, especially at the driver's position. An early medical review would probably have recommended that more appropriate heater performance in the crew compartment be included in the vehicle's design specifications.

The rocket motor in the Stinger, like that in the MLRS, uses ammonium perchlorate–based propellant. Recommendations to wear the protective mask to prevent respiratory tract irritation from the high concentrations of hydrogen chloride gas following a Stinger firing proved to be inappropriate: a soldier must also hold his breath for 40 to 60 seconds after firing a Stinger to prevent any additional performance decrement. The protective equipment of choice (the mask) interferes with the soldier's ability to use the weapon: the facemask prevents the soldier from placing the weapon against his cheekbone. Using a different propellant would have solved this problem. However, the Stinger was one of the first weapons systems evaluated as part of the HHA Program; the weapon had already been fielded and its design could not be changed.

Unfortunately, because these shortcomings have not been properly addressed, they are perpetuated. Increased costs and additional health concerns inevitably result as combat and materiel developers attempt to improve or incorporate existing equipment into developing systems.

History

In 1866, the army replaced the union repeating gun with the Gatling gun—a six-barrel machine gun that employed a new, improved, steel-jacketed cartridge.[1,6] The redesign solved the sharp-trauma hazard: the misalignment of the gun parts had caused soft metal particles to be shaved off; the steel-jacketed cartridge

Fig. 6-5. White Armored Car (M1913-1914), shown at the U.S. Army Ordnance Museum, Aberdeen Proving Ground, Maryland. Built by the White Motor Company, this vehicle weighed about 2 tons and was a built-up armored truck. It had dual rear wheels with pneumatic tires and a caliber .30 Vickers-Maxim machine gun in the rounded turret. It was used by General Pershing's troops along the Mexican border in 1916 during their pursuit of Pancho Villa.

prevented this shaving. However, we have no idea whether the Gatling gun eliminated other health hazards such as toxic fumes, segmental vibration, or impulse noise, because *these were not recognized* as health hazards.

The cavalry's conversion of the horseless carriage into a moving armored fortress was probably one of the earliest steps in the development of the tank. At least as early as 1902, a heavy, low-powered, armored car with a periscope was developed (Figure 6-5).[7]

The U.S. Army used some versions of early armored vehicles along the Mexican border in 1916. Armored cars are lighter-armored, wheeled, and carry a machine gun. Tanks have heavier armor, heavier weapons, and are tracked vehicles. However, the development of tanks required the concomitant development of two major technologies: an internal combustion engine capable of providing sufficient power to move the heavy tanks, and tracks that would permit the vehicle to cross rough terrain.[7]

Tanks, like machine guns, were developed during an era when occupational health hazards were not a concern. Although specific health hazards associated with the earliest tanks were not documented, we can assume that the steady-state noise and whole-body vibration from the primitive track design would have caused severe health problems for soldiers in the tanks, and that the engines would have caused exposure to heat and toxic combustion products. Soldiers in tanks during World War I definitely experienced health hazards that were different from the impulse noise and blast overpressure traditionally associated with artillery and small arms:

> Inside the tanks, the crews worked manfully to steer and control their lumbering charges. There was very little room to move about in, most of the space being taken up by the large petrol engine in the centre. The interior was dimly lit by a naked electric light bulb, fed from the batteries. Vision to the outside was provided through narrow glass prisms, which had a habit of splintering into a driver's eyes when hit by a bullet.[7]

The first major tank battle occurred in northern France on 20 November 1917, when 378 tanks moved from behind British lines (see Figure 1-5, Chapter 1, Occupational Health in the U.S. Army). The crews inside these tanks experienced noise and vibration so intense that their wireless transmitters could not be used.[7] Semaphores were adopted as a less-than-ideal alternative. (Even now, the noise in tanks is so extreme that tank commanders often use hand and arm signals to communicate.)

The Armored Medical Research Laboratory was established at Fort Knox, Kentucky, in early 1942 as the U.S. Army's first organized attempt to evaluate the medical consequences of weapons systems designs. During World War II, the staff—physicians, medical and physical scientists, and engineers—compiled an impressive array of reports covering a wide range of human factors and health issues such as fatigue, heat stress, and toxic gases.[8,9] The laboratory made extremely valuable contributions regarding the identification, evaluation, and control of health hazards associated with the use of military equipment. The medical department, however, had yet to grasp the importance of systematically reviewing new military items for health hazards posed to the operators and maintainers.

THE HEALTH HAZARD ASSESSMENT PROGRAM

Weapons and equipment development continued after World War II, yet AMEDD was still not integrated into the MADP, through which new materiel items are developed and fielded. As a consequence of the questions that had been raised during the final stages of development of the M198 howitzer and the BFV system, the application of technology to new or improved systems was seen to be limited by soldier performance decrements and adverse health effects. Thus, army leadership—including the vice chief of staff, surgeon general, deputy chief of staff for personnel, and deputy chief of staff for operations—directed the formalization of a process to address, as early as possible in the MADP, health hazard issues associated with new materiel. The U.S. Army Health Hazard Assessment Program, which was formally established with the publication of AR 40-10, requires that a medical review of materiel items be performed at critical decision points during the MADP.[3]

In 1987, the Department of the Army undertook a large-scale effort to address the hazards of increasingly powerful and sophisticated weapons systems: greater noise and blast overpressure, more shock and vibration, and higher concentrations of toxic fumes and gases.[10] The army's deputy chief of staff for personnel initiated the Manpower and Personnel Integration (MANPRINT) Program.[11] MANPRINT integrates the full range of human factors engineering, manpower, personnel, training, HHA, and system safety considerations, with the goal of improving the performance of the individual soldier and the total system throughout the MADP. This ensures that the human aspects of the soldier–machine interface are considered early in the design and development of weapons systems.

The HHA Program is a primary domain within the overall MANPRINT Program. Careful coordination and interaction between HHA Program activities and other MANPRINT domains are essential for a cohesive, comprehensive, and efficient MADP. Thus, the MANPRINT joint working groups integrate the HHA report throughout all MANPRINT domains (such as human factors engineering; system safety engineering; and manpower, personnel, and training assessments). In addition, the U.S. Army Systems Acquisition Review Council verifies that the Office of The Surgeon General (OTSG) has completed the proper HHA report, and that appropriate action is taken by the materiel developer or the combat developer to resolve health hazard issues. AR 40-10 defines a *materiel developer* as "any organization responsible for developing or modifying materiel" and a *combat developer* as "any organization responsible for developing or modifying doctrine on how the Army will fight."[3(p15)]

Organizational Support

The AMEDD organizations that have major roles in supporting combat and materiel developers within the HHA Program, including technical expertise (which can include manpower), are the OTSG, the Health Services Command (HSC), and the Medical Research and Development Command (MRDC). Together, these organizations (*a*) coordinate the program and establish program policy; (*b*) review requirements documents, serve on MANPRINT joint working groups, and assist in preparing the System MANPRINT Management Plan (SMMP); and (*c*) conduct biomedical research.

Program Coordination and Policy Establishment

The OTSG is the proponent of the HHA Program, and thus establishes program policy and provides coordination for the program. The HHA coordinator, assigned to the Preventive and Military Medicine Consultants Division of the OTSG, provides this coordination. Normally, HSC's U.S. Army Environmental Hygiene Agency (USAEHA) prepares the HHA reports, but occasionally the MRDC prepares them.[12,13]

Requirements Documents

The army's requirements for a particular materiel system that is necessary to correct a battlefield deficiency, based on current army combat doctrine, are contained within a *requirements document*. The combat developer prepares the requirements document and staffs it worldwide for comments on the concept. This is known as the *concept-based requirements system*.

Several components within the HSC, including the AMEDD Center and School (formerly called the Academy of Health Sciences), review and comment on these documents. Preventive medicine personnel at Medical Department Activities (MEDDACs)—which support Training and Doctrine Command (TRADOC) schools and integrating centers—work with the Director of Combat Development to review requirements documents and provide relevant health hazard assessment guidance.

Biomedical Research

The OTSG and the MRDC play important roles in biomedical research. The OTSG is responsible for identifying the health hazard assessment–related biomedical research needs. The MRDC and the OTSG both establish and prioritize HHA research requirements; the MRDC then performs the HHA research as a part of its larger medical research and development programs. Such research may consist of laboratory investigations, the development of technology and methodology, mathematical modeling, field evaluations, or epidemiological surveys.

Biomedical research can be used to improve or develop new tools to advance HHA capabilities. For example, the HHA Program may be using tools (such as biomedical databases, prediction models, and methods for evaluating protection) that are unable to measure the specific health hazards of a developing system. The HHA Program has a mission to develop technology-based research efforts aimed at answering health hazard–related questions that are militarily unique and that have no direct correlates in the civilian occupational health community. Examples of militarily unique biomedical research issues include

- developing standards for
  - exposure to carbon monoxide;
  - short-term, high-level exposures to hydrogen chloride and ammonia from missile firing;
  - exposure to lead from the firing of self-propelled artillery;
  - short-term, high-level exposures to hydrogen fluoride and hydrogen bromide as combustion and decomposition byproducts of halon fire-extinguishing agents;
  - whole-body vibration from operating tactical vehicles; and
  - exposure to acoustical energy;
- and characterizing the toxicity of
  - military smokes and obscurants,

- propellant compounds, and
- materials that come in direct contact with the soldier.

The identification of health hazard research needs usually results from voids in basic data that are to be applied to the HHA of materiel. These research needs, in addition to the identified deficiencies and requirements, should be specified in key MADP planning documents (such as Mission Area Analysis and the Battlefield Development Plan). However, the incorporation of these research requirements into the HHA's research effort requires close coordination between planning agencies, especially TRADOC, the U.S. Army Materiel Command (AMC), and the OTSG. Therefore, it is essential that combat system and technology developers, test and evaluation personnel, and human factors and system safety personnel notify the OTSG when potential health hazard research requirements come to their attention. In addition, the MANPRINT joint working group should document health hazard research requirements in SMMPs.

Biomedical research is funded by the MRDC, the materiel developer, or the Program Executive Office budget, depending on whether the research is related to a specific materiel system. The MRDC provides funds for generic, armywide, HHA-based, research needs that are not system specific. However, funding for health hazard research that is relevant to specific materiel systems relies heavily on research, development, testing, and evaluation funds from the materiel developer or Program Executive Office budget. This research forms the basis for the materiel developer to provide customer funds to the MRDC.

Funds for health hazard research that is required to address specific health hazards associated with a particular materiel-acquisition program should be identified as early as possible in key acquisition program management documents, including the SMMP, to ensure that adequate resources are available in a timely manner.

The Health Hazard Assessment Report

The HHA report is a standardized, systematic, multidisciplinary evaluation of the health risks associated with a materiel system. The HHA report determines if materiel systems pose any potential health hazards, and presents recommendations for corrective or preventive measures or both. The report is designed to document the logical process for developing recommendations (Table 6-1). AR 40-10 defines the report's content and preparation.[3]

An initial HHA report is usually prepared early in the developmental cycle and identifies

- potential health hazard issues associated with a materiel solution for a projected battlefield deficiency (an item is either developed or purchased to solve a deficiency), and
- pertinent health standards based on both developmental and predecessor systems.

TABLE 6-1

FORMAT FOR THE HEALTH HAZARD ASSESSMENT REPORT

Paragraph Topics	Contents
References	Listing of source materials
Summary	Executive overview with a brief system description, potential health hazards, and a brief assessment of the system with major recommendations
Background	System description, use scenario, acquisition strategy, summary of previous assessments/text reports used to evaluate the system
Identification of Issues	Listing of potential/actual health hazards associated with the system
Assessment of Issues	Data analysis and conclusion compared to health standards
Recommendations	Recommended actions for hazard control/elimination with risk assessment codes
Identification of Preparer	Preparing organization, point of contact, date prepared

Adapted from US Department of the Army. *Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process*. Washington, DC: DA; 1983. Army Regulation 40-10: 9.

The initial report's recommendations focus on both data that will be required and design specifications that address specific potential health hazards.

Required Data

Information and health standards are the key ingredients of an HHA report, but information is often difficult to obtain from materiel and combat developers. In general, both descriptive and quantitative information concerning the materiel system must be available to the independent medical assessor (IMA) who conducts the assessment. (The IMA—who can be either civilian or military—is not employed by the combat or materiel developer, but rather by the AMEDD organization that is completing the HHA report.) Health standards must also be made available, so that the IMA can compare or evaluate the severity of health hazards associated with the materiel system.

Definitive statements about levels of risk associated with potential health hazards are impossible to make without quantitative data. However, in the case of an initial HHA report, only data from a predecessor, or similar, system may be available. Quantitative information about materiel systems should include health hazard–related data (such as noise and vibration signatures and toxic-gas measurements) from technical testing, user testing, special hazard evaluations, previous HHAs, human factors engineering assessments, safety incident and system safety assessment reports, and modeling efforts.

Combat and materiel developers should also provide descriptive information, including a comprehensive account of components, subsystems, special materials, simulators and other training devices, special support and maintenance equipment, special salvage or disposal requirements, and system employment (such as operating and training doctrine; logistics support concepts; nuclear, biological, and chemical requirements; and expected environmental conditions).

Health standards (such as medical exposure limits, health conservation standards, and materiel design standards) are essential to gauge the severity of quantified hazards. Comprehensive biomedical databases are very helpful in gauging real levels of risk, especially when quantified hazards exceed established limits, although such databases are often unavailable.

Preparation Sequence

The IMA uses a systems approach in analyzing hardware and doctrine. This approach analyzes all components and subsystems, all phases of the system's "life cycle," how personnel interact with the system, the special operating conditions, and anticipated environmental conditions. Then, the IMA compiles a comprehensive inventory of potential health hazards and procedures from the analysis of hardware and doctrine. The inventory may include items such as materials, procedures, and design deficiencies. After compiling the inventory, the IMA analyzes the quantitative data available for each potential hazard, and requests further data to complete the analysis. Raw or intermediate data may need to be reduced, converted to a more useful form, or reorganized to a form more suitable for interpretation. When data are adequate for interpretation, the IMA compares them against pertinent health standards to ascertain whether the quantified levels are acceptable, given the frequency and duration of exposure expected.

The IMA then recommends means to eliminate, control, or reduce health hazards that pose an unacceptable degree of risk. These exposure controls can be tailored to the specific system and its operational requirements, and more than one type of control may be necessary for some hazards. Such control measures include engineering controls (such as redesign, system modifications, and retrofits), administrative controls (such as exclusion of high-risk personnel, and limiting duration or frequency of exposure), and requiring that personal protective equipment (PPE) be worn.

For each hazard, the IMA estimates the degree of risk that could result from noncompliance with recommended control measures. A scale of risk assessment codes (RACs) is used to classify the degree of each hazard (Table 6-2), which is useful in establishing priorities for control actions. The RACs relate hazard severity and hazard probability. The hazard severity (divided into categories) and the hazard probability (divided into levels) integrate to yield a number (1 to 5). The lower the number, the higher the risk assessed. For example, consider category II, level E in Table 6-2. The probability of occurrence is improbable (unlikely to occur, but possible), and the hazard posed may cause severe bodily injury (critical); therefore, the RAC is 4. The goal has been to make the RAC process as objective as possible, but the professional judgment of the IMA remains a subjective component.

Hazard severity assesses the worst potential consequence. Several factors define this assessment, including the degree of injury, occupational illness, health-related performance degradation, and possible bodily system damage. *Hazard probability* assesses the likelihood that a hazard will occur, based on factors such as location, exposure (in cycles or hours of operation), and population affected. The decision-making

TABLE 6-2

RISK ASSESSMENT CODES

Severity Category	Probability Level				
	A	B	C	D	E
I	1	1	1	2	3
II	1	1	2	3	4
III	2	3	3	4	5
IV	3	5	5	5	5

I (Catastrophic): hazard may cause death or total loss of bodily system

II (Critical): hazard may cause severe bodily injury, severe occupational illness, or major damage to a bodily system

III (Marginal): hazard may cause minor bodily injury, minor occupational illness, or minor damage to a bodily system

IV (Negligible): hazard would cause less than minor bodily injury, minor occupational illness, or minor bodily system damage

A (Frequent): likely to occur frequently, or continuously experienced

B (Probable): will occur several times in life of an item, or will occur frequently

C (Occasional): likely to occur sometime in life of an item, or will occur several times

D (Remote): unlikely, but possible to occur in life of an item, or, unlikely, but can reasonably be expected to occur

E (Improbable): so unlikely it can be assumed occurrence may not be experienced, or unlikely to occur, but possible

Adapted from US Department of the Army. *Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process*. Washington, DC: DA; 1991. Army Regulation 40-10: 11–12.

authorities in the MADP use RACs to determine which health hazards must be either resolved or accepted before a materiel system can progress to the next level of development or production.

Health Hazard Assessments During the Materiel Acquisition Decision Process

Just as HHA concerns should be integrated throughout all MANPRINT domains, so they should also be integrated throughout all phases of the materiel system development and acquisition cycle. Initially, the materiel or combat developer must submit draft system requirements documents to the USAEHA, the MRDC, or HSC's AMEDD Center and School for a medical review. These organizations identify potential health hazards and applicable health standards and return their comments to the materiel or combat developer. HHAs should be used during (*a*) program initiation, (*b*) concept exploration, (*c*) demonstration and validation, (*d*) full-scale development, and (*e*) production and deployment.

Program Initiation

When the MADP is being initiated, the combat developer should assign responsibilities and formulate requirements documents. The combat developer should incorporate health hazard considerations and criteria into requirements documents based on predecessor or similar systems. AMEDD sources may provide such information. In addition, designated preventive medicine personnel assigned to TRADOC installations should identify responsibilities and tasks needed to control potential health hazards and include them in the SMMP.

Concept Exploration

During the concept exploration phase, the combat and materiel developers should ensure that requirements for an HHA are included in acquisition program management documents. The combat and materiel developers should also submit a request for an HHA report to the OTSG. This request should include any available health hazards–related test and evaluation data contained in other program documents.

Other required program acquisition documents may provide useful HHA-related information. These documents are the Human Factors Engineering Assessment, Safety Assessment Report, and safety and health data sheets. In addition, the OTSG, the USAEHA, and the MRDC also provide health hazard consultation as required.

Demonstration and Validation

During the demonstration and validation phase of the MADP, the combat and materiel developers and the IMA collect health hazard data, which will form the basis for an updated HHA report. AMEDD elements continue to furnish health hazard consultation to the materiel developer to control health hazards. When the developer is unable to address these issues,

AMEDD may assist in collecting data and in refining collection requirements and methods. In addition, formal requirements documents should specifically address health hazard considerations peculiar to a developing system.

Full-Scale Development

During the development phase of the MADP, test personnel collect data to address unresolved health hazard issues. The materiel developer should request an updated HHA report from the OTSG to determine the developing system's health-risk status. The results of this assessment should be included in the SMMP and other acquisition program safety and health documents such as safety and health data sheets, safety assessment reports, human factors engineering assessments, and MANPRINT assessments. The materiel developer corrects or controls remaining health risks, or documents management decisions that accept risks associated with major hazards. Contract specifications are developed and refined to ensure compliance with health hazard requirements.

Production and Deployment

Health hazard–control procedures adopted as a result of HHA report recommendations should be incorporated into acquisition program technical publications and training materials. *Production testing* documents the developing system's conformance with HHA-related contract specifications. Test personnel collect required data on unresolved health hazard issues during postproduction testing (such as Follow-on Operational Test and Evaluation) and submit it to AMEDD for review. The materiel developer ensures that (*a*) proposals for engineering change proposals receive proper review for health hazard implications and (*b*) decisions that resolve remaining health hazard issues are documented and implemented.[13]

FINDINGS OF HEALTH HAZARD ASSESSMENTS

About 100 HHAs per year have been done on army materiel systems since the program was formalized in 1983. (Approximately two-thirds of these assessments require a formal HHA report.) Nine general categories of health hazards have been identified (Table 6-3). An HHA will typically address army *developmental* and *nondevelopmental* items for each of these nine possible hazard categories. AR 70-1 defines a developmental item as one that is "under development or which was developed by the army."[14(p89)] The same document defines a nondevelopmental item as

> those items available for procurement to satisfy an approved materiel requirement from existing sources (such as commercial items and items developed by other government agencies, U.S. military service, or countries) requiring little or no additional development.[14(p91)]

Usually, the more complex and sophisticated the materiel system, the more categories of potential health hazards that will need to be addressed. The HHA report that is appended at the end of this chapter was selected for inclusion in this textbook because it addresses five categories of health hazards—an unusually high number—and deals with a system that is currently under development.

Acoustical Energy

Acoustical energy is defined as the potential energy that exists in a pressure wave, transmitted through air, which can interact with the body to cause hearing loss or damage to internal organs. It includes *steady-state* (also called *continuous*) noise from engines and helicopter rotors, *impulse* noise from firearms, and *blast overpressure* from mortars and towed artillery (free-field waves) and heavy weapons on crew-served vehicles (complex waves).[3]

Lighter, Air Cushion Vehicle, 30-Ton Capacity

The Lighter, Air Cushion Vehicle, 30-Ton Capacity (LACV-30) is an air-cushion cargo transport vehicle capable of operating over water, beaches, ice, and snow. This vehicle is powered by two sets of gas turbine engines, which drive lift fans, and two propulsion propellers (Figure 6-6).

An HHA of the LACV-30 identified the power train as a source of high levels of steady-state noise (see Chapter 7, Noise and the Impairment of Hearing, for a discussion of steady-state noise). Based on Military Standard 1474, the HHA report recommended that crew members and passengers use single hearing protection (such as the DH-132 CVC Helmet, the SPH-4 Aviator's Helmet, or approved ear plugs) to protect themselves from noise-induced hearing loss.[15]

Bradley Fighting Vehicle

The BFV is a tracked, light-armored vehicle. Both versions—the M2 Infantry Fighting Vehicle (IFV) and the M3 Cavalry Fighting Vehicle (CFV)—are equipped

TABLE 6-3

HEALTH HAZARD CATEGORIES

Category	Description	Examples	Related Publications
Acoustical Energy	Potential energy in a pressure wave, transmitted through air, which can cause hearing loss and damage internal organs	Steady-state noise: engines and helicopter rotors Impulse noise: small arms Blast overpressure: mortars, towed artillery (free-field wave) heavy weapons on crew-served vehicles (complex wave)	AR 40-5 MIL-STD-1474 MIL-STD-1294 DA PAM 40-501
Biological Substances	Pathogenic microorganisms, their toxins and enzymes	Sanitation concerns such as waste disposal, food handling, and personal hygiene	AR 40-5 FM 21-10 TB MED 530 TB MED 577
Chemical Substances	Excessive airborne concentrations of mists, gases, vapors, and particulate matter; also toxic liquids and solids	Combustion products from weapons or engines Exposures via inhalation, ingestion, dermal or eye contact	AR 40-5 MIL-STD-1472 MIL-HDBK-759 21 CFR 177 21 CFR 182 29 CFR 1910
Oxygen Deficiency	Sudden reduction of atmospheric O_2 to < 21% (by vol)	In confined spaces and high altitude: can cause shortness of breath; impaired vision, coordination, and judgment, progressing to unconsciousness and death	TB MED 288 DHEW(NIOSH) Pub. 80-106 29 CFR 1910 ANSI Z117.1
Radiation Energy	*Ionizing*: any form of radiation sufficiently energetic to ionize molecules in matter *Nonionizing*: emissions from the EM spectrum with insufficient energy to ionize molecules	Alpha and beta particles, gamma and X rays, neutrons UV, visible, IR, microwave, and RF radiation	AR 40-5 AR 40-14 AR 40-46 AR 40-583 AR 385-9 AR 385-11 MIL-STD-1425 TB MED 522 TB MED 523 TB MED 524 10 CFR 0-199 21 CFR 1040
Shock	Mechanical impulse or impact received by the body	Acceleration: recoil from weapon Deceleration: opening of parachute harness	MIL-STD-858 MIL-STD-1290 SAE-J* 855
Temperature Extremes	Injuries from excessive heat and cold, which can be exacerbated by humidity	Heat: heatstroke, hyperthermia Cold: frostbite, hypothermia	AR 40-5 MIL-STD-1472 TB MED 81 TB MED 288 TB MED 507
Physical Trauma	Injury to eyes or body from impact or strain	Penetrating Blunt: crush injury, bruise Musculoskeletal: lifting heavy equipment	AR 40-5 TB MED 506 29 CFR 1910 ANSI Z87.1
Vibration	Adverse health effects caused by contact of oscillating mechanical surfaces with the human body	Whole body: aircraft and vehicle operators and passengers Segmental: operators of hand-held power tools	MIL-STD-1472 ANSI S3.18 ISO 2631†

* Society of Automotive Engineers
†International Standards Organization
Adapted from US Department of the Army. *Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process*. Washington, DC: DA; 1991. Army Regulation 40-10, App C: 12–13.

Fig. 6-6. The Lighter, Air Cushion Vehicle, 30-Ton Capacity (LACV-30). The LACV-30 is capable of around-the-clock operations regardless of the weather. It easily transports wheeled and tracked vehicles, containers, and bulk cargo on its 1,660 ft^2 deck. Its maximum payload is 35 tons, cruise speed is 45 mph, and endurance is 8 to 10 hours. U.S. Army transportation units received their first production craft in 1982.

with a turret-mounted 25-mm gun, a 7.62-mm machine gun, and a tube-launched, optically-tracked, wire-guided (TOW) antitank missile launcher (see Figure 6-3). The IFV carries a nine-man infantry squad and a commander, gunner, and driver. The CFV carries a crew of five: the commander, gunner, driver, and two reconnaissance crew members.

HHAs of the BFV identified high steady-state noise levels—due to the design of the suspension and drive system—and impulse noise when the guns were fired. The HHA report recommended that crew members wear double hearing protection, such as the DH-132 CVC Helmet worn with approved ear plugs. The HHA report also recommended that use of the vehicle be limited during training to prevent noise-induced hearing loss.[16]

M-120 Series 120-mm Battalion Mortar System

The M-120 Series 120-mm Battalion Mortar System (BMS-120) is a smoothbore, muzzle-loading, indirect fire system, which consists of the M-120 Towed Mortar, transported by a quarter-ton truck, and the M121 carrier configuration mounted in a modified M113 Armored Personnel Carrier (Figure 6-7).

The BMS-120 generates high-impulse noise levels, and a blast attenuating device (BAD) is used to reduce exposures at crew locations. An HHA report on the BMS-120 recommended that

- firing be limited when a BAD is not installed,
- all personnel within 200 m of the mortar wear ear plugs, and

Fig. 6-7. 120-mm Battalion Mortar System (BMS-120). The BMS-120 provides dismounted (walking alongside) and mechanized infantry units increased range and lethality with high-explosive, illumination, and smoke-screening rounds. Concurrently with the acquisition of the BMS-120, a new family of enhanced ammunition is being developed. This M121 carrier-mounted configuration is shown with a BAD (blast attenuating device) mounted on the muzzle of the mortar.

- the number of rounds fired per 24 hours be limited.[17]

M109 155-mm Howitzer Improvement Program Self-Propelled Howitzer

The M109 Howitzer Improvement Program (HIP) Self-Propelled Howitzer (SPH) is an aluminum-armored, self-propelled, air-transportable field artillery weapons system. It is designed to provide support to armored and mechanized infantry units. The HIP includes many survivability improvements and has a projectile range (increased over previous self-propelled 155-mm howitzers) of up to 30 km with rocket-assisted projectiles (Figure 6-8).

Several HHAs have been completed on the M109

Fig. 6-8. The M109 155-mm Howitzer Improvement Program (HIP) Self-Propelled Howitzer (SPH). The HIP includes a new cannon and mount, an on-board fire-control system, a navigation system, automotive improvements, additional ballistic protection, NBC (nuclear-biological-chemical) protection for the crew, a driver's night-vision device, built-in test equipment, and secure communications. HIP modifications will be applied to all M109 SPHs not converted to M109A4 or M109A5, under the designation M109A6 Paladin, shown above.

HIP SPH. This system generates high levels of steady-state noise. The particular blast overpressure experienced by the crew and resupply vehicle personnel is a function of a series of complex variables such as the type of charge, hatch and vehicle configuration, and quadrant elevation of the gun tube. Thus, the HHA report recommended that

- the crew use hearing protection,
- certain restrictions apply to vehicle and hatch configurations, and
- the number of rounds fired per day be limited, based on the type of projectile and the zone of the charge fired.[18]

Biological Substances

In the broadest sense, the term *biological substance* includes exposure to pathogenic microorganisms and their toxins and enzymes. In the specific sense used in HHAs, biological hazards include sanitation concerns such as waste disposal, food handling, and personal hygiene.[3]

Composting Toilet and Aerated Vault Toilet

The Composting Toilet and the Aerated Vault Toilet technologies are self-contained human waste–disposal systems designed for use at remote training and operational sites to replace chemical and pit latrines (Figure 6-9). The composting toilet is a large chamber into which wastes and organic bulking agents are placed. The Aerated Vault Toilet accomplishes natural aerobic decomposition of waste into humic material through aeration by a series of air channels, baffles, and a fan.

An early HHA of the two technologies recommended appropriate administrative controls and maintenance procedures to minimize harborage and

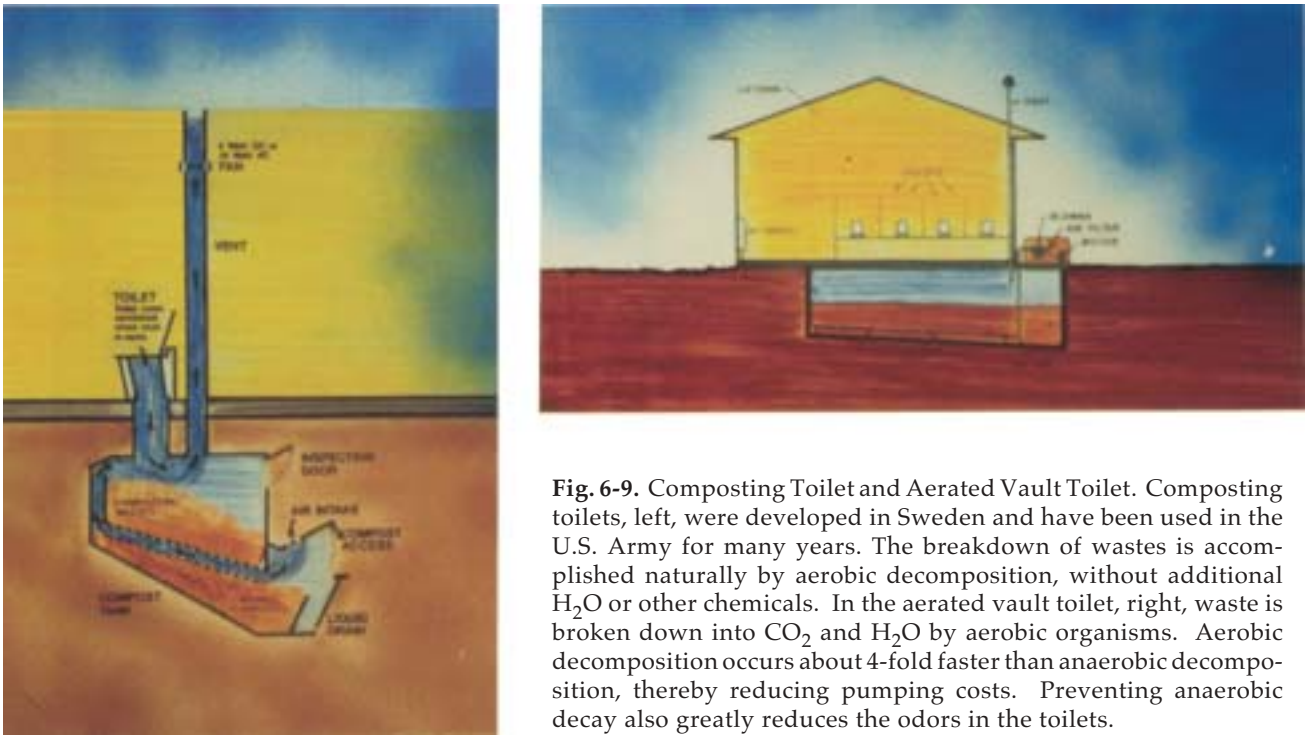

Fig. 6-9. Composting Toilet and Aerated Vault Toilet. Composting toilets, left, were developed in Sweden and have been used in the U.S. Army for many years. The breakdown of wastes is accomplished naturally by aerobic decomposition, without additional H_2O or other chemicals. In the aerated vault toilet, right, waste is broken down into CO_2 and H_2O by aerobic organisms. Aerobic decomposition occurs about 4-fold faster than anaerobic decomposition, thereby reducing pumping costs. Preventing anaerobic decay also greatly reduces the odors in the toilets.

breeding of insect and mammalian vectors of disease (primarily flies and rats), including

- enrollment of compost handlers in the Medical Surveillance Program for Wastewater Treatment Plant Operators, and
- daily cleaning (when in use) of the toilet seats and surrounding surfaces with soap and water.

Additional study of the dissemination of coliform bacteria via aerosols and direct contact was recommended to serve as a paradigm for the spread of these human pathogens.[19]

Resuscitation Fluids Production System

The Resuscitation Fluids Production System (REFLUPS) is a compact, self-contained unit designed to produce 75 L per hour of sterile, pyrogen-free water for injection, and to reduce transport and storage requirements in remote areas. The processed water is mixed with a fluid concentrate to reconstitute a variety of products for intravenous administration. The system will be used for on-site production of intravenous fluids at medical treatment facilities (MTFs) operating in combat zones and aboard naval vessels.

The HHA of the REFLUPS recommended a specific method to evaluate the system's ability to remove viral contamination. In addition, the HHA recommended that each lot of water for injection and reconstituted intravenous fluids be checked for compliance with U.S. Pharmacopeia standards for sterility and pyrogens.[20]

Chemical Substances

Hazards from chemical substances (not only the combustion products from weapons or engines but also other toxic materials) arise from excessive airborne concentrations of mists, gases, vapors, fumes, or particulate matter. Toxic effects may be caused by exposure via inhalation, ingestion, or eye or dermal contact. Hazards may also be caused by exposure to toxic liquids and solids by ingestion or eye or dermal contact.[3]

Avenger

The Avenger, originally called the Pedestal Mounted Stinger, is a component of the Forward Area Air Defense System (FAADS) and is employed in the rear battle area. The Avenger consists of a Stinger missile and a .50-caliber machine gun pedestal, which are turret-mounted on a High-Mobility, Multipurpose, Wheeled Vehicle (HMMWV), M998. The system is used against enemy fixed- and rotary-wing aircraft (Figure 6-10).

An HHA of the system during early developmental testing identified excessive levels of hydrogen chlo-

Fig. 6-10. Avenger Air Defense System. The Avenger enhances the Stinger missile with new capabilities such as shoot on the move, day/night operations, and multiple rapid sequential engagements. Avenger integrates the Stinger missile, a gyrostabilized turret, forward-looking infrared, laser rangefinder, identification of friend or foe, and a .50-caliber machine gun. It is operated either from the vehicle cab or remotely by a crew of two: the driver and the gunner.

ride gas in the HMMWV during certain Stinger missile firings, depending on the angle and direction of firing. The peak exposures of hydrogen chloride were in excess of 300 ppm (the militarily unique standard is now 100 ppm for 10 min). Thus, the materiel developer recommended and adopted engineering controls (such as exhaust deflectors, door and window seals, rigid doors, improved latches, and crew cab reinforcement) to eliminate the performance decrement resulting from acute exposures. The materiel developer also tested to verify that these engineering controls were effective.[21]

This system was redesigned to rectify HHA-identified hazards. It was used in Operation Desert Storm without report of adverse health effects to the soldiers who operated it.

Landing Craft Utility

The Landing Craft Utility-2000 (LCU-2000) class vessels are welded, steel-hulled marine vessels powered by two turbocharged diesel engines (Figure 6-11). The vessels are used for transporting rolling stock and general dry cargo on the ocean and coastal and inland waterways. They are also used for beaching and retraction on undeveloped and remote coastlines, assisting in discharging and backloading ships in a roll-on/roll-off or logistics-over-the-shore (LOTS) operation. The vessel is operated by a crew of 13: 11 enlisted personnel and 2 officers.

An HHA of the LCU-2000 identified a lack of ventilation for the control of toxic gases, fumes, organic vapor solvents, and particulate matter that were generated in the vessel's machine shop during degreasing, welding, soldering, sanding, and grinding operations. Thus, the HHA report provided detailed guidance for designing local exhaust ventilation. The materiel developer subsequently adopted these recommendations.[22]

M43A1 Protective Mask

The M43A1 Protective Mask is intended to be used by crew members operating rotary-winged aircraft and is designed to protect the face, eyes, and respira-

Fig. 6-11. Landing Craft Utility-2000 (LCU-2000). LCU-2000 ships are 174 ft long by 42 ft wide and displace 1,087 tons when fully loaded. Their speed is 12 knots and range is 5,000 miles. The main deck level houses the mess, sick bay, and recreation room. The crew quarters are on the second level; the pilot house is on top. A stern module contains the engine room and associated machinery.

Fig. 6-12. M43A1 Aircraft Chemical-Biological (CB) Mask. The M43A1 mask consists of a form-fitting facepiece with spherical lenses fitted close to the eyes, an integrally attached CB hood and skull-type suspension system (fitted over and suspended from the head), an inhalation-air distribution assembly for regulating air flow to the mouth and nose, lenses and hood assembly, an exhalation valve assembly, an electronic microphone, and a portable motor-blower filter assembly for maintaining overpressure in the mask and hood.

tory system from field concentrations of chemical, biological and riot-control agents (Figure 6-12). The M43A1 was designed to improve the M43 Protective Mask by enhancing both minimum protection and nuclear-biological-chemical (NBC) survivability. In addition, replaceable prescription lenses were an added feature of the M43A1.

A planned product improvement for the mask is a change in the mask's formulation from bromobutyl/natural rubber to correct these deficiencies: (*a*) the faceblank cracks prematurely and (*b*) patch testing revealed a high percentage (1 in 200) of positive skin sensitization reactions among wearers. Civilian industry practice does not accept skin sensitization in excess of 1 in 10,000. Therefore, the HHA report recommended that none of the candidate formulations be used in fabricating rubber articles intended for use where repeated dermal contact is expected. The materiel developer accepted this recommendation and additional research is being done on the faceblank formulations.[23]

Oxygen Deficiency

When atmospheric oxygen is displaced from an enclosed or confined space, or when a system is operated at high altitudes, oxygen concentrations can be decreased below that which is commonly found in ambient air (21% by volume). Reduction of oxygen concentration to approximately 16% causes shortness of breath and impaired coordination and judgment. This condition, hypoxia, can cause visual, mental, and motor impairment and progress to unconsciousness and death.[3]

> When the oxygen level falls to 17 percent (129.2 mm Hg), the first sign of hypoxia, a deterioration of night vision, which is not noticeable until normal oxygen concentrations are restored, may occur. Physiological effects are increased breathing volume and accelerated heartbeat. At 14 percent to 16 percent (106.4–121.6 mm Hg) oxygen, physiological effects such as increased breathing volume, accelerated heartbeat, poor muscular coordination, rapid fatigue, and intermittent respiration may occur. Between 6 percent

Fig. 6-13. Air Defense Antitank System. The ADATS is designed to operate autonomously or to use forward area air defense command, control, and intelligence data, during day or night, in obscurants, in adverse weather, and in battlefield environments where electronic and physical countermeasures are present. The system is operated by a crew of three: driver, gunner, and commander. This program was cancelled in the early 1990s both as a cost-saving measure and because the threat in Europe had changed.

and 10 percent (45.6–78 mm Hg), effects such as nausea, inability to perform, and loss of consciousness may occur. Less than 6 percent oxygen (45.6 mm Hg) results in spasmatic breathing, convulsive movements, and death in minutes.[24(p2)]

Air Defense Antitank System

The Air Defense Antitank System (ADATS) is the Line-of-Sight-Forward Heavy (LOS-F-H) component of the FAADS, designed to operate at or near the front lines (Figure 6-13). The system carries eight ready-to-fire laser beam-rider missiles designed specifically to counter low-level helicopters and fixed-wing aircraft. The crew of three (driver, gunner, and commander) use radar, forward-looking infrared (FLIR), and television sensors to detect, acquire, and identify targets. The missile fire unit is mounted on an armored tracked vehicle, the XM1069, which is a derivation of the M3A2 BFV chassis.

An initial HHA of the ADATS identified two shortcomings in the design of the vehicle's NBC air filtration system, one regarding the amount of filtered breathing air supplied to each crew member, and the other regarding the source of air during the backup mode of operation. These are typical deficiencies in tactical vehicles with ventilated facepieces; they are designed to deliver an average volume of 3 standard cubic feet (standardized for temperature and pressure) per minute of filtered air per person, which is less than the respiratory requirement for physically active crew members (eg, a loader or a gunner). The recycled air from within the vehicle was filtered, but no makeup air was introduced; typical carbon filtration does not filter or remove carbon monoxide. Thus, the HHA report provided the materiel developer with information concerning the minimum quantity of breathing air required, and proper design of the air source.[25]

Bradley Fighting Vehicle with Dual Shot Automatic Fire Extinguishing System

The BFV with Dual Shot Automatic Fire Extinguishing System (AFES) is a proposed product improvement to install two additional 5-pound halon fire extinguishers in the crew compartment. The system will provide the crew and squad compartments with the capability to detect and suppress slow-growth fires and two consecutive, explosive, hydrocarbon fires.

However, the HHA discovered two possible shortcomings of the system: oxygen deficiency and excessive levels of halon (the neat agent itself is toxic). The release of an excessive amount of Halon 1301 (which is the only halon fire-extinguishing agent allowed in crew compartments) into the BFV crew compartment will displace oxygen. Testing of the Dual Shot AFES determined that, under certain circumstances, the National Fire Protection Association's and the OTSG's recommended concentration for Halon 1301 was exceeded at several locations inside the vehicle (Table 6-4). Thus, the HHA report recommended that the combat and materiel developers adopt operating procedures to control exposures to both excessive Halon 1301 and reduced oxygen levels during AFES discharge. The report also recommended that warnings that such events are possible be included in the technical and training manuals for the BFV.[24]

Radiation Energy

Ionizing radiation—alpha and beta particles, gamma and X rays, and neutrons—is sufficiently energetic to strip electrons from molecules. This frees electrons and positive ions, which are then available to interact with other matter. *Nonionizing* radiation—emissions from the electromagnetic spectrum including ultraviolet, visible, infrared, and radio frequencies (including microwave)—has insufficient energy to ionize other molecules. Its biological effect is caused by exciting electrons to higher energy levels, thereby making molecules more chemically reactive. Lasers are a special category of nonionizing radiation technology; they amplify collimated electromagnetic radiation within the nonionizing spectrum.

Improved-Chemical Agent Monitor

The Improved-Chemical Agent Monitor (I-CAM) was originally developed for the United Kingdom's

TABLE 6-4

HALON 1301: RECOMMENDED CONCENTRATIONS AND PERSONNEL EXPOSURE TIMES

Concentration (% by vol)	Permitted Exposure Time (min)
≤ 7	15.0
7–10	1.0
10–15	0.5
> 15	Prevent exposure

Adapted from US Army Environmental Hygiene Agency. *Health Hazard Assessment (HHA) for the A2 Bradley Fighting Vehicle System (BFVS) with Dual Shot Automatic Fire Extinguishing System (AFES).* Aberdeen Proving Ground, Md: USAEHA; 1990. Report 69-37-4776-90.

Fig. 6-14. Improved-Chemical Agent Monitor (I-CAM). The I-CAM detects vapors of chemical agents by sensing molecular ions of specific mobilities and uses timing and microprocessor techniques to reject common battlefield interferences. It consists of a drift tube, signal processor, molecular sieve, membrane, and expendable items such as batteries, confidence testers, and dust filters.

Ministry of Defense. It is a hand-held ion mobility spectrophotometer, used for chemical agent vapor detection (Figure 6-14). The I-CAM contains nickel 63, a beta-particle source, and is used to detect nerve and blister agents on personnel and equipment. The basic CAM has been improved, and maintenance procedures no longer require the removal of the assembly that contains the radioactive source.

The HHA report recommended that control procedures for radiation protection be developed and implemented for personnel who handle the nickel 63, and that specific radiation-safety instructions be incorporated in the I-CAM technical and training manuals.[26]

Enhanced M16A2 Rifle Optical Sight

A daylight optical sighting device is being considered for use on the Enhanced M16A2 Rifle and other weapons. The device will be used for battlefield observation up to 1,000 m, and will permit target engage-

ment by riflemen and gunners up to 600 m. The developer suggested that tritium be used in the sight as a light source and that the sight be optically hardened to protect the user from directed-energy weapons. The HHA of the optical sight recommended, however, that an alternate light source (such as promethium 147) be used because tritium emits a low-energy beta particle that can diffuse out of its encapsulating material and migrate to clean surfaces. It can then permeate the air of storage and use areas and be inhaled or percutaneously absorbed. Tritium also requires elaborate laboratory analytical detection and measurement techniques.[27]

Firefinder Mortar Locating Radar, Block II Program

The Firefinder Mortar Locating Radar (MLR) is a mobile phased-array radar system that is used to detect and locate high-angle-of-fire enemy weapons (mortars, short-range artillery, and rockets), to permit rapid engagement with counterfire. The system consists of an operations control group housed in an S-250 shelter, an antenna/transceiver group (ATG) and two MEP-112A 10-kW diesel generators (Figure 6-15). The Block II Program mounts all three of these subsystems on a pallet for placement on the cargo bed of a standard U.S. Army 5-ton truck to improve mobility, transportability, and emplacement and displacement time.

However, measurements of the radiofrequency (RF) radiation present during operation of the ATG demonstrated that the power density levels (see Chapter 15, Nonionizing Radiation, for a discussion of power density levels) may exceed the permissible exposure levels (PELs). Thus, an initial HHA recommended that personnel be prohibited from performing operations in front of the antenna while the system is radiating. In addition, the report recommended that RF radiation warning signs be placed so they are visible to personnel standing on the ground next to the antenna.[28] The materiel developer subsequently adopted these recommendations.

Fig. 6-15. Firefinder Mortar Locating Radar (MLR), Block II Program. The MLR is deployed close to the forward line of troops with direct support artillery battalions. In fiscal year 1990, the army approved the system's reconfiguration so it could be carried by 1¼-ton capacity HMMWVs (High-Mobility, Multipurpose, Wheeled Vehicle). Future improvements will also include eliminating the S-250 operations shelter, reduced emplacement time, faster access to data, increased program memory and digital map storage, improved throughput and processing, remote operation capability up to 100 m, and better probability of detecting the location of enemy weapons.

Fig. 6-16. Armed OH-58D Kiowa Warrior Scout Helicopter. The OH-58D uses a new drive train consisting of a four-bladed rotor, 650-hp engine and compatible transmission and tail rotor systems. Beginning in fiscal year 1991, the armed version was equipped with air-to-air Stinger missiles. An air-to-ground weapons suite will arm the aircraft with Hellfire missiles, Hydra 70 2.75-in. rockets, and/or a .50-caliber machine gun. The aircraft is operated by a crew of two, has a maximum gross weight of 5,500 pounds, and a maximum level speed of 118 knots.

Observation Helicopter-58D Kiowa Warrior Scout

The OH-58D Kiowa Warrior Scout is an improved, close-combat, aerial-reconnaissance, intelligence-gathering, target-acquisition and -designation surveillance system (Figure 6-16). It is assigned as an aeroscout helicopter for attack helicopter companies and air cavalry companies, and as an aerial observation helicopter for field artillery support sections. A mast-mounted sight (MMS) above the rotor contains a laser rangefinder and target designator (LRF/D).

An HHA of the optical radiation hazards associated with the LRF/D determined that it emits optical radiation in excess of current exposure limits for this specific laser (see Chapter 15). Thus, the HHA report recommended that the developer restrict unprotected personnel from entering the laser beam within 23 km of the laser, and require ground personnel (such as maintenance, test, and training personnel) to use laser eye protection.[29,30]

Shock

AR 40-10 defines shock as the "delivery of a mechanical impulse or impact to an individual transmitted from the acceleration or deceleration of a medium with which he has contact."[3] It is not to be confused with either physiological shock or electrical shock. The opening forces of a parachute harness and the forces delivered to the body as a result of weapon recoil are examples of this kind of shock.

Tactical Assault Personnel Parachute

The Tactical Assault Personnel Parachute (TAPP) is being developed for use in training and combat airborne operations. The design allows for a lower rate of descent to reduce the potential for landing injuries. With the TAPP, the combat jump altitude will be as low as 300 ft above ground level (AGL) and the training jump altitude will be as low as 800 ft AGL.

An initial HHA of the TAPP required the materiel developer to conduct tests to assess the potential health hazards of musculoskeletal trauma resulting from excessive opening forces and impact velocity, and set the criteria for data collection. The HHA recommended that both the current and the improved paratrooper helmets be included in the TAPP test program to evaluate the effect of helmet mass on neck loads during opening shock, and the effect of crushable

foam on reducing deceleration of the head during parachute landing falls.[31]

Temperature Extremes

The human health effects associated with high or low temperatures, possibly in conjunction with high humidity, can be exacerbated by a materiel system. Heat stress can cause heat disorders such as heat-stroke and hyperthermia. Cold-induced disorders include frostbite and hypothermia.[3]

HHAs have addressed the hazards of temperature extremes and humidity associated with the use of several materiel systems. The potential for heat stress is inherent in the use of almost any protective overgarment, particularly a totally encapsulating ensemble such as the Self-Contained Toxic Environment Protective Outfit-Interim (STEPO-I). Similarly, the potential for cold injury is inherent in materiel systems that operate in cold ambient temperatures, such as the Landing Craft Mechanized-8 (LCM-8).

Self-Contained Toxic Environment Protective Outfit-Interim

The STEPO-I is used to provide respiratory and per-cutaneous protection for depot personnel working in highly toxic or oxygen-deficient environments while they process, handle, store, transport, dispose of, or decontaminate chemical agents. Two versions of the STEPO-I have been considered to replace the M-3 Toxicological Agent Protective (TAP) suit. Both consist of a fully encapsulating, impermeable, butyl-rubber–coated, nylon suit fitted with breathing and cooling systems.

An HHA report addressed the heat-stress concerns associated with the suit and recommended the preferential use of one suit and an ice vest when ambient temperatures exceed 80°F. The report also recommended that the materiel developer collect test data to support development of *safe stay-wear times* for both versions of the STEPO-I.[32] The concept of safe stay-wear time seeks to strike a balance between protecting the wearer from both exposure to chemical agents and heat stress. It is generally defined as the length of time that the suit can be worn to provide adequate protection from chemical contamination without compromising the wearer's health due to heat stress.

Landing Craft Mechanized-8 Mod 1, Service Life Extension Program

The Landing Craft Mechanized-8 Mod 1, Service Life Extension Program (LCM-8, SLEP) is a U.S. Navy-

Fig. 6-17. Landing Craft Mechanized-8 (LCM-8) Mod 1, Service Life Extension Program (SLEP). The LCM-8, Mod 1, SLEP is a product-improvement program intended to restore the mission capability and supportability characteristics of the existing fleet and extend its service life by 20 years. The primary modification is the replacement of the old twin Detroit Diesel 6-71 engines with new 12V-71 diesel engines and associated hardware. The army has a fleet of approximately 96 of these vessels assigned to Transportation Medium Boat Companies.

designed, welded-steel, twin-diesel–powered watercraft. It is approximately 73 ft long and capable of carrying 60 tons (Figure 6-17). The vessel is designed to provide water transport to cargo, troops, and vehicles during LOTS, fixed port, shore-to-shore, inland waterway, and amphibious operations. A pilothouse is located aft of the cargo well and the bow is fitted with a hydraulically controlled ramp. The LCM-8 is expected to operate in ambient temperatures as low as –25°F.

An HHA of the LCM-8 identified the potential for cold stress due to the lack of heating to occupied spaces on the vessel. The HHA report recommended that the materiel developer also use engine-cooling water as a source of heat in occupied spaces. The materiel developer modified the LCM-8s used in Alaska to use engine-cooling water as a source of heat in the pilothouse.[33]

Physical Trauma

Trauma to the eyes or body can occur on impact with sharp or blunt objects, and musculoskeletal trauma can occur when heavy objects such as boxes of ammunition are lifted. PPE such as chemical protective masks, eyewear, or helmets are often assessed for their ability to preclude traumatic injuries.[3]

M43A1 Protective Mask

The M43A1 Protective Mask (see Figure 6-12) is designed to protect the face, eyes, and respiratory system from field concentrations of chemical, biological, and riot-control agents. An HHA of the mask was completed during its development (as an improvement to the XM43 Protective Mask). One of the health concerns identified was the effectiveness of the lenses

Fig. 6-18. M163A2 Self-Propelled 20-mm Vulcan Air Defense System (VADS). Major components of the M163A2 VADS include the M168 20-mm cannon, M61A1 director sight, AN/PVS-2 range-only radar, and the M741 chassis. It carries 1,000 ready 20-mm rounds in a linkless feed system.

in providing adequate eye protection. The HHA determined that the lenses afford the same degree of protection against eye injuries that industrial safety eyewear (which meets current national standards) provides from blunt- and sharp-object penetration.[34]

M163A2 Self-Propelled 20-mm Vulcan Air Defense System

The M163A2 Self-Propelled 20-mm Vulcan Air Defense System (VADS) is a lightweight, lightly armored gun system on a full-tracked vehicle, designed to provide air defense against low-altitude threats in forward combat areas (Figure 6-18). It may also be used against stationary or moving ground targets such as personnel, trucks, and lightly armored vehicles. The system is highly mobile and is capable of high-speed operation on improved roads, cross-country travel over rough terrain, and amphibious operation on streams and small lakes. The M168 20-mm cannon is capable of delivering selected rates of fire of 1,000 or 3,000 rounds per minute.

An HHA of the VADS identified a potential for musculoskeletal trauma when crew members lifted heavy boxes of spare ammunition onto the vehicular platform. The HHA report recommended specific ergonomic procedures for lowering the platform to minimize the likelihood of musculoskeletal trauma. The report also recommended that the materiel developer coordinate with the U.S. Army Human Engineering Laboratory for additional work practices and engineering-design modifications to mitigate the lifting hazard.[35]

Vibration

Segmental and whole-body vibration can occur "by contact of a mechanical oscillating surface with the human body."[3] Whole-body vibrations are transmitted through the feet of a standing person, the buttocks of a seated person, or the supported area of a reclining person, and are found in vehicles, vibrating buildings, and in the vicinity of vibrating machinery. Body segments including the head or limbs can also be

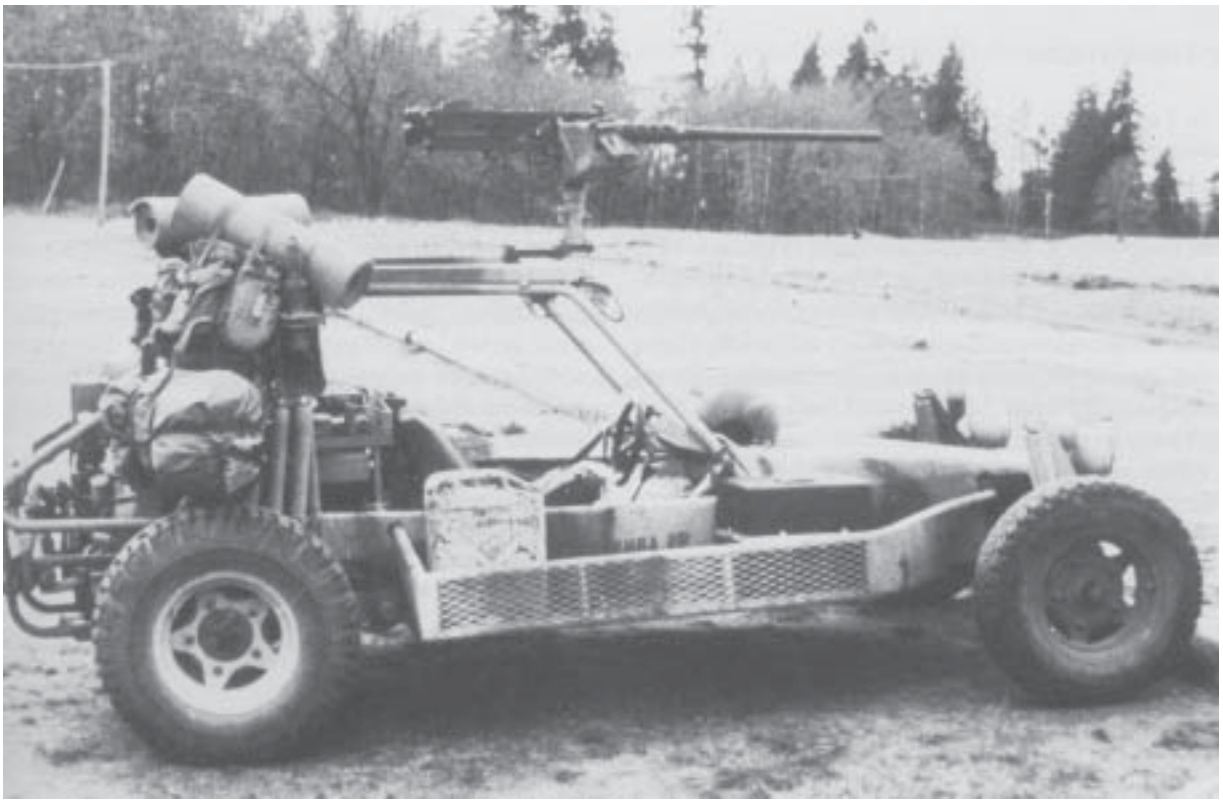

Fig. 6-19. Fast Attack Vehicle (FAV). The FAV is similar to a dune buggy and is used by the U.S. Army's Special Forces units. Although it has limited cargo-carrying and fuel capacity, it was used during Operation Desert Storm and reportedly carried the first coalition forces into Kuwait City.

Fig. 6-20. Counterobstacle Vehicle (COV). The prototype COV pictured here is a highly mobile vehicle capable of clearing and creating major obstacles and emplacements. It is equipped with a combination bulldozer/mineplow and two telescopic arms. The arms are normally used with buckets, but can also accept a hammer, auger, lifting hook, grapple, and other attachments. These attachments enable it to move earth, breach minefields, knock down obstacles, dig defilade positions for armored vehicles, and excavate antitank ditches.

affected by vibrations from handles, pedals, headrests, or a variety of hand-held power tools and appliances.

Fast Attack Vehicle

The Fast Attack Vehicle (FAV) is a maneuverable, lightweight, all-terrain vehicle capable of high-speed, cross-country travel. The FAV serves as a weapons or communications platform for antiarmor, reconnaissance, deep attack, and other missions (Figure 6-19).

During development testing, 50% of the test personnel reported kidney and back injuries that were attributed to excessive levels of whole-body vibration. These injuries were apparently due to inadequate isolation of the vibration through the seats and inadequate shock absorbancy in the vehicles' suspension system. Thus, the HHA recommended that these deficiencies be corrected and that the FAV operators be placed in a medical surveillance program.[36]

Counterobstacle Vehicle

The Counterobstacle Vehicle (COV) is a highly mobile, armored vehicle equipped with a combination bulldozer and mine plow and telescopic arms that are capable of accepting several pieces of modified construction equipment. The original vehicle design was based on the hull and chassis of the M88A1 Recovery Vehicle and was considered as a replacement for the M728 Combat Engineer Vehicle and the M9 Armored Combat Earthmover. The COV will support heavy divisions in the performance of mobility, countermobility, and survivability tasks (Figure 6-20).

An assessment of whole-body test data resulted in recommendations to isolate the crew members' seats from the main vehicle frame by modifying the seats, seat cushions, or both. In lieu of accepting this recommendation, the HHA report advised that, for primary and secondary road surfaces, crew members be restricted to exposure to whole-body vibration for no more than 6.0 continuous hours in any 24-hour period.[37]

The International Standards Organization's (ISO) standards for whole-body vibration are specific to the high frequencies found in heavy equipment. The low frequencies found in wheeled vehicles traversing rough terrain are, however, not considered by this ISO standard. The only definitive evidence of physiological effects of whole-body vibration is the presence of microscopic hematuria. The OTSG has identified the need for a militarily unique whole-body vibration standard, and MRDC is currently conducting research to this end.

SUMMARY

The HHA Program is one of the most militarily relevant applications of occupational health within the preventive medicine arena. Since the formalization of the program in 1983, nearly every weapon and support system developed or procured by the army to assist the soldier in the field has been reviewed for health hazards by AMEDD.

Health hazards are identified, evaluated, and eliminated or controlled through a systematic review and analysis process as materiel progresses through the research, development, and acquisition process. Nine general categories of health hazard exposures have been defined: acoustical energy, biological substances, chemical substances, oxygen deficiency, radiation energy, shock (mechanical impulse or impact), temperature extremes, physical trauma, and vibration.

HHA is one of the principal domains within the army's MANPRINT Program. The health risk to the soldier (as an operator or maintainer of materiel) is evaluated and reduced by a multidisciplinary medical team including industrial hygienists, audiologists, physicists, toxicologists, engineers, biologists, chemists, and occupational medicine physicians.

The HHA Program has paid big dividends to the army's equipment modernization program, but these dividends are difficult to quantify—as they are with most successful preventive medicine programs. Suffice it to say that the recipient of the dividend is the soldier. The one who uses the equipment has every right to expect that the health risks from using military hardware will be reduced to the lowest feasible level. Recent conflicts such as Operation Desert Storm had few or no reported adverse health effects from the use of materiel, which testifies to the success of this AMEDD initiative.

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THEATER HIGH ALTITUDE AREA DEFENSE SYSTEM: INITIAL HEALTH HAZARD ASSESSMENT REPORT

The following HHA report is reproduced in its entirety so that interested readers can more fully appreciate the depth and scope of these investigations. This particular report was selected because (*a*) it demonstrates that one weapon system can expose personnel to several complex health hazards and (*b*) this emerging system could provide air defense support to U.S. military and civilian personnel well into the future.

INITIAL HEALTH HAZARD ASSESSMENT REPORT (RCS MED 388) ON THE THEATER HIGH ALTITUDE AREA DEFENSE SYSTEM 69-37-4847-91 JULY 1991

1. References. A list of references used in this initial health hazard assessment report (IHHAR) is contained in Appendix A. [The references were attached to the original document in the form of an appendix.—*Eds.*]

2. Summary. The Theater High Altitude Area Defense System (THAAD) is an area defense system designed to defeat tactical ballistic missile (TBM) threats directed against military forces and critical assets (e.g., air fields and command centers) and theater strategic targets (e.g., utilities and population, industrial, and government centers). The principal health concerns addressed in this IHHAR are:

a. Chemical substances.

b. Temperature extremes.

c. Oxygen deficiency.

d. Radiofrequency radiation.

e. Acoustical energy.

Assessments and recommendations concerning these issues are addressed in paragraphs 5 and 6, respectively. Additional health hazards may be identified in the future as more information and test data on the THAAD become available. Such information must be provided to support completion of a final health hazard assessment report (HHAR).

3. Background.

a. The THAAD will be a ground launched TBM defense missile system capable of endoatmospheric and exoatmospheric intercepts. The system will complement existing and future air defense systems by extending the TBM defense battle space and coverage beyond that of the PATRIOT Missile System. The THAAD will be fully interoperable with existing air defense forces and organizations. The system is currently in the demonstration/validation phase of a streamlined acquisition process. An Army Systems Acquisition Review Council (ASARC) Milestone Decision Review (MDR) I is scheduled for October 1991. The THAAD program includes plans for the fielding of prototype systems (i.e., a provisional THAAD battalion with two THAAD batteries) to support operational evaluation. The objective of this User Operational Evaluation System (UOES) is to have a deployable national asset with a limited capability to defeat a TBM threat by 4QFY95 (references 1 and 2).

b. The THAAD system design and configuration emphasizes worldwide deployability. The system will be transportable by land, sea, and air (C-130 aircraft) without disassembly of any major component. Assembly at the theater of operations will be limited to routine emplacement activities (e.g., stabilization, erection, cable connection and alignment) (reference 3). The major components of the UOES and objective THAAD systems are similar, but the proposed organization of each is somewhat different due to a limited number of launchers and missiles during the early stages of system development. A UOES THAAD Battery will have one Tactical Operations Center (TOC), one Theater Missile Defense-Ground Based Radar (TMD-GBR), and 12 missile launchers. The objective THAAD Battery will have two TOCs, two TMD-GBRs, and 18 missile launchers. Each type of battery will also have its associated maintenance/support equipment. Air defense artillery personnel, similar to those assigned to the PATRIOT Missile System, will operate and maintain the

THAAD.

(1) Tactical Operations Center. The TOC will be housed in a Standardized Integrated Command Post System (SICPS) rigid walled shelter. The shelter is mounted on a modified M1097 High Mobility Multipurpose Wheeled Vehicle (HMMWV). Standard SICPS features include a 5KW generator, 9000 BTU/hr air conditioner, collective chemical/biological protection, equipment racks, power and signal import/export panels, intercom, and operator seats. The TOC will use common hardware/software being developed by the Army Tactical Command and Control System (ATCCS) and be interoperable with other Army/DoD and allied Air Defense (AD)/C^3I systems (references 3 and 4).

(2) Theater Missile Defense-Ground Based Radar. The TMD-GBR is the primary THAAD sensor/radar system which performs target detection, acquisition, classification, identification, engagement and destruction, and kill assessment functions. It is a phased array radar system which will also provide cueing support to other AD systems (e.g., PATRIOT) and counterfire support by communicating estimated launch points to the command and control network to enhance the detection and destruction of enemy launch facilities (reference 5). The UOES THAAD TMD-GBR will be based upon travelling wave tube (TWT) technology and the objective TMD-GBR will use solid-state technology. Therefore, the radar support equipment used by each of the systems will differ slightly. The UOES system will consist of the radar antenna assembly, array cooling unit (850,000 BTU/hr), a prime power unit (three 500 KW generators), a radar control van/shelter, a high voltage power supply, radar electronics unit, and prime movers. The objective THAAD TMD-GBR will not require a high voltage power supply and radar electronics unit (references 5 and 6).

(3) Missile launchers. Missile launchers will be truck or trailer mounted using standard Army 5-ton trucks. Each hit-to-kill missile will be a certified round contained in a storage/shipping/launch canister (e.g., PATRIOT). The number of missiles/canisters per launcher will be determined by the capacity of the prime mover and C-130 transportability requirements. The missile will be liquid fueled (dinitrogen tetroxide oxidizer and hydrazine propellant) with pressurized/sealed tanks. The launcher will be operated remotely by data-link from the TOC.

c. No previous HHARs have been completed on the THAAD. However, HHARs have been completed on a similar missile system (i.e., Kinetic Energy Anti-Satellite System) and on items which will be used by the THAAD System. These HHARs were reviewed for lessons learned and possible application to the THAAD System (reference 7). Personnel from the U.S. Army Environmental Hygiene Agency's (USAEHA) Health Hazard Assessment Office attended a THAAD MANPRINT Joint Working Group meeting in order to provide health hazard assessment support to the THAAD Program and obtain information on the system (reference 6).

4. Identification of Health Hazard Issues. The following potential health hazards have been identified after reviewing the limited information currently available on the THAAD System. Additional health hazards may be identified as the development of the THAAD System continues and future HHARs are completed on the system.

a. Chemical substances.

(1) Diesel engine exhaust.

(2) Rocket motor propellant and oxidizer.

(3) Fire extinguishing agents.

(4) Nuclear, biological, and chemical (NBC) agents.

(5) Off gassing.

b. Temperature extremes.

(1) Heat stress.

(2) Cold stress.

c. Oxygen deficiency.

d. Radiofrequency radiation.

e. Acoustical energy.

(1) Steady-state noise.

(2) Impulse noise.

5. Assessment of Health Hazard Issues.

a. Chemical substances.

(1) Diesel engine exhaust.

(a) Combustion products from diesel engines include carbon monoxide (CO), oxides of nitrogen (NOx), formaldehyde, acrolein, and sulfur dioxide (SO_2). Carbon monoxide is a chemical asphyxiant which decreases the ability of the blood to carry oxygen to body tissues. High concentrations of CO may be rapidly fatal without producing significant warning properties (reference 8). Oxides of nitrogen are deep lung irritants which produce cough, shortness of breath, and pulmonary edema. Formaldehyde, acrolein, and sulfur dioxide cause skin, eye, and mucous membrane irritation (references 8 and 9). It is also important to note that the National Institute for Occupational Safety and Health (NIOSH) has proposed that diesel engine exhaust and formaldehyde are potentially carcinogenic materials. The NIOSH recommends that personnel exposed to diesel fuel exhaust be informed of this potential hazard and that exposures be reduced to the lowest level feasible (reference 10).

(b) Vehicle engine exhaust. The current host vehicle for the THAAD SICPS, the HMMWV, is powered by a 6.2 liter diesel engine and has a standard exhaust system. Vehicle exhaust concentrations inside the cab are not a problem if the exhaust system is visually inspected as part of the vehicle maintenance program and the integrity of the three piece exhaust system is not compromised. TM-9-2320-298-20 addresses exhaust system maintenance (reference 11). Personnel in the shelters should not be at risk from engine combustion products if vehicle engines are not running when the THAAD system is operational. Design requirements for exhaust systems are contained in MIL-HDBK-759A (reference 12).

(c) Generator engine exhaust. Diesel-fueled generators will provide power to occupied shelters and control vans for the electronics, heat, and air conditioning and other THAAD components. Combustion products from the generators should not be a concern because the generators will be positioned at a distance from the vehicle and the shelters (reference 6). However, a detailed system description and use scenario is required to fully assess this hazard.

(2) Rocket motor propellant and oxidizer.

(a) The THAAD missile is liquid fueled. The propellant is hydrazine, N_2H_4. The oxidizer is dinitrogen tetroxide, N_2O_4 (reference 6). The missiles will be preloaded with the propellant and oxidizer in pressurized sealed tanks (reference 1).

(b) There is a potential for serious exposure to THAAD missile maintenance and operational personnel, and any personnel involved in packaging, storage, handling, and transport of fueled missiles should a leak develop in the pressurized propellant or oxidizer tanks. Both hydrazine and dinitrogen tetroxide are extremely toxic substances (references 13, 14 and 15).

(c) Hydrazine is a suspected human carcinogen and a skin contact hazard. Hydrazine vapors are highly irritating to the eyes, upper respiratory tract, and skin. The liquid is corrosive, producing penetrating burns and severe dermatitis; permanent eye damage and blindness may occur if splashed in the eyes (reference 13).

(d) Dinitrogen tetroxide is a dimer of nitrogen dioxide. When nitrogen dioxide is under pressure, it is converted into dinitrogen tetroxide. When pressure is released the gas released is nitrogen dioxide (references 16 and 17). Nitrogen dioxide is highly toxic. Nitrogen dioxide is a pulmonary irritant. A relatively minor leak could expose personnel to debilitating or possibly fatal levels of NO. Exposure to 100 parts per million (ppm) for one hour can produce debilitating dyspnea or pulmonary edema (reference 17). Exposures of this level could occur if a minor leak developed in the system. However, under normal conditions the rocket propellant and oxidizer are in sealed tanks inside the missile which is stored in a sealed canister.

(e) The current Army adopted maximum exposure levels for hydrazine and nitrogen dioxide are:

Hydrazine			Nitrogen dioxide		
10 min	30	ppm	10 min	5	ppm
30 min	20	ppm	30 min	3	ppm
60 min	2	ppm	60 min	1	ppm
24 hr	0.08	ppm	2 hr	0.5	ppm
			4 hr	0.25	ppm
			8 hr	0.12	ppm
			24 hr	0.1	ppm

These are exposure levels at which Army personnel can continue to function in a military unique operation or emergency situation and be unlikely to suffer irreversible effects. However, a temporary performance decrement may result.

Therefore, these levels must not be used as design standards by materiel developers. Exposures to chemical substances should be controlled to the lowest level feasible in accordance with MIL-STD-1472D (reference 18).

(3) Fire extinguishing agents.

(a) It is expected that an automatic fire extinguishing system (AFES) will be provided for the THAAD to protect both the safety and health of the soldier and the Army's investment in equipment. The documents reviewed for this IHHAR do not address an AFES (references 3, 6, and 19). Therefore, an assessment of the health hazards associated with the AFES cannot be completed at this time.

(b) If an AFES is selected for use in the THAAD and a halon fire extinguishing agent is used, Halon 1301 is the only Office of The Surgeon General (OTSG)-approved halon fire extinguishing agent for use in occupied enclosed spaces (references 20 and 21). Halon 1301 was selected as the most satisfactory and least toxic among 97 agents tested for military vehicle applications (reference 21). Relatively small concentrations of Halon 1301 are required to extinguish fires by inhibiting the chemical reaction of fuel and oxygen (reference 22). The OTSG policy regarding Halon 1301 specifies that the average atmospheric concentration will not exceed 7 percent by volume, and the exposure time for personnel will not exceed 15 minutes. The policy assumes appropriate engineering design to sense the fire and deliver the agent, and to extinguish the fire promptly so that personnel exposures to the Halon 1301 and its toxic pyrolysis products are minimized. Halon 1301 total flooding system design standards may be found in reference 22.

(4) Nuclear, biological, and chemical agents. The SICPS, which houses the TOC, is normally equipped with modular collective protection equipment (MCPE) (reference 4). It is expected that MCPE will be provided for other THAADS shelters (e.g., radar control van) to protect the health of the soldier in an NBC environment. Test data which verify the effectiveness of MCPE are not available. Therefore, MCPE cannot be assessed at this time. Test data must be provided to support a final HHAR on the THAAD MCPE.

(5) Off gassing. The THAAD is required to be capable of storage and operation in extreme temperatures (reference 3). Prolonged storage or use at elevated temperatures could result in the release of gases and vapors from shelter construction materials (e.g., plastics and other synthetic materials). Soldiers occupying THAAD shelters may experience adverse health effects or performance decrement, depending upon the type and concentration of the gases and vapors to which they are exposed. The materiel developer should ensure that only safe construction materials are used in occupied THAAD shelters or vans. Detailed information on such materials is not available. Such information must be provided by the manufacturer to support completion of a final HHAR on the THAAD.

b. Temperature extremes. The THAAD will operate in hot, cold, and basic climatic categories (–50° to 120°F) and in severe cold using arctic kits (reference 3). Therefore, the potential for THAAD operators to experience injury or performance decrements due to exposures to temperature extremes is likely.

(1) Heat stress.

(a) A variety of heat illnesses may occur when personnel are exposed to hot, stressful environments for prolonged periods of time. According to TB MED 507, the commonly reported heat illnesses are heat cramps, heat exhaustion, and heat stroke (reference 23). Equally important is the performance decrement which may occur among THAAD personnel with elevations in core body temperature less than that required to cause heat illness.

(b) In hot / dry or hot / wet environments, the most important mechanism for lowering body core temperature is evaporative cooling. Adequate ventilation will aid in the evaporative cooling of THAAD personnel during hot weather operations. However, the potential for heat stress problems is significantly increased when personnel wear Mission Oriented Protective Posture (MOPP) gear for protection against NBC agents, due to its insulating effects between the wearer's body and the shelter environment (reference 24). Microclimatic cooling is an effective means of cooling personnel wearing MOPP gear.

(c) Reference 25 contains Permissible Heat Exposure Threshold Limit Values (TLVs). The TLVs are based upon the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 100.4°F. Since measurement of deep body temperature is impractical for monitoring workers' heat load, the measurement of environmental factors which most nearly correlate with deep body temperature and other physiological responses to heat is required. At the present time, the Wet Bulb Globe Temperature (WBGT) Index is the simplest and most suitable technique to measure the environmental factors.

(d) The SICPS shelter which houses the TOC for the THAAD system is equipped with a 9000 BTU heater / air conditioner. The cooling efficiency of the air conditioner has not been determined. Neither has a means of cooling the operator if MOPP gear is required to be worn inside the SICPS or other shelters in an NBC environment. Heating, ventilation, and air conditioning requirements in personnel enclosures are contained in MIL-STD-1472D, paragraph 5.8 (reference 18). Additionally, no heating / cooling information is available for the radar control van which is an occupied

shelter. An assessment of potential heat injury to THAAD personnel cannot be completed at this time.

(2) Cold stress.

(a) In cold temperatures, physical and psychological handicaps will be presented to THAAD personnel. In cold weather, personnel efficiency and motivation may be impaired despite the best of cold weather clothing. Personal discomfort increases rapidly as the temperature drops below approximately 10°F. Below 0°F, performance decrement increases rapidly as temperature falls (reference 12).

(b) The type of cold injury produced depends upon the degree of cold to which the body is exposed, the duration of exposure, and certain concurrent environmental factors. Cold injuries may be type-divided into "freezing" (frostbite) and "non-freezing" (trench/immersion foot) (reference 26).

(c) Cold injuries are preventable and successful prevention requires prior planning, cold weather training, and the use of proper clothing and equipment. Specific preventive measures should be directed toward conservation of body heat, avoiding unnecessary or prolonged exposure to cold, moisture, and activities favoring cold injury. Detailed guidance regarding cold injury and its prevention, recognition, and treatment is contained in TB MED 81 (reference 26). The THAAD personnel will be exposed to limited periods of extreme cold since operation of the system will be done from inside shelters and vans. Information addressing the efficiency of shelter heaters is not available and the potential for cold stress injuries cannot be assessed at this time. Heating requirements for personnel shelters are contained in MIL-STD-1472D (reference 18).

c. Oxygen deficiency. Personnel will be working in the THAAD for undetermined lengths of time, and adequate ventilation, as described in MIL-STD-1472D (reference 18), must be provided. Shelter ventilation data are not available. Therefore, it cannot be assessed at this time.

d. Radiofrequency radiation.

(1) Theater Missile Defense-Ground Based Radar.

(a) The TMD-GBR candidate for the THAAD will use a transmitter-amplifier based either on TWT or solid state technology for generating radiofrequency radiation (RFR). The TMD-GBR antenna will be an electronically steerable phased array. This antenna will be able to instantly steer the very narrow main beam anywhere within the ±60° azimuth-elevation cone that is normal to the plane of the array (±60° about boresight) (this is the estimated capability of the system). That cone of instantaneous coverage can also be directed into any azimuth angle around a full circle (360°) by mechanically reorienting the antenna itself. It is unclear at this time what kind of transmission line (waveguide or coax) will be used to interconnect the antenna with the transmitter.

(b) Analysis shows the main beam of the TMD-GBR will be subject to radiation protection control to a range of about 3 km from the face of the antenna. Because of the full azimuth and elevation coverage that is possible for the radar, that range of control probably needs to be applied over the full upper hemisphere of coverage that surrounds the antenna. Analysis also indicates that an extremely high radiating power density level can be expected to a main beam range of about 0.5 km. An extremely high power density level can also be expected in the vicinity of any open or broken waveguide transmission line associated with the transmitter, if waveguide is used.

(c) Modern phased array radars will normally use sophisticated technology to control the direction, sequencing, and total RF power that is directed into any given narrow volume of space at any given time (reference 30). These controls also help to control unwanted irradiation of personnel who are working, or collocated, with the system. Based on the kinds of controls and the detailed mission requirements of the radar, such "built-in" radiation protection could be automatic with the TMD-GBR. If that is the case, the TMD-GBR antenna assembly could possibly be used without concern for control, within 1.4 km of personnel. Some tentative recommendations for control of the system have been made at this time. As the hardware design phase advances, and certainly as soon as an operating model is completed, a comprehensive RFR study and evaluation should be requested from USAEHA in accordance with AR 40-5 (reference 27).

(2) Single Channel Ground-to-Air Radio System (SINCGARS).

(a) Reference 3 specifies the use of the SINCGARS. This radio system utilizes a 50-W average power vehicular transmitter, operating over the 30–80 MHz frequency band, and a manpack radio that operates over the same frequency band at 4.0 W. The output power of the manpack radio is below the threshold for radiation protection control (7.0 W at frequencies less than 1.0 GHz). The antenna for the vehicular radio set is a 3-m whip. Analysis and measurement have shown that the 50-W system is able to produce power densities in excess of 1 mW/cm^2 within 0.7 m of the antenna. This is the PEL for the most restrictive portion of the SINCGARS frequency band. The SINCGARS is, therefore, subject to radiation protection control.

(b) To prevent possible RF shock and burn, personnel should be instructed to avoid contact with the antenna. This shock and burn avoidance procedure normally keeps a person's whole body well outside of the 0.7-m control range,

and as such, constitutes adequate radiation protection for personnel using the SINCGARS.

(3) Joint Tactical Information Distribution System (JTIDS).

(a) Reference 3 specifies that THAAD will interoperate with the JTIDS. The JTIDS utilizes a 200 W peak power transmitter operating over the frequency band of 960-1215 MHz. There is a wide variation in available transmit power and frequency output options, and the option selected is primarily dependent upon the number of users and amount of data flow at a given time. A maximum transmitter duty cycle of 0.1 is normally estimated for the JTIDS, based upon all factors being at worst case. A 0.1 duty cycle results in a maximum average power output of 20 W.

(b) A 6- or 9-dBi gain omnidirectional antenna is used with the system. The selected antenna will be mounted either on the roof of the communication shelter or on top of a telescoping 10-m mast. The radiation element of either antenna is about 1-m long and 3 cm in diameter. The JTIDS will produce power density levels in excess of 10 mW/cm^2 to a range of 30 cm from either antenna. The only practical RFR threat comes from possible RF-shock or burn produced by touching the antenna during transmission.

(c) Personnel will not normally be within the control range of the antenna. However, where contact with the antenna is possible, RF shock and burn are a threat and personnel are instructed to avoid contact with the antenna. This shock and burn avoidance procedure normally keeps a person's whole body well outside of the 30 cm control range and, as such, constitutes adequate radiation protection for personnel using the JTIDS.

(4) Joint Surveillance and Target Acquisition Radar System (JSTARS).

(a) Reference 3 specifies that THAAD will interoperate with the JSTARS. This system serves as a data link transceiver which receives and processes near-real time radar target information about enemy follow-on forces. Two types of RFR sources are used with JSTARS: the Surveillance Control Data Link (SCDL) and the AN/VRC-46 radio.

(b) The SCDL is a wide-band data link operating in the Ku frequency band. The SCDL has the capability of transmitting in an uplink mode with an on-time duration of approximately 25 msec. Computer default settings limit the uplink transmission repetition-rate to once every 600 msec. This low on-time and repetition-rate constitute a very low duty cycle and resultant low average output power. The SCDL utilizes a radome-covered directional antenna which can be mounted either on a mast on top of the shelter or on a 1-m tripod on the ground. Actual transmitter power output and antenna gain values are classified.

(c) Power density levels can be emitted in the beam of the antenna for very short periods of time. However due to the extremely low duty cycle of the transmitter, the maximum average power density level is much lower than the 10 mW/cm2 PEL. The SCDL is not subject to radiation protection control.

(d) The AN/VRC-46 Radio is used for disseminating battlefield intelligence to appropriate users. These radios operate in the 30–88 MHz frequency band at a maximum power output of 35 W. The 3-m whip antennas used with these radios are mounted on the communications shelter roof. Power density levels exceeding the PEL of 1 mW/cm^2 (most conservative PEL in this band) can exist to a distance of 0.7 m from either antenna when the transmitter operates at maximum power output. The only practical RFR threat comes from possible RF-shock or burn produced by touching the antenna during transmission.

e. Acoustical energy.

(1) Steady-state noise.

(a) A steady-state noise level of 85 dBA or greater is considered hazardous (references 27 and 31). This limit assumes no more than 8 hours per day of high noise levels. For exposure exceeding 8 hours per day, noise levels below 85 dBA may be hazardous (reference 31). Prolonged unprotected exposure to hazardous noise levels will cause loss of hearing.

(b) The principal steady-state noise sources on the THAAD are expected to be generators, trucks, MCPE, and winch drive motors.

(c) Steady-state noise data at the operator's position and around the THAAD are not available; therefore, assessment of this issue is not possible. Steady-state noise associated with the THAAD must be collected in accordance with MIL-STD-1474C (reference 32) to support an assessment of this issue.

(d) The recommended design limit for steady-state noise is MIL-STD-1474C Category D (85 dBA). It should be noted that for clarity in communications (speech intelligibility), Category E or F may be appropriate (reference 32).

(2) Impulse noise.

(a) An impulse noise in excess of 140 dBP is considered hazardous (references 27 and 31). Repeated, unprotected exposure to hazardous impulse noise will cause permanent hearing loss. Exposure to impulse noise levels in excess of Curve Z, MIL-STD-1474C (reference 32), even when wearing hearing protective devices (HPDs), is considered

hazardous for hearing conservation purposes.

(b) The potential sources of impulse noise on the THAAD are the rocket launcher and the AFES.

(c) MIL-STD-1474C, Figure 10 (reference 32) lists design limits for exposure of personnel wearing HPD's in terms of level, B-duration, and number of exposure per 24 hours.

(d) Certain AFES designs produce high impulse noise levels on activation. The noise source is the sudden release of the pressurized (750 psi) halon through the valve and nozzle. The noise level at any location in the shelter will vary according to the distance and angle from the nozzle.

(e) If the AFES currently used on Army tactical vehicles is employed on the THAAD, then existing data may be adequate to evaluate this impulse noise hazard. This would entail the analysis of the present AFES data (references 33, 34, and 35) using the distances within the THAAD from nozzle locations to personnel positions.

(f) Impulse noise data at the THAAD operator's position and maintenance personnel locations are not available; therefore, assessment of this issue is not possible. Impulse noise associated with the THAAD must be collected in accordance with MIL-STD-1474C (reference 32) to support an assessment of this issue.

6. Recommendations.

a. Chemical substances.

(1) Diesel fuel exhaust.

(a) Ensure that the design and purchase specifications for the final configuration of THAAD require airborne concentrations of toxic substances, no matter what the source (e.g., vehicle and electric generator exhaust), inside occupied spaces, vehicle cabs, refrigeration and radar control areas and shelters to be controlled to the lowest level feasible and not to exceed current Army adopted exposure limits in accordance with MIL-STD-1472D (reference 18) and AR 40-5 (reference 27). Compliance with these requirements must be followed during all operational modes including extreme low temperature startup. Additionally, provide information as to the use of supplemental heaters for vehicle cabs, engine blocks and batteries. No risk assessment code (RAC) can be assigned at this time.

(b) Ensure that the final configuration of the THAAD positions sources of airborne contaminants (e.g., vehicles, generators and other engine exhaust) as far away from occupied shelter heater, air conditioning, ventilation and NBC filter system air inlets as possible in accordance with MIL-HDBK-759A (reference 12). No RAC can be assigned at this time.

(c) Provide a detailed system description and use/training scenarios for the final THAAD configuration to support completion of a final HHAR. No RAC can be assigned at this time.

(2) Rocket motor propellant and oxidizer. No recommendations are necessary.

(3) Fire extinguishing agents.

(a) Ensure that the design and purchase specifications for the final configuration of the THAAD AFES, if used, includes the current OTSG policy (i.e., the average concentration of Halon 1301 will not exceed 7 percent by volume, and the exposure time for personnel will not exceed 15 minutes). A RAC of 2 [Hazard Severity (HS) II, Hazard Probability (HP) C] is assigned for failure to comply.

(b) Provide detailed AFES design information, if used, for the final THAAD configuration to support completion of a final HHAR. The information should include the fire extinguishing agent concentration inside shelters following AFES discharge and the location of discharge nozzles. No RAC can be assigned at this time.

(4) Nuclear, biological, and chemical agents.

(a) Ensure that the MCPE incorporated into the THAAD is effective in providing an acceptable level of NBC protection to personnel inside occupied spaces/shelters. No RAC can be assigned at this time.

(b) Collect test data which measure the effectiveness of the THAAD MCPE to provide an acceptable level of NBC protection to personnel inside occupied spaces/shelters. Test data should include that data collected during challenges with ambient concentrations of chemical agent (or a suitable simulant) anticipated on a chemical battlefield during typical THAAD operations. Such data must be provided on the final configuration of THAAD to support completion of a final HHAR. No RAC can be assigned at this time.

(5) Off gassing.

(a) Ensure that THAAD design and purchase specifications require shelter and/or control van construction materials which will not release hazardous gases and vapors during prolonged storage or use at high temperatures. No RAC

can be assigned at this time.

(b) Obtain a detailed list of THAAD shelter and/or control van construction materials and associated manufacturers material safety data sheets to support the completion of a final HHAR. No RAC can be assigned at this time.

b. Temperature extremes.

(1) Ensure that the design and purchase specifications for the final configuration of THAAD incorporates the heating and air conditioning requirements for occupied shelters contained in MIL-STD-1472D (reference 18). No RAC can be assigned at this time.

(2) Provide microclimatic cooling for THAAD personnel if MCPE is not included in the final configuration of the system or personnel are required to wear MOPP gear in shelters in an NBC environment. Comply with the cooling requirements for such systems contained in MIL-STD-1472D (reference 18). No RAC can be assigned at this time.

(3) Collect test data which measures the effectiveness of the THAAD heating and air conditioning systems to meet the heating and cooling requirements contained in MIL-STD-1472D (reference 18). Test data should include that data collected during challenges at the upper and lower temperature extremes of the THAAD design operating temperature range. Such data and detailed heating and cooling system design information must be provided on the final configuration of THAAD to support completion of a final HHAR. No RAC can be assigned at this time.

c. Oxygen deficiency.

(1) Ensure that the design and purchase specifications for the final configuration of THAAD incorporates the ventilation requirements for occupied shelters contained in MIL-STD-1472D (reference 18). No RAC can be assigned at this time.

(2) Collect test data which measures the effectiveness of the THAAD ventilation system to meet or exceed the ventilation requirements contained in MIL-STD-1472D (reference 18). Such data and detailed ventilation system design information must be provided on the final configuration of THAAD to support completion of a final HHAR. No RAC can be assigned at this time.

d. Radiofrequency radiation.

(1) Theater Missile Defense-Ground Based Radar. Exclude personnel from the main-beam region of the antenna. Automatic control of the beam direction and intensity (with selectable or variable features) should be specified/designed into the system. A warning light should be used on the antenna assembly to warn personnel not to approach the antenna when the antenna is transmitting. To prevent personnel from entering the radiation control area, RFR warning signs should be placed along any routes into the area. The range of control should be specified as 0.5, 1.4, or 3.0 km, or more, depending upon the automatic controls, mission requirements, etc., that finally are specified for the system. A RAC of 2 (HS II, HP C) is assigned for failure to comply (this RAC applies only within the 1.4-km range). The hazard severity moves to III between 1.4 and 3.0 km, with higher RAC. A RAC of 3 (HS III, HP C) is assigned for failure to comply (between a range of 1.4 to 3.0 km).

(2) The following specific recommendations also apply to the TMD-GBR and affect the design and use of the system. A RAC of 2 (HS II, HP C) is assigned for failure to comply.

(a) Maintain maximum control of all areas that could result in exposure to greater than 5-times the PEL.

(b) The antenna assembly area should be located where operating personnel are not potentially exposed to the radiating field within a range of 1.4 km (required) and 3.0 km (ideally).

(c) All waveguide should be interlocked to prevent operation of the transmitter without all waveguide in place and in good operating condition.

(3) SINCGARS, JTIDS, JSTARS. Warn personnel to avoid physical contact with the vehicular antennas of these radio sets. A RAC of 5 (HS IV, HP C) is assigned for failure to comply.

e. Acoustical energy.

(1) Steady-state noise.

(a) Use Category D, MIL-STD-1474C, (<85 dBA) as the design goal for THAAD steady-state noise at normal operator positions. No RAC is required.

(b) Measure the steady-state noise levels associated with the THAAD at the operator's position, as outlined in MIL-STD-1474C (reference 32), and provide a training scenario. No RAC can be assigned at this time.

(2) Impulse noise.

(a) Use 140 dBP, Curve W, MIL-STD-1474C, as the initial design goal. If the 140 dBP level is unattainable, then use the applicable limits for personnel using HPD's. No RAC can be assigned at this time.

(b) If the AFES used in Army tactical vehicles is employed on the THAAD, measure the distances from the nozzle locations to the personnel positions, and provide a training scenario. No RAC can be assigned at this time.

(c) If the AFES currently in use on tactical vehicles is not used on the THAAD, then measure the noise levels associated with the THAAD AFES at the operator positions, as outlined in MIL-STD-1474C (reference 32), and provide a training scenario. No RAC can be assigned at this time.

7. Preparer Identification. This IHHAR was completed by the USAEHA, Aberdeen Proving Ground, MD 21010-5422, July 1991. The point of contact in the Directorate of Occupational and Environmental Health is the Health Hazard Assessment Office, DSN 584-2925.

APPENDIX A

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