CHAPTER V

HAZARD PROTECTION AND PERFORMANCE EFFECTIVENESS

A. Introduction

I. Hazard Protection

The environment of the fighting man is often markedly different from that of normal civilian life. The historical hazards of battle - the missiles, flame, and projectiles of the enemy - are only some of the unique hazards faced by military personnel. The climate and terrain pose significant threats to health and operational capability - desert heat, arctic cold, and high altitude have always caused significant casualties. The development of new weapons in the past few decades exposes men to lasers, nuclear radiation, and microwaves; in some of these areas, the danger can come from one's own weapon systems (radar, laser rangefinders) as well as from the enemy (nuclear weapons).

The development of faster aircraft and armored vehicles, of surface effect ships and other fighting and transporting machines has exposed the human operator or passenger to acceleration, impact, noise, vibration and other physical forces - often presented at the limits of human tolerance. Finally, the military environment contains many toxic materials and products ranging from chemical warfare weapons to exhaust gases and ammunition fumes as well as military materials which must be assayed for their toxic hazards. Where possible protection must be provided against such toxic agents.

There is an overall strategy to the approach to these hazards. The physical characteristics of the threat or agent must be described - this is usually done by the physical sciences. Then the qualitative and quantitative biological responses to the range or spectrum of the hazard - pressure, temperature, force, concentration - are described in terms of deleterious and non-deleterious effects. Where appropriate, safety limits are set or special protective clothing or equipment provided. The development of prophylactic or adaptive measures is attempted. When required - as in decompression sickness or climatic injury - special treatment methods are worked out for the illnesses or traumatic injuries that result from exposure to a hazard.

The work described in this chapter differs importantly from that discussed in Chapters III and IV. For most of the hazards described, effective treatment does not yet exist. The present and near future work is mainly aimed at describing effects and determing human tolerance so as to set safety limits. An important aspect has to do with predicting the effects - of high G for example - so that weapons and systems designers can integrate the man into a man-machine complex. Effects and responses are defined not only in biological terms, but any adverse changes in military job performance - i.e., in hot climates - are quantitated for the use of operational planners and military staff officers who are estimating strategic and tactical deployment of units. Finally, much of the application of this research is done as interdisciplinary work by teams of biomedical scientists, engineers and physical scientists.

Hazard protection is studied in four major areas: (1) extreme climatic and systems environments; (2) radiation hazards; (3) mechanical force environments; and (4) toxic threats.

II. Performance Effectiveness

The capabilities and limitations of human performance are critical contributers to the design and function of modern weapons systems. Human sensory, perceptual and cognitive abilities are major components of systems for command, control, pattern recognition, decision making, and information processing.

This group of biomedical disciplines and programs is focused on providing human engineering criteria - special senses performance, physical anthropology, human reliability, and assays of the man-machine-environment interactions. Some research is aimed at maximizing human performance, while other work is directed to selection criteria, nutrition, quarters habitability, and such problems as isolation and crowding insofar as these degrade or can be changed to enhance the performance of individuals and crews.

Finally, the DoD must deliver medical care to its people. For those aspects of preventive or therapeutic medicine that are not common to regular medical practice the DoD must do the research to provide its practitioners with the tools and data for effective care. Thus, the DoD has research programs in aviation, submarine, and field medicine aimed at treating patients or preventing disease and injury in these highly specialized military operational environments.

Performance effectiveness is studied in three major areas: (1) human engineering criteria; (2) nutrition; and (3) specialized military medical practice.

Special Aspects

When compared to the more classic work in medicine and surgery described in Chapters III and IV, the research in this chapter is very expensive. The very special research equipment - altitude and pressure chambers, human centrifuges and acceleration sleds, nuclear and microwave energy generators, toxicology and climatic chambers and rooms - are all costly, often one-of-a-kind, and must be over-engineered to be safe when man-rated. The type of research often requires continuous exposure of test subjects on animals for days or weeks - this markedly increases the civilian salary overtime costs for night and weekend shifts. Finally, some of this equipment can only be installed in specially constructed buildings.

B. Extreme Climatic and Systems Environments

I. The Problems

The impacts of heat, cold and work stress have a profound military effect in all three Services. Troops cannot be committed to active combat for several weeks after arriving in desert or tropical climates without at least a fifty percent loss of performance capacity. Some aircraft operations expose personnel to extreme pulses of heat. Sailors stand watches before boilers in compartment temperatures of 160°F or soaked with seawater in freezing winds. The 91,000 cases of cold injury and frostbite in WW II - all in Europe - define the magnitude of the problem facing the Army. Air Force cold exposure is frequently brief, sudden and intense and follows equipment failure. "Work" in the military ergonomics sense means the individual and collective strength and endurance of a military force - the ability of soldiers and Marines to march, carry loads and be physically ready to engage the enemy.

[illegible] effectiveness in the rarefied air of high terrestrial [illegible] by acute mountain sickness (AMS), high altitude [illegible] (HAPE), reduced capability for physical work, and [illegible]. Above 14,000 feet, one quarter to one half [illegible] will have acute mountain sickness and all will [illegible] physical work. The pilot closing on a target [illegible] altitudes up to 12 miles must use oxygen [illegible] in his environment - he cannot adapt, as [illegible] warfare must. The rate of climb of some high performance aircraft may also generate bubbles in an unprotected pilot's blood.

Work	Goals	Years to Goals
Develop vibration effects envelopes and predictions; develop vibration allevia-tion techniques and equip-ment (Army, Navy, Air Force)	Design criteria for protection and pre-vention of performance loss	6-8
Develop biological and electronic criteria to eliminate noise in radio communications; develop predictive data for sonic and environmental im-pacts of military noise producers; develop predictive criteria for signal recognition in high noise environments (Army, Navy, Air Force)	Distortion free radio communication; de-creased environmental noise pollution, improve community acceptance; systems design criteria (radio, sonar)	8-10

III. Five-Year Resources Plan

Funds ($ in K)	FY 72	FY 73	FY 74	FY 75	FY 76
Army	1000	1304	1273	1352	1352
Navy	2013	2553	2696	2696	2696
Air Force	5291	5786	6021	6352	6681

D. Radiation Environments

I. The Problem

The advent of nuclear weapons, the development of high powered electromagnetic radiation sources, and the invention of laser systems, has resulted in a new and unique radiation environment which permeates the entire world. This radiation exposure has no counterpart in man's evolutionary background and was relatively negligible prior to World War II. The growth in electromagnetic radiation sources has been phenomenal and is continuing at an unprecedented rate. Each one of these areas has unique and distinct military uses and has become an essential part of military operations and contingency plans. Each is known to produce adverse biological effects when man is exposed to sufficient doses: with ionizing radiation, cancer, acute radiation sickness and death are well known effects; lasers induce temporary and permanent blindness; while electromagnetic radiation has been shown to cause cataracts and tissue damage.

The major medical problems of ionizing radiation are the assessment of biological interactions affecting mission success (performance decrement, survivability, vulnerability) and the development of methods for the protection and treatment of exposed military personnel.

The eye, because of its ability to concentrate visible light, is highly vulnerable to the damaging effects of laser radiation. At higher energy levels the skin and other organs are also subject to biological damage.

There is an almost complete lack of definitive scientific data on the biological and behavioral effects of moderate and low level exposure to electromagnetic radiation. Little or nothing is known about the interaction between the electromagnetic field and the cellular constituents of the body. Appropriate safety levels are needed because exposure limits define the cost of military equipment and/or its application to national defense needs. For example, the present DoD microwave safety limit is $10mW/cm^2$ and 9 acres are required for Hawk radar site safe area. If the limit went to 1 mW (an HEW standard for some uses), 82 acres would be needed, and if it were 0.01 mW (Russion limit), 6,656 acres would be required.

Ionizing radiation (particulate, gamma, x-rays) research is done by the Air Force (survivability/vulnerability analysis) and the Army (development of chemoprophylactic drugs). By far the largest program on nuclear weapons radiobiological effects is done by the Defense Atomic Support Agency at its laboratory, the Armed Forces Radiobiology Research Institute. There is no DoD program investigating treatment of radiation casualties. At the present time treatment of radiation injury is limited to nonspecific resuscitation and support measures and clinical management in the severe immune suppressed state. General research problem areas include bacterial infections, patient isolation techniques (laminar flow isolation technology), immunological response mechanisms, transfusion, and tissue (bone marrow) and organ transplantation acceptance or rejection. These research problem areas are currently under viguous investigation in the civilian medical community with support based on non-military application. A military program at this time should be oriented toward field applications for mass casualty care.

Laser research is mainly devoted to defining safety limits and criteria for protective devices; each service's program is related to the specific operational or research lasers planned for operational use.

Non-ionizing (microwaves to extra low frequency) radiation programs are new and are vitally needed to provide both operational safety data and environmental protection. The services have divided up the frequency spectrum so that the Air Force program looks at the 3 to 300 MHz range, the Army at 300 to 3,000 MHz and the Navy at less than 3 and more than 3,000 MHz. These frequency selections are related to the present and planned operational equipment in each service.

II. The Program

A. Present

Work	Goals	FY 71 Costs $ in K	Years to Goal
1. Ionizing Radiation			
ARMY: Develop prophylactic drug with a dose reduction factor of 2-3	Reduce casualty number and severity by reducing biological effects of a given dose of nuclear radiation.	674	4-6
AIR FORCE: Define, acquire ability to predict survivability vulnerability to radiation in terms of mission completion capability for the man-system combination.	Develop quantitative crew vulnerability models for new and existing AF systems (F-106, B-52, B-1 - examples). Provide criteria for balanced hardening against nuclear weapons.	750	5-10

Work	Goals	FY 71 Costs $ in K	Years to Goal
2. Non-Coherent Light (ultraviolet, visible, infrared)			
ARMY: Define risk criteria and degradation of visual performance for troops using non-coherent light sources.	Provide safe and improved operation high power visible and near IR searchlights and night vision devices.	150	5-8
NAVY: Support research for optical systems.	Safe, more effective optical systems	50	3-5
AIR FORCE: Define and predict effect of intense light flashes on visual performance of aircrews, provide protection where needed.	Criteria for mission planning and improved operational capability, define nuclear vulnerability for aircrews.	121	3-4
3. Coherent Light (Lasers)			
ARMY: Define risk criteria of Army laser systems. Determine pathology of damage, criteria for protective systems, measurement devices.	Avoidance of injury from laser systems; data for operational planners.	460	5-8
NAVY: Risk criteria for Navy systems. Effects on visual performance. Underwater laser effects.	Safe operation of laser equipment. Better protective equipment.	100	5-8
AIR FORCE: Develop data for AF safety regulation. Assess risks of AF systems. Develop criteria for better protective equipment.	Criteria for safe eye exposure. Better operational safety equipment, methods.	625	5-8

Non-Ionizing Radiation (microwave, radiofrequency, low-frequency)

ARMY: Develop animal models for injury, performance alterations. CNS neurochemistry, low-level chronic exposure, modulation esp. microwave, dosimetry.	Define biological effects of microwave military personnel.	325	5-8
NAVY: Animal models to assess human and ecological effects. Eye, solid organ injury, biophysical interactions; low frequency systems; physiologic responses	Define effects on personnel and ecology of military systems. Provide data for environmental impact statement.	900	5-8
AIR FORCE: Assessment of safety of AF systems. Interaction with medical equipment. Animal models for safety.	Assure continued safety of radar, communication, guidance, navigational systems.	337	5-8

B. Future

Work	Goals	Years to Goal
Develop laser protective devices for eyes; specific therapy for laser damage to eyes, skin, CNS, gonads. (Army, Navy, Air Force)	Protection; treatment	15-20
Develop eye protective devices and/or clothing for non-ionizing radiation (Army, Air Force)	Protection; injury prevention	15-18

III. Five Year Resources Plan

Funds ($ in K)	FY 72	FY 73	FY 74	FY 75	FY 76
Army	1580	2858	2861	2879	2879
Navy	1874	2276	2212	2186	2164
Air Force	2104	2158	2133	2185	2299

IV. Potential New Initiative

The DoD is the largest national user of electromagnetic radiation devices--high frequency radars, electronic countermeasure devices, communication systems, etc. The present knowledge of the biological and psychological effects and hazards from non-ionizing radiation is extremely limited and primarily due to the small DoD program. The required safety limits and protective doctrines and devices are not available. The recent concern with environmental pollution only adds to the need for biomedical data about both acute and long-term (genetic, carcinogenic) effects of non-ionizing radiation on military personnel.

There is early evidence that there may be biological effects at low levels of exposure. Additional effort will be required to study the biological effects of various frequencies, as many effects appear to be frequency specific. One of the major programs should be in the development of adequate dosimetric instrumentation to measure tissue absorbed doses in the laboratory and field. Studies should begin on a prolonged prospective study of military personnel exposed to nonionizing radiation under operational conditions. Animal model systems are needed for the evaluation of pertinent human data and the application of results to operational systems.

There is a lack of sufficient laboratory source generators, of dosimetry techniques, and of trained people. A responsive 5-8 year program is estimated to cost:

Army	-	$ 800K/year
Navy	-	$ 1000K/year
Air Force	-	$ 500K/year

E. Toxicology and Pollution

I. The Problems

The DoD can be regarded as the largest industrial operation in the United States, using and producing large quantitities of toxic chemicals and materials. For many new chemicals there is little available toxicological information. Military personnel are knowingly or unknowingly being exposed to toxic hazards while performing routine or special duties in the field, on an installation, or in combat. The research problem is to protect personnel from harmful chemical exposure which leads to toxic effects and results in death or injury.

There are Service specific requirements for atmospheric contaminants detection in aircraft, submarines, and armored vehicles, which must consider such things as fire extinguishing agents, fuel