United States Air Force
Scientific Advisory Board

Report on

United States Air Force Expeditionary Forces

Volume 3: Appendix I

SAB-TR-97-01

February 1998

Authorized for Public Release

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ABSTRACT (Maximum 200 Words)

This study was produced by the Air Force Scientific Advisory Board (SAB). It was requested and approved by both the Secretary and Chief of Staff of the Air Force. It summarizes the deliberations and conclusions of the study committee on providing an overall picture of the SAB concept for Aerospace Expeditionary Forces.

Aerospace Expeditionary Forces (AEFs) are defined to be "tailorable and rapidly employable air and space assets that provide the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations." Volume 1 presents an overall picture of the AEF concept. Volume 2 details the deliberations and conclusions of the following study panels: Operational Context and Training; Command, Control and Information; Technology Thrusts; and Lean Logistics. This volume, Volume 3, provides detailed deliberations and conclusions of the Environment Panel.

14. SUBJECT TERMS
Aerospace Expeditionary Forces, Air Expeditionary Forces, AEF, Force Protection, Conventional Weapons, Lasers, Chemical Weapons, Biological Weapons, Fatigue, Infectious Disease and Injury, Night Vision Equipment, Radiofrequency Radiation, Ionizing Radiation, Terrorists, Toxic Agents, Dangerous Flora and Fauna, Weather and Climate.

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Executive Summary

This report consists of three Volumes. Volume 1 is the Summary Volume of the report. Volume 2 contains Appendices E–H, and Volume 3 contains Appendix I. The Appendices are titled as follows:

Appendix E: Operational Context and Training

Appendix F: Command, Control, and Information

Appendix G: Technology Thrusts

Appendix H: Lean Sustainment

Appendix I: Environment (Biological, Chemical, and Force Protection)

Environment (Biological, Chemical, and Force Protection): Volume 3, Appendix I

Force protection is the detection, warning, defeat, and/or delay of threats and mitigation of the effects of threats on mission performance. Threats include enemy (terrorist, special purpose and guerrilla force, and small tactical group) operations (kidnapping, standoff, and penetration attack), weapons (biological, chemical, conventional, laser, nuclear, and radiofrequency), naturally occurring phenomena (dangerous flora and fauna, fatigue, high elevation, hunger, infectious disease, night, low-level radiation, thirst, and weather), and occupational hazards (fire, hazardous waste, injury, and toxic agents). The current and future countermeasures for these threats as well as the responsible parties, relevant references, and points of contact are presented in Volume 3, Aerospace Expeditionary Force Environmental Threats and Force Protection. A general introduction and glossary of terms are also provided in Volume 3.

Overview of AEF Environmental Threats and Force Protection

Section Number	Title
1.0	Introduction
2.0	Terrorists
3.0	Biological Weapons
4.0	Chemical Weapons
5.0	Toxic Agents
6.0	Conventional Weapons
7.0	Lasers
8.0	Ionizing Radiation
9.0	Radiofrequency Radiation
10.0	Dangerous Flora and Fauna
11.0	Fatigue
12.0	Infectious Disease and Injury
13.0	Night
14.0	Weather and Climate
15.0	Glossary

Threats, findings, and countermeasures are summarized in the following table. More detailed descriptions are presented in this volume.

Threat	Findings	Recommendations
Biological weapons	The North Atlantic Treaty Organization (NATO) did not share data on biological threats during Desert Storm.	Sharing of these data should be negotiated.
Biological weapons	Harvest Falcon water-purification systems have been deployed incorrectly, with disease resulting. Furthermore, these systems test only for ecolae.	Provide training for proper deployment and expand water testing to known toxins.
Biological weapons	Biological agents can be backflushed into the drinking water.	Develop backflow prevention.
Biological weapons	Environmental surveillance is neither coordinated nor efficient.	Coordinate environmental surveillance.
Biological weapons	Biological, chemical, and radiological detectors are "ad hoc, reactive, duplicative, disruptive, and not truly joint."	Biological, chemical, and radiological detectors should be integrated with each other as well as with the command and control (C^2) system; their warnings should be unique and associated with one set of actions (e.g., don protective gear and egress contaminated area) and should be joint.
Biological weapons	Anyone can bring chem/bio/conventional weapons on base.	No non–Air Force (or joint force) personnel should be allowed on an AEF base unattended; these personnel include truck drivers, maintenance personnel, and food handlers.
Biological weapons	Perimeters are too close to provide chem/bio protection.	Use larger secure perimeters.
Biological weapons	Intermediate stops are vulnerable.	Protect intermediate stops.
Biological weapons	Master sergeants currently run the Air Force nuclear, biological, and chemical (NBC) training.	These non-commissioned officers' efforts should be combined with those of more highly trained toxicologists, organic chemists, microbiologists, physicians, physiologists, and public health specialists.
Biological weapons	There is no single source of data on threat exposures and effects.	Integrate epidemiological, safety, after-action, and personnel data to derive rates.
Biological weapons	Analysis of samples can be critical to bio/chem/toxic threat detection and response.	Provide rapid sample delivery to analysis centers.
Biological weapons	Transporting bio/chem-contaminated patients has not been addressed by all levels of the Air Force.	The medical readiness strategic plan must be reviewed by Air Mobility Command (AMC) and the Air Combat Command (ACC) and a coordinated, mutually accepted plan derived and documented.

Threat	Findings	Recommendations
Biological weapons	There are many threats to be detected and many individual detectors, e.g., Air Base/Port Biological Detection (ABPBD); Joint Biological Point Detection System (JBPDS); Joint Biological Remote Early Warning System; Biological Integrated Detection System (BIDS) (XM31); BIDS P31; Long-Range Biological Stand-Off Detection System (LR-BSDS); Waveguide; Biosensor; M93A1; ORIGEN; enzyme-linked, immuno-sorbent array (ELISA); IBADS; Automated Chemical Agent Detector and Alarm (ACADA); Joint Chemical Agent Detector (JCAD); Lightweight Stand-Off Chemical Agent Detector (LSCAD); Lightweight Nuclear, Biological, and Chemical Reconnaissance System (LNBCRS); Joint-Service Agent Water Monitor (JSAWM); Joint Warning and Reporting Network (JWARN); Multifunction Radical Detector; Environmental Systems Management Analysis Reporting Network; Advanced Chemical Agent Detector/Alarm; Joint Chemical Agent Detector; Joint-Service Lightweight Stand-Off Chemical Agent Detector; Joint Warning and Reporting System; Chemical Agent Monitor (CAM); ICM; Squad Automatic Weapon; M43A1; ICADA; Multipurpose Integrated Chemical Agent Detector (MICAD); Automatic Liquid Agent Detector (ALAD); and Automated Hazardous Warning System.	Develop an infectious disease and toxic agent (e.g., byproduct of burning composite materials) portable, lightweight lab that is reliable, accurate, and covers as many test types as possible (cheaply), perhaps expanding the Environmental Field Assessment and Survey Tool.
Biological weapons	There is no casualty management plan for biological weapons and directed-energy weapons.	This plan should be developed in coordination with Joint Publication 3-11.
Biological weapons	There are multiple personnel protection systems, e.g., Aircrew Chemical Ensemble (ACE), Joint Service Lightweight Integrated Suit Technology (JS-LIST), and Improved Toxicological Agent Protection (ITAP) Ensemble.	Develop one system.
Biological weapons	Air Force Medical Service chemical/biological defense (CBD) planning, training, and readiness are "seriously inadequate."	Provide training.
Biological weapons	It is difficult to move between clean areas through a contaminated area.	Consider Calspan zipper.
Biological weapons	Anthrax delivered by aircraft can kill more than 20 km downwind; in a town of 500,000 people, 95,000 would die and 125,000 would be incapacitated.	Develop stand-off detectors.
Biological weapons	There is no concept of operations (CONOPS) for handling contaminated aircraft.	Develop one.
Chemical weapons	Personnel wearing the current individual protection suits experience heat stress.	Provide shade and water to individuals wearing individual protection suits.
Chemical weapons	Current chem/bio protection places a large heat load on the wearer.	Develop fabrics that breathe one way — humidity out and nothing in.

Threat	Findings	Recommendations
Chemical weapons	Most deployed personnel arrive in theater without proper protective equipment, including bio/chem/weather. Many do not arrive with occupational protective equipment (e.g., welder's hood).	Provide proper protective equipment prior to deployment.
Chemical weapons	The medical assessment is that the Air Force cannot fight using its current bio/chem protection.	Design bio/chem protection for the aircrew.
Chemical weapons	There is an unmet requirement for integrated bio/chem and Gz protection.	Early deployment of Joint-Services Aircrew Mask (JSAM) and Aircrew Eye/Respiratory Protection (AERP).
Chemical weapons	Errors in decontamination of equipment could be deadly.	Develop a biological weapon decontamination expert system to help maintainers, medics, and transport personnel.
Chemical weapons	Errors in decontamination of people could be deadly.	Develop a sensor that declares a chem casualty clean.
Chemical weapons	Mask fit is compromised with movement.	Develop a nonthreatening hood.
Chemical weapons	Current decontaminants are highly toxic and can damage equipment.	Develop nontoxic, noncorrosive decontaminants.
Fatigue	When training occurred at the same pace and time of day as the actual mission, aircrews learned when they need backups.	Training should be at the same pace and time of day as crews will fight.
Fatigue	Different duty cycles between Air Intelligence Agency and Air Combat Command can lead to degraded performance.	All crews should maintain same duty cycle.
Fatigue	New regulation gives waiver of crew rest authority to someone at the wing and does not apply to maintenance personnel.	The authority should be higher and should apply to maintenance personnel as well as aircrews.
Fatigue	Unpredictable duty cycles induce fatigue.	Crews should know when the next mission is so that they can plan their time off.
Fatigue	Meals ready to eat (MRE) are not the correct food for fitness and alertness.	Flight meals should support the Air Force fitness initiative and be compatible with work/rest cycles; e.g., MREs for sleep should have complex carbohydrates; those for waking should have high protein.
Fatigue	Aircrews never train using methadrene and restoline, so they don't know their effects nor do they receive proper briefings on drug effects.	Aircrews should train as they will fight and should receive useful briefings on drug effects.
Fatigue	Some personnel have been deployed for months, resulting in reduced productivity.	Use the Air National Guard (ANG) and Air Force Reserves (AFR) to perform humanitarian AEF missions; this provides flying hours that will be paid for by the Office of Foreign Disasters, keeps personnel current, provides meaningful activity, and frees regular Air Force personnel for combat missions.
Fatigue	Personnel make errors under illness and fatigue conditions.	Develop fitness-for-duty monitors to measure AEF personnel before they perform critical duties; the detector must be tied to empirical data.

Threat	Findings	Recommendations
Fatigue	Shift work causes decreased vigilance.	Critical personnel should not be on shift work.
Infectious disease	Individual sleeping quarters reduce the spread of infection.	Individual sleeping quarters should be provided when airborne infectious threats are expected.
Infectious disease	There is a problem getting specimens to test centers.	Specimens should receive priority transport or the Air Force should adopt the Navy forward-deployed lab in theater.
Infectious disease	Antibiotics are being overprescribed.	The Air Force should develop a procedure for dispersal of antibiotics that does not degrade their future effectiveness.
Infectious disease	There are no procedures for identifying what medical procedures personnel need when returning from a deployment.	Such procedures should be developed and updated based on data.
Infectious disease	Physicians are not familiar with all exotic diseases.	Provide an expert system to physicians to support diagnosis.
Infectious disease	Most exotic diseases have the same symptoms as more common diseases but may require vastly different treatment.	An expert system should be developed to support flight surgeons' diagnoses and treatments; the system would provide both training on exotics as well as tracking information from the deployment.
Infectious disease	There are two infectious disease surveillance systems in the military: one used by the Air Force and Navy, the other by the Army. The two systems are incompatible.	Create compatibility to support epidemiological monitoring.
Infectious disease	The immunization record is not standard and is not maintained.	Treat humans as assets, with maintenance records including immunizations.
Infectious disease	Immunizations are not tracked for deployed personnel.	Build and maintain a database on each human similar to that maintained on each piece of hardware; the database would include immunizations, injuries, illnesses, deployments, Status of Resource and Training; the database should include Reserve and Guard (AFR deployed 6,000 persons outside the continental United States [CONUS] in 1996, ANG 8,500).
Infectious disease	Ten percent of the persons deployed in Southwest Asia have been diagnosed with infectious diseases.	Sentinel systems must be in place around an AEF to determine the base rates of naturally occurring biological agents.
Infectious disease	Threat risk management is qualitative.	Maintain a database to support quantitative medical and other threat risks analysis; the database should be used to develop a mortality rate for Air Force personnel.
Infectious disease	Some vaccines require 10 to 14 days to develop an immunity.	Deployable personnel should maintain immunization.
Infectious disease	There are not sufficient isolation wards in CONUS to handle some infectious diseases.	Prepare an Air Force isolation holding area if there is a threat of these diseases.
Infectious disease	The Air Force has insufficient resources to address infectious disease.	Coordinate with the Public Health Service and the Armed Reserves Corps to maximize effectiveness.

Threat	Findings	Recommendations
Infectious disease	There is no vaccination planning and prioritization system.	Develop one consistent with national policy.
Infectious disease	Some immunizations are short-term.	Immunize against yellow fever and typhoid all persons who *may* be deployed; immunize with gamagobulin (3- to 6-month protection) and cholera (6-month protection) only persons who *are* being deployed.`
Injury	Time is of the essence in injury response; time is lost deglycerizing frozen blood.	Better communication is required to have blood present when necessary.
Injury	Medical response to injury is not broken; e.g., no one would have been saved if a physician had been present at Khobar Towers.	Keep medical response effectiveness.
Injury	Life support is no longer a separate program area.	Make life support a separate program area that requires standardization across all Air Force assets.
Lasers	Force protection personnel do not receive laser eye protection (LEP).	Provide such protection, especially against dazzle effects.
Lasers	Laser eye protection is not funded.	Fund protection for personnel at risk.
Lasers	There are many eye protectors.	Integrate laser, flash-blindness, and night vision goggles (NVGs).
Night	NVGs are not compatible with aircraft lighting systems.	If weapon system operational requirements include covert operations or night search-and-rescue missions, the specification should require aircraft lighting systems to be designed for compatibility with NVGs.
Operational constraints	The time needed to obtain diplomatic clearance far exceeds the time needed to deploy; for example, the medical response to the Ecuadorian aircraft accident was 2 hours, but diplomatic clearance was not obtained for 48 hours.	Prenegotiate diplomatic clearances.
Operational constraints	Coordination is critical, since some duplication of effort has occurred, e.g., American Red Cross and Air Force on the same humanitarian mission.	Set in place specific linear coordination procedures with “approved to execute” authority.
Operational constraints	Only half of the people on the mobility list go; half of those deployed are not on a mobility list.	Only persons to be deployed should be on the mobility list.
Operational constraints	Support personnel are not always provided with vehicles.	Make vehicles available to support personnel as needed.
Operational constraints	For medical and force protection assets, order of arrival is critical.	Assets must be provided in the requested order of arrival.
Operational constraints	Air Force personnel without weapons were deployed to Somalia during a complex situation.	The Air Force should not allow any Air Force personnel to be deployed without a weapon — *not even on humanitarian missions*.
Operational constraints	Things brought in during humanitarian missions can ruin the local market.	Buy supplies locally so that the market can be maintained. (There is an agreement with the Agency for Cooperative Development to address this problem.)
Operational constraints	Humanitarian missions may be to places without financial institutions.	Be prepared to set up a financial institution for disbursement of funds.

Threat	Findings	Recommendations
Operational constraints	Humanitarian missions may be to exotic cultures.	Maintain teams that are trained in international relations.
Operational constraints	Humanitarian missions can happen at any time and need a reliable pool of personnel.	Set up agreements with hospitals for specific personnel who would be ready to deploy for 3 to 12 weeks.
Operational constraints	Humanitarian missions can happen at any time and need a reliable pool of supplies.	All medical supplies should have at least a 12-month shelf life.
Operational constraints	Humanitarian missions can happen at any time and need a rapid-response pool of personnel.	All persons to be deployed should have current passports and visas.
Operational constraints	Cultural clashes degrade performance.	Sensitize deployed personnel to other cultures.
Operational constraints	Many organizations bring individual equipment to a humanitarian mission but all of it may not be compatible.	Standardize equipment for water sanitation, clinics, airport logistics, and communication.
Operational constraints	Most lives are lost in the first 24 hours.	Get there within 24 hours.
Operational constraints	Foreign foods can be hazardous to the health of local populations.	Do not introduce foreign foods.
Operational constraints	Spoiled food can kill.	Uphold strict health regulations for food storage.
Operational constraints	Caregivers can be injured.	All personnel should be deployed with a personal health kit.
Radiation	Individual exposures to low-level radiation are not measured or tracked.	Develop such a system.
Radiation	Low-level radiation training is inadequate.	Provide training.
Radiation	There is no policy for low-level radiation exposure limits.	Provide one.
Radiation	Effects of low-level radiation on performance are unknown.	Study them.
Radiation	Interactions among disparate threats are not understood.	Examine interactions among bio, chem, and radiation threats.
Radio-frequency weapons	China and Russia are developing radiofrequency (RF) weapons.	Develop RF weapon protection for force protection equipment and all personnel.
Radio-frequency weapons	There is no hotline for RF threat help.	Develop one.
Terrorists	There is no protection against trucks with bombs.	Vehicle entrapment areas should be placed at gates; bomb detectors should be used for trucks that must come through the gates.
Terrorists	Barriers equivalent in volume to 500 to 800 sandbags require two days to fill.	Avoid earth-filled barriers.

Threat	Findings	Recommendations
Terrorists	There is no guidance on tailoring force protection, so troops sometimes are too light to fight and too heavy to run.	Develop a security force planner to select optimum protection for the threat and the lift available.
Terrorists	Most air base attacks are stand-off attacks.	Develop stand-off attack technologies to counter artillery.
Terrorists	There is not now constant imaging of the AEF base.	Place a sensor at high altitude with 48-hour loiter capability and vision down to one meter.
Terrorists	The stand-off threat is getting wider.	An identification, friend-or-foe, capability is required at altitude around a base.
Terrorists	The human intelligence force has been severely decreased.	Local embassies must be prepared to provide intelligence.
Terrorists	The security police equipment management agency was stood down leaving a void in the acquisition of commercial off-the-shelf materials.	Centralize acquisition at Lackland.
Terrorists	The security police agency is being moved from Kirtland to Lackland.	Expedite that move.
Terrorists	Current force protection would be overrun in a tank attack.	Provide antitank weapons if tanks are a threat.
Terrorists	In high-threat periods, voice transmissions typically overload the communication system.	Automatically digitize and incorporate force protection information into the command and control system; this information should include the status of checkpoints and the active-duty force protection personnel.
Terrorists	Optimizing a base for defense requires extensive experience and training.	Develop a model to support site selection to maximize defense; identify blast areas; calculate where the perimeter should be, based on the threat, and how to place revetments.
Terrorists	A review of air base attacks from 1940 to 1992 found that 75 percent were stand-off attacks and 22 percent were penetrations; 60 percent resulted in destroyed aircraft and 7 percent denied use.	Force protection must counter stand-off attacks and protect aircraft.
Terrorists	The British military requires common core skills of its deployed personnel: weapon, individual NBC protection, first aid, firefighting, and post-attack reconnaissance and reporting.	Train deployed personnel in weapons, individual NBC protection, first aid, firefighting, and post-attack reconnaissance and reporting.
Terrorists	The British military train under high-intensity threat conditions and have found this to provide the highest transfer of training.	Train at high intensity.
Terrorists	Terrorists around the world are continuously employing new techniques.	Force protection personnel should train with groups that train anti-terrorist groups — the Professional Bodyguards Association (PBA) could provide 10-day courses for five persons at about $1,700 per person.
Terrorists	Force protection experts have stated numerous times that the Air Force is inadequately protected.	Train all personnel to use and carry weapons (you have to protect yourself if you are going to protect the group).
Terrorists	Lack of information is frequently cited on after-action reports.	Brief all persons on threats just prior to leaving CONUS and provide daily updates to that briefing.
Terrorists	Current revetments are not optimal in all conditions.	Site selection should consider optimum barrier selection.

Threat	Findings	Recommendations
Terrorists	Watch items at Taszar Air Force Base are major aircraft mishap, hostile acts, personal injury, and equipment failure.	AEF personnel should have training to respond to major aircraft mishaps, hostile acts, personal injury, and equipment failure.
Terrorists	Air bases do not have adequate force protection.	Use Aviano Air Base as a test for the security evaluation and make upgrades as per the Force Protection Action Team recommendation.
Terrorists	Booby traps kill personnel.	Develop booby trap detectors and expert systems to guide personnel in rendering them safe.
Terrorists	Threat conditions can change rapidly.	Weapons should have non-lethal and lethal options in the same unit.
Terrorists	Trucks carry bombs.	Develop bomb detectors.
Toxic agents	Some lab tests require reagent liquids that can are banned in some countries; some took 12 weeks to get into theater.	Provide military transport for these reagents.
Toxic agents	On-site assessment must be made by highly trained personnel.	The AEF should deploy with a Preventive Aerospace Medical specialist, a public health officer, a physiologist, and a bioenvironmental specialist.
Toxic agents	Personnel untrained in medical and environmental threats often are asked to conduct analyses.	Provide teleconsultation to deployed personnel engaged in medical and environmental analysis; provide greater training to those in CONUS, especially in trauma treatment.
Toxic agents	Tech orders are not current on toxic threats.	Update them.
Weather	Personnel experience dehydration.	Line authority personnel must enforce good water discipline.
Weather	Maintainers have suffered frostbite.	Develop a personnel frostbite warning system for maintainers.

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Foreword

In this 1997 Air Force Scientific Advisory Board (SAB) study on *United States Air Force Expeditionary Forces*, the Committee develops an enhanced Air Force capability to conduct expeditionary operations, the Aerospace Expeditionary Force. A combination of operational concepts, new systems, and technologies training and organizational changes are identified in the three volumes of this report. Volume 1 presents an overall picture of the AEF concept. Volumes 2 and 3 provide added detail and reference information. This volume details the deliberations and conclusions of the Environment (Biological, Chemical, and Force Protection) Panel.

The study results represent an outstanding collaboration between the scientific and operational communities and between government and industry. The Study Committee wishes to thank the many individuals who contributed to the deliberations and the report, as listed in Appendix B. In addition to Scientific Advisory Board members, many ad hoc members devoted their time. Industry also assisted and Air Force Major Command liaison officers were extremely helpful. The Air Force Academy provided critical technical writing assistance and several executive officers from the Air Staff and Major Commands provided outstanding administrative and logistical support. We gratefully acknowledge the assistance of the UK Strike Command and DARPA. Senior leadership including General (Retired) Mike Carns, Lieutenant General George Muellner, Lieutenant General John Jumper, Mr. Ron Orr, Mr. Larry Lynn, and Mrs. Natalie Crawford improved the study greatly through contribution of both their people and their own personal time.

The Study Committee would also like to give special recognition to the SAB Secretariat and support staff, in particular Lieutenant Colonel Jim Berke, and the ANSER team, in particular Ms Kristin Lynch, who provided invaluable administrative and logistical assistance in pulling together the myriad of inputs into this final report. Their efforts are greatly appreciated.

We believe the AEF will become the most frequently used Air Force capability and we are proud to have been part of the establishment of this capability. The men and women of the Air Force want to make the AEF happen and, with a little help, they can and will.

Finally, this report reflects the collective judgment of the SAB and hence is not to be viewed as the official position of the United States Air Force.

Dr. Ronald P. Fuchs
Study Director

February 1998

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Acknowledgments

The ideas in the "Aerospace Expeditionary Force Environmental Threats and Force Protection" volume have been shaped by many minds. The Bibliography sections of the individual chapters provide partial acknowledgment to earlier writers and thinkers. The Points of Contact sections list some of the contributors from our many site visits. These visits were invaluable to us, as we gained insight and knowledge to "what was really going on." The quality of the briefings and presentations was extremely high — a reflection of the dedication and caliber of the contributors.

We wish to extend a special "thank you" to the following individuals who worked so hard to arrange our meetings: Ms. Elona Bean, Ms. Roxanne Constable, Lt Laura Stone, and Col Jimmy Cornette at Armstrong Laboratory; Maj Richard Hoeferkemp at HSC, 1Lt Leah Shea at Wilford Hall, Ms. Brenda Eckstein at CBDCOM (Aberdeen Proving Grounds), Ms. Beth McCoy at SSCOM (Natick), Maj Mark Johnson and SSgt Kristen Fernandez at Eglin AFB, and Col Leo Cropper at Bolling AFB. Capt Kasuda was most helpful in setting up our meeting with the newly established 820th SFG.

We offer further thanks to our hosts Dr. Russell Burton, Dr. Michael Katona, Dr. Don Farrer, Mr. James Brinkley, and Col Terry Childress at Armstrong Laboratory, Ms. Janis Seegar at CBDCOM, Ms. Beth McCoy at SSCOM, Col David Franz and Col Robin Taylor at Ft. Detrick, Col Leo Cropper at AFMOA, Dr. Jeffrey Kantor at Human Systems Center, Col Steve Dunning at Eglin AFB, and Lt Col Rick Hersack at Wilford Hall Medical Center.

We are indebted to our special authors from outside the Scientific Advisory Board, who willingly accepted the challenge to write sections of the report. Accordingly, we would like to thank Robert Galganski, Col Andrew Corso, Dr. John Frazier, Capt Karen Mertes, Lt Col Robert Cartledge, Capt David Cohen, Dr. Michael Murphy, Lt Col James Ice, Dr. Jonathan French, Col Cynthia Terriberry, Maj John Pilcher, Mr. James Priest, and Capt Susan Woods.

To substantiate our findings, we needed data. We are grateful to Ms. Karen Konkle at NAIC/TATD; Col Jay Newbauer at the Air Force Safety Center; Maj Richard Hoeferkemp, Maj Steve Channel, MSgt Gregory Furnish, Lt Col James Ice, and Maj Laura Trent at Armstrong Laboratory; and Col Andrew Corso at HQ USAF/SP for providing the data in a timely manner. The MEDIC CD-ROM provided by AFMIC proved invaluable in our research.

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The Chair, authors, Executive Officer, and Technical Editor are grateful also to their supporting casts — our families, coworkers, secretaries, and the AF/SB staff members — whose understanding and patience made this report possible. To all — thank you.

Dr. Valerie J. Gawron
Environment Panel Chair

February 1998

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1.0 Introduction

Valerie J. Gawron

As part of the Air Force Scientific Advisory Board's 1997 Summer Study, "United States Air Force Expeditionary Forces," the Environment Panel had three primary tasks:

- To identify human factor requirements, such as protective gear and operational alternatives, for conducting AEF operations in chemical and biological warfare environments
- To define force protection and security concepts
- To define potential organizational changes and investment options required to accomplish this portion of the AEF mission

1.1 Overview

The first step in performing these tasks was to identify threats related to human factor requirements and force protection. These threats are listed in Table I-1. Six of the 19 threats were eliminated from further consideration (see Table I-2). Each of the remaining threat areas is described in a separate chapter.

Table I-1. *Threats to an AEF*

Types of Threats
Terrorists
Biological weapons
Chemical weapons
Toxic agents
Conventional weapons
Lasers
Ionizing radiation
Radiofrequency radiation
Dangerous flora and fauna
Fatigue
Infectious disease and injury
Night
Weather and climate
Fire
Hazardous waste
High elevation
Nuclear weapons
Hunger
Thirst

The second step in performing the tasks was to identify experts in each of the threat areas. These experts were asked (1) to describe the current and future threat, (2) to document which organizations in the Air Force and other agencies handle this threat today and how they handle it, and (3) to identify current and future countermeasures and their costs. Knowledge of the threats was necessary (1) for creating operational alternatives to respond to them and (2) for suggesting organizational changes required to accomplish the human factor, force protection, and security portions of the AEF mission. Data, references, and points of contact were needed by the AEF and Force Protection Battlelabs.

Table I-2. *Threats Not Included in the Study*

Threat	***Reason for Elimination***
Fire	There is no unique AEF requirement.
Hazardous waste	There is no unique AEF requirement (see AFI 10-210). Medical waste is disposed of safely. For deceased personnel, the medical provider issues the death certificate and the Services Squadron coordinates disposition of remains from the area. Services Squadron members are fully trained in both peacetime and wartime mortuary operations. The Air Force philosophy is that personnel in the field handle remains as little as possible; the primary objective is to ship the remains home to a port mortuary (Dover AFB or Travis AFB) as soon as possible. If a large number of casualties were encountered or anticipated, the Air Force Services Agency would deploy a trained and certified mortician to assist the Services Squadron with processing remains. Civil engineers are responsible for providing and maintaining latrines. Field-deployable latrines can be erected when facilities do not exist. This system is installed in a tent and contains 12 toilets, two urinals, and a hand-washing sink. Typically, contractors are hired to service the latrines. Civil engineering builds and maintains latrines with regular inspections by public health officers (AFI 48-117). Each human produces about 15 gallons of waste water and 5 pounds of solid waste per day.
High elevation	There is no unique AEF requirement. An excellent review of effects on military performance is “Effects of High Terrestrial Altitude on Military Performance” by Banderet and Burse.*
Nuclear weapons	It is assumed that AEFs will not be deployed where nuclear weapons have been or are likely to be used.
Hunger	There is no unique AEF requirement. Prime BEEF (Base Engineering Emergency Force) handles this threat well by providing MREs. Three MREs weigh about 5 pounds. In addition, forward-deployed equipment will include Harvest Falcon/Eagle sets and food. Local food source approval is handled by public health officers with final approval by the senior medical representative at the site. All other sources are approved by the Army. Procurement is handled by the Contracting Office. The Services Squadron is responsible for ensuring that food is sourced and shipped, primarily through the same sources used for day-to-day operation at home station dining facilities. Standardized Air Force menus and recipes are used whenever possible. Services may deploy cooks, who are responsible for setting up and operating field kitchens; however, field kitchens at deployed locations often are operated by contractors, with Services personnel acting as quality assurance evaluators. This is dependent on the location and duration of the deployment. Spoiled or damaged food usually is disposed of with other trash or buried if there is a large amount.
Thirst	There is no unique AEF requirement. Water-purification systems handle this threat well. In addition, forward-deployed equipment will include water (AFI 10-xxx, “Rapid Response Air Expeditionary Force Planning,” in draft, June 1997). However, line authority should be applied for good water discipline.
* Louise E. Banderet and Richard L. Burse, “Effects of High Terrestrial Altitude on Military Performance,” *Handbook of Military Psychology*, ed. R. Gal and A.D. Mangelsdorf (New York: Wiley, 1991), pp. 233-254.	

1.2 Environment (Biological, Chemical, and Force Protection) Panel Membership

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2.0 Terrorists

Valerie J. Gawron, Robert A. Galganski, and Andrew A. Corso

2.1 Current Threats

Terrorism is "the unlawful use or threatened use of force or violence against individuals or property to coerce or intimidate governments or societies often to achieve political, religious, or ideological objectives."[1] The U.S. policy for dealing with terrorists is "We will not negotiate, we will not pay a ransom, and we will not release prisoners."[2]

A terrorist group is any "politically, religiously, or ideologically oriented group which uses terrorism as its prime mode of operation."[3] There are three categories of terrorist groups: transnational, international, and national. A transnational group "operates without regard to national boundaries and is not controlled by any state." An international group "operates across national boundaries but is controlled by a sovereign state and is therefore restricted in varying degrees in its operations by the policy of the controlling state." Finally, a national group "restricts its operation primarily to one country."[4]

Today, there are more than 300 terrorists groups worldwide.[5] Most of them share five characteristics. They "(1) seek to intimidate by fear, (2) are militarily weak, (3) do not equate tactical success with mission success, (4) are usually urban-based and highly mobile, and (5) generally operate covertly."[6] The typical group is composed of a number of cells, of which there are four types: (1) the operational cell performs terrorist actions and usually includes three to five people; (2) the intelligence cell collects information; (3) the auxiliary cell raises funds, recruits members, and distributes propaganda; and (4) the national command supervises all activities.[7] Similarly, there are four types of members: (1) leadership, who are the planners; (2) the active cadre, who perform the terrorist acts; (3) active members, who provide support; and (4) passive members, who are the target audience for the terrorist acts.[8] Table I-3 shows the demographics of international terrorists.

Table I-3. *Demographic Characteristics for International Terrorists*[9]

Characteristic	***Demographics***	
	Russell & Miller, 1978	***Smith, 1994****
Age	22-25	23-48 (average: 36)
College degree	66 percent	8 percent
Ethnicity	None reported	13 percent Hispanic 50 percent Irish 34 percent Middle-Eastern 3 percent Oriental
Gender	Leaders: 80 percent male Followers: 74 percent male	100 percent male
Socio-economic status	Left wing: middle/upper class	Left wing: middle/upper class Right wing: lower class
* Smith examined only those international terrorists arrested in the U.S.		

Terrorists perpetrate a wide variety of acts to forward their causes. Tables I-4 and I-5 and Figures I-1 through I-4 summarize the terrorist threat. The military is a likely target for terrorist attacks. Figures I-5 through I-8 depict the history of terrorist attacks on the U.S. military. Figures I-9 through I-12 describe anti–U.S. attacks.

Table I-4. *Summary of Terrorist Activities*

Terrorist Technique	*Incidents (percent)*	*Year*
Bombings	49.0	1987[10]
Facility attacks	35.0	1987
Arson	14.0 (average)	1970–1990[11]
Assassinations	13.5	1987
Kidnappings	2.0	1987
Hijackings	0.5	1987

Table I-5. *Summary of Types of Terrorist Operations*[12]

Operation	*Discriminant*	*Indiscriminant*	*Lethal*	*Law Enforcement Intervention**
Ambushes	Yes	Yes	Yes	No
Assassination	Yes	No	Yes	No
Bank robbery	Yes	No	Doubtful†	No
Bombing	Yes	Yes	Likely‡	No
Execution	Yes	No	Yes	No
Extortion	Yes	No	No	No
Hijacking/hostage taking	Yes	Yes	Possible	Yes
Kidnapping	Yes	No	Doubtful	No
Kneecapping	Yes	No	No	No
Rescue of prisoners	Yes	No	Doubtful	Possible
Sabotage	Yes	Yes	Possible	No

* Assumes the law enforcement agency has not received prior specific intelligence from infiltrators, traitors, etc.

† The intent of the act is not killing, although people may die from interference.

‡ If the bomb detonates, the probability is high that people will die. Some bombs are specifically intended to kill victims.

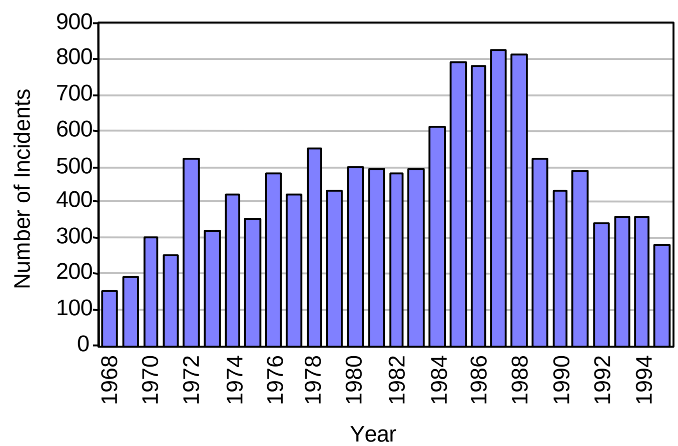


Figure I-1. *International Terrorist Incidents, 1968–1990,*[13] *and Worldwide Terrorist Incidents,1991–1995*[14]

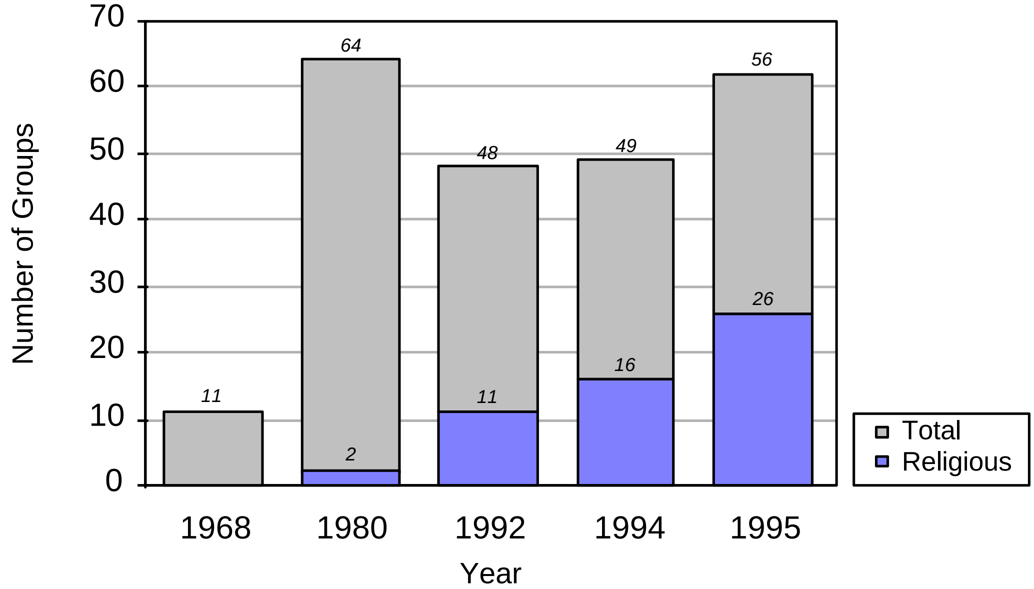


Figure I-2. *Religious vs. Other Terrorist Groups*[15]

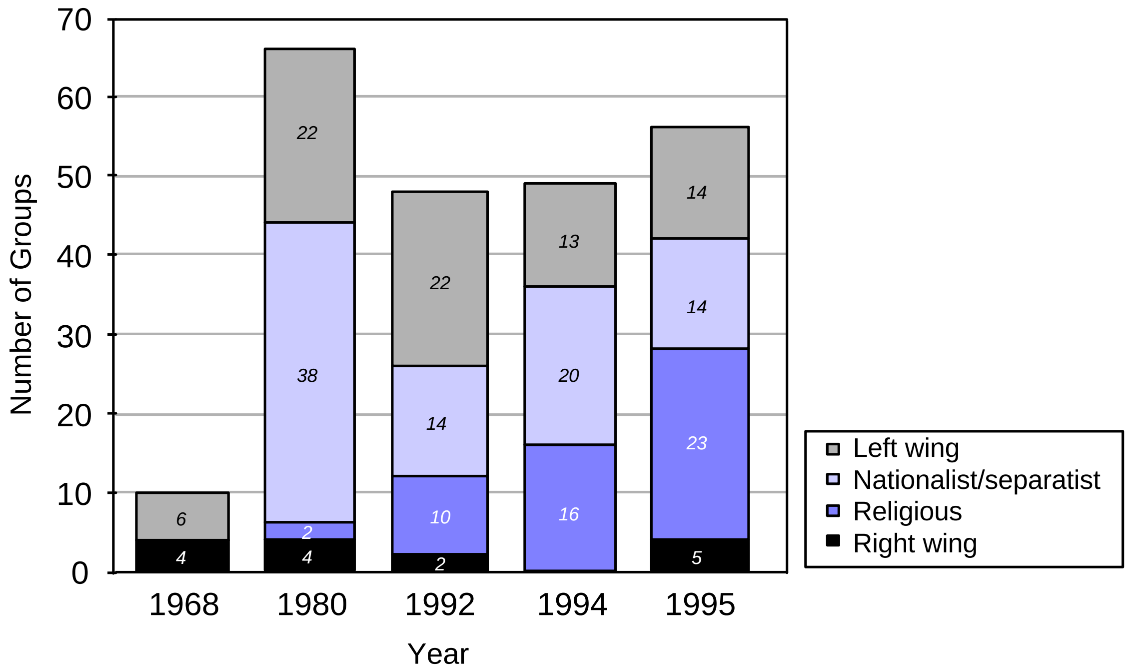


Figure I-3. *Orientations of Terrorist Groups*[16]

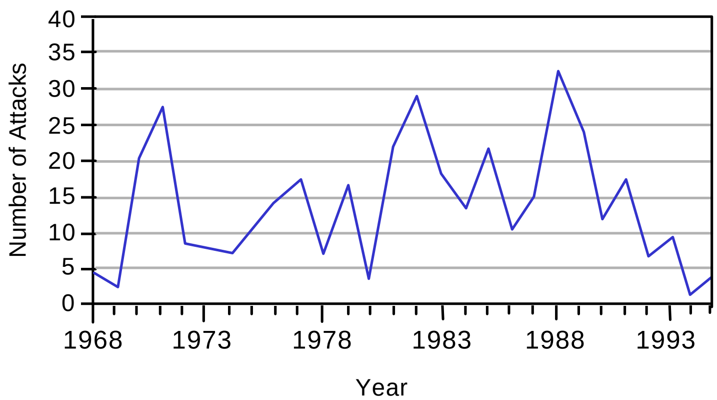


Figure I-4. *Frequency of Attacks on the U.S. Military*[17]

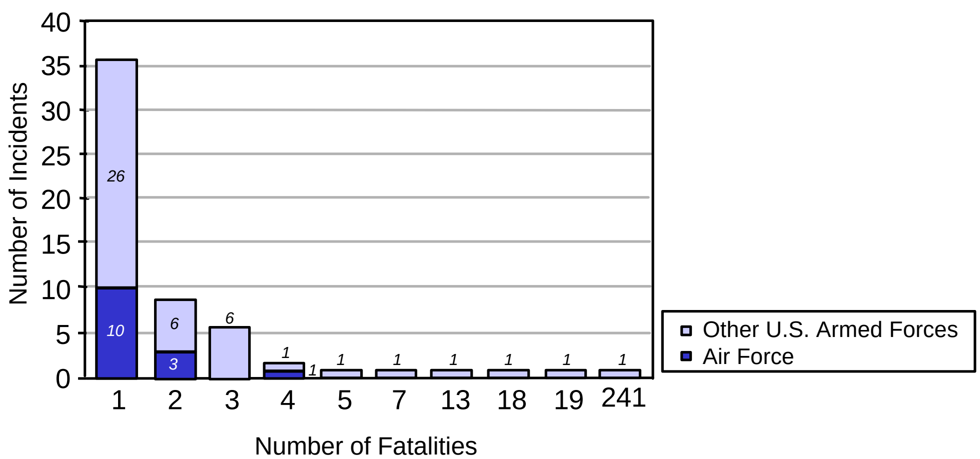


Figure I-5. *Fatalities in Terrorist Attacks on the U.S. Military*[18]

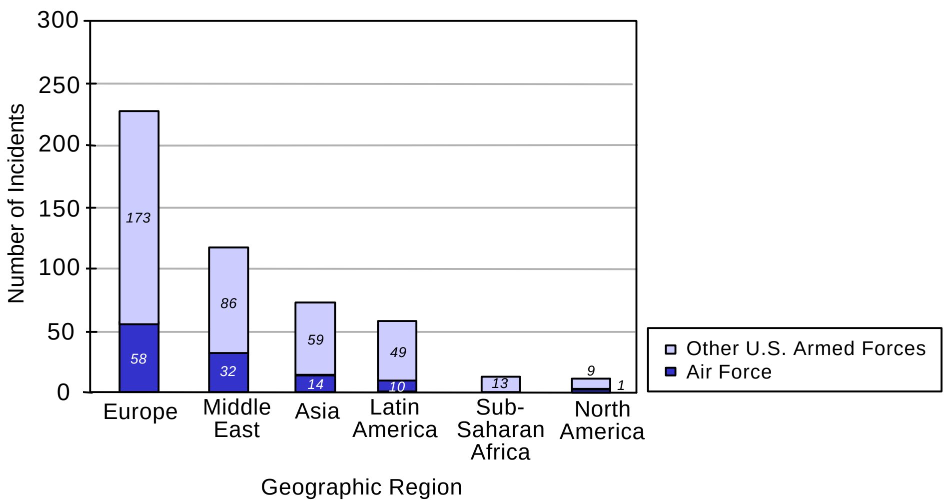


Figure I-6. *Terrorist Attacks on the U.S. Military by Geographical Region*[19]

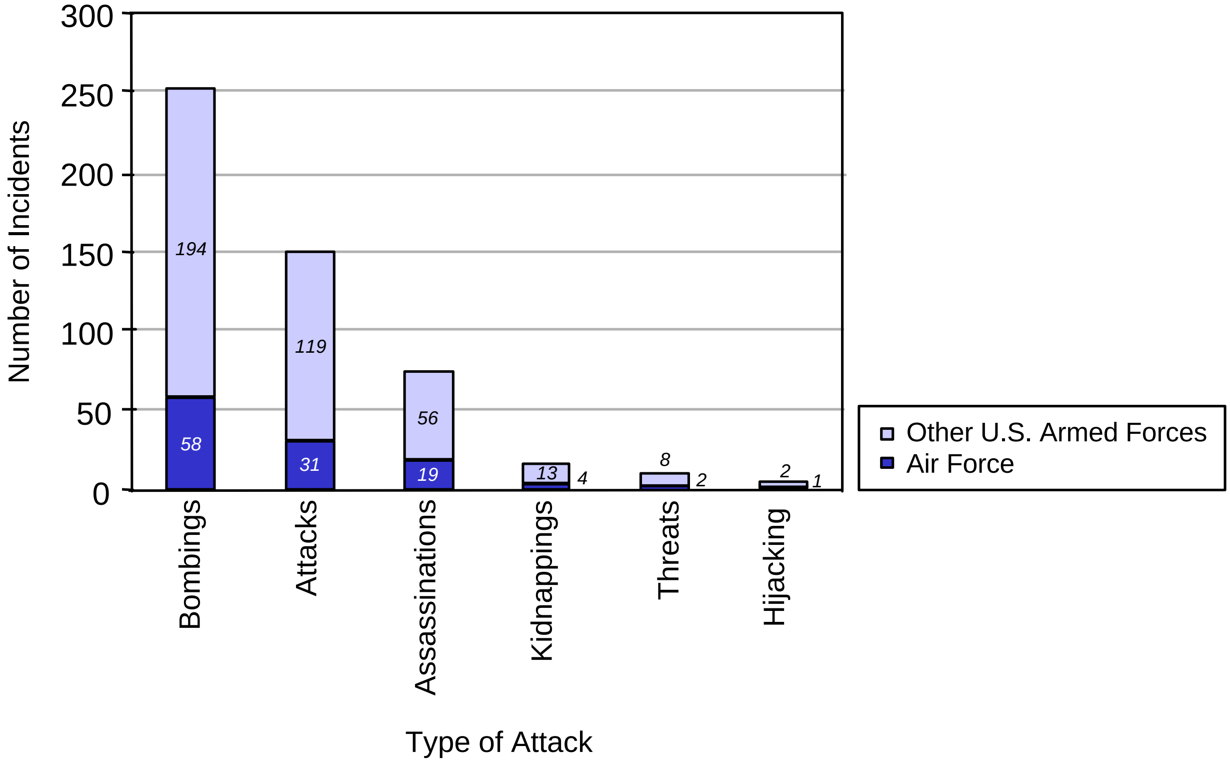


Figure I-7. *Types of Attacks on the U.S. Military*[20]

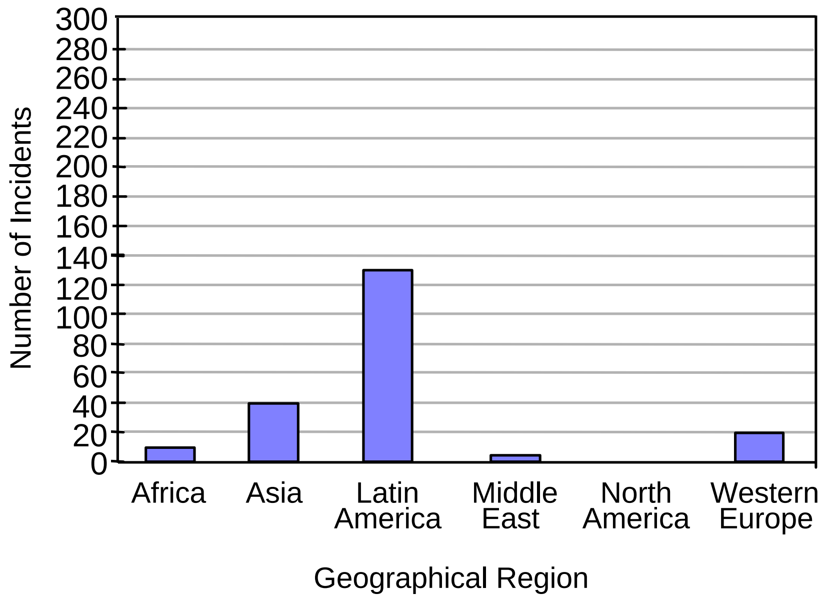


Figure I-8. *Anti-U.S. Attacks in 1990 by Region*[21]

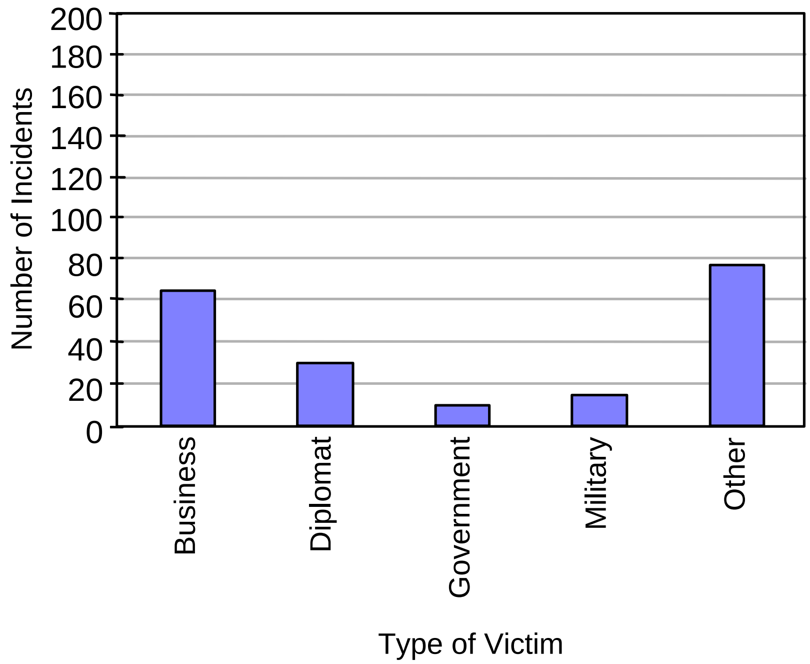


Figure I-9. *Anti-U.S. Attacks in 1990 by Type of Victim*[22]

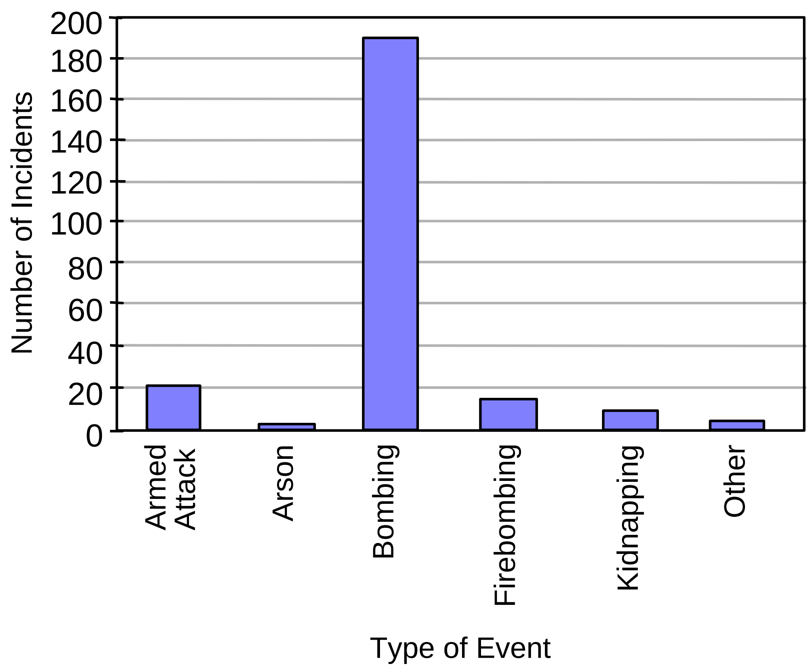


Figure I-10. *Anti-U.S. Attacks in 1990 by Type of Event*[23]

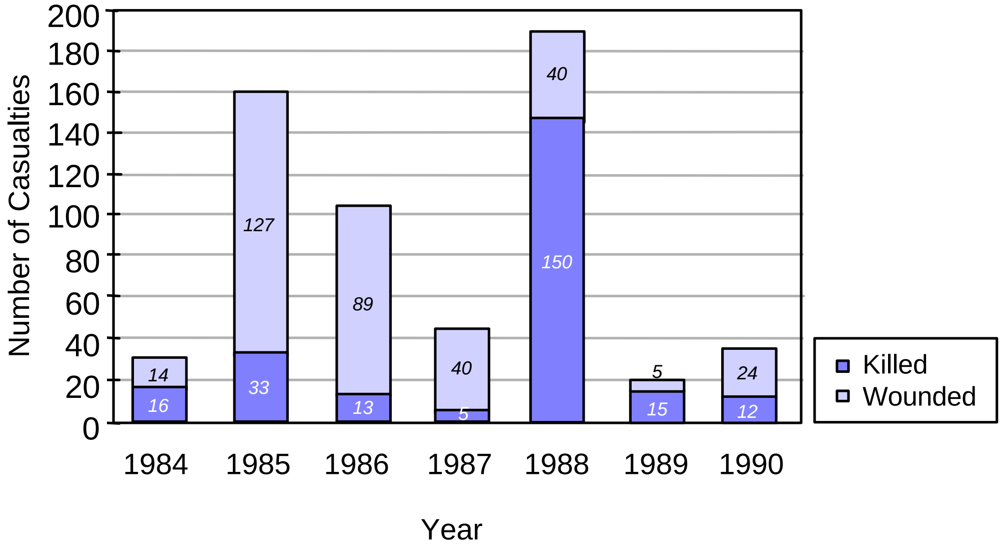
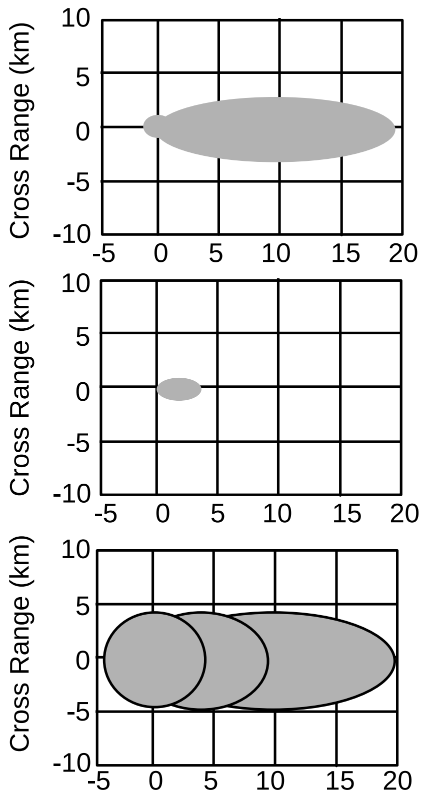


Figure I-11. *Anti-U.S. Attacks, Casualties*[24]

Terrorists have relatively easy access to weapons of mass destruction. "Chemical and biological weapons present the greatest megaterrorism threat, and terrorist groups have already used some of these weapons on a small scale. . . . Nuclear terrorism is also a threat. It is only a matter of time before state-sponsored or state-directed groups obtain nuclear devices that could be used anywhere in the world."[25] Some of the biological agents that can be used by terrorists are anthrax, tularensis (rabbit fever), plague, dysentery, and botulinum toxin.[26] The *Aum Shirikyo* ("Supreme Truth") group demonstrated the prevalence of biological agents when it used sarin in its 20 March 1995 attack in the Kasumigaseki subway station in Tokyo. The group placed packages of the liquid agent on six consecutive trains and succeeded in killing 12 people and sending 5,500 to hospitals. Authorities found botulism and anthrax toxins, in addition to tons of chemicals for producing sarin, at the group's training center. The subway attack was only the beginning of the group's plans — it had raised more than $1 billion and had a Russian Mi-17 helicopter and two drone aircraft for spraying biological agents.[27] A comparison of the damage contours for nuclear, biological, and chemical threats is presented in Figure I-12.



Nuclear

The damage contour shown indicates the 450-rad dose region for the prompt radiation effects and the distribution of fallout from the surface burst of a 20-kiloton nuclear device.

Chemical

The damage contour shown indicates the chemical dosage effects (ranging from 0.1 mg/min/m³ to 100 mg/min/m³) for a large missile filled with large sub-munitions containing GB (aka sarin).

Biological

The damage contour shown indicates the areas of biological contamination for a missile filled with multiple bomblets containing anthrax agent. The areas correspond to 80, 50, and 35 percent casualties.

Figure I-12. *Comparison of Nuclear, Biological, and Chemical Damage Contours Using a Standard Day*[28]

Hostage takers, a special subset of terrorists, fall into one of the following groups: (1) political extremists, (2) fleeing criminals who play outside society's rules, (3) "wronged" individuals who seek personal revenge, (4) religious fanatics who act in the name of God or of their religious leaders, or (5) mentally disturbed people.[29] A hostage taking typically has an intimidation stage, a custodial stage, and a resolution stage (which includes negotiation and liberation). Table I-6 summarizes these stages.

Table I-6. *Three Stages of a Hostage Crisis*[30]

Stages	*Terrorist Goals*	*Hostage Roles and Behaviors*
Intimidation	Control	Comply with terrorist demands.
Custodial	Negotiation Demands Publicity	Communicate with terrorists. Establish rapport. Develop the Stockholm Syndrome.
Resolution Negotiation Liberation	Survival	 Maintain self-control, stay calm. Get down, stay low, blend with the group. Do not try to help the rescue team. Expect firm control. Comply with rescue team instructions.

In the custodial stage, many hostages develop the Stockholm Syndrome. This psychological effect is characterized by high levels of stress, positive bonding to other hostages and to the hostage takers, and an "It's us against them" attitude.[31] The syndrome is likely to occur when the terrorists use minimum violence, mutual liking develops between hostages and hostage takers, and the hostages distrust authority.[32]

Although kidnapping is not the most frequent terrorist activity, U.S. and NATO military personnel are the targets of some kidnapping incidents, and, unfortunately, the terrorist training that used to be required for Air Force security forces has been eliminated. This lack of training could be important. For example, a defined objective of the Brigate Rosse was to oppose the presence of NATO personnel stationed in Italy.[33] In 262 kidnapping negotiations, payment was made in 61 percent of the incidents, police rescued the victim in 21 percent, the victim died in 10 percent, the victim was released without concessions in 6 percent, and the victim escaped in 2 percent.[34]

Unarmed civilians in unprotected environments are the most common targets of armed attacks.[35] Often, these attacks involve explosive devices. Terrorists use a variety of bombs, depending on the desired effects and the size of the target. To achieve maximum casualties, a secondary explosive detonates the primary bomb. Vehicle bombs use large amounts of explosives or cylinders of volatile gas to intensify the explosion. A large, gas-augmented bomb (20,000 pounds) was used in the 25 June 1996 bombing in Dhahran, Saudi Arabia, that killed 19 Air Force personnel and injured hundreds.[36] Letter bombs are intended to maim, rather than kill, the victims. Explosives are used in a typical arson tactic: terrorists, dressed as firemen, fill the fire extinguishers in a designated building with flammable liquid and then set the building on fire. Finally, guided and unguided missiles are common in the terrorists' arsenals: "It is rare that the well-armored terrorist organization does not have at least one or two of these heavy weapons in [its] stockpile."[37]

As devastating as terrorist attacks are, their aftermath also may affect the performance of military personnel. In a follow-up study after a 1995 car bombing at the Saudi Arabian National Guard Modernization Program that killed seven personnel and injured 500 others, Applewhite and Dickens (1997) reported psychosocial disturbances (see Table I-7).

Table I-7. *Frequency of Reported Psychosocial Disturbances*[38]

Type	*Number*	*Percent*
Sleep disturbance	10	19
Safety concerns	9	17
Hypervigilance	7	13
Depressed mood	7	13
Social conflict	6	12
Irritability	5	10
Guilty feelings	5	10
Difficulty concentrating	4	8
Generalized anxiety	3	6
Flashbacks	2	4

There were 645 ground attacks on airfields from 1940 through 1992 (see Table I-8). Only three of these attacks were acts of terrorism, but they destroyed nine aircraft and damaged three. The vast majority (75 percent) were stand-off attacks, which could be anything from snipers to guided missiles. Snipers, for example, can operate from a range of 50 m in an enclosed area to 1,000 m in an open area.[39] Another 22 percent were penetrating attacks; only 3 percent were combined attacks (see Figure I-13). The purposes of the attacks (shown in Figure I-14) were to destroy aircraft (60 percent), harass the defenders (27 percent), capture the airfield (6 percent), or deny use of the airfield (7 percent).[40] Finally, the insertion techniques used in the ground attacks are shown in Figure I-15.[41]

Table I-8. *Ground Attacks on Airfields, 1940–1992*[42]

Conflict	Incidents	Aircraft Destroyed	Aircraft Damaged
World War II	130	367	NA
Korea	3	0	0
Vietnam	493	393	1,185
Falklands	1	11	0
El Salvador	2	15	18
Grenada	2	0	0
Afghanistan	3	9	0
Panama	4	1	0
1991 Gulf War	3	36	0
Philippines	1	2	1
Terrorism	3	9	3
Total	645	843	1,207

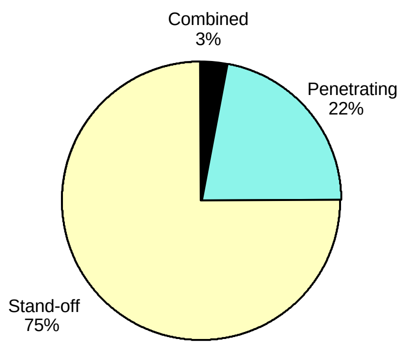


Figure I-13. *Tactics Used in Airfield Attacks*[43]

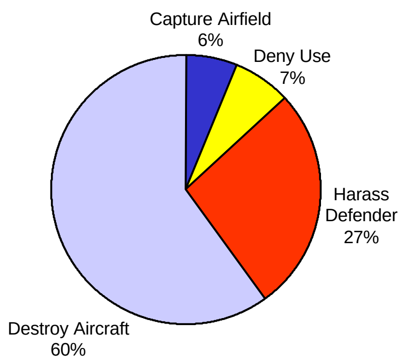


Figure I-14. *Airfield Attack Objectives*[44]

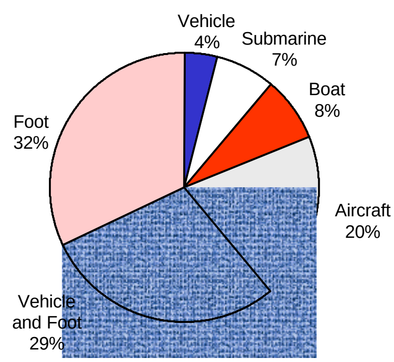


Figure I-15. *Insertion Techniques Used in Airfield Attacks (Except Vietnam)*[45]

Summary

The popular conception that terrorists are poor, young men from the Middle East is clearly incorrect. The opinion that Air Force bases in CONUS and abroad are secure from terrorists also is incorrect. The conclusion that terrorists will not use biological, chemical, or nuclear weapons likewise is unfounded. Therefore, the AEF must be prepared to protect itself against terrorists who possess billion-dollar treasuries and a broad range of weapons.

2.2 Current Countermeasures

Terrorism counteraction refers to "the actions taken by governments to counteract the threat, including specific measures initiated by military units or installations, law enforcement agencies, and security professionals to decrease the probability of an attack against a specific asset. It also includes the actions taken in response to an event, from the use of a tactical team during a hostage-taking situation to the retaliatory bombing of a nation that sponsors a specific event or group."[46] There are three levels of terrorism counteraction: political and diplomatic, strategic, and tactical (see Table I-9).

Table I-9. *Levels of Terrorism Counteraction*[47]

Level	Type of Activity	Specific Action
I. Political and Diplomatic	Negotiations Changes in diplomatic relations Sanctions Military options	
II. Strategic	Threat analysis Asset protection	Intelligence collection Vulnerability surveys Operations security Personnel security Physical security
III. Tactical	Proactive operations Reactive operations	 Tactical responses Hostage negotiations Retaliatory strikes

Terrorism counteraction can be divided into two categories: antiterrorism and counterterrorism. Antiterrorism "includes all of the actions taken to prevent terrorism or a specific terrorist act from occurring. These actions include threat assessments, target hardening, personal protection, and operations security."[48] Counterterrorism "is the response to an actual terrorist event. This includes the tactical response, the criminal investigation, and the emergency operations command and control structure that manages the response to an ongoing terrorist situation such as hostage taking or kidnapping event."[49]

2.2.1 Security Forces

The 366th Support Group at Mountain Home Air Force Base, Idaho, has designed the Fast Action Support Team (FAST), composed of wing staff and operations, logistics, support, and medical personnel, to support force protection. This group makes risk assessments based on the mission, equipment, troops, terrain, and threat. Passive asset security measures currently used include aircraft revetments; camouflage, concealment, and deception techniques; and dispersal plans. Passive personnel security measures include bunkers, semihardened facilities, and warning and notification systems. Additional security measures include fencing barriers, blast and visibility barriers, antivehicle trenches, closed-circuit television, self-locking doors, security bars for windows, mylar film for windows, bulletproof vests, search mirrors, base alerting systems, hand-held metal detectors, explosives detectors, vehicle barriers, Roverado gates, and perimeter lighting.

The 820th Security Forces Group is assigned the task of providing force protection and security for an AEF. The normal security force has 120 to 150 members divided between the headquarters element and the flight elements. These AEF security personnel are stationed at bases throughout CONUS: Davis-Monthan AFB (ACC), Eglin AFB (Air Force Materiel Command), McGuire AFB (AMC), Lackland AFB (Air Education and Training Command), Vandenberg AFB (Air Force Space Command), Westover Air Reserve Base, and El Paso ANG Base. The number of personnel can be modified according to the threat assessment or support from the host nation.[50] The weapons and equipment used by the security force are listed in Tables I-10 and I-11, respectively. Figures I-17 through I-20 provide pictures and specifications of some of the weapons. This core unit has rapid mobility with roll-on/roll-off vehicles; if vehicles are prepositioned, the unit deploys with palletized supplies. The unit also can use specialized vehicles, such as the M-9 Armored Combat Earthmover (shown in Figure I-20) provided by Air Force Civil Engineering, in preparing security measures for an airbase.

Table I-10. *Weapons Used by the 820th Security Forces Group*

M-2 (.50 cal)	M-60 (7.62-mm machine gun)
M-9 (9-mm pistol)	M-249 (5.56-mm squad automatic weapon)
M-16 (5.56-mm rifle)	M-29 (81-mm mortar)
M-19 (40-mm mortar)	M-203 (grenade launcher)

Table I-11. *Security Equipment Used by the 820th Security Forces Group*

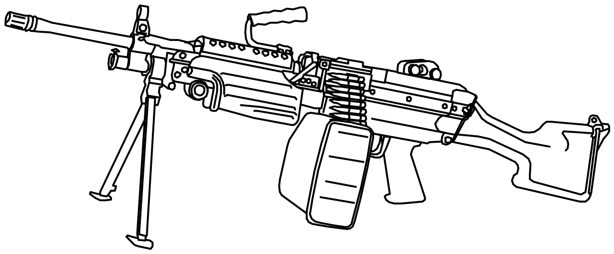
Relocatable sensor system	Under-vehicle surveillance
Tactical automated sensor	Area surveillance systems
Thermal imagers	Up-armored HMMWVs
Body armor	Secure communications

Cartridge	5.56 x 45 mm NATO
Operation	Semiautomatic or automatic
Feed	20- and 30-round magazine
Weight	3.40 kg (without magazine)
Length	1 m
Muzzle velocity	991 meters per second (m/s)
Rate of fire	700-900 rounds/min cyclic
Effective range	400 m

Figure I-16. *M-16A2 Rifle*[51]

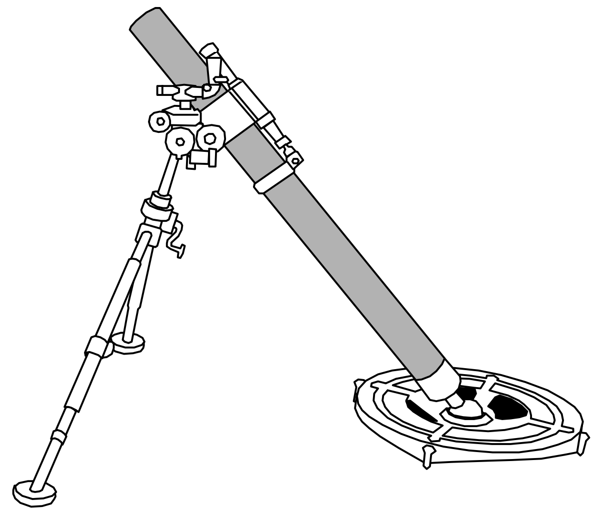
Cartridge	7.62 x 51 mm
Operation	Automatic
Feed	Disintegrating link belt
Weight	11.1 kg
Length	1.105 m
Muzzle velocity	853 m/s
Rate of fire	500-650 rounds/min cyclic
Effective range	1,100 m (with bipod)

Figure I-17. *M-60 Machine Gun*[52]



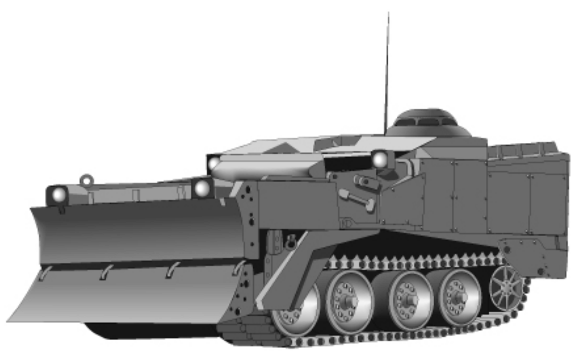
Cartridge	5.56 x 45 mm
Operation	Automatic
Feed	200-round belt or 30-round mag
Weight	6.85 kg
Length	1.04 m
Muzzle velocity	965 m/s
Rate of fire	700-1,000 rounds/min
Effective range	800 m

Figure I-18. *M-249 Squad Automatic Weapon*[53]



Caliber	81 mm
Operation	Drop fired
Feed	Muzzle loaded
Weight	44.94 kg
Length	1.295 m
Rate of fire	27 rounds/min
Effective range	5,675 m

Figure I-19. *M-29A1 Mortar*[54]



Crew	1
Weight (min/max)	16,327 kg/24,490 kg
Length	6.25 m
Width (min/max)	2.79 m/3.2 m
Height (min/max)	2.7 m/3.0 m
Max speed (road)	48.3 km/hr
(water)	4.8 km/hr
Range	322 km
Armament	Smoke-grenade launcher
Armor	Aluminum, Kevlar, steel

Figure I-20. *M-9 Armored Combat Earthmover*[55]

Some members of the security force are well trained in combat arms. Combat arms and maintenance personnel conduct weapons training and qualification for all members of the group's security police on the M-16 rifle, M-60 machine gun, M-203 grenade launcher, and M-249 squad automatic weapon (SAW). In addition, non-security police members of the security force qualify on the M-9 pistol and M-16 rifle if required by their mobility taskings. Selected Red Horse personnel also are armed. "The vulnerability of our airbases and the need for Air Force support personnel to recognize and be prepared for a combatant role require a fundamental shift in the organizational structure of our Air Force and the individual attitudes of Air Force personnel."[56]

In contrast, the Marine Corps trains all deployed personnel first as marksmen, then in job specialties; other Services give martial arts instruction to personnel. In addition to deadly force, the Marine Corps uses numerous nonlethal weapons, such as "goo guns," tire-puncturing blankets on roadways, foam guns, liquid bullets, thermal shells, and acoustic waves. The Federal Bureau of Investigation (FBI) also is adopting some of these weapons. A complete antiterrorist arsenal would include stun grenades, sniper rifles, pyrotechnics and demolition devices, handguns, submachine guns, assault rifles and shotguns, infrared night sights, target designators (e.g., laser targeting devices), breaching and entry devices, and diversionary devices.[57]

However, arming the entire AEF for force protection may be more of a danger than a protective measure. A study more than 20 years ago of Australian police officers showed that more of them were killed and wounded when they were armed than when they were unarmed.[58] Still, more recent reports indicate that even British police officers, who traditionally have been unarmed, may be armed in the near future.[59] Of police officers who have been shot, over half were shot from a distance of less than five feet, two-thirds were shot at night, and half of the shootings involved more than one assailant.[60]

Hostage Rescue Units are key terrorism countermeasures. The best units in the world according to counterterrorism specialist Leroy Thompson, are the (1) British Special Air Service, (2) German *Grenzschutzgruppe* 9, (3) French *Groupement D'Intervention de la Gendarmerie Nationale*, (4) Australian Special Air Service, (5) Israeli security forces, (6) U.S. Delta Force, (7) Spanish *Unidad Especial de Intervencion* and *Grupo Especial de Operaciones*, (8) FBI Hostage Response Team, (9) Italian *Groupe Interventional Speciale*, and (10) Royal Dutch Marines. The ratings were based on each unit's (1) command and control, (2) training, (3) personnel and personnel selection, (4) weapons and equipment, (5) intelligence and research, and (6) versatility and resourcefulness.[61]

2.2.2 Protecting the Air Base

The 820th Security Forces Group is trained to protect an air base using deployable and local assets that are quick to erect and nonpermanent. Some of these security measures are expandable soil- and rock-filled revetments, surveillance systems and alarms, security guards, and patrol barricades. These barricades, for example, are erected from modular, lightweight panels, and they include elevated watchtowers. The development of these barricades is a cooperative effort among the Air Force Research Laboratory, the U.S. Army Waterways Experiment Station, and the Defense Special Weapons Agency (DSWA).[62] Deployable and reusable shelter systems for personnel also provide some protection against terrorists. One such system (an industry effort) is the Modular Erectable Rigid Wall Shelter. This system offers protection against chemical and biological agents and can be decontaminated, but it does have ingress and egress problems.

Protection against the threat of chemical and biological (CB) terrorism is more important than ever. According to an Office of Technology Assessment report, "Interagency coordination for responding to [CB] terrorism has shown marked (and sorely needed) improvement recently. An interagency plan to respond to such eventualities now exists. However, more coordination and more research and development are needed to improve response capabilities. Because of the reality of the CB terrorist threat and because of the potentially disastrous consequences, a concentrated effort by both the executive and legislative branches to expedite such work would be appropriate."[63]

The threat of explosives is not new. Dogs commonly are used to detect explosive devices because "there is no mechanical device that is as accurate, fast, sensitive, mobile, flexible, and durable as a well-trained dog/handler team."[64] However, the use of dogs does have disadvantages: (1) maintaining a canine operation is very expensive; (2) a dog is only as good at its handler, who may suffer performance degradation from any number of causes; (3) the changes in a dog's behavior that indicate the presence of explosives are subtle and may be missed by its handler; (4) a dog may need rest after as little as 20 minutes of work, depending on the weather; (5) a dog can be distracted easily; (6) a dog will not detect a perfectly wrapped explosive device; and (7) a dog can give a false alarm.[65] Further, it is not yet clear to which components of a volatile mixture dogs respond—Figure I-21 shows a system for determining the key components.

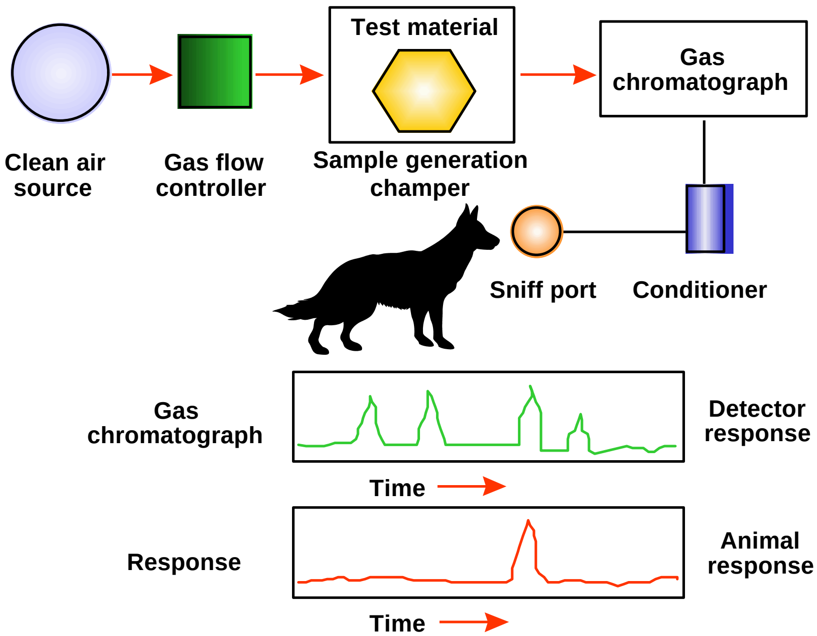


Figure I-21. *Determining the Explosives Components That Trigger Detection Responses in Dogs*[66]

A wide variety of intruder detection systems exist, from relatively simple taut-wire sensors (Figure I-22) and buried coaxial cable sensors (Figure I-23) to more elaborate electric-field sensors (Figure I-24) and, finally, complete intrusion detection and assessment systems (Figure I-25).

Figure I-22. *Taut-Wire Fence Sensor*[67]

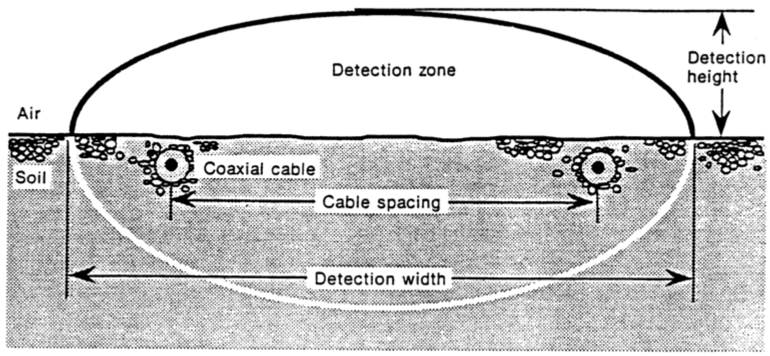


Figure I-23. *Coaxial Cable Sensor*[68]

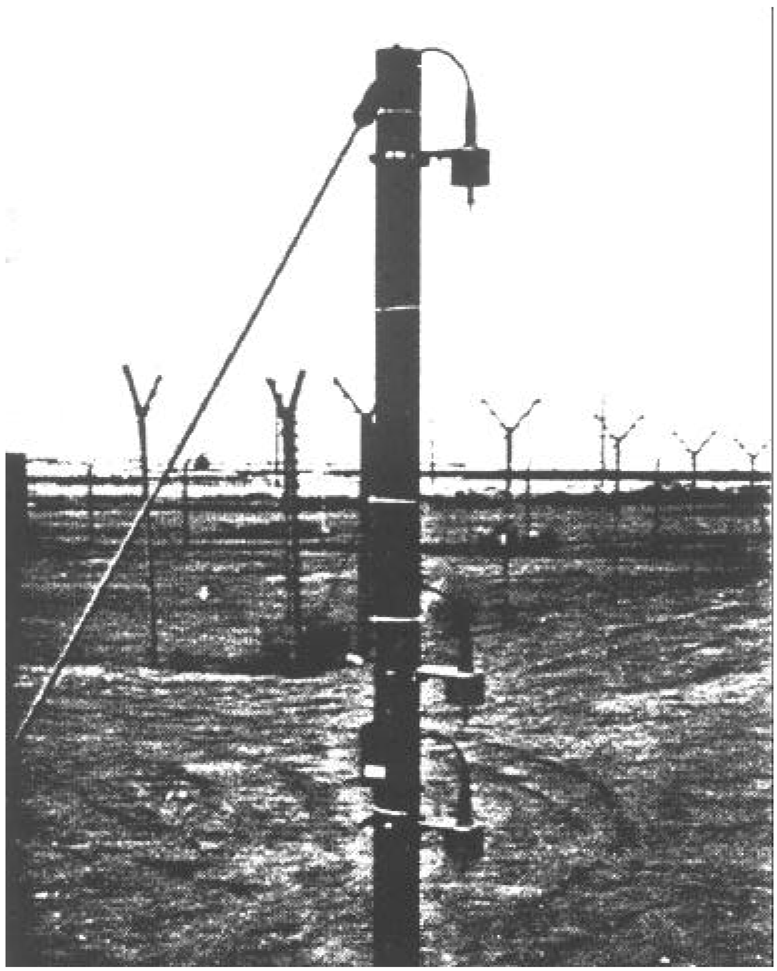


Figure I-24. *Electric-Field Sensor*[69]

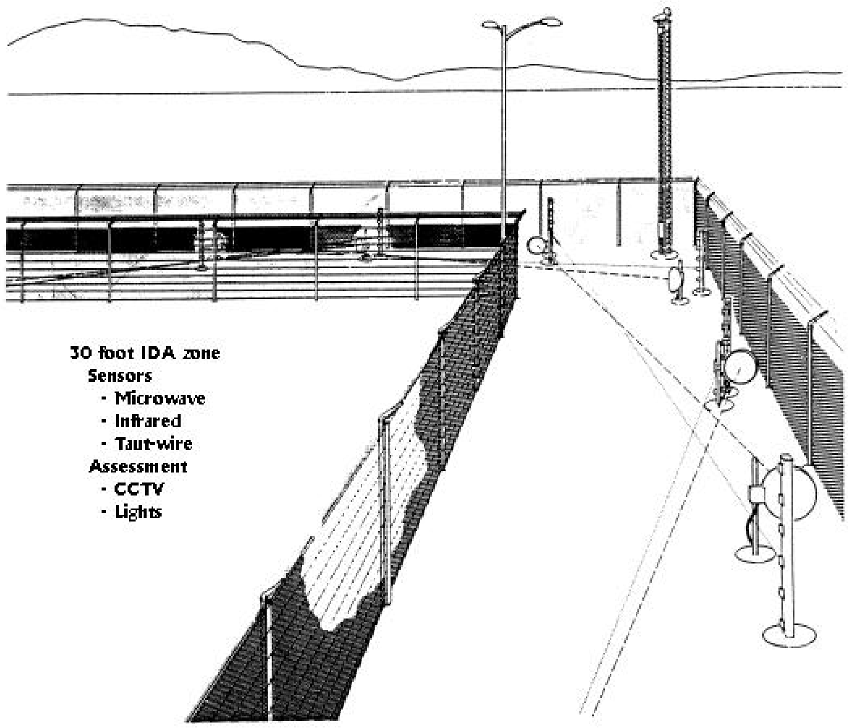


Figure I-25. *Intrusion Detection and Assessment System*[70]

Protective barriers are critical elements in an air base's secure perimeter and around critical assets within the perimeter. The Department of State (DoS) has had various barrier types and designs constructed and crash tested to evaluate their performance relative to specific impact conditions. It is imperative that the barrier chosen provide each facility with comparable, maximum-security protection, regardless of its function, sensitivity, number of employees/persons housed, etc.[71]

Important considerations for barrier selection include attack-vehicle aggressivity, construction, maintenance, climate, and aesthetics. Aggressivity is the vehicle's ability to penetrate a barrier during its attack and depends both on the vehicle's characteristics and the characteristics of the surfaces surrounding the compound. The most important vehicle characteristics are (1) type of vehicle, (2) frontal force-deflection response, (3) weight, (4) center of gravity, (5) front bumper and frame heights, (6) length, (7) turn radius, and (8) engine and transmission. For a conservative representation of a typical attack vehicle, the DOS used a 2½-ton, medium-duty truck in full-scale barrier tests.[72] The results of these tests for both fixed and active barriers are shown in Figures I-26[73] and I-27[74] and Tables I-12[75] and I-13.

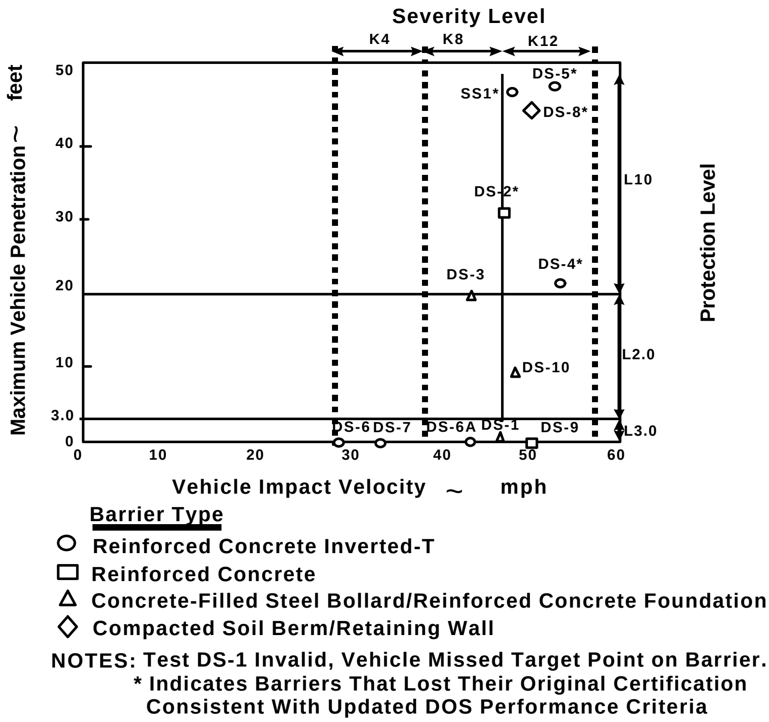


Figure I-26. *Velocity-Penetration Diagram for Crash Tests of Fixed Barriers*

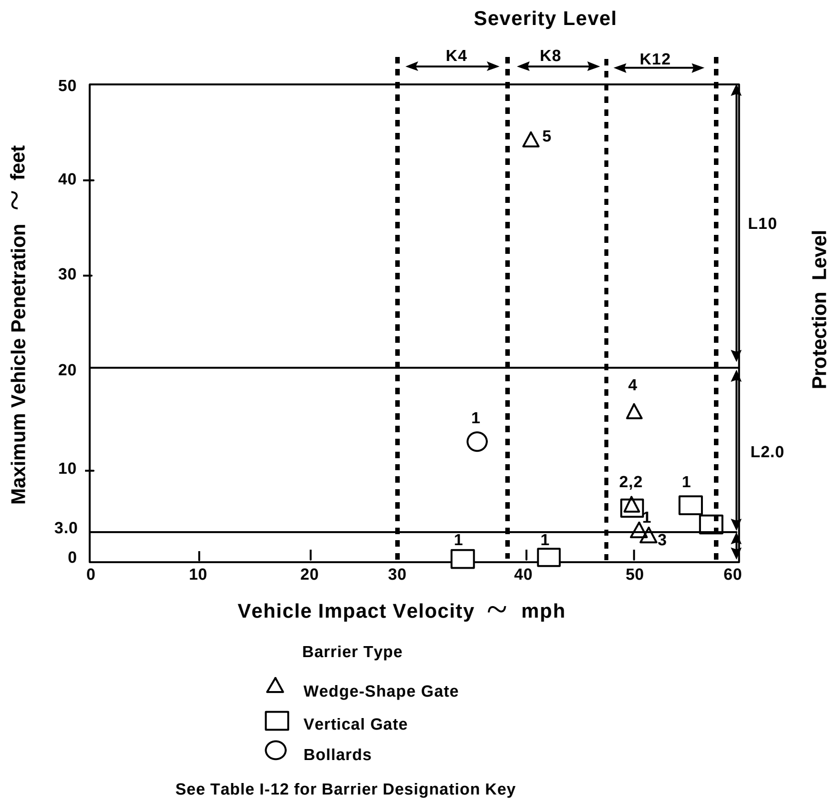


Figure I-27. *Velocity-Penetration Diagram for Crash Tests of Active Barriers*

Table I-12. *Summary of Fixed-Barrier Tests: Barrier and Test Descriptions*

Barrier No.	Barrier Description: Type	Footing: Length (ft)	Footing: Depth (in)	Footing: Width (in)	Cost ($/ft)	Test Description: Vehicle: Make/ Model	Vehicle: Weight (lbs)	Test Conditions: Velocity (mph)	Test Conditions: Angle (deg)	Test Conditions: Grade (deg)	Test Conditions: Center of Impact	Kinetic Energy (10^3 ft-lbs)	Severity Level
DS-1	Concrete-filled steel bollards with channel beam/reinforced concrete foundation	32	48	24	NA*	Ford F600 truck	15,000	47.0	90	0	9.7 ft from target (center) location; test deemed invalid by DOS	1,107	K12
DS-2	Reinforced concrete planter (two units with a 3-ft separation)	9	18	36	NA*	Ford F600 truck	15,000	47.0	90	0	0.8 ft from target (center of separation) location	1,107	K12
DS-3	Concrete-filled steel bollards with steel channel beam/ reinforced concrete foundation	32	48	24	NA*	International school bus	15,000	43.5	90	0	0.5 ft from target (center) location	948	K8
DS-4	Reinforced concrete inverted-T	25	30	42	NA*	Ford F600 truck	14,950	53.5	90	0	0.6 ft from target (center) location	1,429	K12
DS-5	Reinforced concrete inverted-T	25	30	66	NA*	Ford F600 truck	14,820	52.3	90	0	0.3 ft from target (center) location	1,354	K12
DS-6	Reinforced concrete inverted-T	40	30	66	168	Ford F600 truck	14,810	29.2	90	0	15 ft from integral knee-braced end	422	K4
DS-6A†	Reinforced concrete inverted-T	40	30	66	168	Ford F600 truck	14,860	43.8	90	0	15 ft from integral knee-braced end	422	K8
DS-7	Reinforced concrete inverted-T	40	48	39	198	Ford F600 truck	14,840	34.0	90	0	15 ft from one end	573	K4
DS-8	Compacted soil berm/retaining wall	30	NA‡	NA‡	103	Ford F600 truck	14,860	49.4	90	0	Center	1,211	K12
DS-9	Reinforced concrete planter	29	36	42	255	Ford F600 truck	14,830	50.2	90	0	Center	1,248	K12
DS-10	Concrete-filled steel bollards/reinforced concrete foundation	32	48	55	391§	Ford F600 truck	15,050	48.6	90	0	0.4 ft from center (to allow tow cable to clear center bollard)	1,187	K12
SS-1	Reinforced concrete inverted-T	30	48	25	NA*	Ford F600 truck	14,860	47.9	90	0	Center	1,139	K12

* Cost not available.

† Test DS-5A constitutes a second impact of barrier DS-6.

‡ Wall portion of barrier served to hold compacted soil in place: vehicle impact resistance stemmed primarily from soil mass.

§ Barrier DS-10 was constructed alone. Previous Calspan-program barriers DS-6, DS-7, DS-8, and DS-9 were constructed in pairs, resulting in some undetermined cost saving.

Table I-13. *Summary of Fixed-Barrier Tests: Vehicle and Barrier Performance*

Barrier No.	*Vehicle Performance*		*Barrier Performance*	
	Maximum Penetration* (ft)	***Condition***	***Protection Level***	***Condition***
DS-1	0.7	Disabled. Extensive damage to cab.	L3.0†	Bollards and beam deformed in impact region. Foundation cracks present along entire length. Footing plowed (i.e., transited) about 4 in maximum.
DS-2	31.2	Disabled. Cab demolished. Both axles separated from frame.	L1.0‡ (None)	Right-side planter dislodged from ground, became airborne and landed 12 ft from its original position. Physical damage to both barriers limited to concrete spalling.
DS-3	Frame: 0.7 Body: 19.6	Disabled. Body completely separated from frame.	L2.0§	Bollards and beam deformed in impact region. Foundation cracks present along entire length. Footing plowed about 3 in maximum.
DS-4	21.5	Disabled. Cab demolished. Front axle separated from frame.	L1.0‡ (None)	Barrier rotated about its longitudinal axis approximately 60 degrees and was partially dislodged from the ground. Physical damage consisted of spalling on impact-side wall and two cracks on opposite-side wall.
DS-5	48.3	Disabled. Vehicle turned end over end. Cab demolished. Front axle and engine separated from frame.	L1.0‡ (None)	Above-ground portion of wall demolished in immediate impact region.
DS-6	0	Disabled. Moderate damage to cab. Front axle separated from frame.	L3.0	Minor damage: gouges on front surface. Barrier plowed about .0125 in maximum.
DS-6A	0	Disabled. Cab demolished. Front axle separated from frame.	L3.0	Relatively minor damage: gouges on front surface; hairline cracks on rear surface; concrete sheared and broken above top reinforcing bars near impact center. Barrier plowed about .0125 in more (.25 in total for two tests).
DS-7	0	Disabled. Moderate damage to cab. Front axle separated from frame.	L3.0	Relatively minor damage: gouges on front surface; hairline crack in top and rear surfaces.
DS-8	45	Disabled. Vehicle became airborne. Moderate damage to cab. Front axle separated from frame.	L1.0‡ (None)	Concrete block wall demolished and upper wedge of soil displaced in region surrounding impact zone.
DS-9	0	Disabled. Cab demolished. Front axle separated from frame.	L3.0	Relatively minor damage: gouges on front surface; hairline cracks on rear surface; concrete sheared and broken above top reinforcing bars near impact center. Barrier lowered about 1 in maximum.
DS-10	Bed: 3.5 Frame: 9.5 Cab: 29.5	Disabled. Cab and engine separated from vehicle frame and were propelled over barrier. Extensive damage to cab. Front axle separated from frame. Frame and bed restrained by barrier.	L2.0¶	Relatively minor damage: three horizontal cross pipes sheared from two bollard clusters in impact region; four hairline cracks in foundation in same area.
SS-1	47.8	Disabled. Vehicle became airborne. Moderate damage to cab. Front axle separated from frame.	L1.0‡ (None)	Above-ground portion of wall demolished in immediate impact region.

* Measurement to leading edge of vehicle or component/assembly indicated.
† Invalid test: vehicle missed target point on barrier.
‡ Original rating listed in column. Barrier now regarded as unacceptable because it was susceptible to possible second-vehicle follow-through.
§ Performance rating assumes that the bed of a standard, DoS-specified test vehicle would not have traveled more than 20 ft beyond the original barrier periphery.
¶ Barrier DS-10 rated as L1.0 in Reference 10. Revised protection level reflects updated DoS performance assessment criteria.

Kinetic energy is the best indicator of the severity of a vehicle's impact with a barrier. Kinetic energy is simply one-half the product of the vehicle's mass and its velocity squared. The test vehicles were loaded to a gross weight of 15,000 pounds, which is unlikely to be greatly exceeded by actual attacking vehicles. An attacking vehicle's velocity at impact will depend on its engine and transmission system and the distance over which the vehicle accelerates before impact. Figure I-28 shows a velocity-vs.-distance curve for a typical truck of the type tested (with a 360-hp engine).[76]

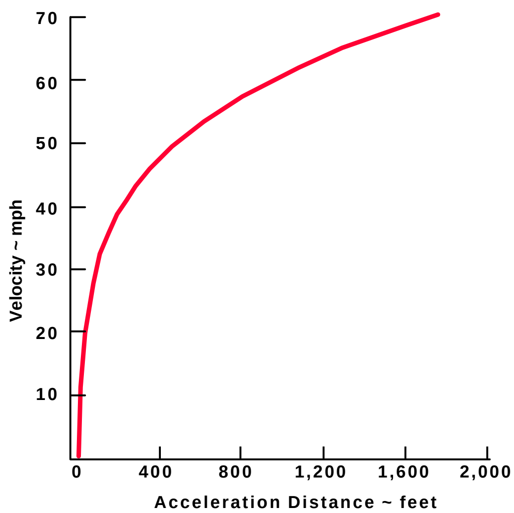


Figure I-28. *Velocity Function for Barrier Test Vehicles*

In addition to velocity, the approach angle of the vehicle is important, and this angle can be dictated by the layout of the compound and the surrounding roads and buildings. For a given facility, many of the possible attack routes can be analyzed to determine the worst case (i.e., the one with the maximum possible attack velocity), for which the barriers should be selected. Figure I-29 shows how these paths would be diagrammed for a hypothetical compound. In the figure, "r" is the radius of curvature of the path, "v" is the velocity, and "θ" is the angle of impact. It is important to note that damage is affected only by the component of velocity directly perpendicular to the barrier — this value is given by the product of the velocity and the sine of the angle.[77]

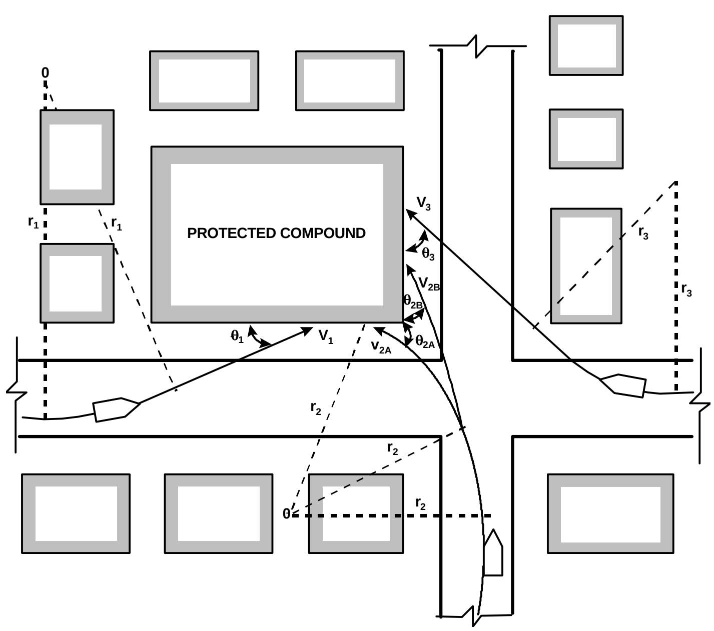


Figure I-29. *Possible Attack Paths for a Hypothetical Urban Compound*

In almost all situations, an attacking vehicle will have to turn before a final straight-line approach. In these cases, the impact velocity will be restricted by the maximum cornering speed, which is simply the square root of the product of the coefficient of tire traction (between the tires and the path surface; for dry asphalt and concrete surfaces, this value will be between 0.8 and 1.0), the radius of curvature of the path, and the acceleration due to gravity (32.2 ft/s^2). After completing its final turn, the attacking vehicle can then accelerate in a straight line until it strikes a barrier. This sequence is illustrated in Figure I-30. Steep grades also should be factored into the velocity calculations: an uphill grade will reduce the vehicle's impact velocity, while a downhill grade will increase the velocity.[78]

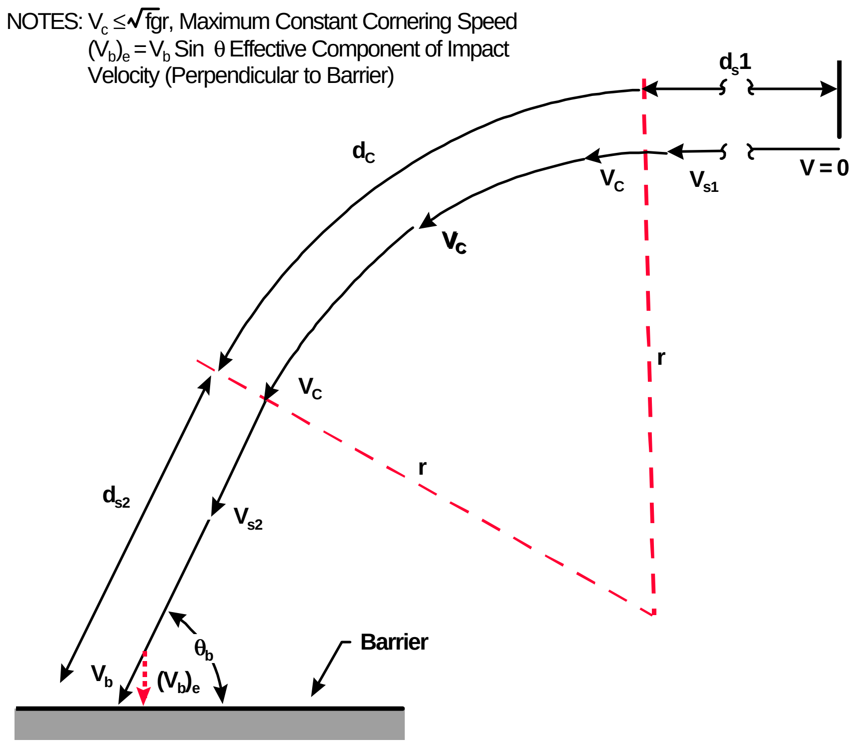


Figure I-30. *Velocity Variation Along a Hypothetical Attack Path*

In Figure I-30:

- V_c represents the maximum possible vehicle velocity (cornering velocity) on path d_c
- d_{s2} represents the length of straight-line acceleration distance after path curvature
- V_{s2} represents the variable velocity on path d_{s2}
- V_b represents the vehicle at barrier impact point
- θ_b represents the vehicle approach angle relative to barrier periphery (< 90°)
- $(V_b)_e$ represents the effective component of barrier impact velocity

Regardless of its speed V_{s1} at the end of path d_{s1}, the vehicle must slow down to a speed V_c upon entering the curved path d_c to maintain its circular motion, i.e., avoid skidding off the road. The maximum magnitude of this cornering is given by

$$V_c = \sqrt{fgr}$$

where:

- f represents the coefficient of tire traction between the vehicle tires and path surface

- g represents the acceleration due to gravity (32.2 ft/s^2)
- r represents the radius of curvature of the circular path

Upon leaving the curved path, i.e., upon entering the straight path d_{s2}, the vehicle can resume acceleration to a higher velocity V_{s2} until it strikes the barrier at some impact velocity V_b.

The following steps can be used to identify the worst-case attack scenario:[79]

- Make a sketch of the compound and outlying buildings and streets.
- For each segment of the compound boundary, identify the longest, straightest, most level path that an attack vehicle could use. Figure I-31 shows how different arrangements of compound boundaries, outlying buildings (i.e., constraints), and pathways result in different attack paths.
  - A path must be at least 8 feet wide to be used in an attack.
  - A path must have no radius of curvature less than 22.5 feet to be used in an attack.
  - Any surface on which a vehicle can be driven can be used in an attack (e.g., street, lawn, or sidewalk).
- For each path, the section of the compound boundary that would be impacted is a critical area. On the sketch, circle and label all critical areas. All entrances are critical areas.
- For each critical area, there are two associated regions. Region 1 is the area immediately outside the compound boundary in which a vehicle would make its final maneuver before impacting the boundary. Region 2 extends radially outward from Region 1 and encompasses the main roadways, shoulders, and sidewalks as well as any open areas (e.g., parks, estates, and vacant lots).

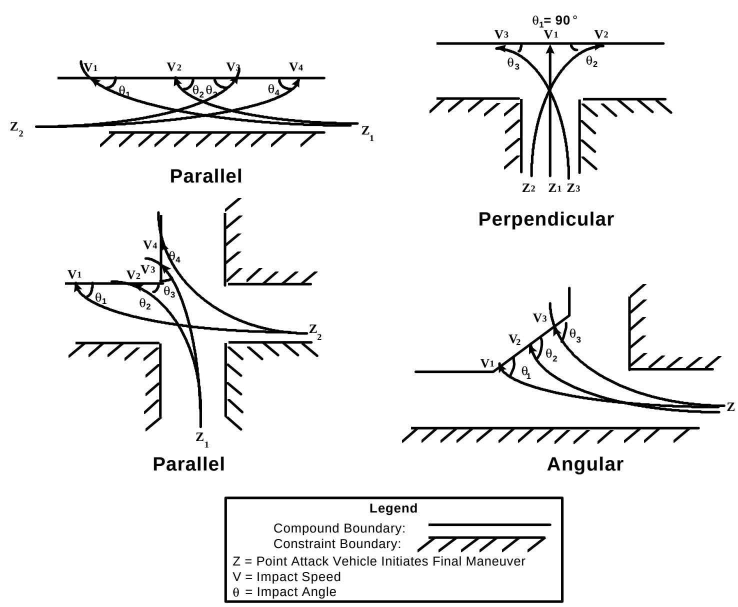


Figure I-31. *Vehicle Attack Paths*

Figure I-32 shows a hypothetical air base with five critical areas and the associated Regions 1. Because of closely spaced buildings on the north and west sides of the compound, it is vulnerable only on its south and east sides. For a particular path, vehicle impact speed would be calculated using the vehicle's speed just outside Region 1.[80]

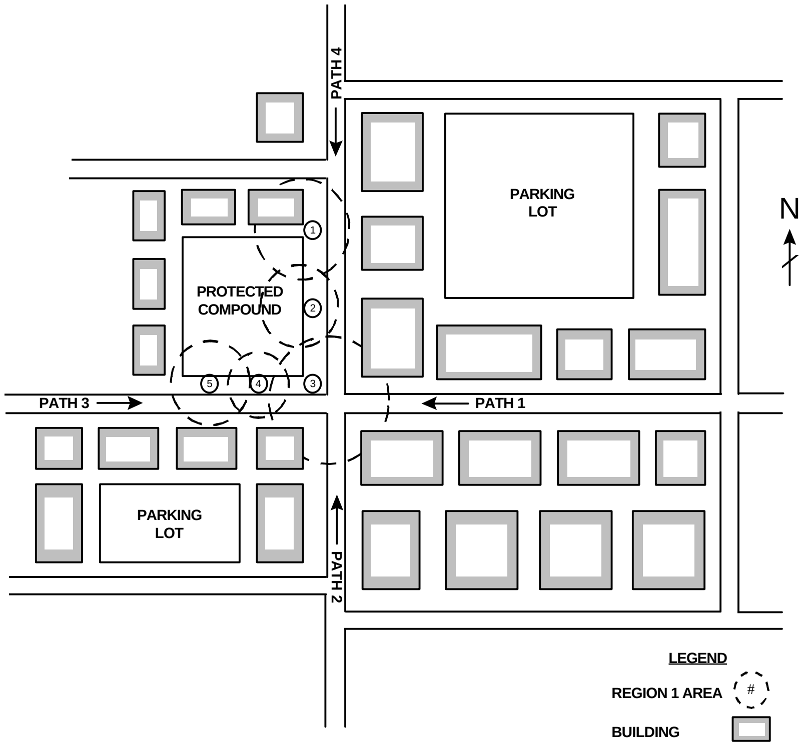


Figure I-32. *Attack Paths and Critical Areas for a Hypothetical Embassy Compound*

A variety of secondary factors should be considered in barrier selection. Poor construction materials or practices can completely undermine the selection of an optimal barrier. Cost should be weighed only in selecting among candidate barriers that will protect against the worst-case attack. When costs are considered, maintenance costs must be included. These costs will certainly be higher for barriers with moving parts than for passive barriers. Climate will play a role. For example, an earth berm might not be appropriate in a very wet region because soil erosion and settling would degrade the barrier.

2.2.3 Protecting Personnel

An assortment of antiterrorist protective gear is available: antiflash hoods, gas masks, Nomex suits with Kevlar reinforcements at the elbows and knees, ballistic vests, and ballistic helmets. The protection afforded by different vest types is shown in Table I-14. The ballistic vests worn by AEF personnel should be Type III.

Table I-14. *Protection Levels of Ballistic Vests*[81]

Caliber	Type I	Type II-A	Type II	Type III-A	Type III
.22 .25 .32 .38 (lead) .44 12-gauge (shot)	Yes	Yes	Yes	Yes	Yes
.22 rifle .45 9-mm Luger .38 Super 12-gauge (buckshot)	No	Yes	Yes	Yes	Yes
.357 magnum .44 magnum	No	No	Yes	Yes	Yes
.30 carbine 12-gauge (slug) .308 Western Intelligence (WIN)	No	No	No	Yes	Yes
7.62 Soviet 7.62 NATO	No	No	No	No	Yes

In addition to security devices and facilities, operational procedures are important. For example, personnel in Dhahran are confined to base, and only 10 to 15 people are allowed to go off-base to work with Saudi personnel. "They follow a very stringent procedure, traveling in semi-armored vehicles, wearing civilian clothes and sometimes body armor. They carry cellular telephones for instant communications. They travel to and from their destinations with no stops. Sightseeing is prohibited."[82]

Personnel moving through or within foreign countries should take basic precautions. The premise is simple: minimize the likelihood of identification as an American or as a member of the U.S. military by keeping a low profile and avoiding nationality indicators.

To keep a low profile:

- Wear local clothing
- Adopt local customs and habits
- Use local currency

To avoid nationality indicators:

- Do not wear the uniform
- Do not display U.S. license plates on vehicles
- Avoid using military language and American slang
- Cover tattoos
- Avoid displaying the flag
- Do not stand at U.S. Government bus stops[83]

Travel, even in the U.S., can be particularly dangerous. For complete protection, a vehicle should (1) be bulletproof; (2) have tinted rear windows, making it harder to detect occupants; (3) have windows closed, or opened less than one inch, as a precaution against grenades; and (4) have antiblowout tires.[84] Table I-15 is a checklist of actions people should take to reduce the probability of becoming terrorist victims. The checklist was originally published by the International Association of Bomb Technicians and Investigators in cooperation with Lockheed.

Table I-15. *Security While Traveling*[85,86]

General Travel Precautions

- Check with corporate security regarding potential problems in the countries you will visit.
- Restrict trip and itinerary information to close family and close business associates.
- Use reliable hotels recommended by colleagues or by the U.S. embassy or consulate.

Upon Arrival

- Maintain a low profile. Avoid any display of company affiliation when registering at the hotel.
- Ensure that locks on the hotel room doors are in working order.
- Do not leave identifying materials in the hotel room.
- Use the hotel vault or secure storage area for valuables.
- Avoid carrying large amounts of cash.
- Beware of friendly strangers.
- Avoid incidents such as civil unrest, demonstrations, crowds, fires, and accidents.
- Avoid actions identifying you as an American.
- Avoid establishing routine schedules.

Automobile Travel

- Keep the vehicle in good working condition and know its capabilities. If possible, have a vehicle with an inside hood latch and locking gas cap.
- Keep the gas tank at least half full at all times.
- Be sensitive to the possibility of surveillance.
- While driving, keep doors locked and windows open no more than two inches.
- Use well-traveled highways.
- Use the center lane on multilane highways to avoid being forced to the curb.
- Be alert to all signals, stop signs, and intersections.
- Be suspicious of distress signals.
- Get around any suspicious roadblock by using the road shoulder or making a U-turn.
- Do not pick up strangers regardless of the circumstances.
- Use your rearview mirror frequently to check for following automobiles.
- Use the horn to attract help if you suspect you are being followed, and drive to a busy area of town where there is a local hospital, police, or fire station.
- Lock the car when it is unattended.
- Separate the ignition key from the other keys if you are leaving keys with a doorman or parking attendant.
- Park the car off the street at night.
- Report immediately any suspicious wires or packages.
- Avoid routines. Vary times and routes as well as your method of travel.
- Maintain a low profile with cab drivers.
- Avoid using cabs for sightseeing. Take bus tours instead.

Aircraft Travel

- Fly U.S. carriers whenever possible.
- When overseas, do not make reservations by telephone. Instead, go to the airport or a local office of the airline to purchase tickets.
- Leave early for the airport to minimize your exposure standing in long lines.
- Once in the terminal, move as quickly as possible to a secured area.

Hostage Survival Information

- Obey terrorist orders.
- Be courteous and polite to terrorists and other hostages.
- Do not debate, argue, or discuss political issues with terrorists or other hostages.
- Talk in a normal voice.
- Avoid abrupt movements.
- Locate yourself away from windows and doors if possible.
- Do not hesitate to answer questions unless your position or purpose of travel may pose a threat to the terrorists or their ideologies.
- Inform your captors if you have any special medical conditions or disabilities.
- Do not discuss possible retaliatory actions that may be taken by your family, friends, or company.
- Keep calm.

2.2.4 Planning for Force Protection

Sound, complete deployment planning is essential (see Table A-1). The planning process begins with intelligence and evolves through deployment planning to vulnerability assessments. Intelligence-gathering on terrorists must include all information sources: open sources, human intelligence, signal intelligence, surveillance of potential targets, and photographic intelligence.[87] Table A-2 (in Annex 1) is an intelligence implementation checklist.

A crisis management team must be in place. The team should include (1) the commander, (2) the vice commander, (3) a law enforcement specialist, (4) an operations specialist, (5) an intelligence specialist, (6) a logistics specialist, (7) a personnel specialist, and (8) a public affairs specialist.[88] This team should conduct vulnerability assessments of the unit and of the installation (checklists for each are in Tables A-3 and A-4). The unit also should maintain a Crisis Management File on each person to be deployed (see Table A-5).

Finally, the team must prepare a Physical Security Plan for the deployment (see Table A-6). The deployed security force must control access to the air base, monitor parking areas, keep visitor areas clean of information, ensure that buildings are not labeled, place barriers around sensitive areas, install intrusion-detection systems, and post security guards.[89] All deployed personnel must maintain constant vigilance and be prepared to respond to terrorist actions, such as bomb threats.

The following items are provided in Annex 1:

- Table A-1. Deployment Preparation Checklist
- Table A-2. Intelligence Implementation Checklist
- Table A-3. Unit Vulnerability Assessment
- Table A-4. Installation Vulnerability-Determining System
- Table A-5. Personnel Crisis Management File
- Table A-6. Physical Security Plan

- Table A-7. Bomb Threat Form
- Table A-8. Bomb Threat Investigation Form

2.3 Future Threats

"Terrorists are developing increasingly complex ways to support their operations."[90] In addition, terrorists are becoming more lethal because of (1) "the terrorists' perennial quest for attention and publicity that results in an organizational imperative towards escalation, (2) the fact that terrorists are simply becoming more adept at killing, (3) increasing state sponsorship that significantly enhances terrorist capabilities, (4) the growth in the number of terrorist groups motivated by a religious imperative, (5) the proliferation of 'amateurs' involved in terrorist acts, and (6) the increasing sophistication and operational competence of 'professional' terrorists."[91]

2.4 Future Countermeasures

A key countermeasure will be yearly evaluations of Air Force installations by FASTs. Evaluations like these will help AEFs, and the installation evaluations can be thought of as "dry runs" for the short-notice evaluations that AEFs will need to conduct.

A number of new technology efforts will help counter the terrorist threat to AEFs.

2.4.1 Expanded Situation Awareness Insertion (ESAI)

During mission execution and engagement phases, aircraft mission success depends on aircrew situation awareness, which is based on timely and accurate information. Currently, threat and target information is provided by pre-mission planning intelligence, and updates are relayed by voice communications. The objective of the ESAI program is to design, develop, evaluate, and demonstrate hardware and software approaches and techniques to provide tactical, strategic, airlift, and special operations aircrews with a timely, enhanced threat alert and situation awareness capability. Emphasis is on direct application of technology developments through demonstrations. The situation awareness enhancement most important to the force protection mission will be more accurate combat identification, which will use traditional and new parameters for friend/foe separation and specific-emitter identification.

Through a Mission Needs Statement, a Statement of Operational Need (SON), and a System Operational Requirements Document, ACC has confirmed the need for expanded situation awareness, including improved threat location and identification. The ESAI program will provide advances in real-time updating of mobile targets and threats for self-defense, combat identification, and targeting; low-cost angle of arrival and precision emitter location techniques; the use of new parameters for friend/foe separation and electronic battle-damage assessment; and optimized response strategy for self-defense of combat aircraft.

2.4.2 Expedient/Modular Physical Protection (EMPP)

The purpose of the Expedient/Modular Physical Protection effort is to develop physical protection measures for force protection at a forward-deployed AEF airbase. In many AEF scenarios, deployed forces will be at high risk of terrorist attack. New technology for force protection will allow updating of force protection criteria for AEF operational parameters, analysis of current and future terrorist weapon effects, rapid site assessments, rapid planning and design of force protection measures, improvements to existing installations and facilities at an airfield, and training in AEF force protection measures. This program should be complete in FY 00.

The program will include three components. The “AEF Force Protection Planning Tool” will be a computer program for the rapid identification and prioritization of force protection measures at an AEF deployment site. The program will have several modules: policy/criteria, threat, site layout, weapon effects, response models, and force protection measures (including standard methods and costs). The “Deployable Defensive Fighting Positions” component is described in the next subparagraph. The “Structural Strengthening” component will develop and test rapid, inexpensive retrofit measures to significantly increase the blast resistance of concrete and masonry structures. The scope of the required work includes modeling, analysis, testing of designs, design methodology, and trials on the types of facilities typically found at commercial airports.

2.4.3 Deployable Defensive Fighting Positions

The deployable defensive fighting positions effort is a component of the Expedient/Modular Physical Protection program. The purpose is to produce deployable protection kits that maximize use of materials available locally and in theater (e.g., AM-2 matting), reduce air-transported weight and setup time from the existing B-1 revetment kit, use modular concepts to adapt protection to the sizes required for critical assets, and provide new equipment to move soil and more efficiently fill revetments. In some cases, existing facilities at an AEF deployment location may have to be strengthened against a potential terrorist attack. Rapid, inexpensive construction processes are needed to significantly increase the strength of concrete and masonry structures. The scope of the required technology includes modular, lightweight panel systems; retrofit of wall, beam, ceiling, and floor structural elements; and modeling, analysis, testing of designs, and design methodology.

Wright Laboratory is evaluating expedient revetment systems at an explosives test range at Tyndall AFB. Initial trials have been performed on a commercially available system. The tests have included new configurations that would be suitable for aircraft revetments and explosive yields larger than those previously tested on this type of system.

2.4.4 SABER 203 Laser Illuminator System and Battlefield Optical Surveillance System

The SABER 203 is an adaptation of the widely deployed M-16/M-203 rifle/grenade launcher. The system consists of a triggering transmitter unit (TTU) that clips onto the M-203 grenade launcher (which is mounted on the M-16 rifle) and an illuminator unit (IU). The IU houses a 250-milliwatt (mW) laser that has a wavelength of 650 nanometers (red) and produces 28 mW at its aperture. The IU fits into the TTU like a grenade round, and its laser is activated by a button on the TTU. The SABER 203 laser fires a continuous-wave beam for 10 seconds; then the beam flickers at 8 to 9 Hz until the TTU button is released. If conventional grenades are needed, the operator simply ejects the IU and loads a conventional round.

The SABER 203 laser illuminator is designed for use by security police in air base defense, peace keeping, and humanitarian operations. It affects hostile forces by illuminating intruders, tagging them with a bright red circle of laser light, and temporarily impairing their vision by flashing laser light in their eyes at safe distances. The SABER 203 enhances the Air Force’s ability to apply force proportional to the threat. The effectiveness of the system will be measured in a series of field trials at Camp Bullis in February 1998 using Air Force Security Forces personnel. Deployment of the first 1,000 units is scheduled for June 1999.

The Battlefield Optical Surveillance System works in the same manner as SABER 203, but it has higher power and emits in the green wavelengths.

2.4.5 Active Denial Technology

The Active Denial program is a joint exploratory development effort between Armstrong Laboratory (AL) and Phillips Laboratory (PL) to develop nonlethal security and area denial applications. A fielded system would delay intrusion to allow threat assessment and validation, initiation of tactical response, and interdiction of the threat. An Active Denial system will give an AEF commander a nonlethal option for force protection with the option of immediate transition to lethal force if necessary. The current focus of the program is to provide proof-of-concept for ground-mobile, helicopter, and C-130-based systems. The research emphasis is on understanding the biological effects of millimeter-wave exposures. The Ground-Mobile Demonstrator will be fielded in FY 03.

2.4.6 Tactical Automated Security System (TASS)

TASS is a rapidly deployable, easily transportable, and quickly relocatable integrated electronic security system that can be tailored for a wide variety of semipermanent, portable, and covert applications. TASS detects intrusions into protected areas, directs responding forces to the intruders, and assesses the strength and composition of the intruding force. TASS enhances the warfighter's capability for early detection and identification of threats to prevent damage or destruction of mission-critical assets and for collection of critical intelligence information. Typical TASS applications include security for main operating bases, bare-base transitions, special operations, transient and dispersed assets, aircraft parking areas, buildings (exteriors and interiors), perimeter approach routes, border surveillance, and drug interdiction. TASS has been used in field training exercises in Korea and is currently being tested at Eskan Village, Saudi Arabia.[92] Initial deliveries will begin in FY 98.

TASS consists of five principal elements: data communications, annunciators, sensors, assessment devices, and power. The TASS data communications consists of radiofrequency transmission networks for reporting alarm data to various annunciators. The annunciators are capable of receiving, processing, reporting, and graphically displaying system sensor alarms at various levels of command. This element includes desktop and laptop computers and hand-held monitors for application in a variety of anticipated TASS semipermanent, portable, and tactical scenarios.

The sensors operate in diverse terrain and under demanding environmental and climatic conditions. The sensor element provides base defense sensors with detection ranges from 3 feet per sensor to 100 feet per sensor and flightline sensors with detection ranges of up to 300 feet per sensor. TASS can accommodate bistatic and monostatic microwave, passive and active infrared, seismic, magnetic, break-wire, and selected fence sensors. The assessment element relies primarily on hand-held and remotely monitored wide-area thermal imagers. These thermal systems allow identification of man-sized targets at 1.5 km and vehicles at 3.0 km during day and night. The tactical sensors will operate for a minimum of 1 week without requiring a battery change. The flight-line sensors operate up to 72 hours without requiring a battery change or recharge.

2.4.7 Perimeter Surveillance/Self-Protection Air Vehicle

The Perimeter Surveillance/Self-Protection Air Vehicle program, a surveillance system hosted by unmanned aerial vehicles (UAVs), will allow AEF perimeter defense to be accomplished with far fewer personnel than needed now. The technology is being developed commercially for traffic control, and a working prototype is scheduled for January 1998. The Marine Corps is considering an advanced concept technology demonstration (ACTD) of the system for battlefield reconnaissance, and development of a perimeter surveillance version could begin immediately. The system could even be adapted for weapons delivery. The vehicle is a mere 36 inches long and weighs only 130 pounds. The control station is the size of a suitcase. The cost of the commercial system is expected to be $60,000.

2.4.8 Air-Delivered Unmanned Combat Aerial Vehicles (UCAVs)

A group of air-delivered UCAVs could be a rapid-response force protection package, conducting air operations anywhere in the world within 24 hours, without tanker support or the crew-rest limitations of human aircrews. This technology is revolutionary, so development and fielding are certainly far-term efforts.

2.4.9 Objective Crew-Served Weapon (OCSW)

The OCSW is the next-generation crew-served weapon system as outlined in the Joint Service Small Arms Master Plan (JSSAMP). The JSSAMP envisions replacing the current inventory of small arms with an Objective Family of Small Arms consisting of an individual weapon, a crew-served weapon, a personal weapon, a sniper weapon, and other mission-specific weapons.

The OCSW will replace selected 40-mm MK19 machine guns and .50 cal. M-2 machine guns (possibly 7.62-mm M-60/M-240 machine guns). The thrust of the program is to develop and demonstrate a lightweight, two-person portable crew-served weapon system that incorporates the latest advancements in electronics materials and small-arms technologies. The system will provide decisively violent and suppressive target effects out to 2,000 meters, including a high probability of incapacitation and suppression against protected personnel and a high potential to damage light and lightly armored material targets (e.g., vehicles, water craft, and slow-moving aircraft). The superior performance characteristics of the OCSW make it an ideal candidate for the primary/secondary armament on a wide variety of current and future vehicles.

The current program is a technology demonstration. Two contractor teams conducted a complete trade-off analysis to define system concepts. In February 1995, the Primex Technologies (formally Olin Ordnance) team was selected to continue developing the OCSW concept and demonstrate a prototype OCSW system. The OCSW program is using Government/contractor Integrated Product Teams (IPTs) to evaluate and implement design decisions and system trade-offs.

The OCSW development team consists of the following:

- Government
  - JSSAMP/Technical Community/IPT
  - Joint-Service Users Advisory Council
- Primex Technologies (Downey, CA)
  - Prime contractor
  - Systems integration
  - Ammunition development
  - Airburst fuze development
- Davron (Orlando, FL)
  - Airburst fuze development
- General Dynamics (Burlington, VT)
  - Weapon/mount development

The Primex team will employ leading-edge technologies to achieve devastating target effects to defeat both visible and non-visible/defilage targets as well as other difficult targets.

The OCSW will exploit lightweight, high-strength materials, modular opto-electronic full-solution fire control, electronic time-set fuzing and high-explosive (HE) air-bursting munitions. The OCSW system will be a highly lethal, suppressive, and deployable weapon system. The rugged, lightweight system will be highly maneuverable and easy to disassemble, assemble, and maintain. The reduced weight and size of the 25-mm HE ammunition will facilitate sustainability on the future battlefield. The OCSW system will be demonstrated in technical, safety, and user testing in FY 99-00.

2.4.10 Objective Individual Combat Weapon (OICW)

The OICW Advanced Technology Demonstration (ATD) provides an enhanced capability for the 21st-century infantryman, with the potential to selectively replace the M-16 rifle, M-203 grenade launcher, and M-4 carbine. Program guidelines were derived from the Small Arms Master Plan and JSSAMP.

The OICW-ATD is managed by JSSAP and will provide superior firepower to the Army, Marine Corps, Air Force, Special Operations Command, Navy, and Coast Guard.

Key Program Capabilities

- 500 percent increase in probability of incapacitation
- New soldier capability to defeat targets in defilade
- Effective range to 1,000 meters
- Day/night fire control; wireless weapon interface
- Substantial weight reduction
- Ergonomic, user-friendly design
- Decisively violent target effects

Technology Advancements

- Weapon recoil mitigation
- Fuzing miniaturization and accuracy
- Warhead lethality and packaging
- Target acquisition and man in the loop
- Laser-ranging accuracy at extended ranges
- Extensive composite use

2.4.11 Precision Location and Identification

The Precision Location and Identification system is the enabling technology for DARPA's Advanced Tactical Targeting Technology program.

2.5 Responsible Parties

366 SPTG

820th Security Forces Group

American Legion

American Society for Industrial Security, 1655 N. Fort Myer Dr., Arlington, VA 22209

Anti-Defamation League of B'nai B'rith

Association of Former Intelligence Officers, 6723 Whittier Ave., Suite 303A, McLean, VA 22101

Chief of Security Forces, AF/SF

Criminal Justice Information Service

FBI Behavioral Science Unit

FBI National Crime Information Center

Force Protection Working Group[93]

HQ USAF/IL

International Association of Bomb Technicians and Investigators, PO Box 6609, Colorado Springs, CO 80934

International Association of Chiefs of Police, PO Box 6010, 13 Firstfield Rd., Gaithersburg, MD 20878

Joint Requirements Working Group

Marine Corps Combat Development Command

National Institute of Justice

Physical Security Action Group

Tactical Response Association, PO Box 8413, Prairie Village, KS 66208

U.S. Air Force Civil Engineering Support Agency, Tyndall AFB

U.S. Air Force Force Protection Battlelab

U.S. Army Rangers

U.S. Army Special Forces

U.S. Army Terrorism Counteraction Office

U.S. Department of State, Bureau of Public Affairs

U.S. Navy Survival, Evasion, Resistance, and Escape School

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3.0 Biological Weapons

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3.1 Current Threats

3.1.1 Agents

The threat of biological weapons continues to escalate with the rapid increase in the development of biologicals, toxins, and hazardous industrial chemicals. The potential threat to AEF operations will increase greatly over the next 20 years with the exploitation of genetic engineering and biotechnological methods. The ease of access to this technology and low relative cost magnify the potential threat from nation-state and terrorist adversaries.

Typical biological agents of concern to Air Force operations include the bacteria, fungi, rickettsia, and viruses listed in Table I-16.

Table I-16. *Catalog of Biological Agents*

Bacterial Agents	***Fungi***	***Rickettsia***	***Viruses***
* Bacillus anthracis	Coccidioides immitis	* Coxiella burneti	* Venezuelan equine encephalitis
Brucella species	Herbicidal fungi	Rickettsia australis	* Variola (smallpox)
Bacillus cereus	Phytophtora infestans	Rickettsia conori	* Yellow fever
Bacillus stearothermophillus	Sclerotium rolfsi	Rickettsia typhi (mooseri)	* Ebola/Marlburg
* Burkholderia mallei	Histoplasma capsulation	* Rickettsia prowazeki	Hemorrhagic fever (HF) with renal syndrome
* Francisella tularensis		Rickettsia rickettsi	
Malleomyces mallei		Rickettsia sibirica	Lassa fever
Malleomyces pseudomallei		Rickettsia tsutsugamushi	Argentine HF
Mycobacterium tuberculosis			Bolivian HF
Pasteurella pestis			Congo-Crimean HF
Pasteurella tularensis			Rift Valley fever
Salmonella (nonspecific)			Dengue fever
Salmonella typhimurium			Hanta virus
Serratia marcescens			Omsk HF
Spores (nonspecific, produced by bacteria)			
* Vibrio cholerae			
* Yersinia pestis			

* Prime for agent of mass destruction or mass illness when employed under suitable conditions.

Toxins are biological agents of natural origin (i.e., obtained from animal, plant, or microbial sources). They pose a significant threat when presented as respirable aerosols. Unlike bacteria and viruses, toxins do not reproduce in the affected host. Classic toxin agents of potential concern to AEF operations are largely protein, such as tetanus, diphtheria, or botulinum toxins. As a general rule, toxins derived from bacterial organisms are more highly toxic than those from plants, marine animals, algae, and other sources. Some toxins, such as staphylococcus enterotoxin B (SEB), can cause extreme illness and incapacitation at low doses but require high doses for lethality.

Biological warfare (BW) agents differ significantly in infectivity. These differences are strain-specific and can range from lethal to avirulent. Infectivity can be affected by a number of factors: (1) strain selection; (2) growth media and the production process; (3) pH, temperature, etc.; (4) adjuvants (e.g., metal salts, detergents, and amino acids); (5) drying; (6) storage (wet or dry); (7) stockpile-to-target sequence; (8) particle size; (9) susceptibility of the host; (10) route of entry; and (11) medical pretreatment.

3.1.2 Delivery Systems

Delivery systems run the gamut from simple to sophisticated. They vary from short- and long-range missiles and rockets directed at point targets to less complex, line-source delivery using airborne spray tanks. Small munitions, hand-held aerosol generators, and garden-sprayer-type devices are readily available to individuals and groups. Regardless of the delivery system, an AEF operation confined to a limited geographical area presents a unique opportunity for effective hostile use of biological weapons.

Aerosol delivery systems for biological agents typically generate invisible clouds of particles or droplets less than 10 micrometers in diameter. These particles remain suspended for long periods and readily adhere to clothing. The effective target area varies greatly, depending on wind speed, humidity, and sunlight, with optimal weather conditions occurring at night. In the absence of any detection or early warning system, the first evidence of an attack may be a large number of casualties fitting a clinical pattern typical of one or more biological agents.

3.2 Current Countermeasures

Current countermeasures include policies, training, personal and collective protection, detection and warning, and decontamination.

3.2.1 DoD Chemical/Biological Defense Management Structure, Guidance, and Policy

Enacted on 30 November 1994, Public Law 103-160, *National Defense Authorization Act for Fiscal Year 1994,* assigned responsibility for overall coordination and integration of the chemical and biological warfare defense program and the chemical and biological medical defense program to a single office within the Office of the Secretary of Defense.[94] The responsible office was established in February 1994 as the Office of the Assistant to the Secretary of Defense for Atomic Energy (Chemical and Biological Matters). In February 1996, in accordance with Public Law 104-106, the single responsible office was redesignated as the Assistant to the Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs, (ATSD [NCB]). One of ATSD(NCB)'s primary tasks is to "ensure close and continuous coordination between the nonmedical and medical chemical and biological defense programs."[95] This coordination includes directing the consolidation, coordination, and integration of the CBD budget for the military departments' nonmedical and medical programs. Medical programs include diagnostics, vaccines, prophylaxis, and treatment. Nonmedical programs include decontamination, threat avoidance, physical protection (masks and shelters), and detection systems. Regardless of the assignment of management responsibility, all the military medical departments have a keen interest in both medical and nonmedical CBD programs. This is especially true for the chemical and biological warfare (CBW) agent detection programs.[96]

The DoD guidance and policy for planning and executing nuclear, biological, and chemical defensive operations is documented in *Joint Doctrine for Nuclear, Biological, and Chemical Defense* — Joint Publication 3-11.[97] Joint-Service implementing instructions and training manuals are published by the U.S. Army (the CBD executive agent) and coordinated with other Services in publications such as the *NATO Handbook on the Medical Aspects of NBC Defensive Operations*.[98] This document and others listed in the

Bibliography section of this chapter provide a basis for understanding and defending against the NBC threat. These source data clearly indicate the DoD intent to incorporate NBC defensive planning, training, and readiness into every facet of joint military operations. This integrated systems approach is appropriate for all AEF operations. Deployed forces must have the inherent capability regardless of the scenario to defend against chemical and biological agents.[99]

3.2.2 Advocacy, Doctrine, Training, and Modeling

The Panel recommends that the Air Force Air Warfare Center be given the lead for BW issues. This arrangement will ensure that the Air Force operational commands have an effective advocate. The action will place responsibility for developing BW CONOPS where it needs to be and should assist measurably in mobility planning. Air Force officers need to be trained in BW issues, and any deploying AEF should have at least one rated officer who is knowledgeable on this subject. The Air Force needs to develop simulation models for biological agent use to assess the impact of that use on operations in high-threat scenarios.

3.2.3 Personal Protection

Available military chemical protective equipment (see Table I-17), which includes protective masks, battle dress overgarments, and protective gloves and overboots, will provide the best protection against biological agent attack. However, most BW agent exposure is through inhalation. The M-40 protective mask, when properly fitted, will protect the respiratory tract, the primary route of infection for biological agents. Regular filter maintenance and replacement are critical, but a properly fitting mask and standard military uniform of good quality and maintenance provide reasonable protection against inhalation and dermal exposure of covered surfaces. Personnel protective equipment includes:

- Advanced Technology Anti-G Suit
- Combined Advanced Technology Enhanced Design Ensemble
- Combined Advanced Technology Aircrew Ensemble
- Joint-Service Lightweight Integrated Suit Technology

In an active biological agent environment, a Mission-Oriented Protective Posture (MOPP) 3 or 4 is adequate for all agents.

3.2.4 Detection

Timely and accurate information is necessary to develop an effective defense against biological agents. The best way to minimize casualties is to detect a dispersed biological agent aerosol prior to its arrival on target. An appropriate alarm will allow personnel sufficient time to don protective gear. Until reliable and accurate detection is available, it is likely that the first indication of a biological attack will be ill or dying unprotected personnel. Table I-17 is a comparison of the capabilities of detector technologies that will be available in the next decade.

The M-31 Biological Integrated Detection System (BIDS) should help mitigate the effects of a large-area biological agent release. It may not be a satisfactory detection system for every release, especially small releases in close proximity to an air base. The current BIDS can detect up to four biological agents in less than 1 hour. The Preplanned Product Improvement to BIDS is proposed to detect up to eight agents within 30 minutes. Both of these systems have a large logistics tail (e.g., a HMMWV). The follow-on detection capability will be the Joint Biological Point Detection System (JBPDS), with an initial operational capability expected in late 2001. It will have a smaller logistics tail and will be able to detect six or more agents within 15 minutes.

The Mark III ACTD, available in late FY 97, will have reduced size, weight, maintenance requirements, and cost. This system should be the key detection system considered in AEF operations when such a detector is needed.

The Air Base/Port Biological Detection (ABPBD) ACTD will provide an interim point-detection capability starting in FY 98. It will be deployed to Eskan Village, Prince Sultan, Bahrain, Camp Doha, Osan, Kunsan, and Pusan. The ACTD objectives are (1) to evaluate the military utility of the ABPBD capability; (2) to develop operational procedures associated with the biological detection capability; and (3) to provide some capability to detect and identify a BW attack and to alarm, warn, and dewarn the force. The residual capability of the system will be (1) biological agent detection with limited identification capability, (2) dewarning procedures (i.e., notification that it is safe to remove protective equipment), (3) command, control, communications, computers, and intelligence (C^4I) linked with the theater NBC reporting system, (4) medical countermeasures, and (5) oronasal (respiratory) protection. A full ABPBD field test at Dugway Proving Ground, Utah, is planned.

The JBPDS will be the long-term solution for biological point detection and is scheduled for fielding in FY 04. A Joint Operations Requirements Document is in the final approval cycle and will identify 852 units to meet Air Force requirements.

Table I-17. *Biological Agent Detector Comparison*

	Detectors								
System Name	BIDS (XM31)	BIDS P31	LRBSDS (XM94)	Fiber-Optic Waveguide	UV Lidar Biosensor	Fox NBCRS M93A1	ORIGEN	ELISA	IBADS
Developer	Army (CBDCOM)	Army (CBDCOM)	Army (CBDCOM)	Navy (NRL)	Army (ERDEC)	Army (ERDEC)	Navy (NMRI)	Navy (NMRI)	Navy (NSWC)
Detection Principle	Physical size, number and luminescence of particles	Agent-specific sensors TBD; probably antigen-antibody	Near-IR laser to detect and track aerosol clouds	Antigen-antibody, antibody-coated fiber-optic probes	Frequency-agile laser for near-IR fluorescence	Pyrolysis mass spectrometry	Automated electro-chemical luminescence antigen-antibody	Enzyme-linked, immuno-sorbent assay	Aerodynamic particle sizer and counter
Transport Mode	HMMWV-mounted	HMMWV-mounted	Stand-off helicopter	Stand-off, possibly UAV	Stand-off helicopter	Independent, high mobility	Man-portable, hand-held	Man-portable	Man-portable
Specificity	4 agents — not specific	8 agents — specific	Bio class — not agent-specific	4 agents — specific	Specific	Vehicle — specific	Antibodies req'd specific	Specific	Not specific
Sensitivity	Low	Low	Moderate	High	Unknown	Moderate	High	High	Low
Responsive-ness	< 1 hour	> 5 minutes	< 1 hour	< 5 minutes	> 5 minutes	> 5 minutes	< 5 minutes	< 5 minutes	10 minutes
Status	In production	Adv Dev (6.3)	Exp Dev (6.2)	Adv Dev (6.3A)	Exp Dev (6.2)	Adv Dev (6.3A)	Adv Dev (6.3B)	Adv Dev (6.3B)	In production
Probable Initial Production	N/A	2000–2002	2005+	2000–2002	2005+	2002–2003	1998–1999	1998–1999	N/A
Cost	High	High	High	Moderate	High	Unknown	Moderate	Moderate	Moderate
Other Considerations	Most likely agents: anthrax, plague, and SEB	Most likely agents: determined by Armed Forces Medical Intelligence Center (AFMIC)	Differentiates chemical from biological		Tunable laser; state-of-the-art insufficient		Requires that antibodies have been inventoried; could use both environmental and clinical samples	Trying to preclude refrigeration for assay probes	Front-end of BIDS; shipboard application

The AEF has a requirement for stand-off detection, identification, and warning of forces about to be exposed to BW agents. No stand-off BW agent detection exists for AEF use at present. The first interim capability will come from the XM94 Long-Range Biological Stand-Off Detection System (LRBSDS). This infrared laser system is a product developed from commercial components. LRBSDS will have one operator and will provide long-range detection with automatic discrimination to assist in identifying aerosol clouds. The system will not be able to identify individual BW agents. Future technology should have:

- Detection capability for all CBW agents
- Identification by agent type
- Capability to identify industrial toxic hazards
- Mobility
- Capability beyond the horizon (i.e., greater than 30 km)

3.2.5 Warning

Current manual methods of warning and reporting must be automated. The Joint Warning and Reporting Network (JWARN) is the first automated system planned, and it should be acquired for AEF use. To allow proper training, future systems should encompass all CBW agents and toxic industrial chemicals. The system also should permit operators to conduct modeling and simulation scenarios.

3.2.6 Collective Protection

The Air Force currently does not define any collective protection requirement, although the senior leadership states that forces must operate safely in a CB environment. For AEF operations, collective protection should be required in all realistic BW scenarios, even for operations shorter than 7 days. Although expedient options are available, the use of available or expedient systems requires training and maintenance.

3.2.7 Decontamination

The current capability to decontaminate personnel, equipment, vehicles, aircraft, facilities, or work areas is very limited. There are no easy decontamination options for electronics or sensitive equipment. Over the past several decades this topic has not received the science and technology resources to make a significant leap forward.

Improved systems for decontaminating equipment are being devised in the laboratory. However, these systems are not novel, and they can be highly toxic to humans and damaging to the very equipment to which they must be applied. The science of sterilization provides specifications for destroying microbes, but this knowledge base requires practical delivery systems to be of value to the AEF. Future decontaminants must be much better targeted.

The most complete way to decontaminate anything is to do it in a closed space with an aerosol decontaminant. This technology exists in the agricultural industry, where fogging of produce, under pressure, to reduce spoilage is routine. Aerosol delivery of active decontaminants under pressure is exactly what is required to reach small and inaccessible locations within aircraft.

Appropriate decontamination facilities may be necessary. The sporting industry has devised systems for use in sports such as tennis. Positive-pressure bubbles large enough for several tennis courts could be made to order for decontaminating aircraft. Smaller versions would be suitable for decontaminating parts and components before shipment for repair, a task that currently is too difficult. Decontamination of localized pieces of terrain, however, probably will be achievable only by waiting for the natural decay cycle (sunlight is a natural decontaminant) of BW agents to be completed. Some microbial agents resist natural decay for years.

The Air Force can use technological advances such as those discussed above by taking the following actions:

- Focus attention on the practical delivery-system concepts required for air base operations.
- Direct science and technology managers to provide the resources to enable order-of-magnitude advances.
- Test and evaluate system concepts in simulations.
- Accept incremental improvements as they become available.

3.2.8 Vaccines and Vaccination Planning

The ultimate goal of the Army Medical Biological Defense Research Program is to provide medical protection against all of the validated biological threat agents. Exploratory development is conducted in the areas of: experimental aerosol models, vaccine candidates, and preliminary safety and efficacy data. Advanced technology demonstrations will address the following issues: characterization of seed stocks; *in vivo* and *in vitro* safety, efficacy, and toxicity of candidate solutions; development of preclinical parameters to support an investigational new drug application; and demonstrations of candidate countermeasures. Efforts aimed at providing vaccines, treatments, and definitive diagnostic capabilities are beginning to realize some success. Candidate vaccines for ricin, SEB, botulinum toxin, and anthrax all have demonstrated efficacy in preclinical studies of aerosol agent challenges. The first-generation, toxoided vaccine for ricin is the only available medical countermeasure successfully developed to date for this agent. This product, developed under good manufacturing practices, transitioned to advanced development in FY 95; it is undergoing preclinical efficacy and safety testing. An improved anthrax vaccine that is less reactogenic, is easier to produce, and provides at least equivalent protection against aerosol challenges is under development. Molecular biological tools have been used to delete the bacteria's toxin-producing genes and enhance production of protective immunogens. Recombinant gene technology also has led to progress in the development of a subunit vaccine candidate for the botulinum A toxin and an altered botulinum protein that competes with the action of native toxin. A first-generation toxoided SEB vaccine candidate improved the level of immunity to the agent, showed excellent protection from lethal challenge, and gave encouraging results for reduction of incapacitating effects. Other vaccines in the development pipeline include improved tularemia, plague, Venezuelan western and eastern equine encephalomyelitis, and Q Fever vaccines.

Other than vaccines, there are few pretreatment drugs available for most of the likely threat agents. Most of the therapeutic drugs maintained for endemic infectious diseases, coupled with the in-place combat casualty care program, will suffice for a majority of the required postexposure treatments.

The Joint Vaccine Acquisition Program (JVAP) is under the direction of the Joint Program Office for Biological Defense. This program appears to have extensive coordination with various oversight committees. The thrust of the program is to optimize biological warfare protection for the armed forces. Considerations for each vaccine development include (1) the most likely BW agent threats to be used, (2) the likelihood of deployment to geographic areas hosting the BW threat, (3) lethality and efficacy of the BW threat agents, (4) vaccination effects, (5) the vaccination sequence time line, (6) cost, and (7) risk, which includes development, testing, licensing, and liability. The JVAP Office has a long-term development and production program schedule. The effort was contracted in 1997 to a single integrating contractor, which likely will be supported by numerous companies to cover the challenging, broad range of BW agents. Continuing Air Force Medical Service (AFMS) involvement in the vaccine development program is specifically required to ensure that Air Force requirements are appropriately incorporated in future vaccine development, production, and stockpiling programs. Because inoculation planning is a national policy issue, it is deliberately omitted here. However, any AEF initiatives to enhance readiness and deployment planning for the Air Force must account for authorized BW inoculations. The most likely BW threat agents typically have been assumed to be the same for all forces assigned to a specific theater, even though the official threat may change occasionally. This assumption probably should be challenged by a more insightful look at the missions and locations of deployed AEF personnel.

A senior review panel at the Air Force Human Systems Center (HSC) recommended (and the Panel endorses this recommendation) that a vaccination planning and prioritization system consistent with national policy be developed to overcome the BW CONOPS deficiency. The overall system would relate the automated deployable force database to the threat and the time-phased deployment plan. The planning system would provide procedural guidance for AFMS implementation and integrate deployment-specific tactical and strategic intelligence with clinical standards (to be developed) and personnel-specific deployment planning data. The planning and prioritization system would account for the state of health of individual deployment personnel and their BW agent vaccinations. The system would include factors such as urgency of conflict and deployability, likelihood of exposure to specific agents, specific agent lethality, latency effects, efficacy of antibiotics and antitoxins, vaccine status, and effectiveness as a function of the time-phased immunization sequence.[100]

It will be difficult to devise a single system to account for multidimensional factors such as urgency of conflict; personnel deployability/deployment status; individual health status; likelihood of exposure; specific agent lethality; latency and time-line effects; efficacy of antibiotics and antitoxins; and the status, effectiveness time lines, potential side effects, and policy constraints of vaccines. Any given deployment scenario requires a system that yields an optimal time-phased immunization sequence for the entire deployed force, subject to the linear constraints of time and stockpiles. Policy constraints must be clearly defined for the system to work effectively. Clinical standards also are required. There also are considerable uncertainties in both the future BW threat and in the capacity of the vaccine program to meet the current validated threat. Maintenance of the science and technology base for new and improved vaccines is vital to ensure mission success for the AEF. The planning and prioritization system requires a responsive threat-data collection effort, particularly for the geographic-specific tactical threats. These efforts often are developed through human intelligence-gathering techniques and other methods. The system will have to account for an expanding, reactive threat environment in which altered or newly engineered BW agents may be used. The system also will have to account for the missions and locations of deployed AEF personnel. The technical challenge is to develop a dynamic decisionmaking system that embraces the constraints, factors, and stochastic variables discussed herein and produces timely, usable BW vaccination design criteria and guidance. The solution concept requires data collection, analysis, and the development of an analytical, dynamic decision-system model that incorporates the threats, vaccines, personnel data, deployment plans, and policy.

3.2.9 Joint Operations

The AEF must consider joint-Service force protection options when deployment planning is likely to include BW detection and protection options. The Army chemical companies are well trained in current BW detection and protection. The AEF also should consider Marine Corps assets, such as the Chemical-Biological Immediate Response Force, whenever AEF force protection planning must include BW agent scenarios. The AEF must plan to leverage sister-Service assets in any likely BW threat scenario to ensure mission success.

3.3 Future Threats

The potential is enormous for new, militarily useful, infectious, and incapacitating or lethal biological agents. With the ready availability of new biotechnological methodologies and genetic engineering techniques, biological materials — heretofore very difficult to produce with consistency — now can be produced readily in large quantities with relative ease and defined toxicity characteristics. These new and novel disease and incapacitation threats can grow faster than countermeasures can be developed. This does not mean that the standard agents of the past 40 years will disappear. The threat likely will be additive, with combinations of agents making detection and protection even more difficult.

As we produce effective vaccines or treatments, the challenge to our adversaries is to increase virulence or in some way bypass protective measures. The technology to meet these challenges is readily available and within the capability of developing countries today.

Existing technologies for useful pharmaceuticals that regulate potentially harmful pathophysiologic disease processes in man can readily be used to produce subtle bioregulators that are harmful in the wrong form or dose or when administered by the wrong route, at the wrong time, or over a long period of time. For the most part, these materials would not be detectable until adverse performance or lethality was discovered. Diagnosis will be very difficult or even not possible in a timely manner. The identical tools used today to engineer useful biologicals, antidotes, and treatments can be exploited by an adversary to produce agents for incapacitation or lethality.

3.4 Future Countermeasures

The Air Force can respond in three general ways to the future threat: through technology-based defense, by expanding and enforcing the biological weapons nonproliferation treaty, and by mobilizing world public opinion against the use of BW agents. This last response is preferred because the other two responses are difficult to accomplish. However, the nation must pursue all these responses simultaneously if it is to contain the problem.

The future for timely detection of the realm of all BW agent threats is not promising when viewed from the likely scenarios for their use. Our primary investment should be in maintaining a strong science and technology base in three areas: (1) medical defense, (2) detection, and (3) protection. Next, investments should be equally large in human intelligence gathering and in countering the proliferation of BW agent development worldwide.

The science and technology base must be emphasized to fully exploit current available technology. For example, chips on which artificial sensors are attached have achieved detection of spore-forming bacteria. It is likely that these chips can be read remotely or even embedded in a collector. By using neural network technology for interpretation of agent properties on these chips, data can be developed, described, and then related to biological agent-specific databases to achieve rapid identification. This order-of-magnitude leap in detection technology should be fully funded and exploited now.

Decontamination time and the constraints of working in MOPP 3 or 4 ensembles (see Chapter 4, Chemical Weapons, for MOPP details) to turn aircraft will reduce sortie generation in a BW environment. New concepts for using radiofrequency radiation to destroy biological agents, although high-risk in terms of payoff, have significant force-multiplier potential and should be boldly exploited.

The future is difficult to predict. The future threat of subtle agents that stress normal physiological processes, combined with targeted toxicities to organ systems, will make detection, protection, and therapeutic regimens more difficult to define. The future when airmen, sailors, and soldiers, especially those in critical tasks, are physiologically monitored 24 hours per day may indeed be near.

Modeling and training to test future countermeasures will be even more critical. By 2020, all aspects of CBW involving Air Force operations will be simulated, and this simulation will be integrated into all other Air Force and joint-Service simulations. This achievement is important to the Air Force for a number of reasons:

- The Air Force must be able to test and evaluate its operational capabilities against BW, as it must against all threats.
- Because of the complex nature of air base operations in a biological threat environment, tests and evaluations using real Air Force units are enormously expensive. The Air Force will not be able to afford such tests and evaluations in the future unless they are conducted through simulation.
- The threat, very real now, will only increase over time.
- Simulation will provide much more accurate evaluations because real, live tests are constrained for reasons of safety for personnel involved.

Simulation technology is most certainly progressing rapidly enough for the assertion to be achievable in 25 years. Moreover, the BW knowledge base is comprehensive and available now to begin the task. Finally, the task to achieve total simulation is admirably suited to incremental progress, delivering direct operational benefit with each step forward.

A supply of potable water is absolutely essential to any operation. An AEF needs reliable, field-deployable detection of biological and chemical agents in water supplies. The Air Force and Army initiated the Joint Chemical/Biological Agent Water Monitor (JCBAWM) program to provide rapid response to terrorist actions and battlefield fallout, effective surveillance of military water supplies on base or in the field, and advanced technology to benefit public health. The concept is a portable, field-deployable modular water monitor. The biological module is being developed by AL/CFD. This monitor will consist of a Portable Sampling and Processing System (PSPS) to recover biological agents from water and process agents to ensure sensitive and accurate detection. This monitoring system has been submitted for a patent. The identification system is an adaptation of a miniature, portable, DNA-based detector. The Army's Edgewood Research, Development, and Engineering Center (ERDEC) will develop the Chemical Agent Water Monitor module. A prototype of the entire system will be available in FY 01.

Other technical innovations should be exploited to provide better, less manpower-intensive detection and protection options against future BW threats. The conventional high-altitude endurance UAV, Global Hawk, configured with an appropriate detection capability, can provide a highly useful platform for stand-off detection of large-scale BW agent use around airbases. Global Hawk, currently an ACTD, will be capable of sustained high-altitude surveillance and reconnaissance. With a total endurance of more than 42 hours at an altitude of 60,000 feet, this UAV can loiter for 24 hours over a target 3,000 nmi from its launch site. This range and endurance, in conjunction with its wide-band satellite and line-of-sight communications capabilities, may make the Global Hawk a key component in integrated stand-off detection and monitoring systems. The Air Force will decide the future of the Global Hawk when the ACTD ends in late 1999.

A key enabler of UAV detection will be the high-power semiconductor laser technology (HPSLT) program, which offers useful potential applications in air base protection and hazardous-agent detection and warning. Semiconductor lasers are valuable because of their many attractive features for military applications: robustness, efficiency, small size, and suitability for mass production. This program is an effort to continue to improve the power and beam quality of semiconductor lasers for a wide variety of civilian and military applications. Hazardous agent detection and warning is just one of the many near-term applications of HPSLT. Although HPSLT development is high risk, it offers the potential for significant improvement in air base protection with reduced forward footprint.

Microsensor detection technology will be another enabler for advanced detection methods. The Georgia Tech Research Institute is developing an advanced microsensor for detecting chemical and biological agents. This device will have application in hand-held detection equipment, in perimeter-monitoring systems for forward operating locations, and in point detection in areas where potentially hazardous chemicals are used (e.g., chemical storage sites). The sensor is an optical waveguide interferometer mounted on a 1- by 3-cm microchip. The interferometer senses changes in the refractive index of its surface. In testing, the sensor has detected benzene and toluene vapors (in parts-per-million concentrations) and ammonia (in concentrations of 100 parts per billion). By treatment of the interferometer's surface with various chemically sensitive materials, the sensor can be tuned for particular agents and will provide positive identification of agents.[101]

Seek Smoke is an advanced detection system that uses lasers to detects clouds of chemical and biological warfare agents. This system would be one component of an integrated CBW warning system. A series of Seek Smoke detectors would provide complete coverage of the perimeter of an air base and provide enough warning to enable personnel to don individual protective equipment (IPE) or move to appropriate shelter. Figure I-33 illustrates the role of Seek Smoke in air base protection.

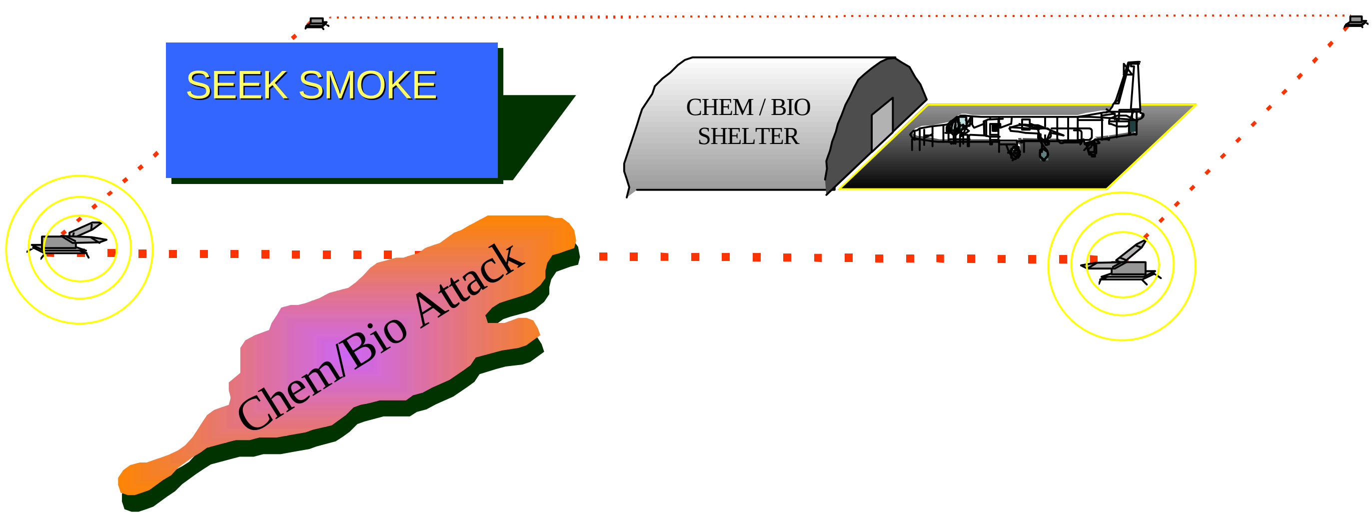

Figure I-33. *Seek Smoke*

Another potentially useful technology is the Remote Vital Signs Monitor, scheduled for completion in November 1997. This device uses low-power radiofrequency waves to measure small movements of the chest, even in clothed individuals. Peaks and nulls of the reflected waveform indicate heart rate and respiration, which are indicators of physiological stress. Both long-range (approximately 100 m) and short-range (approximately 10 m) versions have been developed. In a BW environment, medical personnel could use this system to determine vital signs through protective clothing.

3.5 Responsible Parties

ACC CES/ESX

ACC/DRS

AFOTEC 28 TS/ACC

Air War College

Armed Forces Medical Intelligence Center

Defense Advanced Research Projects Agency

DET5, 366 TRS

HQ USAF/SG

Joint NBC Defense Board

Joint Program Office for Biological Defense

Joint-Service Intervention Group

Joint-Service Mask Working Group

Joint-Service Materiel Group

Naval Medical Research Institute, Biological Defense Research Program

Readiness Board

SAF AQP

U.S. Air Force Civil Engineering Support Agency

U.S. Air Force Material Command/Human Systems Center (HSC/YAC)

U.S. Air Force Readiness School

U.S. Air Force Research Laboratory

U.S. Army Aeromedical Research Laboratory

U.S. Army Chemical and Biological Defense Command

U.S. Army Chemical School

U.S. Air Force Civil Engineer Support Agency

U.S. Army Medical Materiel Development Activity

U.S. Army Medical Research and Materiel Command

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4.0 Chemical Weapons

Henry L. Taylor and Valerie J. Gawron

4.1 Current Threats

Many nations worldwide are considered capable of using chemical weapons. An AEF faces a chemical warfare (CW) threat in the following geographical areas: Europe, Korea, the Middle East (including Southwest Asia), North Africa, the Asian mainland (including Southeast Asia), Japan, Iceland, the Philippines, Guam, the Shemya and Adak islands, Alaska, and the Azores. The spectrum of agents consists of persistent mustard gases (blister agents) and the most hazardous of nerve gases, which include Tabun, sarin, VX, and Soman. These agents can be delivered by aircraft, missiles, and terrorists. For an aerial delivery, the CW agent would disperse through the target area as shown in Figure I-34. The dissemination methods and lethal doses of current casualty and harassing chemical agents are listed in Table I-18.

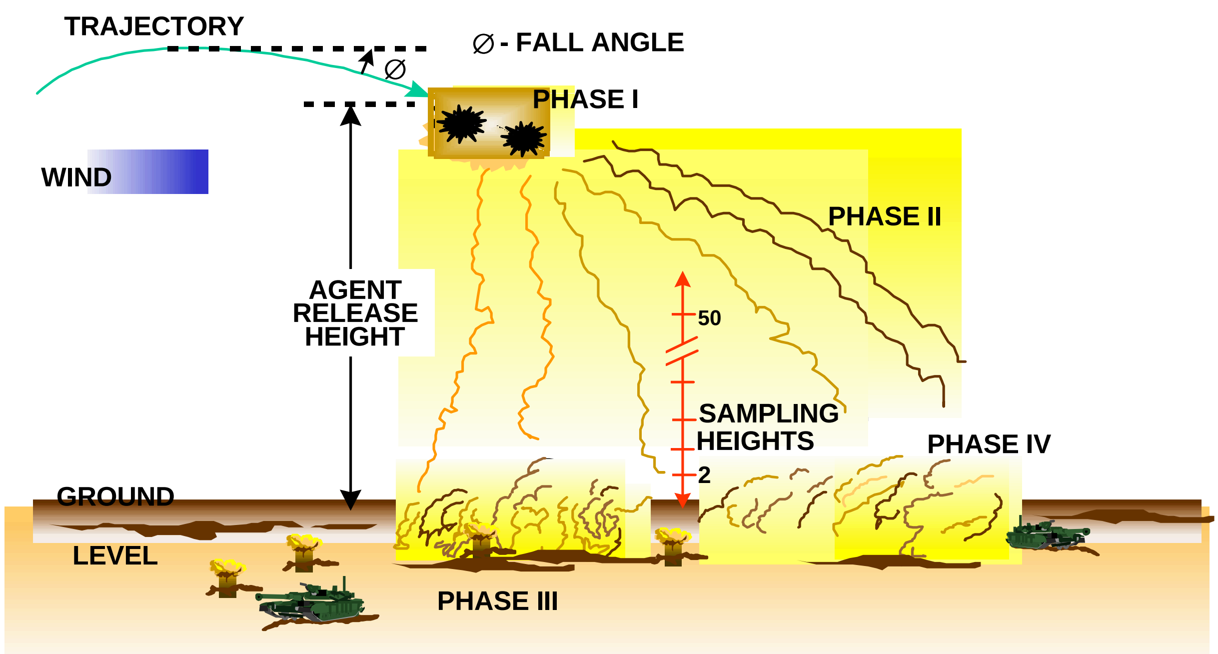

Figure I-34. *Atmospheric Dispersion of Chemical Warfare Agents*[102]

Table I-18. *Characteristics of Casualty and Harassing Chemical Agents* [103]

Types of Agents	*Common Name*	*Dissemination*	*Lethal Dose (mg/min/m³)*
Casualty Agents			
Incapacitants	BZ	Aerosol	None
	Sarin (GB)	Vapor, liquid	100
	Soman (GD)	Vapor, liquid	500
	Tabun (GA)	Vapor, liquid	400
Poison Gas	VX	Vapor, liquid	10
	Chlorine	Vapor	19,000
	Hydrogen cyanide	Vapor	2,000-5,000
	Lewisite	Vapor	1,300
	Mustard gas	Vapor	1,500
	Phosgene	Vapor	3,200
Harassing Agents			
Irritants	CN	Aerosol	11,000
	CS	Powder	25,000
	CR	Liquid, aerosol	25,000

4.1.1 Vulnerability

In considering AEF vulnerability, the Panel assumes that Air Force personnel will be constrained to fight in a potential or actual chemical environment and that the host nation will not provide adequate collective protection. In the absence of adequate collective protection, the CW individual protective equipment must be worn during times of CW vulnerability. However, wearing IPE imposes significant vulnerability due to the thermal burden on the user. CW IPE consists of an overgarment, helmet, footwear covers, mask, hood, and gloves. In *Personnel Protection and Attack Actions* (Air Force Manual 32-4005), the Air Force prescribes MOPP variations, which are described in Table I-19.[104]

Table I-19. *Air Force Mission-Oriented Protective Postures*[105]

MOPP 0	*MOPP 1*	*MOPP 2*	*MOPP 3*	*MOPP 4*
Equipment issued, prepared, and kept readily available	WORN Overgarment Helmet CARRIED Footwear covers Mask/hood Gloves	WORN Overgarment Helmet Footwear covers CARRIED Mask/hood Gloves	WORN Overgarment Helmet Footwear covers Mask/hood CARRIED Gloves	WORN Overgarment Helmet Footwear covers Mask/hood Gloves

Air Force Manual 32-4005 also says that during the above MOPP levels:

- The web belt and canteen may be worn if desired in MOPP 1 and 2.
- Individuals must carry or keep at hand protective equipment, such as field gear, M8/M9 paper, nerve agent antidotes, and decontamination kits.
- MOPP variations are to be used only as directed.

Heat stress from wearing IPE seriously degrades human performance. Many studies reviewed by Taylor and Orlansky support this finding.[106] They report that under some conditions performance will degrade significantly within 1 hour, although endurance can be extended beyond this point (1) if ambient workplace temperatures are not severe, (2) by enforced drinking of water, and (3) by frequent rest periods. Air Force Manual 32-4005 and its attachments provide hydration standards (Table I-20), MOPP 3 and 4 task-time multipliers (Table I-21), and estimated work-rate times in MOPP 3 and 4 for light, moderate, and heavy work (Tables I-22, I-23, and I-24).

Table I-20. *Hydration Standards (Quarts per Hour) for People in MOPP 3 and 4*[107]*

	Air Temperature			
Work Rate	***60 to 69°F 16 to 20°C***	***70 to 79°F 21 to 26°C***	***80 to 89°F 27 to 31°C***	***90 to 99°F 32 to 37°C***
Light	†	0.5	1	1-2
Moderate	1-2	1-2	‡	‡
Heavy	1-2	‡	‡	‡

* People must be encouraged to drink the amount of water indicated in the table even if not thirsty, because thirst alone will not ensure adequate water intake. Before beginning work in protective equipment, drink one-half to one quart of water. Cool water is the drink of choice. Avoid sugary soft drinks and electrolyte solutions except under medical guidance. Also, limit coffee or soft drinks containing caffeine because caffeine is a diuretic.

† At cooler temperatures, dehydration is not the performance-limiting factor. Thirst may govern intake.

‡ Under these more severe conditions, heat stress usually will limit performance before dehydration becomes a serious problem. Water intake during work will not prolong work periods, but rehydration during rest periods is very important.

Table I-21. *MOPP 3 and 4 Task-Time Multiplier[108]*

		Task-Time Multiplier		
Work Rate	***Activity Examples***	***20 to 49°F -7 to +9°C***	***50 to 84°F 10 to 28°C***	***85 to 100°F 29 to 38°C***
Light	Tower operators Operations officers Pilot ground activities Command post activities	1.2	1.4	1.5
Moderate	Refueling Avionics shop Aircraft maintenance NBC survey team	1.3	1.4	3.0
Heavy	Armament crew Rapid runway repair Heavy aircraft repair	1.7	2.1	5.0

Note: The task-time multiplier accounts for both work and rest times. Therefore, the time derived using the chart is the estimated total time to do the task, including rest times.

Table I-22. *Estimated Work-Rate Times (in Hours) in MOPP 3 and 4 for Light Work*[109]

Temperature F	Temperature C	Body Heat Level	50 Percent: MOPP 3 & 4	50 Percent Variation: No Fatigue Option	50 Percent Variation: Ventilation Option	70 Percent: MOPP 3 & 4	70 Percent Variation: No Fatigue Option	70 Percent Variation: Ventilation Option	90 Percent: MOPP 3 & 4	90 Percent Variation: No Fatigue Option	90 Percent Variation: Ventilation Option
100	38	Conserv.	1.2	1.2	2.3	0.8	0.8	0.8	0.6	0.6	0.6
		Maximum	1.8	1.8	3.5	1.2	1.2	1.2	0.9	0.9	0.9
90	32	Conserv.	8.8	>12.0	>12.0	2.1	2.3	10	1.2	1.2	1.5
		Maximum	>12.0	>12.0	>12.0	3.2	3.5	>12.0	1.8	1.8	2.2
Estimated work times at and below 80°F (27°C) exceed 12.0 hours.											

(Humidity Level)

Table I-23. *Estimated Work-Rate Times (in Hours) in MOPP 3 and 4 for Moderate Work*[110]

Temperature F	Temperature C	Body Heat Level	50 Percent: MOPP 3 & 4	50 Percent Variation: No Fatigue Option	50 Percent Variation: Ventilation Option	70 Percent: MOPP 3 & 4	70 Percent Variation: No Fatigue Option	70 Percent Variation: Ventilation Option	90 Percent: MOPP 3 & 4	90 Percent Variation: No Fatigue Option	90 Percent Variation: Ventilation Option
100	38	Conserv.	0.4	0.5	0.5	0.3	0.3	0.4	0.3	0.3	0.3
		Maximum	0.6	0.7	0.7	0.5	0.5	0.6	0.5	0.5	0.5
90	32	Conserv.	0.6	0.7	1.1	0.5	0.6	0.7	0.4	0.4	0.4
		Maximum	0.9	1.1	1.7	0.8	0.9	1.1	0.6	0.6	0.6
80	27	Conserv.	1.1	1.5	>12.0	0.8	1.0	2.1	0.6	0.8	1.0
		Maximum	1.7	2.3	>12.0	1.2	1.5	3.2	0.9	1.2	1.5
70	21	Conserv.	2.4	>12.0	>12.0	1.6	5.0	>12.0	1.2	2.3	>12.0
		Maximum	3.5	>12.0	>12.0	2.4	7.5	>12.0	1.8	3.5	>12.0
60	16	Conserv.	>12.0	>12.0	>12.0	>12.0	>12.0	>12.0	4.9	>12.0	>12.0
		Maximum	>12.0	>12.0	>12.0	>12.0	>12.0	>12.0	7.4	>12.0	>12.0
Estimated work-rate times at and below 50°F (10°C) exceed 12.0 hours.											

(Humidity Level)

Table I-24. *Estimated Work-Rate Times (in Hours) in MOPP 3 and 4 for Heavy Work*[111]

Temperature			Humidity Level								
			50 Percent			70 Percent			90 Percent		
				Variation			Variation			Variation	
F	C	Body Heat Level	MOPP 3 & 4	No Fatigue Option	Ventilation Option	MOPP 3 & 4	No Fatigue Option	Ventilation Option	MOPP 3 & 4	No Fatigue Option	Ventilation Option
100	38	Conserv.	0.3	0.3	0.4	0.2	0.3	0.3	0.2	0.2	0.2
		Maximum	0.5	0.5	0.6	0.3	0.5	0.5	0.3	0.3	0.3
90	32	Conserv.	0.4	0.5	0.6	0.3	0.4	0.4	0.3	0.3	0.3
		Maximum	0.6	0.8	0.9	0.5	0.6	0.6	0.5	0.5	0.5
80	27	Conserv.	0.6	0.7	1.2	0.5	0.6	0.8	0.4	0.4	0.6
		Maximum	0.9	1.1	1.8	0.8	0.9	1.2	0.6	0.6	0.9
70	21	Conserv.	0.9	1.3	>12.0	0.7	1.0	2.4	0.6	0.7	1.3
		Maximum	1.4	2.0	>12.0	1.1	1.5	3.3	0.9	1.1	2.0
60	16	Conserv.	1.4	5.7	>12.0	1.1	2.9	>12.0	0.9	1.9	>12.0
		Maximum	2.1	8.6	>12.0	1.7	4.4	>12.0	1.4	2.9	>12.0
50	10	Conserv.	2.9	>12.0	>12.0	2.1	>12.0	>12.0	1.9	>12.0	>12.0
		Maximum	4.4	>12.0	>12.0	3.2	>12.0	>12.0	2.9	>12.0	>12.0
Estimated work-rate times at and below 50°F (10°C) exceed 12.0 hours.											

The reviews by Taylor and Orlansky also clearly indicate that wearing IPE degrades not only individual performance, but also the performance effectiveness of a combat unit. The primary causes of such performance degradation are as follows:

- "Heat stress due principally to the weight, insulation, and low moisture vapor permeability of the overgarment"
- "Reduced manual dexterity due to the constraints imposed by the gloves, overgarment, and boots"
- "Restricted vision due to the design and optical characteristics of the mask; e.g., reduced field-of-view and poor optical quality of the mask faceplate"
- "Restricted communication (hearing and speaking) due to the mask and hood"
- "Respiratory stress due to air resistance of mask filters and outlet valves"[112]

The effects of heat stress are well documented.[113] In addition, computer models to predict the effects of heat stress are available.[114, 115] If the level of CW IPE, the ambient environmental conditions, the physical condition of the personnel, and the proposed mission are known, the model can accurately predict the physiological limit of AEF personnel operating in a CW scenario. The model is most effective in forecasting work/rest cycles, water requirements, and tolerance time.[116]

The Air Force has a well-developed vulnerability study process and should maintain this capability.[117] Inputs to the simulation and analysis include the threat (agents, delivery systems, targeting accuracy, and objective), the CW factors (prophylaxis, IPE, and individual and collective protection factors), and the AEF air base representation (mission tasking, resources and facilities, and procedures). The output of the simulation assesses the CW impact, identification of deficiencies and vulnerabilities, and recommendations for improvements. Figure I-35, Projected Sortie Generation Capability, shows a notional output.

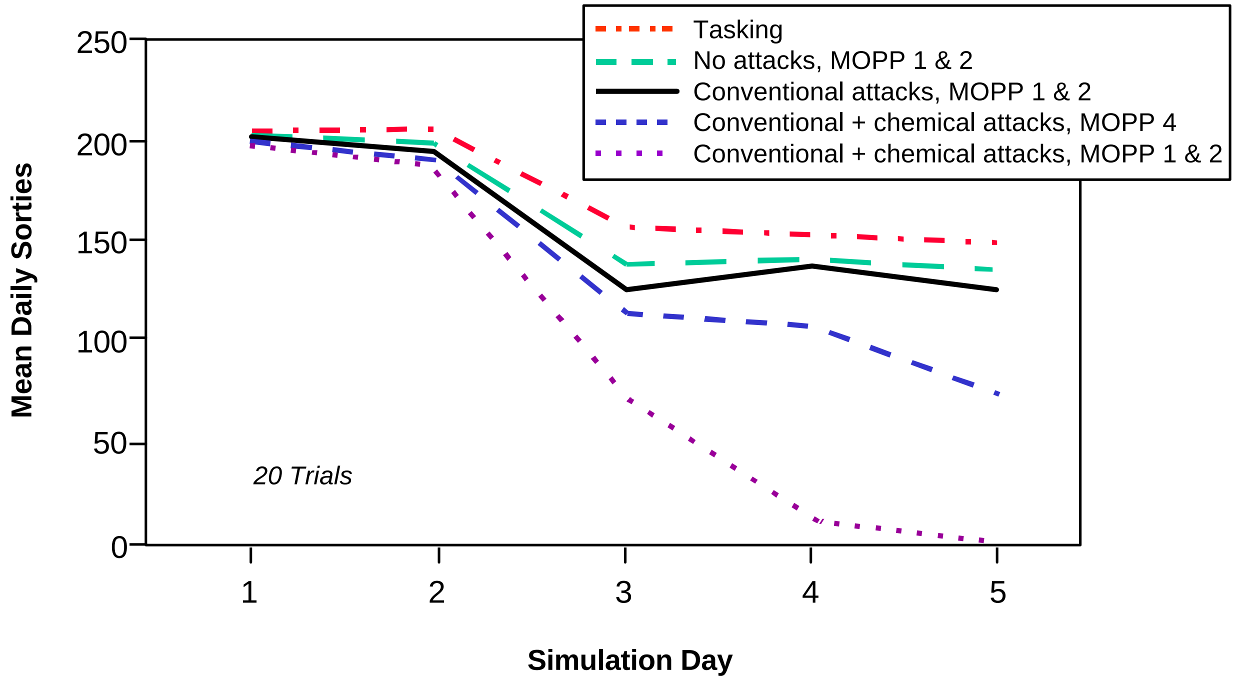

Figure I-35. *Projected Sortie Generation Capability*[118]

Curve A (no attacks, MOPP 1 and 2) and Curve B (conventional attacks, MOPP 1 and 2) show little degradation from the expected performance (the tasking level), which indicates that wearing MOPP 1 and 2 with no attacks or under only conventional attacks produces minor degradation from the tasking level. In this situation, the MOPP level can be raised to 3 or 4 in a short period of time. Curve D illustrates the effect on human performance of wearing the MOPP 4 CW IPE, whether the attack is conventional or CW. Curve C illustrates the substantial risk of being in MOPP 1 or 2 during a CW attack, i.e., the effect on sortie generation when not fully protected in a CW environment.

4.1.2 Performance Degradation of Maintenance Tasks

Under CW threat conditions, aircraft maintenance technicians of the AEF will be required to wear CW IPE while preparing aircraft for subsequent sorties. The effects on performance of wearing the CW ensemble are well documented: it restricts movement, vision, communication, and endurance. Maintenance personnel also have to work more slowly and carefully to prevent compromising the CW ensemble. The times required to perform some tasks increases, thereby reducing the sortie generation rate.

Taylor and Orlansky reviewed an Air Force field study designed to evaluate the impact of CW IPE on the performance of a number of F-16 maintenance tasks (see Table I-25). The tasks were performed in both fatigues (generally two times each) and the MOPP 4 CW ensemble (generally six times each). For the last two attempts of the tasks in CW IPE, four interventions were introduced: (1) training; (2) work-around procedures; (3) modification to aircraft, aerospace ground equipment, and tools; and (4) changes to the job guides. The purpose of these interventions was to reduce the performance degradation and to eliminate compromises of the CW ensemble (it had been compromised in 19 of 26 tasks performed in an earlier phase of the study). The task times for both fatigues and the CW ensemble are shown in Table I-25, which is represented graphically in Figure I-36.[119]

Table I-25. *F-16 Maintenance Task Times (in Minutes) in Fatigues and in CW IPE*

Task No.	Task	CW Initial Attempt	CW Best Time	Fatigues Initial Attempt	Fatigues Mean Time
1	Build up drop tank	614	296	244	279
2	Remove and replace (R&R) main generator constant speed drive	175	69	82	107
3	Raise/tilt and rotate/lower ejection seat	85	53	58	44
4	R&R jet fuel starter	63	23	73	47
5	R&R angle-of-attack transmitter	197	71	127	96
6	R&R nosewheel steering feedback potentiometer	34	18	28	26
7	R&R environmental control system turbine	71	50	83	53
8	R&R jettison remote interface unit	97	52	66	51
9	R&R fire control radar antenna	115	66	84	106
10	R&R hydraulic pressure transmitter	31	12	16	12

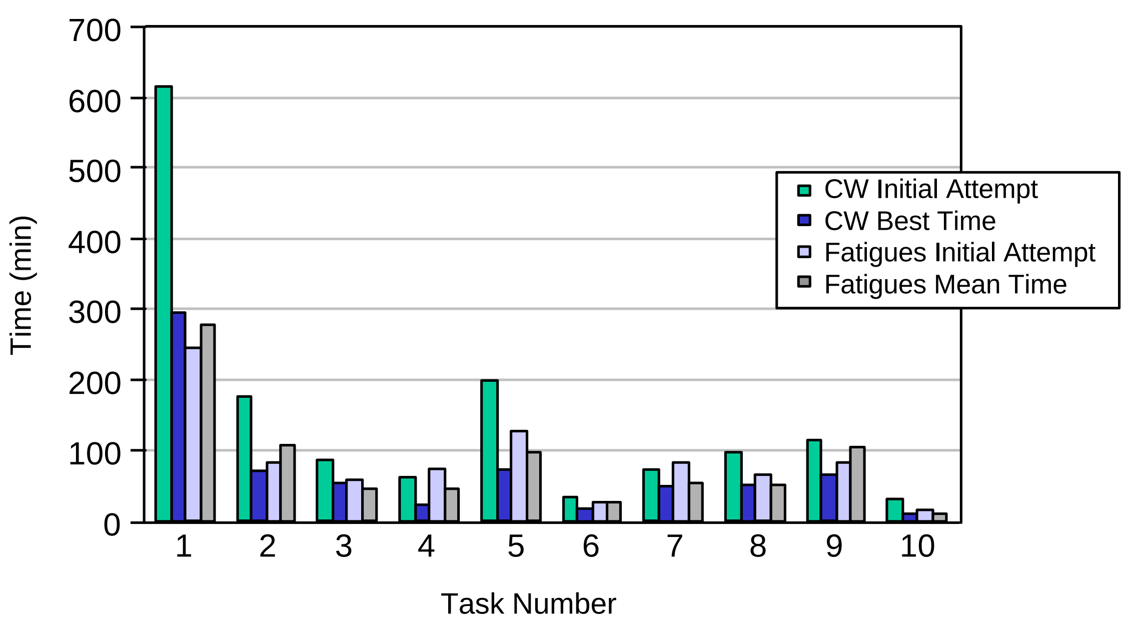

Figure I-36. *F-16 Maintenance Task Times*

Improvement in performance time from the initial attempts to the best times in the CW ensemble ranges from 30 percent to 63 percent, with an average improvement of 52 percent. Training clearly made a difference, but the performance improvement with training was confounded by the other interventions. A comparison of the best times in the CW IPE and in fatigues shows that 6 of the 10 tasks took less time in the CW ensemble, whereas the remaining 4 tasks had approximately equal task times. The study clearly substantiates the benefits of practicing maintenance tasks in CW IPE.[120]

4.1.3 Overall Current Threat Assessment

The Air Force and its AEFs are susceptible to the CW threat in a number of areas. Table I-26 lists these areas and the problems in each area. In the table, “red” status means that personnel will be injured if the limiting factor is not countered. “Yellow” indicates a potential for injury. As the table shows, investments are needed to organize, train, and equip AEF-deployable personnel.

Table I-26. *AEF Susceptibility to the CW Threat*

Area	*Status*	*Limiting Factors*
Organization	Red	There is no effective advocacy at the Combat Commands. There is no central procurement strategy.
Predeployment preparation	Red	No CW-specific doctrine exists. No Air Force combat center is working on CW issues. Air Force mobility planning is not working on CW issues. Air Force CW knowledge and training are insufficient. There is no simulation modeling of CW agent impact on air operations. Inadequate weather effects are included in simulation modeling of CW agent dispersion.
Stand-off detection	Red	Air Force has no stand-off detection capability. Air Force does not have a Joint-Service Lightweight Stand-Off Chemical Agent Detector (JSLSCAD) CONOPS.
Detection	Yellow	Point detectors are too slow, cannot detect low-level lethal amounts of an agent, cannot identify the agent, and are not mobile. Point detectors cannot detect agents inside cargo aircraft. No CONOPS for point detectors is developed. No point detectors for drinking water exist. JSAWM does not detect all CW agents.
Warning	Red	There are a number of nonintegrated detectors. Detectors lack prescriptive warnings.
Personal protection	Yellow	Mask fit generally is poor. Mask seal leaks when facial hair is present. Wear time is limited. Mask limits vision. Air Force trains only in MOPP 4. CW ensemble may impose heat stress and may reduce tactile agility.
Collective protection	Red	Air Force has insufficient and unsupportable collective protection systems. Air Force leadership has not made a decision on collective protection. Transport aircraft are at risk for carrying chemical and biological weapons.
Decontamination	Red	There is an insufficient number of M-17 units and no training. Other systems are corrosive and toxic. Decontamination is time-intensive.
Sustainability	Red	No continuous operations training for CW environment is available. CW equipage is inadequate for protection of the force.
Casualty management	Yellow	Air Force lacks a CONOPS for CW casualty management in AEF deployments. It is impossible to measure vital signs of a person in MOPP 4.

4.2 Current Countermeasures

Public Law 103-160 mandates joint-Service acquisition programs for NBC defense. The Defense Authorization Act for FY 94 directed the Secretary of Defense (SECDEF) to: (1) appoint a single focal point in the Office of the Secretary of Defense (OSD) for CB defense research, development, and acquisition (RD&A) programs; (2) designate the Army as the executive agent for CB defense; and (3) consolidate all CB defense RD&A programs into OSD funding lines. A December 1993 SECDEF letter designated the Assistant to the SECDEF as the focal point, appointed the Army as the executive agent, and called for a Joint Task Force to develop and implement the plan. A Joint-Service Agreement was signed August 1994, which established the management structure and provided for an integrated and coordinated effort. Program Budget Decisions 250 and 250C consolidated funding into OSD funding lines and designated the Ballistic Missile Defense Organization as the funds manager. Under this organization the Joint-Service Integration Group (JSIG) provides joint requirements, doctrine, and professional training. The Joint-Service Materiel Group (JSMG) provides joint RD&A, technical oversight, logistics, and sustainment. The JSMG addresses the commodity areas of:

- Individual protective equipment
- Collective protection
- Contamination avoidance
- Decontamination

A chemical weapon attack does not cause permanent damage to equipment, and the threat of chemical weapons can largely be negated by adequate warning and detection systems, the use of chemical protective clothing, and proper training of personnel. In a CW environment, collective protection is required. Deterrence against the use of CW has been effective in recent AEF actions (e.g., Operation Desert Storm), and a good chemical defense posture continues to be an effective deterrent. The chemical warfare doctrine for the AEF must be based on both survivability of personnel and sustainment of the AEF mission. Survivability of AEF personnel relies on adequate warning; the ability to rapidly don chemical warfare masks; use of chemical protective garments, overboots, and gloves; collective protection; decontamination; medical pretreatment; and first aid if exposed.

4.2.1 Current Detection Support to AEF

Current detection equipment consists of M8 and M9 paper, an M256 detector kit, an M272 water-testing kit, the chemical agent monitor (CAM), and the M221 Automatic Chemical Agent Detector and Alarm (ACADA). Chemical agent detection system performance has improved markedly from the mid-1980s to the present. During a simulant test (circa 1987) of the Survivable Collective Protection System — Medical, the Graseby CAM was used in “decontamination processing” in a surface-scanning mode in an attempt to locate “hot spots” of chemical (simulant) contamination on casualties. This scanning technique had limited success. The indication of a “hot spot” generally indicated peak vapor concentration levels in the milligrams per cubic meter (mg/m^3) range. If CAM were the only screening tool, lower, but still incapacitating, contamination levels could conceivably build up in the “toxic safe” operating room without warning.

The Prime Base Engineering Emergency Force (BEEF) Implementation Guidance specifies the following chemical detection instruments for deployment:

- CAM, nerve gas/blister agent point source monitor (4 each)
- M8A1, nerve agent monitor (4 each)
- M256 kit, nerve, blood and blister vapor–detector ticket (25 each)

The placement of monitors will be part of an overall chemical monitoring plan developed by Readiness Flight based on the number of deployed monitoring assets, locations of critical air base assets, local meteorology, the number of chemical reconnaissance (Recon) teams available (Recon teams may be supplemented by personnel from the manpower pool), and the geography of the base. Chemical Recon teams will perform M256 kit tests on declaration of alarm “Black” and run a predetermined monitoring route. Generally, the nerve agent vapor monitors will surround the base, allowing detection of agents prior to their arrival, depending on prevailing winds at the time of attack. Monitors also will be placed in areas of high personnel concentration, work centers, and available hardened shelters. Liquid-agent detectors will be placed in open areas near work centers to determine whether there is a contact hazard from chemical agents after an attack.

Four types of detectors are required: warning/protection systems, dewarning systems, verification systems, and treatment systems. Warning/protection systems detect (1) theater ballistic missile (TBM) attacks (hundreds of thousands of detectors are needed to cover the target area); (2) spray attacks (two detectors are needed, one on each corner of the upwind edge); and (3) backpack attacks (about 25 detectors are needed along the upwind edge). Dewarning systems detect (1) TBM attacks (about 25 detectors are needed along the downwind edge); (2) spray attacks (two detectors are needed, one on each corner of the downwind edge); and (3) backpack attacks (about 25 detectors are needed along the downwind edge). Verification systems detect (1) TBM attacks (one to several thousand detectors are needed to cover the target area); (2) spray attacks (two detectors are needed, one on each corner of the downwind edge); and (3) backpack attacks (about 10 detectors are needed along the downwind edge). Treatment systems detect (1) TBM attacks (about 100,000 detectors are needed to cover the target area); (2) spray attacks (about eight detectors are needed along the major axis); and (3) backpack attacks (about 100 detectors are needed along the upwind edge).

Equipment developed for land or sea mobile forces may or may not be adequate. Specifically, fixed-site respiratory protection requirements exceed current mask capability. In addition, IPE may impose an unnecessary thermal burden. Also, stand-off detection is not applicable to on-target attacks. Furthermore, collective protection and/or body cooling may be required for sustained operations. Finally, point detectors are unable to provide “warning” within time constraints.

4.2.1.1 Liquid Agent Detection, M8 paper

The M8 paper is a currently fielded detector. The kit contains 25 perforated 2.5-inch by 4-inch sheets of paper that contain red, yellow, and green dyes. Contact with a chemical agent causes a specific color change for G, V, and H liquid agents only. The M8 paper is used to test whether specific surfaces are contaminated and to identify the agent. This detection kit is inexpensive.

4.2.1.2 Chemical Agent Detectors, M9 Paper

The M9 detector consists of adhesive-backed material worn in bands around the individual’s upper arm, wrist, and ankle, and the M9 can be attached to equipment. A nonspecific color change occurs when any liquid chemical agent with a droplet-diameter greater than 100 micrometers contacts the material. The M9 detector is currently in production.

4.2.1.3 Chemical Agent Detector Kit, M256/A1

The M256/A1 Chemical Agent Detector Kit (Table I-27), which is currently available, contains 12 sampler detectors used to detect and classify airborne chemical agents. The detector kit is used after a chemical attack to determine when it is safe to remove the mask. The kit contains M8 paper, which permits the detection of liquid agents. The kit also uses an enzyme-substrate reaction, agent vapor adsorption, and chemical reaction to provide detection. One of the limitations of the kit is that it responds to some battlefield interference materials. Table I-27 lists the detection capabilities of the kit.

Table I-27. *M256/A1 Chemical Agent Detector Kit Capability*

Agent	Sensitivity (mg/m^3)	Response Time (min)
GB	0.005	15
VX	0.020	15
Mustard	2.000	15
Phosgene oxime	3.000	15
Lewisite	9.000	15
Hydrogen cyanide	9.000	25
Cyanogen chloride	8.000	15

4.2.1.4 Water Testing Kit, Chemical Agent, M272/E1

This kit can be used to detect the presence of chemical agents in water. The M272/E1 is a development effort to improve an existing product. The kit will increase the nerve, mustard, and lewisite agent detection sensitivity by a factor of 4, and it will increase the blood agent detection sensitivity by a factor of 10.

4.2.1.5 Chemical Agent Monitor

The CAM is a chemical monitor for both personnel and equipment. The CAM detects mustard and nerve agents and is used “post attack” as a vapor detector. There are serious limitations on its usefulness for every CW agent. The improvement to the CAM will reduce the level and frequency of maintenance of the CAM and provide unlimited shelf life. The CAM is in production and was fielded in U.S. Army Reserves Europe (USAREUR) in FY 94. The basis of issue is two to four for chemical units and teams, but probably should be four per six-aircraft package in an AEF.

4.2.1.6 Nondevelopment Item (NDI) for an Automatic Chemical Agent Detector and Alarm, M22

To expedite an automatic chemical agent alarm capability, the JSMG for NBC Defense initiated an ACADA/NDI. The ACADA has four components: the GID-3, M90, RAID-1, and the A2. In August 1996, the Graseby GID-3 was selected for the ACADA production program, which began the same year. The GID-3 uses the same ion-mobility spectroscopy principle as the CAM, but the GID-3, as with other currently available point-detection sensors, is designed to detect a “gross contamination level” local (point source) threat and to alert unprotected personnel to seek chemically protective shelters or to don protective masks and ensembles. The GID-3 is a human-portable (it weighs 7.2 pounds and is 0.14 cubic feet in volume), point-sampling alarm system to detect and identify nerve and blister agents. It can operate as an area warning device and in collective protective equipment (CPE) roles. It is a commercial product manufactured by Graseby Ionics England that costs $15,000. The response times and sensitivities of the GID-3 are shown in Table I-28.

Table I-28. *Response Times and Sensitivities of the GID-3*

Agent	Response Time (sec)	Sensitivity (mg/m^3)
Nerve agents (GA, GB, GD, VX)	10	0.03
Nerve agents (VX)	10	0.1
Blister agent (HD)	10	0.1
Blister agent (L)	20	0.1
Blood agent (AC)	6	10.0

4.2.1.7 Automatic Liquid Agent Detector

The ALAD will detect liquid nerve and blister CW agents. It is a self-contained, battery-powered, portable unit with an AC power adapter (AC power must be used below 60° F). The unit is powered by a lithium battery, which provides power for at least 30 days. The ALAD has a low false-alarm rate. A 200-micrometer droplet of CW agent will cause the metallic paint on the sensor to swell, and the alarm will sound. The depot cost is $1,078. Currently, the deployment package is not designated to go with the AEF.

4.2.2 CW Individual Protective Equipment

CW IPE is used by all U.S. military personnel and provides protection from vapor, liquid, and aerosol CW agents. Currently, each aircrew member is issued a chemical bag and a mobility bag. Air Force Instruction 32-4001 lists the chemical bag requirements. A chemical bag consists of four complete CW ensembles. Two of those ensembles are hand-carried by the member when deploying to CW threat areas.[121] Once each CW ensemble is opened, it is certified for 30 days without exposure to an agent, 24 hours with exposure. A new suit is certified for 45 days and 36 hours, respectively. Additional chemical gear is either prepositioned (e.g., for the Airborne Warning and Control System) or hand carried (e.g., for fighter aircraft). All personnel on base are issued two suits apiece. A consolidated mobility bag includes four hoods and four gloves. The transition between the current two-bag and the near-term one-bag system has not been planned for combat.

The CW IPE, which was initially procured in 1984, is designed for extended wear (up to 30 continuous days) and is disposable at the end of this time, even if not contaminated. However, the CW IPE is too heavy, too hot, uncomfortable, outdated, not washable, and not flame resistant. Most important, the CW IPE reduces human performance. The standard CW protective overgarment is worn in all environments during imminent threat of chemical attacks. It consists of a shell that is 50 percent nylon and 50 percent cotton with water-repellent treatment. The liner is 0.09-inch-thick (90-mil), carbon-impregnated polyurethane foam. The overgarment has a 13-year shelf life and provides 24-hour protection and 22-day field wear. The CW glove is worn under the standard-issue glove; it consists of 25-mil butyl rubber with a cotton inner glove. It provides 24-hour hand protection and 14 days of field wear. A lighter and thinner (14-mil and 7-mil) tactile CW glove can be used in place of the standard CW glove for operations that require greater tactility. The 14-mil glove provides 24-hour protection and 14 days of field wear; the 7-mil glove provides 6 hours of protection and 14 days of field wear. The overboots are worn over standard combat boots to provide CW protection, in addition to weather and biological agent protection. They are made of polyvinyl chloride and provide 12-hour protection and 14 days of field wear. The CW protective undergarment is a two-piece, snug-fitting undergarment worn under the standard duty uniform. It is made of stretchable fabric, provides up to 12 hours of vapor protection, and has a 15-day field service life.

A Tropical Skin Protectant is being used by the Army as an adjunct to IPE (Sabarée et al., 1997).

4.2.2.1 Aircrew Uniform Integrated Battlefield (AUIB)

The semipermeable AUIB combines CW protection with flame resistance. The outer shell is 95 percent Nomex and 5 percent Kevlar polytetrafroethylene (PTFE) laminate. The inner layer is 90-mil, carbon-impregnated, flame-resistant polyurethane film/nylon tricot laminate. The CW IPE works particularly well if the mask fit is satisfactory.

4.2.2.2 Aircrew Chemical Ensemble (ACE)

The ACE program is a reprocurement. The system was previously developed, tested, and fielded during Operation Desert Storm. The ACE is a single-piece coverall that provides flame protection and 24 hours of continuous vapor protection even after 10 launderings. The thermal burden of ACE, which replaces the previous three-layer system, is equal to or better than its predecessor. The Human Systems Program Office will procure 40,000 units. Production of ACE was scheduled to be complete by the first quarter of FY 97.

4.2.3 Collective Protective Equipment

AEF personnel operating in a CW environment will require periodic relief from continuous wear of the CW combat ensemble. Shelters will allow an AEF to sustain and, if required, to relocate operations in a CW environment. Shelters also will permit the AEF command post and communications center to operate in a safe, MOPP 0 environment. CPE is any structure that provides CW-safe areas for personnel rest and recuperation, latrines, showers, and dining. Some CPE is designed to accommodate all these functions. These collective protection facilities have been located at air bases in Europe and Korea.

The collective protection facilities are divided into two main parts: the toxic-free area (TFA) and the contamination control area (CCA). Figure I-37 illustrates the collective protection system components. The CCA provides an area for personnel moving from the CW environment to the TFA. The TFA is supplied with filtered air, which provides overpressure to prevent CW vapor agents from entering the area. The air enters the CCA through small rooms (air locks), which have a very high flow of filtered air to purge residual vapors. The air flows through the air locks, the vapor hazard area (VHA), and the liquid hazard area (LHA) to exit the CCA. Personnel doff and don their IPE in the VHA and LHA when they enter and exit the collective protection facilities. All currently fielded systems rely on impregnated, activated carbon for collective protection. Activated carbon has a limited capacity, and the impregnation degrades over time. The degradation of the filter effectiveness must be monitored, and the filter canister must be changed periodically to ensure the effectiveness of the CPE. These tasks increase the requirement for logistic support for shelters in AEF operations.

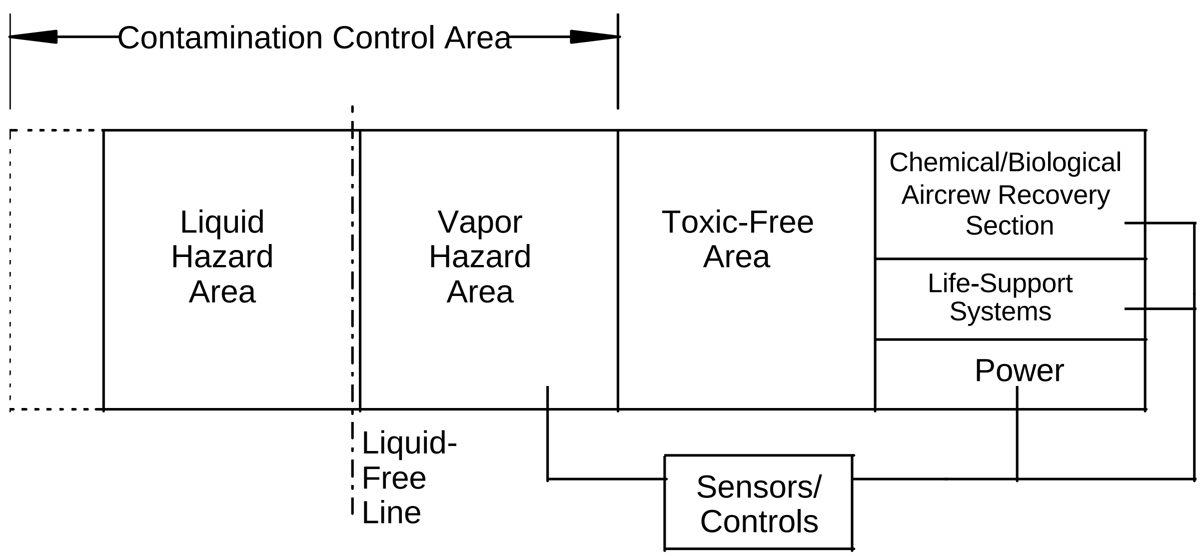

Figure I-37. *Collective Protection System Components*[122]

4.2.3.1 Testing of Collective Protection Systems

In 1986, the Air Force Tactical Air Warfare Center conducted a test of the chemical integrity of five representative collective protection facilities in Europe. The test was designed to validate airflow, overpressure, and purge time of the facilities. Three of the facilities were squadron operations buildings, one was a communication center, and one was an operation support center. The test evaluated the chemical integrity of each facility under static conditions, not during personnel processing. The test did not evaluate the filter life, the filter capacity, or the capability of the system to filter CW agents.

The overall operational effectiveness of the facilities and the specific operational deficiencies of the five facilities are classified. The report recommended that the identified operational deficiencies be resolved as soon as possible. The report further recommended that the collective protection facilities be retested to verify correction of the operational deficiencies.

The Air Force prepared a SON, USAF DOC-85-I-X, dated 6 July 1990, for a transportable collective protection system (TCPS). This document identified the need for air-transportable, rugged, reliable, and logistically supportable CW protection for personnel deploying rapidly to bare bases. The need for such a system also exists with regard to AEF operations. In response to this need, the Aeronautical Systems Division (ASD), with the assistance of the Human Systems Division, developed the TCPS and performed developmental test and evaluation. The Tactical Air Warfare Center conducted initial operational test and evaluation (IOT&E) on the TCPS in May 1991. Three unique TCPSs (four versions) were tested. Each TCPS tested had a CCA with an airlock attached to the TFA. Each TCPS had an air filtration system, an air conditioner, a heater, a low-pressure warning system, a personnel support system, and a support kit. The following are the TCPSs that were tested:

- An expandable shelter/container (ES/C), Army, Model A, modified to provide CW protection. This system is a liquid-wall structure that is then deployed for bare-base operations (Harvest Bare package). Two versions of the ES/C were tested:
  - ES/C Version 1 had an M28 conformal liner and filtered-air overpressure
  - ES/C Version 2 had all seams and openings taped in the TFA (except the air lock entrance) and used filtered-air overpressure
- An Army-developed, expandable, modular personnel tent (TEMPER), modified with an M20 conformal liner and used filtered-air overpressure
- A stand-alone TCPS, which consisted of two attached CCAs and used filtered-air overpressure

The purpose of the IOT&E was to evaluate the operational effectiveness and suitability of the TCPS in a CW environment. Nine critical operational issues (COIs), six effectiveness objectives (user criteria), and seven suitability objectives were used in the IOT&E. Testing uncovered major problems in the COI areas of 96-hour operation, CCA contamination, and TCPS assembly. The TCPSs did not meet the performance requirements of three effectiveness objectives and three suitability objectives. In the suitability area, significant problems were found in reliability, maintainability, and technical data. Twenty-five service reports for deficiencies and seven service reports for enhancements were submitted as a result of the IOT&E.

The overall evaluation indicated that the operational effectiveness of the TCPS and its suitability were unsatisfactory. The report recommended that the Tactical Air Command not procure the TCPS until all major deficiencies had been corrected and verified.[123]

4.2.3.2 TEMPER

One of the current collective protection shelters that appears suitable for the AEF is the TCPS TEMPER with the chemical protective liner. This unit is self-contained and will provide 12 hours of rest and relief for 20 personnel. The Portable Collective Protection System, a joint effort led by the Marine Corps, is designed as a C^2 facility that provides 4 hours of rest and relief for 10 to 12 people.[124]

4.2.3.3 Mobile Collective Protection Shelter (MCPS-F), S-280 C/G

The MCPS-F, S-280 C/G, configuration is shown in Figure I-38. This system weighs 8,500 pounds, fits on a truck, and can be inflated inside an existing structure.

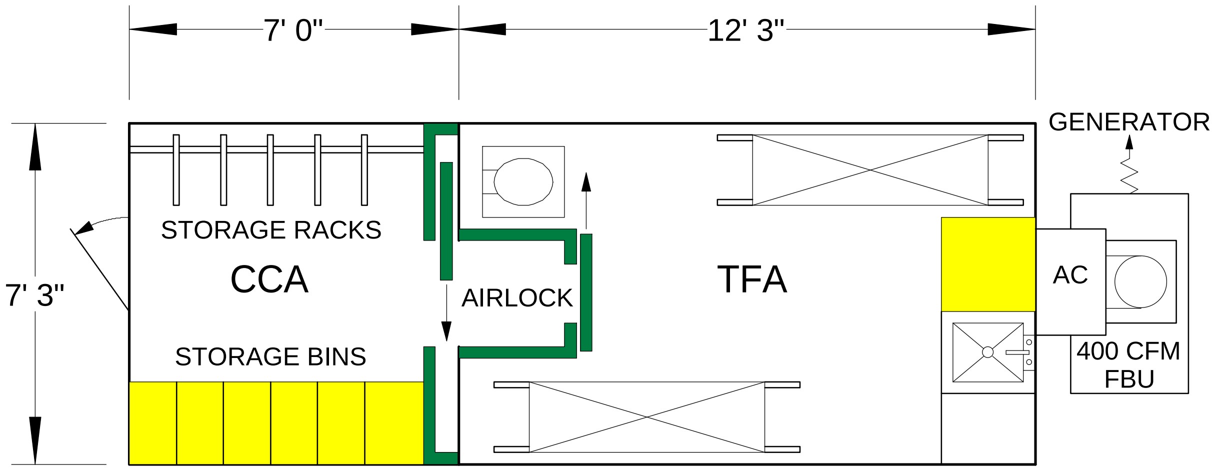

Figure I-38. *Mobile Collective Protection Shelter Layout*[125]

4.2.3.4 Large-Area Night Maintenance Shelter

A large-area night maintenance shelter developed by the Army's Natick Research, Development, and Engineering Center should be considered for predeployment AEF bases. This structure is 24 feet high by 30 feet wide by 100 feet long. It has braided arches, which can support a 10-lb/ft^2 snow load and a 65-mph wind, and is constructed of standard military polyester duck. The beams, which operate on high-pressure air beam technology, weigh 670 pounds, and the fabric weighs 1,450 pounds.[126]

4.2.3.5 Chemically Biologically Hardened Air-Transportable Hospital (ATH)

The Chemically Biologically Hardened ATH provides shelter for sustained operations in a shirt-sleeve environment for medical personnel. This system can be used with CW iso-shelters and TEMPER liners.

4.2.3.6 Deficiencies in Collective Protection

Currently, there are insufficient collective protection shelters to meet AEF needs, and there are no funds programmed to repair or procure collective protection shelters to meet Air Force needs. A collective protection policy of 14 April 1997 permits theater Commanders-in-Chief (CINCs) to determine requirements. As a result, ACC and Pacific Air Force (PACAF) have drafted a Joint Operational Requirements Document (JORD) for collective protection. At present, the major commands have not defined their requirements. PACAF has estimated the repair costs of most existing shelters to be $15 million (Air Force operation and maintenance funds), with $17 million required to purchase TCPSs to meet total major regional conflict requirements. U.S. Air Forces in Europe (USAFE) is holding excess collective protection shelters until the requirements are determined.[127]

4.2.4 Decontamination

Elimination of the hazard of exposure of AEF personnel and equipment to a persistent CW agent requires decontamination. Generally, decontamination involves the use of a water-based caustic or bleach material to neutralize the CW agent. Sodium hydroxide and sodium hypochlorite are two common constituents of decontamination solutions. Decontamination is currently minimally funded in the Joint NBC Defense Program Objectives Memorandum managed by OSD.

4.2.4.1 Vehicle and Facility Decontamination

Currently, the M-17 decontamination units are used for vehicle and facility decontamination. The M-17 consists of a large power washer that physically removes persistent CW agents from vehicles. The M-17 contains only water—it uses no caustic or bleach solution to neutralize the CW agent. At present, there are insufficient M-17 decontamination units in the Air Force inventory. In addition, not all units have M-17 training equipment, and some of the training units are not operational. The lack of M-17 decontamination units negatively affects operations tempo. The Civil Engineering Readiness Working Group is evaluating the addition of M-17 training equipment to mobility equipment allocations. This addition would help the AEF by supplementing the decontamination capability at minimum cost.[128]

4.2.4.2 Aircraft Interior Decontamination

The Air Force has no capability for aircraft interior decontamination. AMC has contracted a study with Dugway Proving Ground to propose a solution to the problem. The six-phase study is nearing completion. As a result of the study, AMC is revising its operational procedures. ACC is incorporating AMC requirements in a JORD.

4.2.4.3 Site Decontamination

The Air Force has limited capability to decontaminate large areas and facilities. The existing capability is limited to M-17 power sprayers. The Air Force is identifying a joint requirement for fixed-site decontamination.

4.2.4.4 M-291 Skin Decontamination Kit

The M-291 Skin Decontamination Kit is deployed. The kit should be used within three minutes of exposure to a CW agent to completely decontaminate areas of exposed skin. The kit is only for external use, and the contents may slightly irritate the skin or eyes.

4.2.4.5 M-258A1 Personal Decontamination Kit

The M-258A1 is fielded and is for external use only. The kit contains three decontamination-1 packets containing dry wipes and three decontamination-2 packets containing wet wipes. The solutions in the kit will neutralize nerve and blister agents. The kit can be used to decontaminate the skin, small equipment items, small areas, and the protective mask.

4.2.4.6 M-295 Kit

The M-295 pouch contains four pads that can be used to wipe localized patches of CW agent on vehicles. The M-295 contains a resin that is both absorptive and detoxifying. The M-295 should be procured for individual decontamination for all AEF personnel.

4.2.5 Medical Treatment

The standard medical treatment for nerve agent exposure consists of a pretreatment and antidote treatment. The pretreatment, taken when ordered by the unit commander, is one pyridostigmine tablet every eight hours for seven days. This pretreatment reduces the severity of nerve agent toxicity, shortens the duration of the treatment, and increases the survival rate. Treatment after exposure to a nerve agent consists of atropine and praldoxine chloride (2-pam chloride). These drugs are usually contained in a packet referred to as an "Auto-Injector." Each packet has three atropine injectors and three 2-pam chloride injectors. This treatment is extremely effective for exposure to sarin and VX and probably less effective for Tabun. The treatment for exposure to Soman is time- and dose-critical because of the well-known binding of Soman to critical sites in the pathogenesis of unreversible poisoning. The military has recently added an anticonvulsant (Valium) to prevent seizures. The convulsant antidote for nerve agents is diazepam, which is used as adjunct therapy for nerve agent poisoning to protect against seizures and brain injury and to increase survival rates.

The problem in not having firm medical operational concepts and quantified, mission-driven performance requirements is that any new developmental system's performance may seem appropriate. To some extent, proponents of CB warfare agent detector research, development, test, and evaluation (RDT&E) traditionally have tended to promote system performance that represents their state-of-the-art sensor/processor capability. Without firm system performance requirements to contradict the assumption, the state-of-the-art capability may appear adequate for medical operations. Therefore, "perceptual" requirements in support of an overall casualty management system are useful. The "evacuate and replace" philosophy, implicit in the recent HQ USAF/SG initiative to re-engineer the Medical Readiness CONOPS, suggests that CB warfare agent detection and warning should be integral to the entire casualty treatment and evacuation process. The Panel's perception is that the Air Force will be directed to make every effort to return stabilized CB warfare casualties to combat.

4.3 Future Threats

The potential for advanced CW agents in the future is substantial. Biotechnology and genetic engineering will permit the development of new chemical agents with increased lethality. Highly controlled biological methods now can be used to produce significant quantities of well-defined chemicals and chemical mixtures, heretofore possible only by very difficult chemical synthesis processes. The final step in the production process is purification. All these processes are well known to chemists. Many of these chemicals and their analogs will be so toxic that purification may not even be necessary. It is to be expected that these agents alone or in combination also will have increased persistence. Future proliferation of pesticides and herbicides with advanced nerve agent properties by the world's agricultural chemical industry also is predicted. Although many of these pesticides and herbicides may prove to be too toxic to use in agriculture, they will have military value.

4.4 Future Countermeasures

Detection is a major CW defense shortfall for the Air Force. Specific CW agent detection and diagnostic requirements must be based on Air Force missions and their unique aerospace and toxicological considerations.[129] Particular attention must be paid to AEF requirements. The most important CW agent detector performance requirements are specificity, sensitivity, reliability, and response time.

4.4.1 Future Detection

Future detection methodology is expected to consist of the Joint Miniature Chemical Agent Detector (JCAD; also identified in the literature as JMCAD) and the JWARN system. Detection of CW agents may also be a valuable mission of UAVs.

4.4.1.1 Joint Chemical Agent Detector

The objective of JCAD is a single solution that addresses joint-Service requirements. The program will provide warfighters with a new chemical warfare agent detection system that has significantly enhanced levels of sensitivity. A draft JORD is currently in coordination. JCAD has features that evolved from the desires of the individual Services.

- **Air Force.** The system will detect toxic agents inside cargo aircraft on the ground and in flight.
- **Army/Marines.** The system will be used by light ground forces, so it must be portable by one person.
- **Navy.** The system will detect toxic agents on shipboard surfaces and equipment, in interior spaces, and on personnel.

The HSC is the lead agency for JCAD, which should bring about a significant increase in CW agent detection capability. The projected engineering and manufacturing development schedule for JCAD ends in FY 00. With its projected performance, JCAD could serve several highly useful purposes for the AFMS. JCAD will improve current decontamination-processing procedures — a major CONOPS concern. Of particular interest are previously decontaminated casualties that may have become recontaminated during staging or transport to the aeromedical staging facility or to the aeromedical evacuation (AE) aircraft. Also, JCAD could be used for both onboard monitoring and for surface scanning of casualties (prior to aircraft entry), AE crew members, medical staff, supplies, and equipment. Another JCAD application will be to measure contaminant concentrations in and on AE aircraft. These concentrations must remain below background levels, so that the aircraft are neither hazardous nor capable of becoming distributors of CB agents. The toxicological and aeromedical requirements for the Critical Care Air Transport Team (CCATT) and the stabilized casualties may result in more demanding JCAD sensitivity requirements.[130]

A senior review panel at HSC recommended that senior AFMS experts in toxicology and aerospace medicine participate in HSC's JCAD performance requirements assessment.[131] Their participation will ensure that unique medical considerations (e.g., the effect of cumulative dosages) for the CCATT and stabilized CB warfare casualties are included in the requirements assessment. The panel projected that JCAD can meet its performance specifications using current sensor technology, as long as the toxicological and aeromedical considerations do not significantly increase sensitivity requirements.[132]

4.4.1.2 Joint Warning and Reporting Network

The JWARN program was initiated "in response to both Army and Marine Corps Operational Requirements Documents (ORDs). The Army ORD for the Multipurpose Integrated Chemical Agent Detector (MICAD) was issued in 1992. The Marine Corps ORD for the Automated Hazardous Warning System (HAZWARN) was issued in 1994. The two programs were combined in 1997 as the JWARN program. JWARN is designed to enhance the situational awareness in the battlespace and to provide real-time hazard information to influence current operations. JWARN is an integrated system of detectors, transmitters, receivers, computers/processors, and application software. It will interface with the command, control, communication, and intelligence (C^4I) architecture of both services. It will provide [relief map overlays for CB weapon effects], operator-selected agent iso-intensity concentration contours, and automatically-formatted NBC1 and NBC4 reports. Sensors and detectors currently in development are required to be compatible with JWARN. The Air Force recognizes the contribution of an integrated detector network to airbase defense and is currently evaluating its potential JWARN requirements. AFMS also has interest in JWARN and similar integrated information/intelligence architectures. The [senior review panel] recommended that the AFMS develop requirements for a corollary Integrated Information and Intelligence System compatible with the (future) airbase command center's system. The AFMS system should also have the capability to display specific threat agent contours, project personnel exposures, and forecast casualty rates. Other potential applications include support of predeployment planning and automation of patient records for CB warfare casualties and cadavers."[133] This system will provide real-time assessment of the threat and contamination through a network of available and future detectors. A draft JORD is currently in coordination.

4.4.1.3 Joint-Service Lightweight Stand-Off Chemical Agent Detector

This joint-Service program will provide a system to detect and identify all known chemical and biological agents. The Army is the lead service. The system will automatically scan hemispherically to a range of 5 km and report the concentrations and locations of agents. A draft JORD is in coordination.

4.4.1.4 Joint Chemical/Biological Agent Water Monitor

A supply of potable water is absolutely essential to any operation. An AEF needs reliable, field-deployable detection of biological and chemical agents in water supplies. The Air Force and Army initiated the JCBAWM program to provide rapid response to terrorist actions and battlefield fallout, effective surveillance of military water supplies on base or in the field, and advanced technology to benefit public health. The concept is a portable, field-deployable modular water monitor. The biological module is being developed by AL/CFD. This monitor will consist of a PSPS to recover biological agents from water and process agents to ensure sensitive and accurate detection. This monitoring system has been submitted for patent. The identification system is an adaptation of a miniature, portable, DNA-based detector. The Army's Edgewood Research, Development, and Engineering Center will develop the Chemical Agent Water Monitor module. A prototype of the entire system will be available in FY 01.

4.4.1.5 Unmanned Aerial Vehicle

UAVs have great potential to serve as remote detectors and monitors of CB agents. In particular, the Global Hawk, currently an ACTD, is a likely platform for CB agent sensors. The Global Hawk will be capable of sustained high-altitude surveillance and reconnaissance. With a total endurance of more than 42 hours at an altitude of 60,000 feet, this UAV can loiter for 24 hours over a target 3,000 nmi from its launch site. This range and endurance, in conjunction with its wide-band satellite and line-of-sight communications capabilities, may make the Global Hawk a key component in integrated stand-off detection and monitoring systems. The Air Force will decide the future of the Global Hawk when the ACTD ends in late 1999.

A key enabler of UAV detection will be the HPSLT program. Semiconductor lasers are valuable because of their many attractive features for military applications: robustness, efficiency, small size, and suitability for mass production. This program is an effort to continue to improve the power and beam quality of semiconductor lasers for a wide variety of civilian and military applications. Hazardous agent detection and warning is just one of the many near-term applications of HPSLT.

4.4.1.6 Microsensor Detection Technology

The Georgia Tech Research Institute is developing an advanced microsensor for detecting chemical and biological agents. This device will have application in hand-held detection equipment, in perimeter-monitoring systems for forward operating locations, and in point detection in areas where potentially hazardous chemicals are used (e.g., chemical storage sites). The sensor is an optical waveguide interferometer mounted on a 1- by 3-cm microchip. The interferometer senses changes in the refractive index of its surface. In testing, the sensor has detected benzene and toluene vapors (in parts-per-million concentrations) and ammonia (in concentrations of 100 parts per billion). By treatment of the interferometer's surface with various chemically sensitive materials, the sensor can be tuned for particular agents and will provide positive identification of agents.[134]

4.4.1.7 Light NBC Reconnaissance System (LNBCRS)

The LNBCRS is a program led by the Marines to provide rapid, accurate NBC combat hazard information. The system is a base vehicle equipped with hand-held, portable, and vehicle-mounted detection and identification devices. LNBCRS is designed to accommodate current and future detection and identification equipment. The program originally was a joint Marines-Army venture. Recently, the Air Force joined, requesting 35 systems. The program now is in the engineering, manufacturing, and development (EM&D) phase. A CONOPS is in draft, and HSC/YAC is the responsible Air Force office.

4.4.1.8 Seek Smoke

Seek Smoke is an advanced detection system that uses lasers to detects clouds of CBW agents. This system would be one component of an integrated CB warning system. A series of Seek Smoke detectors would provide complete coverage of the perimeter of an air base and provide enough warning to enable personnel to don IPE or move to appropriate shelter. Figure I-39 illustrates the role of Seek Smoke in airbase protection.

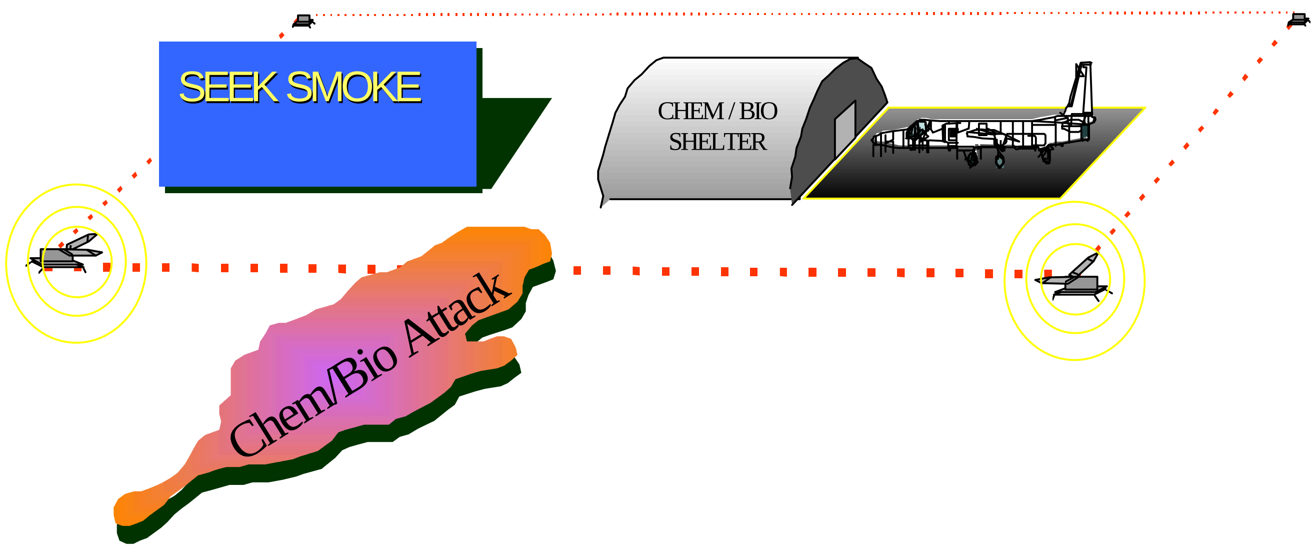

Figure I-39. *Seek Smoke*

4.4.2 Future CW IPE

The future CW IPE developmental programs and procurements include the Aircrew Eye/Respiratory Protection (AERP) and the JS-LIST.

4.4.2.1 Aircrew Eye/Respiratory Protection

AERP is an Air Force reprocurement of an aircrew CW mask system previously fielded in Operation Desert Storm. The mask, which replaces the MBU-13/P, can be worn by aircrew in high-performance aircraft, large transports and tankers, and helicopters. AERP can be used inside and outside the cockpit and combined with CW IPE. The AERP integrates aircraft oxygen supply and communication equipment, and it has Valsalva and antifogging capability and a drinking tube. Over 15,000 mask/hoods have been procured; the final inventory objective is 33,800. Aircraft that have yet to field AERP are the B-1B, B-2, E-3B/C, E-8C (JSTARS), F-16 C/D, AC-130U, MC-130M, and RC-135; fielding is expected by FY 03. Individual aircraft design and installation schedules are to be determined.

4.4.2.2 Joint-Service General-Purpose Mask (JSGPM)

The JSGPM is an Army-led program to replace the current ground support personnel mask with an improved CW mask. The JSGPM will offer improved protection, visual field-of-view, communications, and integration with other IPE. At the same time, JSGPM will have lower breathing resistance, weight, bulk, and cost. JSGPM is maintenance free. The first units will be delivered in FY 07.

4.4.2.3 Joint-Service Aircrew Mask (JSAM)

The JSAM is a joint Navy and Air Force venture, with the Navy working on the operational requirements and the Air Force's HSC leading the technical effort. The objective of the JSAM program is to provide aircrews with individual head-eye-respiratory protection against CB warfare agents and radiological particles. For aircrew in high-performance aircraft, the JSAM will protect against fatigue and *g*-induced loss of consciousness that can occur at high rates of acceleration. The draft JORD states that the JSAM will be a lightweight CB mask compatible with existing IPE and life-support equipment. The system also must provide flame and thermal protection while reducing the thermal burden on personnel. Aircrews will be able to don the JSAM in flight. Initial production will begin in FY 04.

4.4.2.4 JS-LIST Ensemble

JS-LIST is a Marines-led four-Service program to provide ground support personnel with improved CW IPE that can be worn with existing personal-use equipment. JS-LIST will reduce the thermal burden of CW IPE to the equivalent of the battle dress overgarment and provide 24 hours of liquid/vapor protection after 10 launderings.

4.4.3 Future Collective Protection Equipment

Proposed solutions for AEF shelters for CW environments include (1) the CB Ingress-Egress Unit, (2) the Modular Air-Inflatable CB Personnel Shelter, and (3) the Air-Inflatable CB Dock for aircraft maintenance.[135]

4.4.3.1 CB Ingress-Egress Unit

The CB Ingress-Egress Unit will be adaptable to any shelter or modular building. The unit will have an air-beam structure and will be compact in storage. Its CCA will have three decontamination areas: (1) a diatomaceous earth chamber, (2) an UV light chamber with CW IPE garment disposal to a container outside the chamber, and (3) a chlorine solution chamber. Air will flow from the TFA (any shelter or modular building) through the three chambers. The conceptual floor plan is shown in Figure I-40.

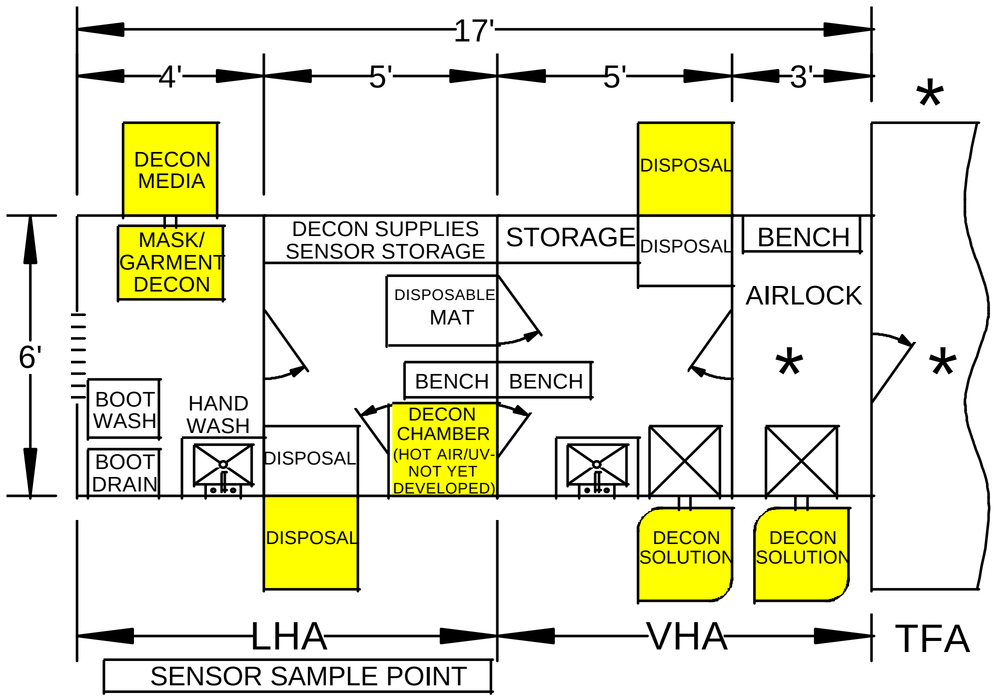

Figure I-40. *Chemical-Biological Ingress-Egress Unit*[136]

4.4.3.2 Modular Air-Inflatable CB Personnel Shelter

In the Modular Air-Inflatable CB Personnel Shelter, the CCA will be contained in one module and the TFA will be contained in separate modular units. Figure I-41 is a conceptual representation of this system.

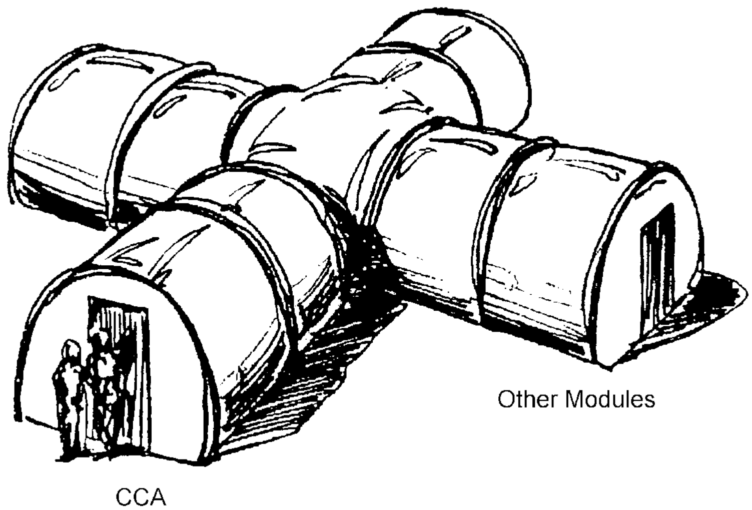

Figure I-41. *Modular Air-Inflatable Chemical-Biological Personnel Shelter*[137]

4.4.3.3 Air-Inflatable CB Dock for Aircraft Maintenance

Figure I-42 is a notional representation of how an air-inflatable maintenance shelter might work.

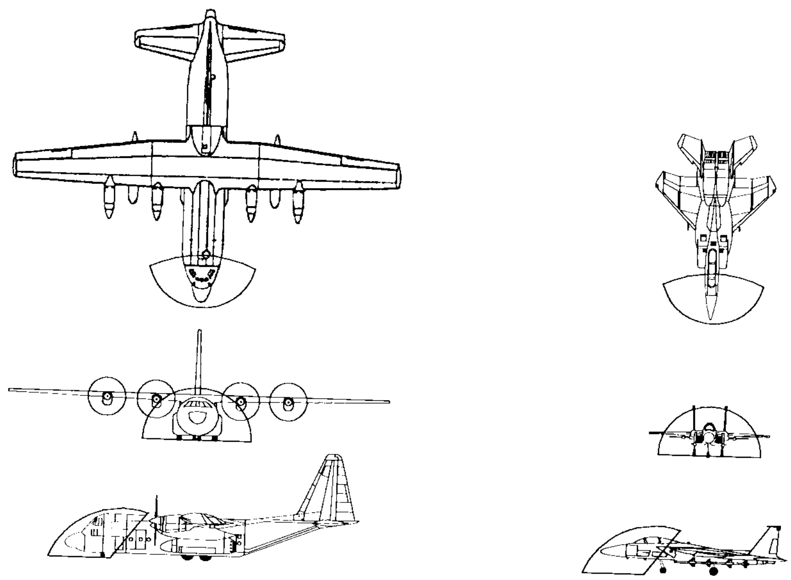

Figure I-42. *Air-Inflatable Chemical-Biological Dock for Aircraft Maintenance*[138]

4.4.3.4 Advanced Integrated Collective Protection System (AICPS)

The AICPS is a fully integrated system with an advanced air filtration system, environmental control unit, and power generation system designed to be installed on tactical vans and shelters. The carbon filtration system will increase mission life by a factor of 2, and it is 65 percent lighter than existing systems. The AICPS is a self-contained system that can be used with Standard Integrated Command Posts, expandable shelters, and vans. It appears to have promise for the AEF.

4.4.3.5 CB Warfare Protection for Transport Aircraft

A promising concept in collective protection is a system that decontaminates the air supply in a transport aircraft and provides positive pressure within the flight deck to prevent contaminated air from entering the aircraft. The aircrew will be able to operate in a shirt-sleeve environment, instead of donning cumbersome IPE. The Air Decontamination System will employ one of two decontamination technologies: pressure-swing adsorption, which uses a "molecular sieve" to filter CW agents; or catalytic oxidation, which destroys and sterilizes CW agents. Currently, the catalytic oxidation system is thought to be the preferred method because it completely eliminates the agents and can be incorporated into both the auxiliary power unit and the environmental control system of the aircraft.

4.4.4 Future Decontamination

4.4.4.1 The Sorbent Decontamination System (SDS)

The SDS will be a sorbent-filled, hand-held mitt applicator, replacing the resin in the M295 kit. The M295 resin, XE-555, is nonreactive and expensive. The SDS contains a reactive, free-flowing powder that is highly adsorptive and renders CW agents nontoxic. The SDS can be used for both personal wipe-down operations and spray-down operations, but it will be used for immediate decontamination only. For spray-down operations, the SDS replaces DS2 and M11/M13 — it is less expensive, noncorrosive, and requires no water. Limited production is expected in FY 02.

4.4.4.2 Modular Decontamination System

The Modular Decontamination System is used to decontaminate exterior surfaces. The system has a Decontaminant Application Module (XM21) and a High-Pressure Washer Module (XM22). The XM21 is a diesel engine driving a diaphragm-type pump, which can be operated from a .75-ton trailer or from the ground. This module contains two hose reels and two electrically powered scrub brushes with 75-foot cords. It pumps liquid decontaminants, including DS2, liquid field expedients, Formalin, bleach, or diesel fuels. The XM22 also has a diesel engine and produces high-pressure spray (to 3,000 pounds per square inch [psi] at 5 gallons per minute [gpm]) at temperatures to 200°F. The module includes high- and low-pressure hoses, nozzles, and hose reels. It has hydrant adapters for urban water sources and a personnel showering bar. The XM22 has two stand-alone modules, one for removal of gross decontamination, the other for rinsing the applied decontaminant.

4.4.5 Future Medical Pretreatment and Treatment

The future medical CW countermeasures must be designed to protect the AEF through pretreatment protective measures, topical skin protectant barriers, antidote therapy that reverses or reduces the toxicity of CW agents, and improved management of casualties. Medical CW countermeasures must stay abreast of new and more toxic CW agents and improve both protective regimes and survival rates.

4.4.5.1 Topical Skin Protectants

Topical skin protectants are the only pharmaceuticals that protect against sulfur mustard, a CW agent that causes severe blisters. Research to develop drugs for a specific treatment or pretreatment against sulfur mustard has top priority.

4.4.5.2 Pretreatment Drug for Cyanide

Cyanide used as a CW agent causes death within minutes. A pretreatment drug that will protect from a CW cyanide attack is scheduled to enter advanced development.

4.4.5.3 Remote Vital Signs Monitor

Another potentially useful technology is the Remote Vital Signs Monitor, scheduled for completion in FY 98. This device uses low-power radiofrequency waves to measure small movements of the chest, even in clothed individuals. Peaks and nulls of the reflected waveform indicate heart rate and respiration, which are indicators of physiological stress. Both long-range (~100 m) and short-range (~10 m) versions have been developed. In a CB environment, medical personnel could use this system to determine vital signs of IPE-clothed personnel through the protective clothing.

4.4.6 Chemical Warfare Analysis

The objective of the Chemical Warfare Analysis effort is to validate CW computer models and to evaluate the interactions between aircraft systems and CW agents. The analysis will include data from a number of transport aircraft (C-5, C-141, C-130, and C-17) and will use the C-17 data as its baseline model. The program will include:

- Assessment of contamination control procedures during loading and unloading of transport aircraft loads
- Investigation of available technologies for aircraft and personnel protection
- Identification of contaminant introduction into aircraft, including air infiltration and engine ingestion

- Identification of susceptible aircraft materials and components
- Evaluation of the effects of a typical persistent agent (Soman) on aircraft materials
- Investigation of the potential hazards of resurgence (by desorption and evaporation) of CW agents from previously decontaminated materials
- Evaluation of existing decontamination methods
- Recommendation of survivability-enhancing design features and operational procedures

4.5 Responsible Parties

Aberdeen Proving Ground

ACC CES/ESX

AF/ASD

AF/CFD

AF/ILEOR

Assistant to the Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs

Chemical and Biological Defense Information Analysis Center

HQ USAF/SG

Joint-Service Integration Group

Joint-Service Materiel Group

Navy Forward-Deployable Laboratory

SAF/AQP

U.S. Air Force Civil Engineering, Prime BEEF

U.S. Air Force Material Command/Human Systems Center (HSC/YAC)

U.S. Air Force Medical Service

U.S. Air Force Research Laboratory

U.S. Army Natick Research, Development, and Engineering Center

4.6 Points of Contact

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5.0 Toxic Agents

Stephen R. Channel, John M. Frazier, Robert A. Hughes, and Valerie J. Gawron

5.1 Current Threats

The Aerospace Expeditionary Forces face an array of environmental threats that may affect personnel performance and degrade mission execution. Exposure to hazardous chemicals and materials is one of these threats. Hazardous chemicals may be encountered as a consequence of flightline operations (e.g., jet fuel, solvents used in maintenance), proximity to industrial plants, accidental release during transportation, or deliberate release by hostile forces. Table I-29 lists some potential sources and compounds likely to be encountered.

Table I-29. *Potential Sources and Agents of Toxic Agent Exposure*

Sources	*Materials/Compounds*
Flight operations	Jet fuels, petroleum, oil, lubricants, high-energy fuels (e.g., hydrazine), solvents (e.g., trichloroethylene)
Industrial plants	Acids, organic chemicals, air and water pollutants
Contingency responses	Smoke, obscurants, fire-suppression agents
Mining and agricultural activity	Arsenic, ammonia
Hostile action and terrorist activity	Chemical warfare agents, industrial chemicals (e.g., chlorine gas)

Poisoning is the most obvious threat. For example, seven cases of toxic agent poisoning were reported in AEF IV between December 1996 and May 1997. Six of these occurred on a single day due to smoke inhalation; the seventh was a medical overdose. The "Infectious Disease and Injury" chapter of this report covers medical aspects of AEF operations. However, operational procedures and constraints may exacerbate the problem. First, the technical orders for toxic agents and systems that use these agents are not current. Second, untrained personnel often take the samples needed for toxicological analysis. Finally, some of the reagents needed to perform these analyses are banned in some countries.

5.2 Current Countermeasures

5.2.1 Intelligence

Timely, accurate, and current information is essential for planning deployment operations. Agencies such as the Armed Forces Medical Intelligence Center at Fort Detrick, MD, and the Central Intelligence Agency are expanding their capabilities to gather and analyze environmental threat data. As a preliminary step, medical intelligence officers of AEFs must consult these sources. Fundamental information about industrial plant locations, water sources, and transportation infrastructure are invaluable when selecting beddown sites and determining security countermeasures. Computer simulation models, such as AFTOX, are available to assess the impact of hazardous chemical releases. These models, which predict the flow of toxic agents through an area, and indoor-air quality models can be used to calculate agent concentrations and transport distances and should be used as planning tools.

One information resource is AFMIC's "Medical Environmental Disease Intelligence and Countermeasures" (MEDIC).[139] MEDIC is a tool that is readily available (on CD-ROM) to the base-level Public Health Officer (PHO) and flight surgeon for use in advising Air Force personnel about health conditions in the countries to which they are deploying. MEDIC was developed in collaboration with the Services, so it is a single source for the medical and public health information required for a deployment. However, MEDIC is not yet a complete reference for toxicological threats.

5.2.2 Preventive Medicine Assets

Each AEF includes medical personnel. At a minimum, a Preventive Aerospace Medical (PAM) team, consisting of a flight surgeon, a PHO, and a bioenvironmental engineer should be included in the first deployed elements to provide immediate on-site expertise to the commander. Given proper communication support, the PAM team has access to expert consultant agencies (listed later in this chapter) that can direct environmental sampling activities to more accurately assess potential hazardous exposures. At the AO, the team takes environmental samples, which it sends to the Armstrong Laboratory's Analytical Services branch (AL/OEA) at Brooks AFB.

There are several options available to the commander to expand this capability. The Army's Center for Health Promotion and Preventive Medicine (CHPPM) and the Theater Army Medical Laboratory (TAML) are specifically designed to provide on-site sampling capabilities; in fact, it was the CHPPM that provided the environmental hazard assessment for Bosnian peacekeeping operations. The Navy Forward Deployable Laboratory and the Air Force Theater Medical Surveillance Team provided expert consultation in the Persian Gulf AO. However, neither group has environmental sampling capability because they focus on infectious disease threats.

The Epidemiology Team is another asset; it is described more fully in the "Infectious Disease and Injury" chapter of this report. The typical team includes a preventive medicine physician, a PHO with epidemiological training, a public health craftsman, a medical entomologist, a laboratory officer, and a bioenvironmental engineering craftsman (or bioenvironmental engineer). These teams are deployed in addition to the normally deployed medical assets to provide in-theater, technical specialty assistance for prevention and control of communicable disease, biological warfare effects, and environmental disease. These teams currently do not have toxicology sampling capability, but they have potential to serve in this role. Epidemiology Teams maintain a state of deployment readiness.

5.3 Future Threats

The AEF can expect new chemicals and materials to be introduced constantly into operational areas as components of new weapon systems and as changes to existing systems. In some cases, the use of new materials (e.g., advanced composite materials) is a result of increasing performance requirements, although acquisition programs are supposed to use only materials approved by the Department of Defense (DoD). However, environmental regulatory actions drive much of the use of new materials (e.g., deicers and replacements for halon and ozone-depleting chemicals), which may be replaced with even more toxic materials.

These regulatory actions will place more restrictions on operations throughout the world, including the continental U.S. Certain materials are strictly controlled by environmental regulations in the U.S. and other countries. For example, Sweden has strict regulations on cadmium, which may have an impact on the use of certain weapon systems (e.g., cadmium-plated aircraft brake components) and Norway has stringent environmental controls for jet fuels. Constraints like these may preclude using certain territories as air bases or staging centers for AEFs, thus lengthening supply lines and increasing airlift requirements.

5.4 Future Countermeasures

Future countermeasures include enhanced materials design, on-site environmental assessment, consultation, and protective equipment.

5.4.1 Materials Design

A key countermeasure to the future threat is to ensure that the materials used in weapon systems and those necessary to sustain operations do not themselves increase the health threat to deployed personnel. DoD Regulation 5000.2 directs materials developers for current and future weapon systems to integrate hazard assessment into the acquisition cycle.[140] The Operational Toxicology Branch of the Air Force Research Laboratory works closely with the Materials Directorate to meet this requirement. Commanders must emphasize hazard assessment to ensure that an AEF does not use materials that will limit operational flexibility or degrade mission effectiveness.

The issue of regulatory constraints is closely related to the problem of material design. Material designers must consider these factors and choose materials that make operational sense. At a minimum, AEF planners must have access to an up-to-date, central source of worldwide environmental regulations. Such a central source does not exist currently, but it should be a joint effort to ensure uniformity of information and to prevent duplication of effort.

5.4.2 On-Site Environmental Assessment

As mentioned previously, several current organizations have fragmented capabilities to provide the AEF commander with on-site, deployment-specific expertise. The recently formed Deployment Toxicology Users Group (DTUG) is a joint organization specifically chartered to identify research tasks to enhance the commander's tool kit for environmental hazard assessment. The DTUG has identified several needs, including reduced footprint and self-servicing sampling devices, as high-priority items for meeting future deployment requirements. The work of the DTUG and similar joint efforts should be strongly supported at the command level to ensure that operational needs are adequately addressed.

Current organizations such as the TAML, CHPPM, and Epidemiology Teams provide a substantial framework for providing "on call" expertise for the AEF commander. Augmentation and integration of personnel of all the Services into these organizations would be a major step forward in providing the widest range of expert resources to any deployment command. The guiding principle for using these resources should be to send only what is needed, when needed, for the minimum necessary time.

5.4.3 Consultation

Communications technology currently can provide reliable access to experts in toxicology, occupational medicine, and intelligence assessment. Future technologies will combine real-time, on-site analysis, remote sampling, and computer modeling to allow those experts to generate site-specific risk assessment summaries and to update those summaries as conditions change. Such a system could be similar to, or part of, the telemedicine capability described in the "Infectious Disease and Injury" chapter of this report.

5.4.4 Protective Equipment

The most effective strategy to counter environmental toxic hazards is to avoid exposure. Avoidance should be the goal of deployment planning and employment. Any individual protective equipment, such as the Army's Toxicological Agent Protective (TAP) Ensemble (a butyl-rubber garment), degrades performance because of heat burden, weight, loss of dexterity and facility with ground support equipment, and the requirement for decontamination. The "Chemical Weapons" chapter of this report describes these effects in detail.

The Improved TAP (ITAP) Ensemble is an attempt to reduce these effects. This system has a new integrated cooling subsystem and a self-contained breathing apparatus, but it uses the existing mask, gloves, and boots. The system will reduce thermal burden and weight, ease decontamination, and improve the interface with ground support equipment. However, the ITAP Ensemble remains less than satisfactory for sustained AEF operations. Production of this ensemble began in 1997; the Air Force inventory objective is 760 units.

5.5 Responsible Parties

Armed Forces Medical Intelligence Center, Fort Detrick, MD

Armed Services Biomedical Research, Evaluation, and Management

Bioremediation Technologies

Center for Health Promotion and Preventive Medicine

DoD Halon Steering Group

Environmental Protection Agency

Environmental Safety and Occupational Health

Joint Army–Navy–NASA–Air Force Toxicology Committee

Joint Working Group on Low-Level Exposure, Aberdeen Proving Grounds

National Academy of Sciences, Committee on Toxicology

National Institute of Occupational Safety and Health

Naval Medical Research Institute

Navy Environmental Health Center

Public Health Officer

Society of Environmental Medicine

Society of Toxicology

Tri-Service Toxicology

U.S. Air Force Civil Engineering Support Agency, Tyndall AFB

U.S. Air Force Medical Operations Agency

U.S. Air Force Research Laboratory

- Operational Toxicology Branch (formerly AL/OET, Toxicology Branch)
- Vulnerability and Modeling Branch (formerly AL/CFBE, Biodynamic Response to Operational Hazards Branch)

U.S. Air Force Surgeon General

Walter Reed Army Institute of Research

Wright Laboratory, Airbase Technology Branch (WL/FIVC

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6.0 Conventional Weapons

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6.1 Current Threats

The ability of Aerospace Expeditionary Forces to protect themselves against conventional weapons is limited by several factors in current Air Force organization, procedures, and equipment.

- **Organization:** The equipment management agency for Security Police (SP) was disbanded, leaving SP units no way to acquire commercial off-the-shelf materiel. Also, the SP agency is moving from Kirtland AFB to Lackland AFB; this may temporarily disrupt the effective functioning of that agency.
- **Predeployment Preparation:** First, there is no guidance for tailoring force protection, so units are sometimes "too light to fight and too heavy to run." Next, optimizing a base for defense requires extensive experience and training, and force protection planning may be too time-consuming to fit the "ready, fire, aim" concept of AEF operation. Finally, after-action reports frequently cite lack of information as a problem. This problem is compounded because human intelligence (humint, i.e., spies) has been severely reduced and hence current threat information in the face of new weapons and techniques constantly being developed is insufficient.
- **Stand-Off Detection:** A large majority of airfield attacks between 1942 and 1992 were stand-off attacks. Also, mines have been placed around many airfields. The lack of stand-off detection capability hampers efforts to counter these threats.
- **Detection:** An effective detection capability is required. First, fewer personnel are available to patrol large perimeters. Second, truck bombs can easily be carried into an air base. Finally, the region around an AEF base may be mined.
- **Warning:** In high-threat periods, voice transmissions typically overload the communications systems. Also, current means of warning personnel are ambiguous and may not be heard by all personnel.
- **Protection:** First, there is no protection against trucks with bombs. The sand bags needed to secure a single building (500 to 800 bags) require two days to be filled. Where barriers do exist, they are not optimized. Second, current force protection measures would be overrun in a tank attack, and the force protection personnel and some crew chiefs typically are the only armed personnel on an air base. Third, force protection personnel are not prepared to neutralize booby traps. Finally, threat conditions can change quickly — perhaps more quickly than AEFs can respond.
- **Sustainability:** First, fewer personnel will be deployed. Second, the order of arrival of personnel and equipment is critical to force protection.

The conventional weapons that threaten AEFs can be delivered from airborne, ground-based, and seagoing platforms. Table I-30 lists types of conventional weapons that could be used against an AEF.

Table I-30. *Types of Conventional Weapons*

Delivery Platform	*Type of Weapon*
Airborne	Aircraft
	Missiles
	Antiaircraft artillery
	Aerial mines
	Bombs
Ground-based	Tanks
	Artillery
	Land mines
Seagoing	Surface ships
	Submarines
	Sea mines

6.1.1 Ground Attacks

From 1940 through 1992, ground attacks on airfields have occurred in Vietnam (493 attacks), Panama (4), Afghanistan (3), Korea (3), El Salvador (2), Grenada (2), the Falklands (1), and the Philippines (1).[141] During World War II there were 130 airfield ground attacks in Northern Africa, the Pacific Islands, and Europe. There were three during Operation Desert Storm. Figure I-43 shows the worldwide distribution of these attacks. The objectives of the attacks are listed in Figure I-44, the means of attack in Figure I-45, and the tactics in Figure I-46.

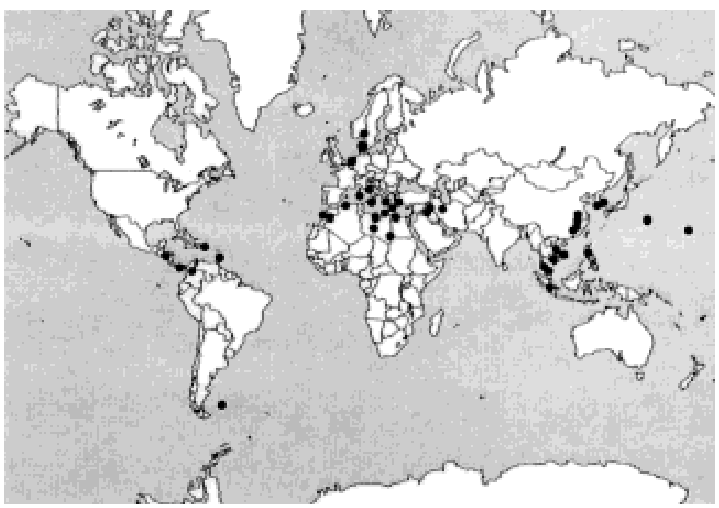

Figure I-43. *Locations of Ground Attacks on Air Bases, 1940–1992*[142]

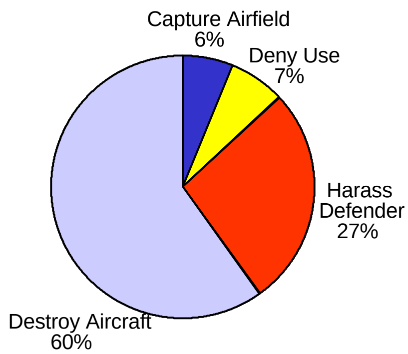

Figure I-44. *Airfield Ground Attack Objectives*[143]

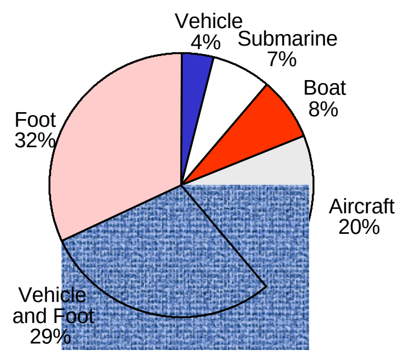

Figure I-45. *Insertion Techniques Used in Airfield Ground Attacks (Except Vietnam)*[144]

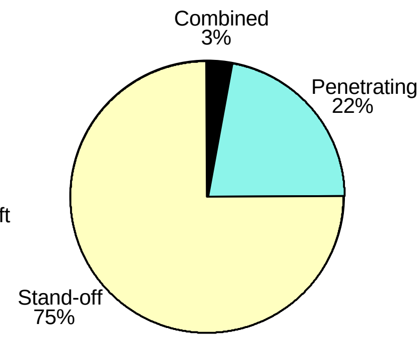

Figure I-46. *Tactics Used in Airfield Ground Attacks*[145]

The stand-off threat includes mortars, surface-to-air missiles, and rifles. Figure I-47 illustrates the sizes of the areas threatened by these weapons. The distances given in the figure are the ranges from which an enemy, using the particular weapons, could threaten an AEF air base.

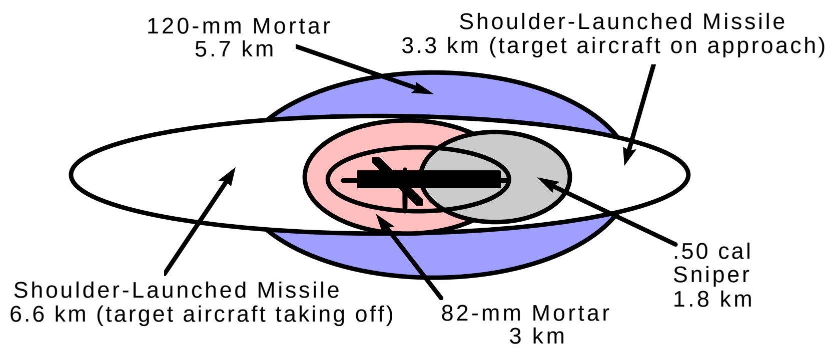

Figure I-47. *Size of the Stand-Off Threat Footprint*[146]

6.1.2 Air-Launched Weapons

The chief threat from air-launched weapons is guided missiles released by aircraft to attack specific targets. These air-to-surface missiles (ASMs) are a threat to installations, personnel, and equipment. The guidance systems usually are inertial, command, wire, or radar, and the coordinates of the targets are programmed into the weapons before release. The pilot releases the missile within range of the target and the missile directs itself to the target. Radar guidance allows the missile to self-correct its targeting. There are 13 fielded ASMs that could threaten an AEF; one is inertially guided, two are command-guided, four are wire-guided, five are radar-guided, and one is laser-guided. These weapons have effective ranges of from 1.6 to 135 nautical miles. Only one of these systems is nuclear-capable. Table I-31 summarizes the characteristics of these missile systems.[147]

Table I-31. *Characteristics of Current Air-to-Surface Missiles*

Guidance	***Range (nmi)***	***Warhead***	***Fielded Systems***
Command	4.3 – 8.1	Conventional	2
Wire	1.6 – 2.7	Conventional	4
Radar	21.6 – 81	Conventional	5
Laser	5.4	Conventional	1
Inertial	135	Nuclear	1

6.1.3 Defensive Weapons

Defensive weapons primarily are theater-defense missiles (TDMs) — ballistic missiles that usually are used against stationary ground targets. However, a few of these missiles have the guidance systems necessary for use against aircraft and other ballistic missiles. TDMs threaten an AEF's installations, personnel, and equipment. There are 37 fielded TDM systems; they are ground-, ship-, and silo-based and have ranges of 4.3 to 270 nmi. Five of the systems are capable of carrying nuclear warheads. Table I-32 summarizes the characteristics of these TDMs.[148]

Table I-32. *Characteristics of Theater-Defense Missiles*

Guidance	Range (nmi)	Type	Warhead	Fielded Systems
Command	4.32 – 24.3	Theater defense	Conventional	18
Radar	4.3 – 27	Theater defense	Conventional/nuclear	14
Infrared	5.4 – 48.6	Theater defense	Conventional	4
Inertial	270	Antiballistic missile	Nuclear	1

6.1.4 Offensive Weapons

Offensive weapons include surface-to-surface missiles (SSMs), ASMs, antisubmarine missiles (ASUBMs), and rockets. These weapons can be either ballistic missiles (BMs) or cruise missiles (CMs); they have ranges of 16 to 7,020 nmi. Offensive weapons can be targeted at nonmoving building-, battlefield-, or city-sized targets. There are 70 fielded systems in this category, all of which can carry nuclear warheads. Fifty of the systems also can carry chemical warheads. Table I-33 summarizes the characteristics of these offensive weapons.[149]

Table I-33. *Characteristics of Offensive Weapons*

Guidance	Range (nmi)	Type	Warhead	Fielded Systems
Inertial	19 – 7,020	BM, SSM, ASM, ASUBM	Nuclear or chemical	50
Radar	19 – 216	BM, SSM, ASM	Nuclear	16
Unguided	16	Rocket	Nuclear	1
Infrared	43 – 59	SSM, CM	Nuclear	3

6.1.5 Specific Missile Threats

Tables I-34 through I-36 list the specific missile systems that could threaten AEFs. The lists include the type of guidance system and the nations that possess the systems.[150, 151]

Table I-34. *Air-Launched Weapon Systems*

Name	Guidance	Country
Mathogo	Wire	Argentina
Martin Pescador	Command	Argentina
Hongjian 8 (HJ-8)	Wire	China
CAS-1	Radar	China
HY-4	Radar	China
YJ-1	Radar	China
C-101	Radar	China
AS 11	Wire	France
AS 12	Wire	France
AS 15	Command	France
AS 30	Laser	France
AM 39	Radar	France
ARMAT	Inertial	France

Table I-35. *Defensive Weapon Systems*

Name	Guidance	Country
HQ-2	Command	China
CSA-N-2	Radar	China
FM-80	Command	China
KS-1	Radar	China
Crotale	Command	France
FAW-1	Radar	Iraq
Barak/Adams	Closure	Israel
Arrow	Infrared	Israel
ASPIDE	Radar	Italy
TAN-SAM	Infrared	Japan
SA-1	Command	Russia
SA-2	Command	Russia
SA-3	Command	Russia
SA-4	Command	Russia
SA-5	Radar	Russia
SA-6	Radar	Russia
SA-8	Command	Russia
SA-10	Radar	Russia
SA-11	Radar	Russia
SA-12	Radar	Russia
SA-13	Infrared	Russia
SA-15	Command	Russia
SA-19	Command	Russia
SA-N-1	Command	Russia
SA-N-3	Command	Russia
SA-N-4	Command	Russia
SA-N-6	Radar	Russia
SA-N-7	Radar	Russia
SA-N-9	Radar	Russia
SA-N-11	Command	Russia
SH-08	Command	Russia
SH-11	Inertial	Russia
SAHV	Infrared	South Africa
Sky Bow	Radar	Taiwan
Rapier 2000	Closure	UK
GWS 30 Sea Dart	Radar	UK
GWS 25/26 Seawolf	Closure	UK

Table I-36. *Offensive Weapon Systems*

Name	Guidance	Country
SS-300	Inertial	Brazil
CSS-2	Inertial	China
CSS-3	Inertial	China
CSS-4	Inertial	China
CSS-5	Inertial	China
CSS-6	Inertial	China
CSS-7	Inertial	China
CSS-8	Inertial	China
CSS-N-1	Radar	China
CSSC-X-5	Inertial	China
CSSC-X-6	Radar	China
CSSC-7	Radar	China
CSS-N-3	Inertial	China
CSS-N-4	Radar	China
CAS-1	Radar	China
MM 38	Radar	France
Hades	Inertial	France
S-3	Inertial	France
M-4	Inertial	France
M-5	Inertial	France
ASMP	Inertial	France
Prithvi	Inertial	India
Agni	Inertial	India
Al Hussein	Inertial	Iraq
Al Abbas	Inertial	Iraq
FAW 70	Radar	Iraq
Gabriel	Radar	Israel
Jericho	Inertial	Israel
SSM-1	Radar	Japan
HATF	Inertial	Pakistan
Frog-7	Unguided	Russia
SS-1	Inertial	Russia
SS-11	Inertial	Russia
SS-13	Inertial	Russia
SS-17	Inertial	Russia
SS-18	Inertial	Russia
SS-19	Inertial	Russia
SS-21	Inertial	Russia
SS-24	Inertial	Russia
SS-25	Inertial	Russia
SS-N-2	Infrared	Russia
SS-N-3	Infrared	Russia
SS-N-6	Inertial	Russia
SS-N-7	Radar	Russia
SS-N-8	Inertial	Russia

Table I-36. *Offensive Weapon Systems (cont.)*

Name	Guidance	Country
SS-N-9	Infrared	Russia
SS-N-12	Radar	Russia
SS-N-14	Inertial	Russia
SS-N-15	Inertial	Russia
SS-N-16	Inertial	Russia
SS-N-18	Inertial	Russia
SS-N-19	Infrared	Russia
SS-N-20	Inertial	Russia
SS-N-21	Inertial	Russia
SS-N-22	Infrared	Russia
SS-N-23	Inertial	Russia
SS-N-25	Radar	Russia
SUW-N-1	Unguided	Russia
AS-4	Radar	Russia
AS-6	Radar	Russia
AS-15	Inertial	Russia
AS-16	Radar	Russia
AS-17	Radar	Russia
KH-41	Radar	Russia
RBS-15	Radar	Sweden
Ching Feng	Inertial	Taiwan
Hsiung	Radar	Taiwan
A-3TK	Inertial	UK
Sea Eagle	Radar	UK

6.1.6 Conventional Weapons Threat to Personnel

The primary close-quarters warfighters in an AEF are likely to be pararescue jet personnel (PJs). These personnel have a number of concerns about their ability to protect themselves from conventional weapons. These problems highlighted by PJs, although very specific, indicate the nature of the Air Force's weakness in countering the threats.[152]

- The woodland camouflage pattern has too much black coloring. The black areas absorb light. Regardless of deployment location, PJs think that the tri-colored desert camouflage provides better concealment.
- A single helmet suitable for both air operations and ground combat is needed. It should have removable communications gear.
- A waterproof survival radio is needed. PJs double-bag their current radios in zip-lock bags to give some measure of waterproofing.
- Packs should accommodate a tap for water.
- A small, infrared strobe light for signaling is needed.
- A fully automatic, 12-gauge shotgun with 30-round capacity is needed for breaking enemy contact.
- The procurement process does not provide the required equipment in a timely manner. Items take too long to be fielded, so they are technologically obsolete by the time they get to the users.

6.2 Current Countermeasures

6.2.1 Ground Attack Countermeasures

The "Current Countermeasures" section of the "Terrorists" chapter of this report thoroughly addresses ground-attack countermeasures.

6.2.2 Air-Launched Weapons Countermeasures

The only current countermeasure against ASMs is interception with surface-to-air missiles (SAMs), such as the Patriot system.

6.2.3 Defensive Weapons Countermeasures

As with the air-launched weapons, the only countermeasure is to intercept incoming missiles with SAMs.

6.2.4 Offensive Weapons Countermeasures

The most effective countermeasure for these missiles is interception with SAMs. ASMs and radar-guided missiles can be defeated through electronic warfare and decoys.

6.2.5 Training

The U.S. Atlantic Command has established a Joint Preparation and Onward Movement Center at Fort Benning, GA, to provide training and indoctrination for U.S. personnel who will deploy to support Operation Joint Endeavor. The center will train personnel in joint and NATO staff procedures, weapons familiarization, cultural and environmental issues, and cold weather operations. This training will make each individual a more effective part of the overall "countermeasures system."

6.3 Future Threats

6.3.1 Attacks on AEF Assets

Given the current and future emphasis on lean AEFs, the loss of just a few key assets could cripple mission effectiveness. Table I-37 lists high-value aircraft and inventories (as of May 1994) that could be choke-points in structuring AEFs.

Table I-37. *Selected High-Value Aircraft*[153]

Aircraft Type	*Total Inventory**	*Primary Aircraft Authorized*†
AC-130	19	18
B-1	95	86
B-2	20	16
C-5A/B	82	76
E-3 AWACS	34	29
E-8 JSTARS	20	20
EF-111	46	40
F-117	54	47
KC-10	59	57
KC-135	19	15

* Number of airframes owned by the Air Force
† Number of aircraft in operational service

6.3.2 Ballistic and Cruise Missiles

The future threat of ballistic and cruise missiles is clearly described in OSD's *Proliferation: Threat and Response*. That description is excerpted here. As explained below, the technological keys to advances in these threats are target acquisition and accuracy of guidance and navigation.

The threat from ballistic and cruise missiles is likely to grow. The OSD expects "that states with more launch capability than demonstrated by Iraq during the Gulf War will launch large scale salvo attacks against high priority targets, with smaller numbers of missiles being directed against targets of opportunity. Salvo attacks maximize damage and compensate for the inaccuracy of older technology missiles."[154]

"The potential for coercion is perhaps the long-range ballistic missile's greatest value to a proliferator and the greatest challenge for those seeking to restrain that state. Beyond their coercive value in threatening distant cities and ability to drain military resources seeking to counter that coercive threat, missiles — if sufficiently accurate and/or lethal — can also pose major direct military threats."[155]

"From the perspective of the leader of a state, ballistic missiles are an effective instrument — even the weapon of choice—to threaten the rear of U.S. and coalition forces in the face of U.S. air superiority. Missiles are much less expensive than acquiring and maintaining a world-class air force competitive with U.S. military aviation; missiles with a low profile infrastructure and mobile launchers are much less vulnerable than aircraft to U.S. offensive operations; missiles are easier to control than other means of deep strike; and even when armed with high explosives, missiles can have considerable psychological effects when used against urban targets."[156]

"Attempts may be made to accelerate development by purchasing ballistic missile technology and technological know-how from other countries. While technological aspects of developing ballistic missiles are challenging, they are well and widely known. Thus, attempts to block a determined adversary are likely only to slow development. As more nations begin deploying ballistic missile defenses, their adversaries will likely begin developing countermeasures to these defenses, which need not be expensive or involve high technology, to create difficulties for the defense, especially for missiles targeted to terrorize civilians."[157]

"Cruise missiles may be even less expensive and more accurate than ballistic missiles, and their smaller size may make them an even more elusive target for counterforce operations. Furthermore, they may also be more difficult to defend against than manned aircraft because of their lower radar cross-sections. Even though short-range anti-ship cruise missiles are already widely available, there are only a few countries that possess long-range land-attack cruise missiles. However, there are no technological barriers preventing developing nations from developing or purchasing these relatively inexpensive, potentially very accurate delivery systems."[158]

"Even unsophisticated unpiloted aerodynamic vehicles — or cruise missiles — could be configured to accomplish a variety of missions. Such aerodynamic vehicles are widely available, inexpensive (to purchase, support, and operate), small, mobile, easy to hide, capable of being launched from a variety of launch platforms (air, ground, ship, or submarine) without significant modifications to the missile, potentially hard to detect in-flight, and (with global positioning systems (GPS)) accurate to a few tens of meters. Depending on the details of the design, they could be difficult to detect, track, and defeat with current active defenses."[159]

"Although they can be designed to deliver their payloads to great distances (both the United States and the former Soviet Union built cruise missiles with range capabilities of more than 3000 km), the majority of aerodynamic vehicles can only achieve short ranges of less than 250 km. It should be noted that the effective range of an aircraft-carried cruise missile is a function of both the aircraft's range (when carrying this load) and the missile."[160]

"There is little proliferation, as yet, of long-range land-attack cruise missiles. But because of the Tomahawk's apparent success in the Gulf War, indigenous development programs for long-range cruise missiles can be anticipated among proliferant nations. These nations may also purchase technology, hardware, and complete systems from other countries."[161]

"Countries intent on obtaining . . . missile capabilities must either buy the necessary hardware or establish their own capability. In the case of military attack, they also must devise ways to protect their capabilities from destruction. These countries use a variety of covert and overt strategies to attain their goals, all of which make it difficult for us to determine the status of their programs."[162]

"With the removal of specialized equipment for tracking an airplane, surface-to-air missiles . . . can be adapted as single-purpose ballistic missiles as shown on the chart [Table I-38]:"[163]

Table I-38. *Proliferation of Ballistic Missiles Derived From Russian SA-2 Surface-to-Air Missile*[164]

Country	*Proliferation Process*
China	• Produced its own SA-2: the CSA-1 • Modified the CSA-1 into a SRBM: the CSS-8 (range 150 km) • Sold the CSS-8 to Iran
Iraq	• Attempted to convert the SA-2 into 300-km range SRBM (Al Fahd 300) • Attempted to use the SA-2 as second-stage sustainer for 2,000-km range IRBM (Tammouz I)
India	• Developed two versions of the Prithvi SRBM — ranges 150 km and 250 km • Used the Prithvi as second stage for the Agni IRBM — intended range 2,000 km

"Proliferants must have accurate information concerning the location and status of targets — what is the precise distance and direction between the launch points of the . . . delivery systems and the intended target?—what ports and airfields are supporting operations?"[165]

"The availability of satellite imagery has had a major impact on the ability of proliferants to obtain the data needed for effective targeting. The key systems here have been SPOT and LANDSAT — French and American satellites, respectively, that provide imagery. In peacetime, data from these satellites are commercially available. More recently, data from Russian imagery satellites have also become available on the open market."[166]

"SPOT and LANDSAT can provide reasonably high resolution images in the range of 10-30 meters. Resolution refers to the size of an object on the ground that can be seen in the sense that it can be distinguished from other objects. Location accuracy depends on the availability of reference information—visible known locations that can be identified. For SPOT, accuracies on the order of 15 meters or better are possible when imagery covers areas with known and precisely located reference points. Depending on the number of SPOT or LANDSAT satellites that are in orbit, considerable time can transpire between successive images of the same location."[167]

"During peacetime, proliferants might make use of imagery from SPOT and LANDSAT to develop accurate maps of targets in other states. . . . Useful information might also be developed concerning military capabilities, such as the locations of airfields that might be used by military forces during a conflict."[168]

"In the future, higher resolution data are likely to be commercially available to include 1-meter-scale data from U.S. firms and 5-meter-resolution imagery from the next generation of SPOT satellites. Currently, advertised resolutions (which are best possible values) might not be achieved if the target of interest is not aligned with the satellite's track. The payoff from this access to satellite imagery would be the ability to identify ports, airfields, and other facilities that are in use and to obtain information concerning the dispositions and locations of military forces not otherwise subject to observation. . . . Access to timely imagery of at least moderate resolution would be a significant improvement in military capabilities."[169]

"The availability of low cost systems that provide high accuracy navigation and guidance is a recent development. NAVSTAR GPS and GLONASS (its Russian counterpart) use constellations of satellites to send signals that can be utilized to provide high accuracy navigation. GPS receivers are available in stores and catalogs at prices of $200-$500."[170]

"GPS broadcasts protected military and in-the-clear civil signals with accuracies of less than 10 meters and 30-50 meters, respectively. If the Selective Availability security feature is removed from GPS, it will provide in-the-clear accuracy of approximately 3 to 5 meters."[171]

"The accuracy of navigation can be improved considerably by performing sophisticated processing on the GPS signal or by combining information from GPS with location data provided by other sources such as fixed reference stations (differential GPS) or inertial measurement systems."[172]

"GPS is based on signals that are broadcast by satellites. As is the case with any signal, attempts might be made to jam a GPS-equipped delivery system. This might be done with systems that have limited range located near probable targets . . . . The effectiveness of such jamming interference would depend on a number of factors; for example, is GPS the only guidance system employed or is it complemented by other navigation aides?"[173]

6.4 Future Countermeasures

Future countermeasures include enhanced situation awareness displays and physical protection.

6.4.1 Soldier System

Soldier System is the Army's program to provide soldiers with everything they wear, carry, and consume in combat. The Soldier System includes improved individual equipment, weapons, clothing, and communications, command, control, and subsistence items to enhance the soldier's overall effectiveness and survivability on the battlefield. Soldier System items include several related programs that respond to changing threat requirements and advances in state-of-the-art technology. Soldier Modernization (Annex K of the Army Modernization Plan) is the basis for Soldier System efforts. Soldier Modernization is a cohesive plan for the coordinated development of Soldier System items and is the roadmap for near-term, midterm, and far-term efforts. A cohesive, integrated program like Soldier System could benefit AEFs.[174]

For the near term, the Soldier Enhancement Program (SEP) is a key element of the soldier support and modernization process. SEP projects are primarily modified nondevelopmental items, which are focused in four general areas: weapons and munitions; combat clothing and individual equipment (CIE); communications and navigation aids; and food, water, and shelter. Current SEP projects include Enhanced Load-Bearing Vest, Inconspicuous Body Armor, Second-Generation Extended Cold-Weather Clothing System, Armor Crew/Infantry Protective Mask, Medium Machine Gun, Modular Weapon System, M249 Vehicle Mount, Fighting Position Excavator, Lightweight Video Vision Device, Stabilized Binoculars, Individual Soldier Enhanced Ration, and Small Unit Shower.[175]

Mid-term CIE research and development efforts are focused on the design of lighter-weight equipment, ballistic and laser eye protection, and improved chemical-protective clothing that takes advantage of the latest technology and advanced materials. These efforts concentrate on the Self-Contained Toxic Environmental Protective Outfit, the Joint-Service Lightweight Integrated Suit Technology (JS-LIST), and improved laser eye protection. Other key elements include the Land Warrior (LW), Air Warrior (AW), and Mounted Warrior (MW) systems.[176]

LW is a first-generation integrated fighting system for dismounted combat soldiers. This system will enhance soldiers' battlefield capabilities by integrating warfighting components and technologies into a cohesive system. The development, procurement, and logistics efforts will be timely and cost-effective to ensure that the system is delivered to the soldiers when they need it. LW subsystems include an individual soldier computer, global positioning system, and communications system; enhancements to CIE; integrated headgear with head-up display (HUD) and image intensifier; improved chemical/ biological mask; and a modular weapon system with thermal sight and infrared laser aiming light. AW and MW will be similar efforts for aircrew and mounted personnel; the requirements for these programs are being defined.[177]

The 21st-Century Land Warrior is a far-term effort to identify less mature technologies to meet longer-term soldier deficiencies. The emphasis of this program is on the design of lightweight equipment and high-technology areas in computers, communication, and night-vision devices.[178]

6.4.2 Expanded Situation Awareness Insertion (ESAI)

During mission execution and engagement phases, aircraft mission success depends on aircrew situation awareness, which requires timely and accurate information. Currently, threat and target information is provided by pre-mission planning intelligence; updates are relayed by voice communications. The objective of the ESAI program is to design, develop, evaluate, and demonstrate hardware and software approaches and techniques to provide tactical, strategic, airlift, and special operations aircrews with a timely, enhanced threat alert and situation awareness capability. Emphasis is on direct application of technology developments through demonstrations. The situation awareness enhancement most important to the force protection mission will be more accurate combat identification, which will use traditional and new parameters for friend/foe separation and specific-emitter identification.

Through a Mission Need Statement, a Statement of Operational Need, and a System Operational Requirements Document, Air Combat Command has confirmed the need for expanded situation awareness, including improved threat location and identification. The ESAI program will provide advances in real-time updating of mobile targets and threats for self-defense, combat identification, and targeting; low-cost angle-of-arrival and precision-emitter location techniques; the use of new parameters for friend/foe separation and electronic battle damage assessment; and optimized response strategy for self-defense of combat aircraft.

6.4.3 Expedient/Modular Physical Protection (EMPP)

The EMPP effort is developing physical force protection for forward-deployed AEF air bases. In many AEF scenarios, deployed forces will be at high risk of terrorist attack. New technology will allow updating of force protection criteria for AEF operational parameters, analysis of current and future terrorist weapon effects, rapid site assessments, rapid planning and designing of force protection measures, improvements to existing installations and facilities at airfields, and training in AEF force protection measures. This program should be complete in FY 00.

The program will include three components. The "AEF Force Protection Planning Tool" will be a computer program for the rapid identification and prioritization of force protection measures at an

AEF deployment site. This tool will have several modules: policy/criteria, threat, site layout, weapon effects, response models, and force protection measures (including standard methods and costs). The "Deployable Defensive Fighting Positions" component is described below. The "Structural Strengthening" component will develop and test rapid, inexpensive retrofit measures to significantly increase the blast resistance of concrete and masonry structures. The scope of the required work includes modeling, analysis, and testing of designs; design methodology; and trials on the types of facilities typically found at commercial airports.

6.4.4 Deployable Defensive Fighting Positions (DDFP)

The DDFP effort is a component of the EMPP program. The purpose is to produce deployable protection kits that maximize use of materials available locally and in-theater (e.g., AM-2 matting), reduce air-transported weight and setup time from the existing B-1 revetment kit, use modular concepts to adapt protection to the sizes required for critical assets, and provide new equipment to move soil and more efficiently fill revetments. In some cases, existing facilities at an AEF deployment location may have to be strengthened against potential terrorist attack. Rapid, inexpensive construction processes are needed to significantly increase the strength of concrete and masonry structures. The scope of the required technology includes modular, lightweight panel systems; retrofit of wall, beam, ceiling, and floor structural elements; and modeling, analysis, testing of designs, and design methodology.

Wright Laboratory is evaluating expedient revetment systems at an explosives test range at Tyndall AFB. Initial trials have been performed on a commercially available system. The tests have included new configurations that would be suitable for aircraft revetments and explosive yields larger than those previously tested on this type of system.

6.4.5 Active Denial Technology

This program is a joint exploratory development effort between Armstrong Laboratory and Phillips Laboratory to develop nonlethal security and area denial applications. A fielded system would delay intrusion to allow threat assessment and validation, initiation of tactical response, and interdiction of the threat. An Active Denial system will give an AEF commander a nonlethal option for force protection with the option of immediate transition to lethal force if necessary. The current focus of the program is to provide proof-of-concept for ground-mobile, helicopter-, and C-130-based systems. The research emphasis is on understanding the biological effects of millimeter-wave exposures. The Ground-Mobile Demonstrator will be fielded in FY 03.

6.4.6 Tactical Automated Security System (TASS)

TASS is a rapidly deployable, easily transportable, and quickly relocatable integrated electronic security system that can be tailored for a wide variety of semipermanent, portable, and covert applications. TASS detects intrusions into protected areas, directs responding forces to the intruders, and assesses the strength and composition of the intruding force. TASS enhances the warfighter's capability for early detection and identification of threats to prevent damage or destruction of mission-critical assets and for collection of critical intelligence information. Typical TASS applications include security for Main Operating Bases, bare-base transitions, special operations, transient and dispersed assets, aircraft parking areas, buildings (exteriors and interiors), perimeter approach routes, border surveillance, and drug interdiction. TASS has been used in Field Training Exercises in Korea and is being tested at Eskan Village, Saudi Arabia.[179] Initial deliveries will begin in FY 98.

TASS consists of five principal elements: data communications, annunciators, sensors, assessment devices, and power. The data communications element consists of radiofrequency transmission networks for reporting alarm data to various annunciators. The annunciators are capable of receiving, processing, reporting, and graphically displaying system sensor alarms at various levels of command. This element includes desktop and laptop computers and hand-held monitors for application in a variety of tactical scenarios requiring a semipermanent or portable security system.

The sensors operate in diverse terrain and under demanding environmental and climatic conditions. The sensor element provides base-defense sensors with detection ranges of 3 to 100 feet per sensor and flightline sensors with detection ranges up to 300 feet per sensor. TASS can accommodate bistatic and monostatic microwave, passive and active infrared, seismic, magnetic, break-wire, and selected fence sensors. The assessment element relies primarily upon hand-held and remotely monitored wide-area thermal imagers. These thermal systems allow identification of man-sized targets at 1.5 km and vehicles at 3.0 km day or night. The tactical sensors will operate for a minimum of 1 week without a battery change. The flightline sensors will operate up to 72 hours without requiring a battery change or recharge.

6.4.7 Mine Detection

The focal point for mine detection technologies is the Stand-Off Minefield Detection System Branch, Directorate of Combat Developments, U.S. Army Engineer Center at Fort Leonard Wood, MO.

6.4.7.1 Hand-Held Stand-Off Mine Detection System (HSTAMIDS)

One of the most effective obstacles to mobility of ground forces is the land mine. For AEFs, land mines may hamper efforts to establish and maintain air bases in the area of operations.

The presence of mines in areas of high metal clutter and the proliferation of nonmetallic mines are very difficult problems for ground forces. The Army is developing HSTAMIDS to detect both metallic and nonmetallic mines. This system will replace the current hand-held mine detector (AN/PSS-12), which is unable to detect mines with low or no metallic content. HSTAMIDS will be particularly useful in locations and situations in which the Ground Stand-Off Minefield Detection System (GSTAMIDS) and Airborne Stand-Off Minefield Detection System (ASTAMIDS) cannot be used, such as along footpaths, in bad weather, in rough terrain, under overhead cover, and when noise discipline is in effect.

HSTAMIDS will detect mines by means of multiple sensors, including standard metal detection, ground-penetrating radar, and a forward-looking infrared sensor (which will be helmet-mounted). The operator will receive audible and visual notification of the presence of a mine. HSTAMIDS uses a microprocessor to run automatic target recognition algorithms that discriminate mines from clutter and track the locations of an unlimited number of mines. Developmental testing of HSTAMIDS will begin in June 1998.

6.4.7.2 Vehicular Mounted Mine Detector (VMMD)

The VMMD program is an Army ATD of the capability to detect mines across the full width of a vehicle by means of sensors mounted on the vehicle. The system will be mounted on a HMMWV, and it will detect mines in a 3-meter swath. The VMMD uses multiple sensors (infrared, ground-penetrating radar, and electromagnetic induction) and employs sensor fusion and automatic target recognition techniques for a high detection rate with a low false-alarm rate. The infrared package includes both 3- to 5-micron and 8- to 12-micron sensors and provides the stand-off detection capability. The ground-penetrating radar operates in the 1- to 3-GHz band, which is a trade-off between the low frequencies needed for ground penetration and the high frequencies needed for high spatial resolution of targets. The electromagnetic induction sensor detects standard metallic mines. The system has a fully integrated global positioning system capability, which enables the VMMD to accurately mark mine locations both physically and electronically. The ATD should be complete in FY 97.

6.4.7.3 Ground Stand-Off Minefield Detection System

The Army's GSTAMIDS program will field a mine detection system for ground vehicles in on- and off-road mounted operations. The system will detect metallic and nonmetallic antitank mines from stand-off distances by means of forward-looking sensors and sensors mounted on teleoperated platforms. GSTAMIDS can be used to verify minefield information derived from ASTAMIDS or other sources, and it will gather raw mine and minefield information in weather and vegetation conditions in which ASTAMIDS cannot be used. Data are collected, processed, and displayed to the crew in the GSTAMIDS-equipped vehicle or in the host vehicle of a teleoperated GSTAMIDS platform. When the sensor detects a possible mine, GSTAMIDS provides both visual and audible signals in time for the driver to stop or maneuver around the mine. The GSTAMIDS-equipped vehicle then will mark the mine and report its location. The system could be fielded as early as FY 03.

6.4.7.4 Airborne Stand-Off Minefield Detection System

ASTAMIDS is an Army ACTD of the capability to rapidly detect minefields in day, night, and limited-visibility operations. The system will detect metallic and nonmetallic, buried and surface mines. ASTAMIDS consists of an airborne sensor and a ground-based Minefield Detection Algorithm and Processor (MIDAP). The current prototype is mounted on a UH-60 Black Hawk helicopter, but the fielded system will be carried on an unmanned aerial vehicle.

The sensor assembly contains sealed optics, a scanning mechanism, and infrared detectors. The sensor interfaces with a radar altimeter, a global positioning system receiver, and a digital data recorder. In the prototype, data will be downloaded to the MIDAP on the ground, but in the fielded system the data will be transmitted to the MIDAP in real time. The MIDAP will identify and display mine locations on a digital map and on raw imagery displays.

6.4.8 Explosives Detection

In high-threat operations, AEFs will have to screen traffic and materiel entering the air base. Significant progress has been made in the detection of explosives. Automated X-ray systems routinely screen checked baggage in several international airports. However, a number of newer technologies are in development. Quadrupole resonance has undergone extensive laboratory testing and demonstrated acceptable detection rates of selected explosives with very low nuisance alarm rates. Other bulk detection systems that screen for car bombs use high-energy X-rays and neutrons.

Current trace-detection technology can simultaneously detect and identify less than one nanogram of explosives of interest (RDX, PETN, volatile explosives, marking agents, etc.). For trace detection to be successful, the explosive sample must be collected from a surface or from an air stream and separated from the background material. Some current systems use very fast (5 to 10 seconds) gas chromatography to separate the explosive molecules from other chemicals. Trace detection systems have been used in airports and to protect Federal installations. The same technology is being incorporated into walk-through portals for screening people, and these detectors can be mounted on vehicles for operation at vehicle check-points. Optical trace detection techniques are emerging with the sensitivity and specificity to detect explosives either in the vapor phase or on surfaces, but none of these systems is yet available commercially.

6.5 Responsible Parties

U.S. Air Force 342nd TRS, Detachment 1 (Pararescue School), Kirtland AFB, NM

U.S. Air Force 720th Special Tactics Group, Hurlburt AFB, FL

U.S. Air Force 820th Security Forces Group

U.S. Air Force Force Protection Battlelab

U.S. Air Force Research Laboratory

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U.S. Army Rangers

U.S. Army Special Forces

U.S. Navy Survival, Evasion, Resistance, and Escape School

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7.0 Lasers

Robert M. Cartledge and Valerie J. Gawron

7.1 Current Threats

Historically, concern about laser threats has focused on high-energy lasers designed to damage structures. Some programs, such as the Strategic Defense Initiative and Airborne Laser (ABL), are intended to defeat incoming intercontinental missiles and warheads. Other high-energy lasers could burn through canopies. However, the more likely near- and midterm threat to military operations and personnel is low-energy lasers, which are effective against vulnerable Air Force subsystems — sensors and eyes. Lasers that easily can be integrated into military systems and devices, such as rifles or binoculars, can jam night-vision systems or cause permanent loss of visual acuity at tactical ranges.

Tactical lasers are pervading the battlefield in applications such as precision-guided munitions, rangefinders, target designators, communication devices, and triage systems. As the 21st century approaches, Aerospace Expeditionary Forces are likely to encounter laser weapons in air defense, nonlethal, and antisensor applications. Human-portable and vehicle-mounted laser systems will be inexpensive to field, easily integrated with existing pointing and tracking technology, and difficult to detect. Laser effectiveness has already been demonstrated in operations other than war, when red-emitting lasers were used by U.S. soldiers to disperse crowds in Somalia. The devices were so effective that the Air Force has initiated the Saber 203 program to build laser systems for use by force protection personnel.

Unlike other threat technology in which the military dominates development and application, laser innovations are being spearheaded by the commercial sector. Lasers are commonly used for medical, industrial, scientific, entertainment, and consumer applications. The market size for laser sales in 1996 was $2.6 billion, with over 100 million lasers sold worldwide.[180] Lasers are being built that emit nearly any wavelength, and in the past decade the output powers from commercial systems have increased by more than 100 times. Lasers that several years ago were mounted on optical tables now are hand-held.[181]

Lasers affect operations by degrading sensors and eyes through jamming or damage. Glare from visible lasers can obscure HUDs and bloom forward-looking infrared (FLIR) radar. Injuries to personnel can include retinal burns, internal ocular bleeding, and cataracts. These injuries impair vision, reduce acuity, and degrade target detection and other critical combat vision tasks. Personnel and sensors are susceptible at energy levels of 10^{-6} joules per square centimeter (J/cm^2); external optics are susceptible at levels around 1 J/cm^2; structures can be damaged at 1,000 J/cm^2. However, only a few milliwatts can cause damage, and even supposedly safe levels can disrupt performance. In laboratory tests on 18 military personnel, "significant visual disruption was found following exposure to 'safe' levels of laser light, and this effect was increased during simulated dawn/dusk conditions."[182]

The U.S. military has formal requirements to counter laser threats. In the past 11 years, the Services have prepared seven separate Operational Requirements Documents (ORDs), Statements of Operational Need (SONs), and Mission Need Statements (MNSs): (1) Tactical Air Forces (TAF) SON 505-87, Aircrew Ocular Protection; (2) Strategic Air Command SON 017-87, Integrated Protection Aircraft Transparency; (3) Combat Air Force (CAF) Air Mobility Command (AMC) 319-93, MNS for Aircrew Life Support Systems; (4) CAF (TAF 505-87-A) I.A. for Aircrew Laser Eye Protection; (5) ORD for Improved FLIR Capability (December 1993) with modification requested by the U.S. Army Infantry Center (June 1994);

(6) U.S. Army Infantry Center ORD for Advanced Laser Protection System (October 1996); and (7) Naval Air Systems Command (N88) Draft JORD for Aircrew Laser Eye Protection (ALEP).

Although the Services have recognized the threats, key deficiencies in equipment and other counter-measures remain. These deficiencies increase the vulnerability of AEF personnel, who face increasing use of lasers in today's battlespace. The Air Force must address many issues to protect the force from the laser threat.

- No laser eye protection (LEP) is available for aircrews or special forces personnel.
- No airborne laser warning receivers exist.
- Aircrews do not receive routine laser safety or threat training.
- Operational units do not have access to laser mission planning or threat assessment systems.
- Aircrews do not use flight simulators that train them to react to temporary laser blindness.
- Medical diagnostic and treatment methods for care of laser eye casualties are inadequate.
- Current LEP is unsafe for flying because it reduces visibility of the symbology on aircraft HUDs, and it is not compatible with the colors used in crew stations.
- For ground-based laser threats, the Services have no system for calculating the effects of distance from the source on LEP effectiveness.
- No LEP is effective against the newest agile lasers.

The laser threat is clearly defined in a Human Systems Center report, "Treatment of Directed-Energy Casualties Strategic Plan."[183] Much of the description in this chapter is taken verbatim from that report.

7.1.1 Military Uses of Lasers

"Lasers are used as part of a variety of weapon systems by the military of all advanced and many developing nations. Lasers are used principally as target [designators] and range finders, but their potential for damaging or destroying material assets have been demonstrated. The effectiveness of a laser weapon against a particular target depends on many factors: its wavelength, power or energy, beam divergence, and range to the target, as well as atmospheric conditions. Laser weapons are generally divided into two categories: low energy and high energy."[184]

"Low-energy laser weapons, though typically used for targeting, can attack the sensors on military equipment and the eyes of personnel. All known fielded laser weapon systems are of the low energy variety."[185]

"DoD has established a policy of not deploying lasers for blinding. This policy does not preclude the possibility that blinding lasers will be used against U.S. Forces as antipersonnel weapons."[186]

"While one foreign weapon . . . has been demonstrated, the greatest existing hazard is from low energy lasers used for targeting and range finding; these devices typically operate in the visible and near-infrared region."[187]

"Targeting [near-infrared] lasers can also [injure] an enemy intentionally or as a secondary effect of painting a potential target with a sighting laser. While targeting lasers would produce small, but militarily important, numbers of casualties (pilot, tank crew, forward observers, etc.) as a result of their intended use, it is reasonable to believe that, if effectively used, their use as [blinding devices] could have a significant impact on the numbers of casualties."[188]

Laser hazards are particularly troublesome because so many lasers are used for ancillary military functions, and the likelihood for exposure is increasing.[189] The U.S. has over 50,000 lasers in the inventory, most used for target designation or for illumination with night-vision systems. However, many of these systems can cause injury at great distances. For example, the eye-safe distance for the Low-Altitude Navigation, Targeting, and Infrared for Night (LANTIRN) system is about 15 nautical miles. Aircrews performing two-ship lasing maneuvers for LANTIRN delivery of precision-guided munitions are at risk for injury if one aircraft crosses through the LANTIRN laser beam.

Because of the lack of ALEP, some systems, such as the Air Commander's Pointer (ACP), cannot be used. The ACP is a laser illuminator that enhances the effectiveness of night-vision goggles by serving as a "floodlight." This system can be used to covertly highlight targets at stand-off distances when flying with NVGs.

"Laser threat analyses are classified as are specifics of most weapons. However, advanced nations, and many developing nations, make use of laser targeting devices for guiding . . . munitions. Laser-related weapons are on sale world wide making them readily available to almost any potential enemy. An example of commercially available systems is a Chinese targeting laser system, the ZM-87 Laser Weapon, displayed at IDEX '95 (International Defense Exhibition) in Abu Dhabi, March 1995.[190] The Russians have offered to sell truck-mounted high-energy lasers,"[191] and a Russian cargo ship may have fired a laser beam at a Canadian CH-124 on 4 April 1997.[192] "To date, however, no high-energy laser weapon is known to be fielded."[193, 194]

"Much of the technology and technical information needed to build laser weapons is widely disseminated in unclassified documents. . . . Given the availability of such technical information and the availability of low-cost commercial lasers, laser based weapon systems can be constructed by any reasonably trained physicist."[195] Also, widespread reporting of laser incidents could educate terrorists about the potential use of lasers to disrupt aviation. Books have been published that can serve as terrorist handbooks for laser weaponry.[196] With this guidance, terrorists could point very small, invisible-light lasers, without risk of detection, at cockpits during terminal flight operations and cause accidents by injuring the aircrews (e.g., with immediate, permanent loss of visual acuity).

"An example of a non-weapon program with military potential has been identified in Australia."[197]

"A CO_2 laser system has been developed by scientists at the University of Tasmania in Hobart to conduct controlled burning of forest undergrowth. The system was designed to replace conventional techniques (torches, electronic igniters, or matches) which were dangerous and costly. The system allows debris from logging operations to be ignited at distances of from 100 meters to 1.5 kilometer."[198]

"The laser system consists of a 200-W CO_2 laser and its power supply supported by a gasoline-fueled power generator, water cooling system, and gasoline supply. The laser and focusing optics are mounted on a modified, fully adjustable gun mount for aiming the beam. The entire system is mounted on a 2-ton truck with a specially stabilized flat tray. Focusing is accomplished using beam expanding optics and a Cassegrain telescope. According to its inventor, Dr. Michael Waterworth, the device is a unique instrument which has never been built anywhere else in the world. It is extremely simple to operate and should sell for around $86,500 per unit."[199]

7.1.2 Threats From Nonmilitary Lasers

Laser light shows and other civilian sources are threats to military and civilian aviation. In addition to physical damage, laser light can have a variety of effects on aircraft operations. Glare can block visibility of runways or instruments, and a laser flash can cause momentary distraction that degrades flight performance, cockpit procedures, crew coordination, or communication with air traffic control. Near-infrared (NIR) laser light also will wash out NVGs.

In recognition of the laser threat, the Federal Aviation Administration issued "interim guidance (FAA Order 7400.2) to protect airspace near airports from laser light show flight hazards."[200] This order, which is based on the work of the Laser Safety Committee of the G-10 Aerospace Behavioral Engineering Committee of the Society of Automotive Engineers, limits laser light levels near airports.[201] Unfortunately, these guidelines govern only airspace near airports. They do not govern airspace overseas and do not account for the impact of laser jamming of NVGs or other military systems. In addition, civilian lasers can threaten aircraft well away from airports. For example, the yellow (589 nanometers) laser in the Apache Point Observatory near Albuquerque, NM, has an eye-safe distance of 217 nautical miles. The use of this laser could have jeopardized the flight safety of aircraft stationed at Holloman AFB, had not the observatory, the FAA, and the Air Force agreed to restrictions on its use.

The National Aeronautics and Space Administration's (NASA's) Aviation Safety Reporting System collects data on laser incidents. The following are just a few of the many documented in this database.[202]

- In November 1994, a 737 was outbound from Los Angeles when a green laser beam came through the side window of the cockpit. The beam struck both pilots, flash-blinding them for 5 to 10 seconds. The first officer had burns on the outer eye and some blood vessel breakage. However, the injury could not be attributed specifically to laser exposure, and the energy required to cause these effects is much greater than reasonably would be expected at the distances and conditions of the incident.
- In January 1995, one crew member of a 727 departing Cleveland, OH, received a bright blue-green light in one eye. His vision was impaired for the next 1.5 hours.
- In August 1996, the crew of a commercial airliner noticed a laser tracking the aircraft as it made its approach into Phoenix, AZ. One member was flash-blinded, saw spots for about 30 minutes after exposure, and lost night vision for 1.5 hours.

7.1.3 Effects of Lasers on Personnel

"Ultraviolet, visible and infrared energy weapons typically use lasers . . . [to] deposit energy into their targets. . . . This energy deposition results in an increase of the temperature of the target which produces the damaging effect. . . . If personnel absorb sufficient energy, injurious bioeffects will be produced. The type of effect and the injury produced will depend upon the energy absorption process, the amount of energy absorbed, and the affected organs."[203]

"The bioeffects (injuries, thresholds, etc.) for low energy lasers are relatively well known down to about 1 nanosecond pulse duration. Visible lasers can produce effects ranging from transient, reversible effects, such as glare, flash blindness, and after images, to retinal burns because of the lens's ability to focus, and thus concentrate, the incident energy on the retina. . . . In very severe burns, subretinal and retinal hemorrhages into the vitreous humor as well can be produced."[204]

"The beams from these devices [operating in the NIR] can penetrate the cornea and be focused by the lens on the retina where they can deposit sufficient energy to cause damage to the retina. . . . Retinal burns can range from small localized coagulation to large area disruption of the retina with hemorrhages."[205] "Retinal burns result in varying degrees of loss-of-sight depending on the location, severity, and size of the burn."[206] "Hemorrhages can be contained within the retina or can . . . [extravasate] into the vitreous. The contained hemorrhages appear to have more serious consequences because they can produce progressive detachment of the retina as a result of the toxic effect of blood on neural tissue."[207]

"If exposed to pulsed lasers or if the eye moves during exposure, multiple injuries may be produced."[208] "They may take the form of 'smearing' burns in the case of continuous wave lasers or multiple discrete burns if exposure is to a pulsed laser. Pulsed lasers, if of high intensity, produce a mechanical injury component due to the production of an acoustic shock wave as the energy is absorbed."[209]

"Ultraviolet and far infrared lasers pose little danger to the retina because their energy is absorbed by the cornea and is not focused on the retina. These lasers, however, can produce corneal and skin burns if of sufficiently high intensity."[210]

"Detailed descriptions of these bioeffects are available from a number of sources.[211, 212, 213] The knowledge of the bioeffects of lasers are due in part to the occupational health hazards and the attendant safety standards for laser use. In particular, the American National Standards Institute (ANSI) Standard for Maximum Permissible Energy provides thresholds for laser injury. Case studies of accidental injuries have also been compiled by USAMRD [U.S. Army Medical Research Detachment]. This laser injury database is now a paper based system but a searchable computer based system is being developed. Laser retinal injuries are principally due to thermal insult and have been the most common accidental injuries. Most military injuries to date have been due to range finders such as the ANGVS-5 hand held range finder."[214]

7.2 Current Countermeasures

Current countermeasures include protective equipment, preventive and protective actions, casualty treatment, training, and laser effects modeling and simulation.

7.2.1 Protective Equipment

While suitable and affordable protection technologies have been available since the early 1990s, the Air Force has not budgeted (in a Program Objective Memorandum) for ALEP. In addition, the Air Force has never had ALEP approved for night operations. The laser visor (called the Barnes visor) used during Operation Desert Storm was approved for day operations only, but it is no longer available from the manufacturer. The visors have not been replaced, despite increased use of lasers and development of new tactics that place personnel at risk for eye injury. The Air Force procures ALEP very infrequently, and usually only in crises. This acquisition approach has led some companies to eliminate their production capabilities. In addition, none of the NVGs in the Air Force are hardened against laser jamming or damage. LEP for ground personnel is available from the Army and Marine Corps, but some of the LEP is for day use only. However, this LEP is not suitable for aircrews since the visual decrements caused by the protection are too severe for use in cockpits, and it is not compatible with the colors used in cockpit displays.

ALEP is designed to prevent eye injury from lasers, and constant protection against invisible laser wavelengths probably will be necessary because most laser devices and many first-generation laser weapons emit invisible wavelengths. Personnel will have no warning of a laser's presence until they receive eye injury. There are two primary mechanisms for laser protection: absorption and reflection. Absorption technologies, such as glass and organic dyes, absorb laser energy as it passes into the ALEP. Reflection technologies, including dielectric stacks, rugates, and holograms, interfere with the optical path and direct the light away from the user's eye. These technologies are used for advanced protection applications in which visibility through the eyewear is as important as the protection.

As an interim measure for protection against the most likely near-term visible threats and protection from hazards from laser light shows, the Air Force Research Laboratory (AFRL) is assessing the technical utility of an ALEP system used by the Royal Air Force (RAF). The RAF system, called Spectacle Laser Aircrew Protection, uses a hybrid of dyes and dielectric technologies to provide NIR and green-wavelength protection. A major issue is that the amount of protection in the visible waveband is so great that it might interfere with the visibility of the HUD and other instruments.

As more laser wavelengths are added to the threat mix, it will be impossible to protect against all wavelengths and still fly aircraft safely. Multiple approaches will be necessary to counter laser threats. Absorbing dyes, reflective filters (rugates and holograms), tristimulus filters (combinations of dyes and reflective coatings), and agile technologies (tunable filters and smart coatings) can provide protection.

Self-protection and invisible-threat protection for NIR wavelengths can be met today by absorptive-dye technology that is available immediately in visor and spectacle configurations. These configurations have had extensive flight assessment in all Air Force fighters. Unfortunately, absorptive dyes block some far-red and near-blue wavelengths, making them less than ideal for cockpits that have multipurpose color avionics displays, such as those in the F-15E. Still, dyes have been rated highly by aircrews flying in A-10s, F-16s, F-4s, and similar aircraft. Surprisingly, the dye-based visor (called the FV-6MR), which was transitioned by the Armstrong Laboratory in late FY 95, also provides sun protection and serves as a high-contrast blue-blocker. Some aircrews preferred the FV-6MR over the standard sun visor because the FV-6MR transmits slightly more light.

7.2.2 Preventive and Protective Actions

In addition to wearing LEP, personnel can take a number of actions to prevent eye exposures to laser light and to protect themselves in the vicinity of laser use. Some of the actions are best characterized as "last resorts" if protection or tactics cannot prevent exposure.

- Use laser-protective goggles or visors specifically designed for the threat wavelengths.
- Go "heads-down" in the cockpit. Take cover if on the ground.
- Avoid looking directly at light sources, if possible.
- Maneuver the aircraft to obstruct the laser beam's illumination of the cockpit.
- Use your hand to shield your eyes.
- Make use of billowing smoke, clouds, or fog, as they scatter laser energy.
- Use sunglasses or sun visors, if nothing else is available. They will reduce all incident light somewhat.
- Minimize the use of binoculars and sighting devices or other direct-view optical devices.
- Use hardened optical systems that block harmful laser light.
- Cover skin with clothing to prevent skin burns.
- Use countermeasures, as taught or directed.[215]

7.2.3 Treatment of Laser Weapon Casualties

The Human Systems Center report "Treatment of Directed-Energy Casualties Strategic Plan" and the Air Force School of Aerospace Medicine report "Medical Management of Combat Laser Eye Injuries" are thorough treatments of this topic. Sections of "Treatment of Directed-Energy Casualties Strategic Plan" are repeated here verbatim.

7.2.3.1 Treatment Doctrine

"Although there are still differing opinions on specific aspects of treating laser injuries, treatment is reasonably well defined for retinal injuries and superficial burns. Both the USAF[216] and USA [U.S. Army] have developed informal doctrines for triage, diagnosis, and treatment of laser injuries in the field. . . . While differing in specifics, both documents provide essentially the same scenario for handling laser casualties. The Army has also developed a visual acuity testing card for use by medics."[217]

"The objective of triage is to determine if blood is present in the eye. If a laser injury is suspected in the field, the casualty is evacuated as soon after injury as possible to optimize treatment. If blood is not present and loss of sight is minimal, the casualty may be held in theater for recovery or returned to duty. If blood is present, the casualty is evacuated to a fourth or fifth echelon facility and placed under the care of an ophthalmologist."[218]

"The specific care and treatment is left to the judgment of the ophthalmologist. Corneal burns are treated in a similar fashion as burns of other etiologies through the use of antibiotic coverage and eye dressings. Retinal burns without hemorrhaging are generally treated with rest."[219] Ocular and oral corticosteroids have not been proven effective for the treatment of retinal burns or hemorrhages. In addition, the use of eye patches for retinal damage is discouraged because patching deprives patients of residual vision (which may be quite good), magnifies their visual impairment, and increases their dependence on others. Personnel with vitreal hemorrhages should remain at bed rest with their heads positioned so that the blood settles away from the visual axis, particularly for the first few days. "Removal of blood from the vitreous and, especially, subretinal hemorrhages is necessary because of the toxicity of iron on nervous tissue. Surgical intervention is performed only after evacuation to a hospital with specially trained ophthalmologists and surgical facilities."[220]

7.2.3.2 Materiel

"The equipment required for triage, [routine] diagnosis, and initial treatment in the field are no different than those available for treating eye injuries and burns from other causes. The equipment required consists of ophthalmoscopes and eye charts. The same is true of medications, dressings, etc."[221]

7.2.3.3 Evacuation

"Casualties with non-hemorrhaging retinal burns, according to the existing doctrines, will be assigned a low priority for [evacuation], if not allowed to recover in the theater for possible return to duty. The successful treatment of casualties with retinal [hemorrhages] will require rapid evacuation to a facility with adequate ophthalmological resources. Retinal burns, with or without hemorrhaging, are sterile injuries if the globe of the eye is not penetrated. If no other injuries exist, the casualties are normally ambulatory and can be evacuated as such. In those cases where the eye is patched or the casualty is totally blinded, an escort or wheelchair attendant may be required for transportation to and loading/unloading operations of evacuation aircraft. Again, if the globe is not penetrated, there is no hazard associated with transport in the reduced cabin pressure of air evacuation aircraft."[222]

7.2.3.4 Facilities

"Definitive [and advanced] diagnosis of laser eye injuries requires specialized equipment and facilities. In particular, fluorosein [*sic*] angiography, and digital ophthalmalscopic equipment are needed for diagnosis. These facilities, in addition to requiring skilled ophthalmologists, are not amenable to either standard or augmented ATC [Air-Transportable Clinic] or ATH configurations. Aspiration of retinal hemorrhages, and especially subretinal hemorrhages, require complete surgical facilities which will only be available in CONUS."[223]

7.2.3.5 Training

"The most important need is training for medical personnel responsible for the diagnosis and treatment of laser induced injuries in the field [and for management of advanced injuries requiring] air evacuation. The USAF does not have any identifiable training program on this subject for critical care physicians, general medical officers, or flight surgeons. The Army has a ½ day session in [its] Flight Surgeon training program which could be adapted for, or used by, the other services."[224]

7.2.3.6 Protection of Medical Facilities and Personnel

"The threats will be principally from targeting lasers. While such attacks are apt to be unlikely, the only protective gear needed will be laser protective goggles appropriate to the laser threat. USAF facilities and equipment will not be susceptible to low level lasers. High power far infrared lasers could inflict damage to facilities and personnel. It is not expected that these line-of-sight weapon will be widely deployed or be effective against rear echelon facilities. However, should they be deployed, there is not protection currently available."[225]

7.2.3.7 Research and Development

"Research of laser bioeffects, injury mechanisms, and injury thresholds is ongoing and will continue as new laser weapons are developed. At present, the mechanisms of injury by high energy pulse widths of less than 1 nanosecond are particularly uncertain due to the nonlinear optical properties of the eye which alter pulse shape and energy deposition. The understanding of the relationships of photochemical, photothermal, and mechanical effects on the resulting injury are also incomplete."[226]

"The Army is leading research and development for laser injury treatment and prevention. A treatment doctrine for higher levels of care is in development but nothing is yet available. Pharmacological research is aimed at mediating injury by reducing the progression of the injury, particularly infiltration of neutrophils. The objective of treatment is to reduce the severity and progression of secondary injury; retinal tissue which has been injured is not recoverable. The Army researchers have found that hydroxyethyl starch deferoximine (HES-DFO) has benefit in reducing the severity of permanent injuries by inhibiting neutrophil infiltration of the injury site. Treatment needs to begin within 1-6 hours of injury; if start of treatment is delayed by 20-24 hours, it has little effect."[227]

7.2.4 Aircrew Training

Few aircrews have been exposed to lasers, so most aircrew members have no experience dealing with the effects, either temporary or permanent. Armstrong Laboratory has developed an advanced technology demonstrator, called the Laser Aircrew Safety and Education Demonstrator (LASED), that exposes aircrew members to eye-safe levels of laser glare. The demonstrator is a self-contained unit that demonstrates the hazards of encountering laser fire during a flight mission. The system incorporates a flight simulator with a continuous-wave, diode-pumped laser, which produces actual laser flashes. The premise of the system is that aircrew will understand the personnel effects of lasers better when they have experienced them. LASED provides controlled bursts of laser light at a fraction of the maximum permissible exposure levels, as defined by ANSI. Even at these low levels, enough flash-blindness is produced to momentarily disrupt pilot tasks. Aircrew members can try different types of eye protection to compare their effectiveness. LASED has three different flight scenarios, and it can be programmed for more. For fighter pilots, there is an attack-run scenario in which a single missile is available to engage a ground target. For aircrews on heavy aircraft, there are day and night landing scenarios.

7.2.5 Laser Effects Modeling and Simulation

The Air Force Information Warfare Center (AFIWC) has identified a requirement (Air Intelligence Agency Technology Need for Command and Control Warfare Analysis, Modeling, and Simulation) to provide commanders with the capability to assess, train for, and counter directed-energy weapon threats. To meet that need, the AFRL has initiated an advanced engineering development program called the Laser Threat Analysis System (LTAS), a modeling and simulation software program that calculates personnel effects from ground-based laser threats. The program uses DoD and industry models for laser propagation, atmospheric attenuation, eye hazards, eye damage, flash-blindness, visual impairment, etc. In its databases, LTAS holds relevant information to assess protection requirements against flash-blindness and eye damage impacts. Users access all models through an intuitive user interface, and the system displays the distances for the effects as threat rings on two-dimensional terrain maps.

The first version was delivered to AFIWC in September 1996. Subsequent releases will include vulnerability assessment of sensors and structures to laser threats and the capability to determine whether U.S. use of lasers in specific situations is in compliance with SECDEF policy. While LTAS can operate as a stand-alone system, the strategic goal is to include LTAS in the Air Force Mission Support System and in the Joint Mission Planning System in conjunction with the Navy.

7.3 Future Threats

"High-energy laser weapon development programs have been reported in several countries. High-energy laser weapons can attack the same range of targets [as low-energy lasers] as well as structurally damage the target. . . . High energy lasers are typically in the mid- to far-infrared range and operate either in CW [continuous wave] or pulsed modes. The high energy lasers purpose is to destroy material assets (missiles, tanks, buildings, etc.). The CW lasers bathe objects with high continuous energy causing them to catch on fire or melt. Humans can be injured by direct exposure or by exposure to burning targets. These exposures result in skin burns and corneal surface burns because the energy is in the far infrared spectrum."[228]

"Pulsed high energy lasers not only produce thermal heating but also produce mechanical effects by ionizing air at the surface of the object. The ionization results in the production of a plasma and an associated sonic shock wave. The combination of heat and shock wave serve to 'drill' a hole in the object; the object can also be ignited. In addition to burns, the shock waves can produce sonic booms on the order of 140-145 dB which can produce auditory pain; the shock waves are short enough that they may not produce permanent hearing loss."[229]

Many advanced technologies are in development, so AEFs must be prepared to counter laser weapons in air defense, non-lethal, and antisensor applications. These systems will be small (human portable and vehicle mounted), inexpensive to field, and difficult to detect. Especially with systems using non-visible wavelengths, AEF personnel may have no warning of their use.

7.4 Future Countermeasures

Future countermeasures are limited to eye protection, sensors, and casualty care.

7.4.1 Aircrew Laser Eye Protection

Narrow-band goggles and visor filters that block laser energy at specific wavelengths are the best form of protection. The ideal protector would filter only the laser wavelengths and allow others to pass. Current ALEP technologies have several limitations. First, use of ALEP may result in perceived alteration of colors being viewed (e.g., of aircraft lights, runway lights, and targets), which could jeopardize flight safety or combat effectiveness. Second, advanced ALEP technologies reflect light and they have distinctive optical signatures, so they should be used only under special circumstances. Finally, the level of protection depends on the angle of incidence of the beam to the ALEP device.

The mechanisms of ALEP are absorption (organic dyes, glass), reflection (dielectric stacks, rugates, holograms), and switching techniques. The AFRL is working to develop and transition multiple ALEP technologies by FY 00 that overcome the current technology limitations. The Air Force is the only Service investing in science and technology for ALEP suitable for the near- and midterm.

ALEP developmental programs are divided into out-of-band (invisible) and in-band (visible) categories. The technologies will provide protection against visible threats and improve user acceptance of NIR ALEP. The challenge is to determine which technology provides the best overall value in terms of protection, safety-of-flight, lighting compatibility, cost, manufacturability, aeromedical vision standards, and threat adaptability. Currently, the ALEP program efforts are focused on (1) demonstrating that systems will integrate with advanced cockpits (including helmet-mounted displays and panoramic night-vision systems) without jeopardizing flight safety or combat effectiveness, (2) developing advanced self-protection technologies for the F-15E and F-117, and (3) developing protection for green-wavelength threats to all Air Force aircraft.

To overcome human-factor limitations of dye-based ALEP for NIR protection, dielectric stack technology (DST), manufactured by Pilkington UK, is undergoing Air Force ground and flight demonstrations in the F-15E and F-117. DSTs are reflective technologies that can be designed to block NIR wavelengths without the secondary blockage of blue or red that impairs the effectiveness of absorptive dyes. However, DST ALEP will be more expensive than dye-based ALEP. The AFRL DST effort will reduce problems associated with haze, glare, and optical augmentation.

The major emphasis for current AFRL ALEP technology programs is to develop and transition ALEP for visible threats. Several technologies (glass, organic dyes, holograms, and rugates) protect against visible lasers. During the advanced development effort, the AFRL will test candidate protection concepts to evaluate pertinent parameters and validate analytical models. These parameters will include laser rejection at threat wavelengths (measured in optical density), spectral transmission, luminous transmission, device switching and recovery times, and bandpass transmission, as well as other optical, environmental, and psychophysical considerations (e.g., visual acuity, color discrimination, and depth perception). Performance measures also will be derived from aircraft, life support equipment, and mission integration trials to determine visibility of critical aircraft lighting, avionics, instrumentation, and compatibility with other personnel protective equipment and aircraft equipment items. Finally, ground and flight assessments will be conducted before the technologies transition to engineering and manufacturing development in FY 00.

Coatings are being developed that protect NVGs from laser damage or jamming by near-term laser threats. These technologies are undergoing advanced engineering development at Wright Laboratory and will be available for transition to engineering and manufacturing development in FY 00. In the mid-term, new coatings will be demonstrated that protect against the ABL wavelengths. This protection will be designed for exposures in cases when the ABL beam reflects off targets or clouds.

The Navy is contributing to the development process with scale-up demonstrations of advanced technologies. Holographic film is being applied to spectacles and visors. While the Navy addresses challenges related to moving from the science and technology phase to manufacturing, the Air Force is reducing the human factors and materials risks with its parallel holographic film program in advanced development.

The emphasis within Air Force science and technology development for advanced materials and materials processing has shifted from holographic film to rugate technology. Rugates are reflective coatings deposited on substrates. Unlike other deposition processes, the rugate process is under computer and software control. The power of rugate technology lies in its software flexibility. A rugate can be designed in software to protect against specific threats and then downloaded to the deposition chambers, which in turn apply the coatings. Changes in threats can be handled by changes to software, unlike holographic film, which would require development of new reflective films. Rugates will enable the Air Force to respond to different threats more quickly.

7.4.2 Compact Laser Sensor System

Wright Laboratory, in a joint DoD, Department of Energy, and Environmental Protection Agency laser-sensor research program, developed a miniature stationary Fourier-transform spectrometer to detect threats associated with laser-guided weapons. This sensor — a patented Air Force invention — is designed to operate in a wide range of hostile environments and determine the wavelength, coherence, and arrival direction of laser threats. The device provides 1- to 2-nanometer resolution with high optical throughput. The system is made of low-cost, off-the-shelf components that are permanently encased in a solid block of glass.

7.4.3 Far-Term Technologies

A number of fundamental technologies have promise for future laser countermeasures. Some of the applications that are forthcoming or simply are needed are a laser-protection visor, protective filters for NVGs, spectacles with laser-rejection coatings for additional hazards, and retrofit laser protection for existing sensors.

Each technology has different risks. For example, dyes and holograms have limited threat flexibility, while rugates have the best potential for threat flexibility. Holograms and rugates have limited field-of-view protection and have distinctive optical signatures. No single technology is best in all circumstances, and the choice of technology depends on operational requirements (e.g., human factors, covert operations, cost, and mission).

Protection for far-term laser threats, such as laser systems that generate different wavelengths with each pulse, is more than 10 years away from demonstration. Some technologies being considered for the far-term threats are nanostructures, smart materials, micro-electromechanical systems, molecular modeling, and virtual materials processing.

7.4.4 Treatment of Laser Casualties

The Air Force lacks a Concept of Operations for treating laser casualties. In a CONOPS, the Air Force would need to take doctrine, training, materiel, and facilities into account. The doctrine could "be based upon existing USAF technical reports and U.S. Army field manuals pertaining to the treatment of laser casualties. Many of these documents require revision and updating to incorporate the research and development of improved treatments that have occurred since their issuance."[230] The training element could be incorporated "for a relatively small investment . . . especially if incorporated in other training programs."[231] As for materiel and facilities, "it is expected that most, if not all of the materials and instruments needed will be in existing deployed pallets of equipment and supplies."[232] However, a review of materiel and facilities would be appropriate to ensure their sufficiency.

7.5 Responsible Parties

U.S. Air Force Air Combat Command

U.S. Air Force Materiel Command

U.S. Air Force Research Laboratory

U.S. Air Force Special Operations Command

U.S. Naval Medical Research Institute

U.S. Special Operations Command

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8.0 Ionizing Radiation

David Cohen

8.1 Current Threat

Since the end of the Cold War, the strategy for deployment of forces such as AEFs has recognized that the possibility of a nuclear confrontation is remote, at least in the near term.[233] Unfortunately, marginalizing the threat of nuclear weapons does not eliminate the threat of virulent radiation. The ease with which radioactive materials can be acquired and delivered and the proximity of vulnerable or uncontrolled sources of radiation could pose a significant threat to AEF operations and the long-term health of the Air Force population, especially because the Air Force has not recognized this threat. The Air Force is not unique in this regard — only recently have the other Services, led by the Army, realized the dimensions of this threat and initiated programs to establish the appropriate doctrine and research and development requirements.

Following the Gulf War, the Iraqis disclosed that in the late 1980s they had irradiated zirconium oxide in their research reactors and packed it into iron bombs, easily producing radiological dispersion weapons (RDWs). The RDWs worked as planned: during test trials they contaminated a wide area with "low-level" radiation (LLR). For reasons that were never disclosed, these RDWs were never used against their intended targets, the Iranians, possibly because the Iranians (or, more precisely, their fanatical leaders) were immune to the fear that these weapons were intended to generate.[234] However, the existence of these weapons was a clear indication of the viability of the radiation threat. This chapter includes a description of the biological effects of LLR, confirmation of the reality of the threat, and a discussion of countermeasures, with emphasis on the need for appropriate operational planning and policies.

8.1.1 The Nature of Radiation and Its Biological Effects

Biological effects of radiation depend upon the type of radiation, the amount of energy absorbed into the tissue, the rate of irradiation, and what part of the body is exposed. These effects are either somatic, genetic, or teratogenic. Somatic effects are those that occur in the exposed individual, genetic effects are those that are observed in the exposed individual's descendants, and teratogenic effects are those that cause fetal malformations.[235] This section is a discussion of the physical properties of radiation and how those properties might challenge AEFs. The discussion relies on an understanding of how radiation and its biological effects are measured, so the reader should review the glossary (Section 15.0) before proceeding.

Radiation is simply energy in transit as either particles or waves. The fundamental characteristic of radiation that concerns the AEF is whether the radiation possesses sufficient energy to eject electrons from their orbits in atoms. The amount of work the radiation can do is a measure of its energy, usually quantified in electron volts (eV).

Certain elements (called radionuclides) are unstable because of excess energy. Atoms of these elements gain stability by emitting subatomic particles (alpha and beta particles) and high-energy photons (gamma rays) in the process of radioactive decay. Depending on how the nucleus loses this excess energy, either a lower-energy form of the same material or a completely different nucleus and atom will result. The emissions are collectively called "ionizing radiation" because, when they interact with other atoms, they remove electrons and produce ion pairs in a process called ionization. An ion pair is a positively charged atom and a negatively charged electron (Figure I-48). Ionization requires very large amounts of energy. More than 10 eV are required to ionize a molecule in biological tissue. High-energy electromagnetic radiation, such as X-rays and gamma rays, contains this amount of energy. This is why ionizing radiation is hazardous to health and a threat to the AEF.

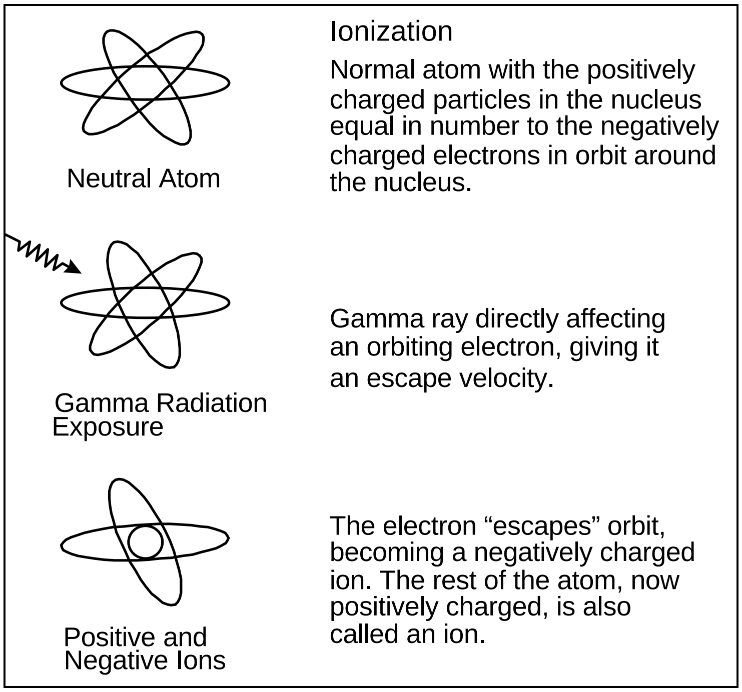

Figure I-48. *Ionization of an Atom by Exposure to Gamma Radiation*[236]

Conversely, nonionizing radiation, which includes radiofrequency radiation (RFR) and ultraviolet, visible, and infrared light, does not possess the energy for ionization. RFR, for example, contains about 10^{-5} to 10^{-6} eV, far less than is required to ionize molecules. However, the energy nonionizing radiation imparts to an electron may be enough to raise it to a higher orbital. This effect can break chemical bonds (an effect of ultraviolet radiation) or produce heating (an effect of visible light and microwaves).

8.1.2 Ionizing Radiation

The action of ionizing radiation may be either direct or indirect. The emitted particles or photons may interact directly with an atom or molecule in a cell by electrostatic attraction or repulsion. Usually, the damage is irreparable: the cell either dies or malfunctions. The radiation also can damage a cell indirectly by interacting with water molecules, the most abundant molecules in humans (55 percent of the mass). Ionizing radiation interacts with water molecules to form ionized pairs, which consist of a free electron (e^-) and an ionized water molecule (H_2O^+), in a process termed radiolysis. These ion pairs rapidly interact with themselves and other nearby molecules to produce free radicals (molecules with unpaired electrons in the outer electron shells). The molecular damage causes biochemical damage that may be amplified and expressed as biological injury in one of three basic processes: DNA damage (which may become expressed), stimulation and release of biological mediators, and alteration of nutritional vascular support. At the molecular level, the initial injury occurs in 10^{-17} to 10^{-5} seconds, but it may require anywhere from seconds to years for expression.[237] The expression time for some cancers is so slow that they may not be observed during the individual’s lifetime. Figure I-49 illustrates the cascade of toxic effects proceeding from exposure to ionizing radiation: ionization and excitation, molecular injury, biochemical damage, and amplification and expression of injury.

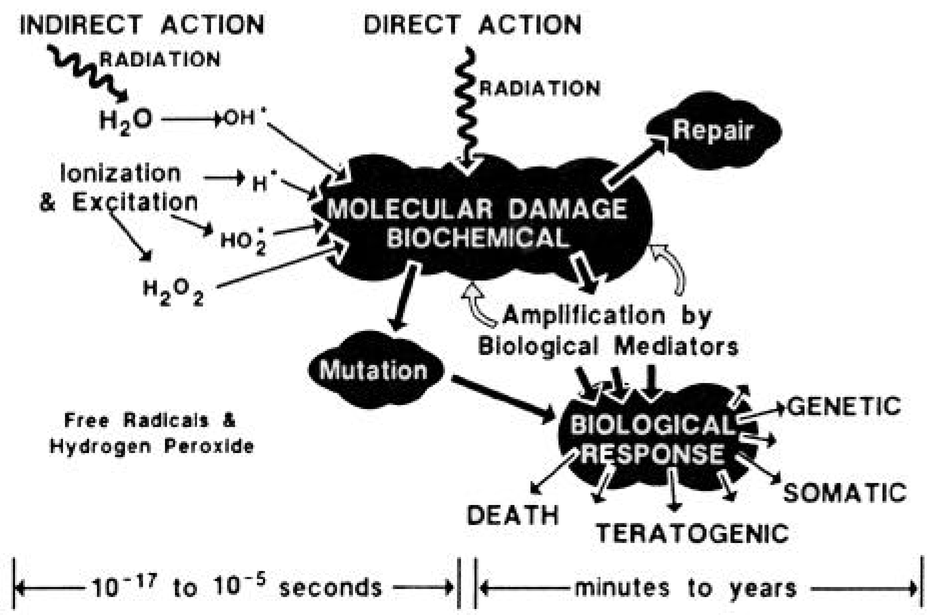

Figure I-49. *Cascade of Biological Effects From Direct and Indirect Actions of Ionizing Radiation*[238]

Although radioactive decay produces different types of emissions that have equal initial energy, these types are distinctive in the manner in which they transfer energy to matter. These differences are meaningful in terms of biological damage and protective measures. The emissions can be quantified according to their relative biological effectiveness (RBE), which is the ratio of the absorbed dose required to produce a given biological effect divided by the absorbed dose of a standard radiation (such as gamma rays) to produce the same effect (Table I-39). The magnitude of the RBE is related to how the energy of the radiation is distributed along its path through tissue. Ionizing radiation interacts with matter along straight tracks, but the rate at which the energy is deposited along the path — the linear energy transfer (LET) — varies by radiation type. Therefore, although the energy may be the same, high-LET radiation, such as alpha particles, produces many more ionizations for a given penetration distance than low-LET radiation, such as gamma rays. This means that a high-LET radiation concentrates energy deposition (i.e., is more destructive to cellular structures like DNA), but it is exhausted much faster and does not have the penetrating power of a low-LET radiation.

Table I-39. *Relative Biological Effectiveness (RBE)*[239]

Radiation	*RBE*
Gamma rays	1
Beta particles	1
Alpha particles (into the body)	10-20

The five types of ionizing emissions are alpha particles, beta particles, gamma rays, X-rays, and neutrons. Gamma and X-ray photons are essentially identical, differing only in their point of origin. Gamma photons originate in the nuclei of decaying atoms, while X-rays originate in the electron shells of heavy metals, such as tungsten or copper. Unlike alpha and beta particles, neutrons carry no electric charge. As a result, neutrons do not interact with the orbital electrons of atoms. Instead, they interact directly with the nuclei of atoms, particularly those of low atomic mass. As will be seen during the discussion of the threat sources, neutrons and X-rays are not an appreciable threat in the AEF environment (they usually are associated with nuclear detonations). Therefore, this discussion will cover only alpha, beta, and gamma radiation. An understanding of the origin and action of these types is crucial to a discussion of operational impacts and countermeasures. Table I-40 is a summary of the characteristics of these emissions.

Table I-40. *Characteristics of Ionizing Radiation Types*[240]

Name and Symbol	*Physical Description*	*Source*	*Speed*	*Range in Air*	*Range in Tissue*	*Shielding Required*	*Biological Hazard*
α **Alpha particle**	Helium nucleus ⊕● ●⊖	Decay of uranium and plutonium	From 0.014 to 0.1 the speed of light	5 cm	Cannot penetrate the epidermis	None	None unless ingested or inhaled in sufficient quantities
β **Beta Particle**	High-speed electron ⊖	Decay of fission products and nuclear-induced elements	Varies	5 meters	Several layers of skin	A few cm of aluminum or moderate clothing	Superficial skin injury or local injury if ingested or inhaled
γ **Gamma Ray**	Electro-magnetic energy	Decay of fission products and nuclear-induced elements	The speed of light	Up to 500 meters, depending on energy	Very penetrating but energy dependent	Dense material such as concrete, steel plate, or earth	Whole body injury, many casualties possible

8.1.2.1 Alpha Particles

Radioactive heavy elements, such as uranium, thorium, and radium, decay by ejecting alpha particles, each of which is composed of two neutrons and two protons (a helium nucleus). The emission of alpha particles is possible because the nuclei of these atoms have many more neutrons than protons. After an atom ejects an alpha particle, a new parent atom is formed that has two fewer neutrons and protons. For example, when uranium-238 (which has an atomic weight, Z, of 92) decays by alpha emission, thorium-234 is created (Z of 90). Because an alpha particle has two protons, it has a positive charge of two. The corresponding high LET of the alpha particle means it easily interacts with other material and quickly ionizes itself out of existence. Typical alpha particles will travel no more than a few centimeters in air and are fully absorbed in the superficial layers of dead cells within the stratum corneum. However, if alpha-emitting material is internally deposited through ingestion, inhalation, or a wound, all the energy will be absorbed in a small volume of tissue (usually fewer than 420 micrometers in diameter) in the immediate vicinity of each emitted particle.[241] Such a concentrated delivery makes it more difficult to repair the damage.[242] However, unless those few cells are critical, the short-term hazard is small.

8.1.2.2 Beta Particles

Beta decay is a process in which a radioactive atom achieves stability by ejecting an electron from its nucleus along with a massless particle called an antineutrino, which carries away some energy. Because the electron is from the nucleus of the atom, it is called a beta particle to distinguish it from the electrons that orbit the atom. The ejection of a beta particle transforms one of the neutrons in the nucleus into a proton. Since the number of protons in the nucleus has changed, a decay product is formed, which has one less neutron but one more proton than the parent. For example, when an atom of rhenium-187 (Z of 75) emits a beta particle, osmium-187 is created (Z of 76). Like alpha decay, beta decay occurs in materials that have a lot of neutrons, such as tritium, carbon-14, and strontium-90. Generally, atoms that emit beta particles are located below the line of stable elements on the chart of nuclides and typically are produced in nuclear reactors.[243]

A beta particle has a single negative charge, and its weight is only a small fraction of that of a neutron or proton. As a result, beta particles have a lower LET than alpha particles. Therefore, in air, beta particles can travel several meters before ionizing; in human tissue, a few millimeters.[244] If large quantities of beta particles strike the surface of the skin over an extended period, they can produce a lesion in the basal stratum similar to a superficial thermal burn (called a "beta burn"). Internally, however, beta radiation can produce significant damage in spheres of tissue around each radioactive fragment. The lower LET means cells may be damaged rather than killed. Ironically, dead cells usually are replaced quickly without significant clinical effects (unless the destruction is extensive), whereas damaged cells often malfunction or become malignant.

8.1.2.3 Gamma Rays

A nucleus usually has excess energy after it emits an alpha or beta particle. Frequently, the nucleus loses this energy by discharging a pulse of electromagnetic radiation called a gamma ray. Like all electromagnetic radiation, which includes visible light and microwaves, gamma rays have no mass and no charge. Unlike other types, though, they do have enough energy to ionize atoms. Gamma rays interact with material by colliding with the electrons in the shells of atoms. Gamma radiation has low LET: about 75 percent of the photons will interact with and lose energy to the atoms of the target tissue. This energy deposition can occur anywhere along a given photon's path, so gamma radiation produces a whole body exposure regardless of whether the source is internal or external. Depending on their initial energies (which can vary greatly), gamma rays can travel from one to hundreds of meters in air, penetrating people as they go. Because the emission of a gamma ray is a consequence of an unstable energy state after a particle emission, there is no such thing as a "pure" gamma emitter. Important gamma emitters include cobalt-60 and cesium-137.

8.1.3 Low-Level Radiation

With a fundamental understanding of ionizing radiation, the next step is to define the sizes of the exposures that will confront AEFs. Since the Manhattan Project, the military and the nuclear industry have been preoccupied with the hazards of high doses of ionizing radiation (in the hundreds of centigrays [cGy] or more). Clearly, such levels are improbable in the current environment and are outside the scope of this report.

Currently, the best guidance for gauging the threat is Allied Command Europe (ACE) Directive 80-63, *ACE Policy for Defensive Measures Against Low-Level Radiological Hazards During Military Operations*.[245] Intended for operations in Bosnia, the directive divides radiation exposure into two broad categories, operationally significant-level radiation (OSLR) and LLR. OSLR doses are comparable to those produced by a nuclear detonation and are in the range of 70 cGy (whole body cumulative dose) and above. LLR doses may be higher than those routinely received by the general public and are in a range from background radiation to 70 cGy. The primary operational difference between the two categories is the onset rate of health problems. Whereas OSLR exposures can produce immediate debilitation or death by acute radiation syndrome (ARS), LLR exposures generally are asymptomatic in the short term; the concern is with long-term health consequences, such as cancer or mutagenesis (radiation-induced genetic changes).

This range for LLR (to 70 cGy) is considerably higher than what the Air Force currently considers LLR. The Air Force primarily is concerned with occupational exposures in the range of 5 millisieverts (mSv) to 50 mSv annual total dose equivalent, which is 0.0714 of the 70-cGy LLR mission limit.[246] The 70-cGy limit is more appropriate for the anticipated threats to the AEF and provides a convenient boundary for a discussion of the effects of LLR on AEF operations.

The overwhelming majority of radiobiological research has focused on high, relatively short-term (days to months) doses, with the supposition that LLR effects do not have immediate military relevance. The only effort related to LLR has been the management of exposures to make future cancer risk "as low as reasonably achievable"[247] without sacrificing mission objectives. Unfortunately, there are no research data to support the notion that LLR will *not* produce human performance degradation. In fact, there are some obvious impacts that must be addressed. Given the rapid deployment, high operational tempo, and lean manning of the AEF, the commander must know how LLR will affect such varied performance aspects as fatigue, decisionmaking, tracking, circadian rhythm adjustment, susceptibility to motion sickness, and *g*-tolerance. The commander also must consider the probabilities that AEF members will develop cancer. This section addresses the evidence for LLR health and performance issues.

8.1.4 Acute Radiation Syndrome

Acute radiation syndrome is a set of symptoms resulting from injuries to the bone marrow, gastrointestinal system, cardiovascular system, central nervous system, gonads, and skin by internal exposure to ionizing radiation. The onset latency and magnitude of ARS are determined primarily by the total radiation dose received, the rate of delivery of the radiation, and the distribution of radiation in the body.[248] Variations in the radiation sensitivity of affected tissues cause symptoms to occur in three successive phases: an initial phase of prodromal ("warning") symptoms (1 to 7 days), a latent period (7 to 21 days), and a manifest illness phase (from the 2nd or 3rd week to the 7th week). For AEF deployments of seven days[249] or less, only prodromal symptoms are operationally important.

8.1.4.1 Doses

Prodromal symptoms are deterministic, which means that severity is directly related to the size of the absorbed dose and that symptoms do not occur at all below a certain threshold. The military generally uses an acute dose of 100 cGy as that threshold.[250] In especially radiosensitive individuals, LLR can produce prodromal symptoms (Table I-41). These symptoms may partially or wholly incapacitate AEF members. Given the lean manning of the force structure and the specialized, critical skills of some personnel (e.g., pilots), a screening test for radiosensitivity could help prevent some casualties.

Table I-41. *Acute Doses of Gamma Radiation for 10 Percent and 50 Percent Incidence of Prodromal Symptoms in Humans*[251, 252]

Irradiation (External)	*Health Effect*	*Dose for 10 Percent Incidence (cGy)*	*Dose for 50 Percent Incidence (cGy)*
Whole body	Anorexia	40	150
	Nausea	55	210
	Fatigue	55	220
	Vomiting	70	280
	Epilation	75	300
	Diarrhea	90	350
	Hemorrhage	100	400
	Death	110	345
Reproductive organs	Sterility		
	Males (temporary)	5	20
	Males (permanent)	150	600
	Females (temporary)	75	300
	Females (permanent)	250	1,000

As Table I-42 shows, the initial prodromal phase, which is of primary consequence to the AEF, is characterized by a combination of gastrointestinal and neuromuscular symptoms. The origin of the prodromal phase is not known, but possible causal factors include endocrine imbalance and malfunctions of the central and autonomic nervous systems.[253] The latent period is relatively asymptomatic and is believed to be the time between initial cell damage and disruption of cell renewal in the affected organs.[254] Personnel who have serious prodromal symptoms may experience significant relief during the latent period and may be able to return to duty for several weeks.

8.1.4.2 Fatigue

Although very little research has been done, it is generally accepted that no prodromal effects will occur at dose rates fewer than 1 whole-body cumulative dose per hour (cGy/hr), regardless of the duration of the exposure. Nevertheless, cycle ergometry tests reveal susceptibility to fatigue below that exposure level, both for continuous exposure at 0.8 cGy/hr over 5 days and for daily exposures of 6.5 cGy (administered in fractioned, 1-cGy/hr doses) that accumulate to 100 cGy midline in the tissue.[255] Susceptibility to fatigue obviously is important to the AEF. The tests simply demonstrated susceptibility to fatigue at low dose-rate exposures; quantitative measures of threshold doses, dose rates, and response-time dynamics are unknown. Nevertheless, this type of subtle effect certainly can impede surge operations and must be studied to determine the best way to conduct operations in an LLR environment.

8.1.5 Long-Term Effects on Health

Depending on the dose, kind of radiation, and observed endpoint, the biological effects of radiation can vary widely. Some effects occur rapidly, whereas others may take years to become evident. Considering the short duration of an AEF deployment, all those effects of ionizing radiation that become evident following the conclusion of an operation are included in this discussion of long-term effects. The time frame of AEF operations dictates a preoccupation with effects that occur in days. However, future AEF operations, as well as overall Air Force operations and legal liabilities, dictate that the AEF commander be concerned about effects that occur after an AEF operation. These effects include lung fibrosis, cataracts, cancer, and genetic defects in offspring.

Radioactive materials and their decay products trapped in lung tissue can cause an inflammatory response and eventual fibrosis within weeks of initial contamination. The degree of fibrotic scarring will depend on the amount and type of material deposited and the time of exposure. The overall reserve capacity of the lungs is so great that such scarring is rarely a serious problem. However, particles remaining in the alveoli will cause damage as long as they are trapped. The rate of removal of particles deposited in the air sacs is difficult to estimate, but animal studies indicate that it would take at least several years for significant amounts to be eliminated.[256] Carcinogenesis is the main hazard.

Cancer is a stochastic effect of ionizing radiation. Stochastic effects (as opposed to deterministic ones) do not have a dose threshold, but increase in probability as dose increases. The higher the absorbed dose, the more likely that the exposed subject will develop cancer. However, the size of the dose is unrelated to the severity of the cancer. In other words, there are no risk-free doses, only low probabilities of developing cancer. Irradiation increases the probability of cancer by damaging genes that control cell proliferation and migration. Essentially, cancer occurs when a single cell accumulates so many mutations in these genes that its proliferation no longer is restrained. The mutations allow the cell and its descendants to develop additional alterations and to amass in increasingly large numbers, forming a tumor that consists mostly of these abnormal cells.

The risk of getting cancer from radiation depends on many factors, such as the dose and how it is administered over time; the site and particular type of cancer; and the person's age, sex, and genetic background. The Biological Effects of Ionizing Radiation (BEIR) V report states "that if 100,000 persons of all ages received a whole-body dose of 0.1 Gy (10 cGy) of gamma radiation in a single brief exposure, about 800 extra cancer deaths would be expected to occur during their remaining lifetimes in addition to the nearly 20,000 cancer deaths that would occur in the absence of radiation."[257] However, this risk of cancer death could be cut by half or more if the radiation exposure were spread over a longer period of time (one year, perhaps).[258] Given a linear risk relationship, an acute exposure of 70 cGy (the low-level threshold) would increase the number of cancer deaths of AEF personnel by 5.6 percent (or 66 additional people from an AEF strength of 1,175).[259] Such cancer deaths normally do not occur for years or decades. For leukemia, the minimum time period between radiation exposure and the appearance of disease (the latency period) is two years. For solid tumors, the latency period is more than five years.[260]

Mutagenesis may arise from chromosomal loss of a gene or of an entire chromosome, which results in codon loss or frame shifts, or point mutations involving base substitutions, which produce amino acid substitutions and stop codons.[261] The overwhelming majority of mutations are not perpetuating and are inconsequential to offspring. Experiments with low-dose-rate, low-LET radiation in mice indicate that the doubling dose for mutations is about 100 cGy.[262] Humans probably are less sensitive to radiation-induced genetic effects than are mice.[263] A mild mutation that survives may express itself as an allergy, asthma, juvenile diabetes, hypertension, arthritis, high cholesterol level, slight muscular or bone defects, or other genetic problems.[264] These defects in genetic makeup leave the individual slightly less able to cope with the ordinary stresses and hazards in the environment. Increasing the number of genetic changes in a family line, each passed to the next generation, increases the likelihood of a congenital defect or disease. A weakened family line ultimately may die out because of infertility or the death of its members prior to reproductive age.

Rapidly dividing cells are among the most radiosensitive, so a developing embryo or fetus is highly vulnerable to the negative effects of ionizing radiation. The principal effects of *in utero* irradiation are prenatal death, growth retardation, and congenital malformations (teratogenesis). Given any possibility of radiation exposure, pregnant women should not be deployed. A recommended monthly dose-equivalent limit for an embryo or fetus is 0.50 mSv.[265]

Long-term health risks are one of the most important and challenging issues for the AEF commander. At present, the Air Force has no policy for determining acceptable risk of cancer induction for various military objectives. Experiences in the Gulf War and in Bosnia and the emergence of an ionizing radiation threat highlight this issue (see the "Future Countermeasures" section).

8.1.6 Behavioral Effects of LLR

Although behavioral and cognitive effects of LLR have not been investigated, results of studies using high radiation levels suggest that small, possibly meaningful changes could occur in the behavior and mental capabilities of AEF personnel. Naturalistic behaviors (normal parts of an animal's response repertoire) may be altered by radiation exposure. In particular, spontaneous locomotor activity, an important component of many responses, including overall activity level, may be depressed by irradiation.[266] Additionally, exposure to ionizing radiation produces a dose-dependent reduction in food and water consumption.[267] Several studies reveal chronic deterioration of motor performance after doses of radiation at or below the mean lethal dose, as well as a lowering of survival probability following exposure to extreme stress.[268] Social behaviors have not received much attention from radiobiologists.

The important point is that exposure of AEF personnel to LLR may produce subtle, but significant, impacts on performance that generally will lower the effectiveness of the AEF. For example, learning and memory may be impaired enough to affect reaction times and decisionmaking, including the frequency with which errors are made. The Soviet literature is replete with reports of memory deficits in patients undergoing therapeutic irradiation. Radiation-induced cognitive effects have been reported after intermediate (not lethal) radiation doses. The degradation created may persist for weeks or months. At low doses of radiation, performance deficits may be slow in developing and relatively long lasting. However, not all tasks are likely to be equally radiosensitive. Tasks with complex, demanding requirements should be more easily disrupted than simple ones.[269]

8.1.7 Radiation Phobia

Although the physiological and behavioral effects of low-level exposure are important, the debilitating fear that the presence of ionizing radiation (regardless of level) can generate may be the most significant impediment to AEF operations. Little is known about the origin of this severe anxiety, so preparing AEF members for an encounter with radiation may be difficult. The available information was derived from the Japanese atomic bomb experience, human radiation accidents, clinical radiation exposures, and animal studies. The animal studies help us to understand possible psychological consequences of the direct effects of radiation on neurophysiology. The human data show how social, cultural, and personal motivations drive human behavior, which can have a serious impact on the AEF mission.[270]

The nuclear reactor mishap at Three Mile Island is a good example of the psychological effects. The accident produced virtually no radiation exposure above background levels. Still, "radiation phobia" evoked sudden and long-term stress reactions that negatively affected job performance. The fear can be heightened by the belief that the nature of ionizing radiation — it is invisible, unfamiliar, manufactured, and, therefore, unnatural — makes it especially hazardous, regardless of dose.[271] The anxiety produced by an encounter with ionizing radiation could create fatigue, inattention, nervousness, depression, and hypochondria and could render some AEF members unfit for duty. AEF units must train their members to accept the fact that LLR exposures usually entail only minimal health consequences, to have confidence in the countermeasures, and to be assured that the leaders will take every precaution to ensure their safety.

8.1.8 Military Threats

The military threat of LLR may occur from several sources: (1) the intentional employment of radionuclides, such as RDWs, (2) damage to nuclear power facilities, and (3) environmental contamination by inadequate radioactive material storage and waste disposal. The opportunity to use LLR against military forces has been around for 50 years, yet only recently has the threat materialized. Iraqi RDW testing, already described in this chapter, is a prime example. In another instance, on 27 November 1995, Chechen rebel commander Shamil Basaev buried a container of cesium-137 in Ismolovo Park, Moscow, and then notified the media.[272] He planted the potent source of gamma radiation to demonstrate how easily terrorists could acquire and deliver radioactive "weapons" in Russia. Still another case is the disappearance of half of the 900 m^3 of radioactive materials stored at the radon factory in Tolstoi-Yurt, Chechnya, including cesium-137, strontium-90, and weapons-grade plutonium-239 and uranium-235. In fact, a Russian government commission concluded that at least 21 sites storing radioactive materials were unguarded during the Chechen conflict.[273]

Incidents like these, public outcry against the use of depleted-uranium (DU) weapons, and the mysterious appearance of Gulf War syndrome highlight the possibility of the hostile use of radiation. Also, the likelihood of such use has increased because of a fundamental shift in terrorist philosophy. In a recent commentary, "Defend Against the Stealth Enemy," former Assistant Secretary of Defense Joseph S. Nye, Jr., and former CIA Director R. James Woolsey concluded that it is increasingly likely that radioactive materials will be employed with conventional weapons.[274] Historically, terrorists seeking to promote a cause risked moral and political backlash if the damage they caused was disproportionate to public perception of their cause. However, in recent years terrorists seem to be more interested in retribution and in eradication of what they define as evil than in fostering popular support. For these terrorists, weapons of mass destruction or terror, if available, can be more effective means to their ends.

This section is a description of the sources of LLR that either can be acquired as the material for RDWs or already are present in the environment into which an AEF will be deployed.

8.1.9 Sources of Radioactive Material for RDWs

Most nations have easy access to radioactive materials (although few are likely to use RDWs, given the extreme retaliation the use would elicit). However, many of these countries, because of economic problems, political instability, or a shortage of resources, do not have the infrastructure to effectively manage and safeguard their radioactive materials.[275] Thousands of sources, particularly those in medicine and industry (but also those in nuclear power generation and weapons development), are used with little concern for control and safety during use, storage, transport, and disposal. This discussion focuses on the opportunities for terrorists to acquire material for RDWs. In particular, AEF planners should pay special attention to those sources that are very potent gamma emitters with long half-lives (e.g., cesium-137 and cobalt-60) or are very toxic (e.g., plutonium). Although the circumstances of RDW use will vary widely, the dispersed radionuclides probably will produce dose-rates less than 1 cGy/hr.

8.1.9.1 Medicine and Industry

Dangerous radionuclides can be found virtually everywhere. For example, during recent security activities in Kinshasa, Republic of Congo, the Armed Forces Medical Intelligence Center discovered two experimental nuclear reactors at academic institutions.[276] The salient point is that a wide variety of radionuclides is available from a variety of sources, so AEF commanders should recognize those sources and the radionuclides employed. Unless otherwise noted, the information in this subsection is taken from an AFMIC report, "Identification of Radiation Sources in a Peacetime Environment."[277]

Several radionuclides are commonly used in laboratories for the analysis of biological functions and may be accessible to potential enemies (Table I-42). Because the quantity and energy of these radioactive materials is typically very small, biomedical radionuclides usually are not an external hazard and may be stored without shielding. One exception is phosphorous-32, which has enough energy to produce beta burns to exposed skin. Also, some laboratories use large amounts of iodine-125 (2 to 10 millicuries) in the form of sodium iodine, which could be a significant hazard (especially to the thyroid) if ingested or inhaled.

Table I-42. *Common Radionuclides Used in Medical Research*

Radionuclide	*Half-Life (Days)*	*Half-Life (Years)*	*Emission*	*Average Energy (MeV)**
Carbon-14 (C-14)	2,100,000	5,745.00	Beta	0.0450
Iodine-125 (I-125)	60.2	0.16	Gamma	0.0350
Phosphorous-32 (P-32)	14.3	0.04	Beta	0.6900
Sulfur-35 (S-35)	87.9	0.24	Beta	0.0490
Tritium (H-3)	4,600	12.60	Beta	0.0057

* Mega-electron volt

Nuclear medicine facilities typically perform diagnostic procedures using technetium-99m for imaging by a gamma scintillation camera. Technetium-99m and similar radionuclides (Table I-43) could produce a debilitating whole-body exposure if large enough quantities were dispersed in a small area. However, the very short half-lives of most imaging radionuclides lessen the possibility of a sustained, credible threat. Of course, these radionuclides are hazardous if ingested or inhaled.

Table I-43. *Radionuclides Commonly Used in Nuclear Medicine for Diagnostic Procedures*

Radionuclide	*Half-Life (Days)*	*Emission*	*Energy (MeV)*
Gallium-67 (Ga-67)	3.25	Multiple gamma	0.093, 0.184, 0.296, 0.388
Indium-111 (In-111)	2.81	Multiple gamma	0.173, 0.247
Iodine-131 (I-131)	8.05	Multiple gamma	0.080, 0.284, 0.364, 0.637, 0.723
Iron-59 (Fe-59)	45.60	Beta Multiple gamma	1.570, 0.475 0.143, 0.192, 1.095, 1.292
Technetium-99m (Tc-99m)	0.25	Gamma	0.140

Teletherapy, or external beam-radiation therapy, uses highly focused fields of ionizing radiation to treat cancer. The fields originate from either of two very potent gamma sources: cobalt-60 or cesium-137 (Table I-44). These sources are housed in steel-reinforced concrete vaults to provide adequate shielding. Close-range, unshielded exposure presents the threat of significant whole-body irradiation. Given the availability and activity, hostile employment of teletherapy sources, especially by RDWs, is a plausible threat to the AEF.

Table I-44. *Radionuclides Commonly Used in Teletherapy*

Radionuclide	*Half-Life*	*Emission*	*Energy (MeV)*
Cesium-137 (Cs-137)	30.00 years	Gamma	0.662
Cobalt-60 (Co-60)	5.27 years	Multiple gamma	1.173, 1.332

The 1987 disaster in Goiania, Brazil, illustrates the magnitude of this threat.[278, 279] On or about 21 September 1987, scavengers dismantled a metal canister from a radiotherapy machine at a cancer clinic in the city. The machine had been abandoned since 1985 and no precautions had been taken to secure the protective housing of the machine. Five days later, a junkyard worker pried open the lead canister, revealing a pretty, blue, glowing powder — cesium chloride. In the following days, the radioactive substance was distributed so adults and children could rub it on their bodies. In a nuclear disaster second only to Chernobyl, the city of Goiania had one of the largest radioactive leaks in history, which was not discovered by authorities for several days. The accident resulted in 4 deaths, 28 cases of ARS, hundreds of cases of exposure, and 3,500 m^3 of radioactive waste. The four people who died received doses ranging from 450 to 600 cGy. All this damage came from an accident in handling 1,400 curies of cesium-137, not from a deliberate effort to contaminate an area.

Another common application of radioactive materials, gamma radiography, is used widely in industry to check the integrity of welds in piping. In this procedure, emissions from a radioactive source inside the pipe expose film outside the pipe. The sources used generally are very energetic and could be a significant threat to AEF operations (Table I-45). Historically, some of the worst radiation accidents involving loss of life have been attributed to exposures to industrial radiography sources. AEFs must exercise extreme care during operations in the vicinity of any industrial sites that have used radiography equipment.

Table I-45. *Radionuclides Commonly Used in Gamma Radiography*

Radionuclide	***Half-Life (Years)***	***Emission***	***Energy (MeV)***
Cesium-137 (Cs-137)	30.0	Gamma	0.662
Cobalt-60 (Co-60)	5.3	Multiple Gamma	1.173, 1.332
Iridium-192 (Ir-192)	0.2	Multiple Gamma	0.296, 0.308, 0.317, 0.468
Radium-226 (Ra-226)	1,620.0	Multiple Gamma	0.180, 0.241, 0.294, 0.350, 0.607, 0.766, 0.933, 1.120, 1.238, 1.379, 1.761, 2.198

8.1.9.2 Soviet Stockpiles

Today, the huge stockpiles of weapons-grade material in former Soviet countries sit lightly guarded (sometimes unguarded), waiting to be bought or stolen. The incident in Ismolovo Park is one of numerous chilling examples. The size of those stockpiles is almost unbelievable: the Russian inventory of plutonium in 1990 was 127,273 kg under military control and 22,727 kg under civilian control. Just 1 kg of plutonium is enough to produce a bomb equivalent to 1,000 tons of TNT.[280]

When the Soviet Union collapsed, its nuclear weapons and material stockpiles fell under the control of four separate governments in desperate economic circumstances: Russia, Ukraine, Kazakhstan, and Belarus. Then, civil war broke out in Ukraine when Crimea declared its independence and in Russia when Chechnya tried to secede. The Russian newspaper *Komsomolskaya*, quoted in the *New York Times*, noted that “train loads of special radioactive freight often cross regions where armed interethnic conflicts are under way.”[281] Given these dire economic and political conditions and the actions of international criminal organizations, Russia simply is not capable of keeping track of its plutonium and enriched uranium inventory. “Russia has no way of knowing for sure if any of its vast supply of bomb ingredients is missing, many of its own nuclear officials and scientists admit,” wrote William Broad in the *New York Times*. He quoted a Russian nuclear scientist, who said, “It’s possible to buy anything in our country, including weapons and samples.”[282]

Economic crisis makes both governments and individuals willing to sell radioactive materials, and terrorists and rogue nations will pay millions of dollars for just a few pounds. In 1994, there were 124 cases of actual or attempted nuclear materials smuggling from former Soviet countries, compared to 56 cases in 1993 and 53 cases in 1992. This trend indicates the increasing threat to deployed U.S. forces. The smuggling operations are generally low risk because the written inventories of radioactive materials are never checked against the actual stocks at many Russian research institutes and storage sites.[283] The difficulty in tracking stocks and stopping smugglers is compounded by the very small amounts of radioactive materials required. Explosive dispersion of less than a pound of plutonium in the vicinity of an AEF base would contaminate the entire area with LLR permanently. Such an attack would create serious anxiety about lethal exposure. The real weapon in this scenario would be fear and a sense of insecurity that would stifle operations.

8.1.10 Environmental Sources of Ionizing Radiation

Initial site surveys and beddown assessments of AEF forward operating locations (FOLs) are the responsibility of HQ USAF/IL (Installations and Logistics), which forwards the assessments to the AEF commander for approval.[284] During this process, every effort should be made to identify FOLs that are not contaminated and are not near sources or potential sources of LLR. However, mission requirements may dictate FOLs near environmental sources of radiation. Terrorist attacks or collateral damage to chemical, pharmaceutical, nuclear power generation, and numerous other facilities may create areas of LLR. This section is a discussion of some of those sources.

8.1.10.1 The Nuclear Fuel Cycle and Radioactive Waste

Radioactive waste is associated with all parts of the nuclear fuel cycle, from uranium mining and fuel fabrication, through use of the fuel to generate electricity, to management of used fuel and its disposal. The waste comprises diverse materials with different physical, chemical, and radioactive characteristics. The threats to AEF operations arise from spent fuel, waste from reprocessing spent fuel, and operational waste.[285] For AEF operations in or near areas containing radioactive waste, the crucial characteristic of the waste is the concentration of radionuclides.

Radioactive waste is classified by its source and its physical and chemical properties.[286] Three general categories of radioactive waste are low-level, transuranic, and high-level. Low-level radioactive waste includes residues from laboratory research, medical institutions, and uranium mill tailings and waste generated in the clean-up of uranium, radium, and thorium processing plants. Low-level waste inventories are increasing, even in Third World countries, with medical institutions generating the most waste. Storage and disposal are major problems, and, therefore, are key opportunities for hostile forces. Transuranic wastes are materials containing radionuclides with atomic numbers higher than that of uranium, such as americium, curium, and plutonium. These wastes originate mainly as by-products of the production and fabrication of plutonium for military purposes. Because they are water soluble, transuranic wastes are a distinct health hazard. High-level waste, which has the most radioactivity and highest concentration of radionuclides, is primarily the spent fuel from civilian nuclear power reactors and by-products of reprocessing spent fuel for civilian, military, or commercial purposes. Details of some of the relevant aspects of the nuclear fuel cycle are in the following subsections.

8.1.10.2 Mining, Milling, and Refining of Uranium

Formerly, uranium was extracted from open pits and underground mines. In the standard process, the crude uranium ore was fed into a series of crushing mills, and the uranium was extracted using an acid or alkali leach process. The wastes were excavated rock with very low uranium residue (called “mine wastes”) and the material discarded during the uranium extraction process (called “mill tailings”). In the past decade, alternative techniques, such as *in situ* leach mining, have become more widely used. In the *in situ* leach mining process, a leaching liquid (e.g., ammonium-carbonate or sulfuric acid) is pumped into an underground uranium deposit, and uranium-bearing liquid is pumped out.[287] Although uranium mines produce significant amounts of uranium and radon and their decay products, the risks to personnel from the radioactive emissions from uranium mines are insignificant.[288]

The milling (refining) process extracts uranium oxide (U_3O_8) from ore in the form of yellowcake, a yellow or brown powder that is about 90 percent uranium oxide. Conventional mining techniques generate a substantial quantity of tailings waste during the milling phase, because generally less than 1 percent of the ore is usable. The newer *in situ* leach mining leaves the unusable portion in the ground and, therefore, does not generate this form of waste.

Tailings contain particles ranging in size from coarse, sandy material to very fine dusts. They normally are handled as a water-based slurry, which is 25 to 40 percent solids and processing chemicals. Except for the added processing chemicals, the tailings are less hazardous than the parent ore. The principal radioactive materials in the tailings are thorium-230, radium-226, lead-210, and other radon decay products. Most tailings are classified as low-level waste with a very small risk of direct radiation exposure, especially when access to the tailings is restricted. The environmental impact of uranium mining is comparable to other base-metal mining operations, which generally are less stringently regulated.

Following extraction, the uranium concentrate may be refined, converted into a hexafluoride gas, or enriched. The most important waste product of these processes is a fairly large amount of DU, which normally is about 80 to 85 percent by weight of the original uranium concentrate. DU is relatively harmless, with its primary hazard arising from its chemical toxicity, not radiation effects.

8.1.10.3 Depleted Uranium

DU is the uranium-238 residue left after uranium-235, the isotope required for nuclear reactor fuel and nuclear weapons, has been leached out of uranium ore during the enrichment process (i.e., the ore is "depleted" of U-235). The leaching process is imperfect, so DU typically is 0.25 to 0.30 percent fissile uranium-235. DU is primarily an alpha emitter, although it also emits very weak gamma radiation. The gamma radiation is so weak, in fact, that the radiation level inside a tank fully loaded with DU sabot rounds is less than the normal background radiation at many locations around the world.[289]

DU has two properties that make it ideal for military applications: it is extremely dense and its surface ignites and burns on impact (especially with steel). DU is currently used in 30-mm rounds of the A-10, armor, and sabot penetrators and as counterweights in control surfaces of some aircraft. Since the Gulf War, DU can be found in the arsenals of almost of every nation.[290] DU also is readily available to anyone with nuclear reactors or weapons programs.

The two main concerns about DU are slight radioactivity and heavy metal toxicity. On a gram-for-gram basis, the typical uranium alloy has only about 0.002 the radioactivity of an equivalent amount of plutonium-239. Therefore, the radiation hazard associated with uranium is much lower than that associated with plutonium, which itself is not usually hazardous unless inhaled. The radiation hazard is a function of how much DU is inhaled, swallowed, or otherwise enters the body. Even then, the very short range of alpha particles limits the exposure consequences.

Like lead, plutonium, and other heavy metals, DU is toxic. Uranium causes chemical toxicity at exposures of 0.1 milligram per kilogram of body weight. This toxicity damages the cells of the lower portion of the proximal convoluted tubules of the kidney. After exposure, a lag period of 6 hours to several days is followed by chemical necrosis. Even after necrosis, the kidneys show evidence of regeneration within 2 to 3 days, depending on the severity of the initial exposure.[291] Although the actual risk is low, the Services currently have maintenance restrictions in place that prohibit organizational- and intermediate-level maintenance on DU control-surface counterweights.[292] These restrictions could be more of a hindrance to AEF operations than the effects of the DU itself.

During routine Air Force operations, DU is not a hazard, with the exception of the dust formed in DU impacts and burning.[293] DU rusts when exposed to air and turns a dull, black color. Subsequent impacts or fires can produce DU shrapnel or dust. This heavy, black dust is easy to identify, and exposures can be controlled with simple precautions. Gloves must be worn if there is any chance of contact with the dust and personnel must wash carefully before eating, drinking, or using the bathroom. Standard precautions must be taken to prevent inhalation of the dust. Since DU dust is very heavy, it usually is deposited within 50 meters downwind of the fire that generated it. The major long-term hazard from DU dust is contamination of the ground and water supply, which probably will be the responsibility of the host country. Unless Air Force personnel are directly involved in a detonation or fire with DU, hazards are relatively minor, and simple procedures will provide effective protection.

8.1.10.4 Nuclear Reactor Operation

The total release of radionuclides into the environment from nuclear reactor operations is only 0.01 mSv per year per person (the average total annual irradiation from all sources is 3.6 mSv). The operation of a reactor generates long-lived, high-level used fuel and short- to medium-lived low- and medium-level waste products. The most radioactive operational wastes are filter- and ion-exchange resins from the reactor water-purification systems. The radioactivity of the operational waste is predominantly from cobalt-60 and cesium-137. These types of radionuclides would be prime targets for terrorist acquisition.

System malfunctions, accidents, and sabotage can occur. The contents of the reactor at the time of an incident and the ensuing amount of contaminant depend on the reactor type, its application, and the duration of operation. With core damage, the severity of the accident — and, therefore, the risk to personnel — depends on the released radioactivity, which typically consists of iodine-131 and cesium-137.[294]

8.2 Current Countermeasures

Countermeasures are those actions that can be taken either before or during exposure to ionizing radiation to prevent or decrease the acute and chronic biological effects. Three cardinal rules are at the core of any approach to radiation protection.[295]

- **Minimize time spent near a radiation source to reduce total exposure.** Since an individual's total absorbed dose is the product of dose-rate and duration of exposure, reducing the exposure time will reduce the absorbed dose.
- **Maximize distance from a radiation source to reduce exposure.** The absorbed dose from a source is inversely related to the distance from the source. In other words, the greater the distance from the source, the lower the absorbed dose received from that source.
- **Maximize material between personnel and the radiation source.** Radiation travels in a straight line, and some types (gamma and, to a much lesser extent, beta) are capable of penetrating solid objects. When passing through objects, radiation loses energy by interacting with atoms within the objects. In general, materials that have higher atomic numbers (i.e., greater electron density) will offer better protection.

Once deployed, the AEF may not be mobile until redeployment, so maximizing distance from radiation sources may be difficult if the FOL is evenly contaminated. This problem can be overcome by innovative fielding arrangements, duty schedules that reduce exposure times, and shielding arrangements that enervate gamma energy.

The Air Force Radiation Assessment Team (AFRAT) provides commanders with viable solutions to operational obstacles imposed by the presence of radioactive materials or radiation hazards. The team can provide complete threat identification and assessment, site characterization, and consultation for mitigation, force protection, and remediation activities. The AFRAT has expertise in depleted-uranium weapons, tactical nuclear weapons and the tactical environment, releases of radioactivity from nuclear facilities, bioeffects of ionizing radiation, and toxicological effects of radioactive materials.

The Marine Corps' Chemical/Biological Incident Response Force also has the capability to handle radiological incidents for the DoD. This group's mission is to secure the site of an incident, decontaminate personnel and equipment, and clean the site.

8.2.1 Detection

The Army uses the Alpha RADIAC, AN/PDR-77, to detect and measure alpha, beta, gamma, and X-ray radiation. The system incorporates commercially available measurement electronics, an alpha probe, a beta/gamma probe, and an X-ray probe. The RADIAC set has a digital liquid-crystal display, is auto-ranging, and has adjustable audio and visual alarm thresholds. The AN/PDR-77 is the primary device used to support the storage and movement of nuclear weapons, to respond to nuclear accidents, and to maintain equipment containing radioactive materials. Fielding of the AN/PDR-77, which began in July 1994, is complete. The AN/PDR-77 replaced the AN/PDR-56F and AN/PDR-60, which used 30-year-old technology that was difficult and costly to support. Neither of the replaced systems was sensitive enough to accomplish the Army's alpha-detection mission.

8.2.2 Shielding and Individual Protective Equipment

Shielding and IPE work on the same principles. First, they insert material between the person and the radiation source so that the particles or waves will expend all of their energy ionizing the material's atoms before they reach the person. Second, they provide a physical barrier to contaminated material, so that it cannot contact the skin or enter the body. The normal duty uniform suffices for external protection from alpha and all but the most energetic beta particles (like those emitted by phosphorous-32). For very energetic beta particles, thicker clothing, such as a battle-dress overgarment, is required to prevent skin contact or particle penetration through more than the first few layers of skin. Because the primary hazard is internal contamination, the clothing must be worn with a face mask for protection against aerosols. As the percentage of very small particles increases, the mask must provide a finer filter pitch, greater face coverage, and a better seal.

Low-LET gamma rays have considerable penetration capability. However, most sources of gamma rays are weak enough that protective clothing will provide adequate protection. For example, weapons-grade materials (uranium-235 and plutonium-239) emit gamma rays with a maximum energy of 185 kiloelectron volts (keV), with most of the emissions below 30 keV. The primary danger is from inhaled alpha particles and heavy metal toxicity. Conversely, readily available materials, such as colbalt-60 and cesium-137, are potent gamma emitters that may require personnel to remain in shielded areas when off duty to control cumulative dose.

Generally, the denser the material, the better the shielding.[296] The existence of natural and manufactured shielding should be a criterion for FOL selection. Terrain features such as caves, ditches, ravines, culverts, overpasses, tunnels, and empty bunkers can be used as expedient shelters. Basements provide excellent protection. Many materials at or near the FOL may afford substantial shielding. Use of some of these materials, such as concrete, requires significant engineer support and time, which the AEF may not have. Earth, however, affords excellent protection and can be employed with a minimum of engineering effort. Table I-46 lists the shielding potential of some common materials.

Table I-46. *Shielding Potential of Common Materials Against Gamma Rays*[297]

Material	0.05-Value Layer Thickness*
Steel	1.8 cm (0.7 in)
Concrete	5.6 cm (2.2 in)
Earth	8.4 cm (3.3 in)
Water	12.2 cm (4.8 in)
Wood	22.4 cm (8.8 in)

*Reduces dose or dose-rate by one-half.

The commander must weigh the radiation protection of IPE against performance degradation to select the appropriate MOPP level.[298] The adequate level of protection will depend on the AEF's capability to monitor and detect LLR and to warn and decontaminate personnel and equipment. Although performance degradation is unavoidable, the amount of degradation can be reduced by acclimatization and training. Practical considerations of temperature and work rate will balance radiation effects—there is a trade-off between heat and fatigue casualties and radiation casualties. In some cases, commanders may have to choose between increased cancer risk and heat casualties to accomplish the mission. In addition, providing personnel with enough uncontaminated drinking water and rest will be a primary concern and an important limiting factor in AEF operations.

8.2.3 Decontamination and Treatment of Radiation Casualties

Treatment is the category of actions that are performed after exposure to minimize, halt, or reverse biological damage. Decontamination is the first step in the treatment process, and in most situations nothing further will be required. If the irradiation is significant or there is internal contamination, then various drug therapies and procedures are available. However, the interactions between ionizing radiation and conventional injuries or chemical and biological agents are not well understood. This section focuses on methods to treat inhaled or ingested radioactive material. A discussion of surgical and patient-handling procedures in a contaminated environment is outside the scope of this report, and information on these topics is available from AF/SG or the Armed Forces Radiobiology Research Institute (AFRRI).

8.2.3.1 External Decontamination

As much of the externally deposited radionuclide as possible must be removed to reduce the surface dose-rate and prevent the contamination from being absorbed into the body. To limit the spread of contamination, this removal should be accomplished before treating internal injuries, if time permits. The decontamination must be done carefully to avoid irritation or further injury to the skin, which could increase percutaneous absorption. In most cases of external exposure, 90 to 95 percent of patient decontamination can be accomplished simply by removing the outer clothes and shoes.[299] Since the chemical nature of the contamination usually is unknown, it may be necessary to use several agents to decontaminate the skin, although ordinary soap and water usually will suffice. Decontamination should start with the mildest cleanser and then move to more powerful ones as required. In order of use, the decontaminants might be (1) ordinary soap and water, (2) an abrasive soap, (3) detergents, (4) oxidizing agents (e.g., sodium hypochlorite [bleach]), (5) complexing agents (e.g., citric acid), and (6) chelating agents (e.g., ethylenediaminetetraacetic acid [EDTA] and diethylenetriamine-pentaacetic acid [DTPA]).[300]

8.2.3.2 Internal Decontamination

The biological effects of internally deposited radioactive particles can be mitigated by four methods: dilution, blocking, mobilization, and chelation.[301] In the dilution method, large quantities of a stable element are administered to decrease the concentration of the radionuclide and lower the probability that the radionuclide will be absorbed into the tissue. Blocking prevents the uptake of the radionuclide by saturating the metabolic process in a specific tissue with a stable element. The mobilization method increases a natural turnover process that induces a release of some forms of radionuclides from body tissues. Lastly, chelation is a type of mobilization in which organic compounds exchange less firmly bonded ions for other inorganic ions to form a relatively stable nonionized ring complex. This process converts the radionuclides into a more soluble form that is more readily excreted from the body. Table I-47 lists the agents employed for these methods for common radionuclides.

Table I-47. *Decontamination Methods and Agents for Common Radionuclides*[302]

Method	*Radionuclide*	*Agent**
Dilution	H-3	Water
Dilution	P-32	Phosphorus (neutrophos)
Blocking	I-131, Tc-99m	KI (Lugol's solution)
Blocking	Sr-89, Sr-85	Al-phosphate (Phosphojel), Al-hydroxide (Amphojel), Na-alginate (Gaviscon)
Mobilization	Cs-137	Ferric ferrocyanide (Prussian Blue)
Mobilization	Rb-86	Chlorthalidone (Hygroton)
Chelation	Cf-252, Cm-242, Am-241, Pu-239, Ce-144, Pm-143, La-140, Y-90, Zn-65, Sc-46	DTPA
Chelation	Pb-210	EDTA
Chelation	Hg-203, Co-60	Penicillamine

* Many decontamination agents are available only as investigational drugs through the Department of Energy.

Mobilization was used to treat victims of the Goiania disaster.[303] The victims were administered Prussian Blue, an iron compound that bonds with cesium-137, to help them excrete the radionuclide. Unfortunately, more than a week passed before they received the Prussian Blue. By that time, much of the cesium-137 had moved from the bloodstream into the tissues, from which it is far more difficult to remove. Four of the patients did not survive. Treatment of internal decontamination is urgent because the radioactive material will continue to irradiate the casualty internally until radioactive decay and biological elimination remove the radionuclide. Another consideration in treatment is protecting medical personnel. The patient's body shields attending medical personnel to some degree, but, in the case of potent gamma radiation, the patient can be a threat to others until the emitters are eliminated.

8.3 Future Threats

The future threats of ionizing radiation are unlikely to differ from those the AEF faces today, but the severity and likelihood of occurrence of the threats certainly will be higher.

In AEF IV, two people were discovered to have had a radiological exposure — probably from an occupational source — prior to the deployment and were unable to perform their duties. In a lean operation like an AEF, the loss of two key personnel could be critical. Even in the absence of a threat in the area of operation, the possibility of such exposures makes LLR countermeasures essential.

8.4 Future Countermeasures

Future countermeasures include operation planning, radioprotection, detection, and modeling.

8.4.1 Planning for Operations in LLR

Preparation is essential for the AEF to successfully operate in LLR environments. Preparation has several facets: planning to ensure that the commander has a clear policy that balances mission objectives against short-term performance degradation and long-term health risks; training personnel to properly assess the radiological situation, employ countermeasures, and control anxiety; and equipping personnel with the proper diagnostic instruments and medical assets.

Prior to a deployment, the AEF commander must have a flexible policy of engagement in the LLR environment that balances the exposure hazards with mission objectives. For example, if peacetime regulations are applied, a RDW easily could shut down an AEF operation with relatively low dose-rates. A peacekeeping mission may not have enough national security value to merit a 5 percent increase in cancer deaths. The LLR Integrated Concept Team (ICT), an Army initiative with tri-Service support, is using the radiation exposure-state categories in ACE Directive 80-63 as starting points for a comprehensive policy.[304] Directive 80-63 lists six categories of low-level exposure, which are based on risk of induction of fatal cancer two years after exposure: less than 0.05 cGy, 0.05 to 0.5 cGy, 0.5 to 5 cGy, 5 to 10 cGy, 10 to 25 cGy, and 25 to 70 cGy. For operations other than war, personnel exposure is limited to a maximum, whole-body cumulative dose of 25 cGy, except when greater exposure must be accepted to save human lives. During wartime operations, the total cumulative dose may be increased to 70 cGy with adequate justification. Currently, the only operational Air Force guidance is that the total accumulated wartime dose should not exceed 150 cGy per person.[305] This limit was probably derived from subhuman primate studies at the AFRRI that assessed the impact of ARS on the performance of rudimentary combat tasks.[306]

To ensure minimal exposure times and effectively control long-term health risks, an accurate record of an individual's dose must be maintained. The record, in conjunction with the mission exposure policy, should dictate future permissible exposures. Because risk increases with accumulation of absorbed dose, regardless of how much time passes between exposures, the record must be kept current throughout the individual's career (and lifetime). Currently, the Air Force does not deploy with the capability to monitor individual doses and dose-rates. Additionally, the system (which is not currently in place) requires that individuals track and record their own exposures.[307] To be a useful aid in exerting adequate exposure control, any recordkeeping system must be objective and automated.

An important planning consideration is who has the authority to order personnel to work under radiologically hazardous conditions. AFI 32-4001 stipulates that the installation commander has the authority to adjust the 150-cGy limit as necessary to ensure critical mission success.[308] However, recent events revealed that such a decision is usually so sensitive that, depending on the exposure levels, the decision may be raised to the Presidential level.

8.4.2 Radioprotection

Certain investigational drugs have been found to offset the negative cellular effects of ionizing radiation. Initial irradiation creates a cascade of deleterious effects that grow in severity. At each of the points where the damage is compounded, radioprotective actions can be taken to suppress the biological expression of injury.[309] The mechanisms of radioprotection include hypoxia, free-radical scavenging, immunomodulation, hematopoietic cell (i.e., those involved in blood cell production) and intestinal stem cell recovery, and modulation of the cell cycle.[310] Successful radioprotection would give the warfighter confidence in the LLR environment while mitigating long-term health effects.

For example, drug WR-2721, developed by Walter Reed, protects cells through free-radical scavenging, hydrogen atom donation, induction of hypoxia, or combinations of these mechanisms. The cells best protected are the hematopoietic stem and progenitor cells. Similarly, glucan helps defeat radiation damage by protecting hematopoietic cells, while selenium promotes the induction of endogenous oxidative substances, such as glutathione peroxidase. The three drugs can build on each other's effects to produce synergistic radioprotection.[311] Antioxidants are quite effective in scavenging free radicals (produced by the passage of radiation through a cell) before they can interact with and damage critical macromolecules like DNA.

Some drugs, such as WR-1065, are believed to have a radioprotectant effect on the genome by decreasing the supercoiling of DNA and promoting DNA repair. For example, Holwitt reports that WR-33278 stimulates topoisomerase I-unwinding of the supercoiled state.[312] This property may have important implications for radioprotection. In addition to general effects, some radioprotectants target specific organs. WR-77913 reduces cataract incidence in irradiated rat eyes when administered prior to irradiation.[313]

The above drugs were studied for their cellular effects, especially their abilities to interrupt some of the actions that lead to cancer, mutagenesis, or cell death; other types of drugs are useful in preventing the somatic effects of the prodromal phase of ARS. Gastrointestinal upset has been blocked in monkeys without behavioral side effects by the intragastric administration of an antiemetic agent called zacropride.[314] A new class of very safe and effective compounds, 5-HT3 antagonists, are set to join the current formulary of antiemesis drugs: thorazine, chlopromazine, and compazine. Generally, such antiemetic agents show better results if administered before exposure.

Paradoxically, many of the biological mediators that typically amplify damage, such as the prostaglandins, leukotrienes, histamines, and serotonin, can effectively protect against the same damage if taken before radiation exposure.[315] As noted above, few studies have investigated behavioral disruption. Yet, over the years of research, some evidence has accumulated that antihistamines (e.g., chlorpheniramine)[316, 317] and opiate antagonists (e.g., naloxone)[318] may offer protection against radiation-induced behavioral problems, at least at high exposure levels.

In theory, radioprotectants could greatly benefit personnel in LLR environments. Yet, after decades of research, the most promising agents are still in the investigational stage, and many are available only through the Department of Energy.[319] For most of the agents currently available, toxicity and undesirable side effects are serious problems, and efficacy of the agent is time-dependent. For example, some agents provide optimal effects only if the agents are administered 30 minutes before exposure. In addition, protective effects have not been demonstrated for the doses and dose-rates that typify the LLR threat. Furthermore, research indicates that the greater the radioprotection, the greater the interference with normal behavior.[320] Nevertheless, the small (although significant) physiological changes caused by low-level exposure might be successfully regulated by combining different types of agents to reduce the toxicity of individual agents while maximizing the overall protective effect.[321]

8.4.3 Detection

The U.S. Army's Advanced Airborne RADIAC System (AARS) will provide rapid, accurate, and safe measurement of aerial radiation readings and calculation of residual ground radiation. The compact (1.5 ft^3 maximum volume), lightweight (15-pound maximum weight) system will be mounted on a helicopter or unmanned aerial vehicle and will function at airspeeds up to 100 knots and altitudes up to 1,000 feet. The AARS is designed to require no more than 45 minutes for installation on a rotary-wing aircraft.

The AARS will use host-aircraft navigation and altimetry data to automatically correlate airborne readings to ground radiation readings and position. The system also will measure total dose and dose-rate and warn the pilot when unsafe levels are reached. Data collected will be stored on a removable-media memory module for post-flight processing and may be transmitted in flight via the aircraft's secure radio. AARS data will be used by field commanders in planning operations and unit movement to minimize the exposure of soldiers to a radiation hazard. The AARS will be compatible with the Army's Maneuver Control System and the Automated Nuclear, Biological, and Chemical Information System.

Variants of the AARS have been devised for each of four different weapon systems: OH-58D Kiowa Warrior (KW), RAH-66 Comanche, OH-58C, and UAV. For the KW variant, the AARS makes maximum use of available on-board aircraft components, such as the radar altimeter, the GPS, and an onboard computer. The AARS program was funded for EM&D for the OH-58D KW, but currently is unfunded.

8.4.4 Modeling and Simulation

Many models are available to estimate doses or predict radiation exposure patterns caused by changes in environmental factors. One such model is the Radiological Environment Modeling System, which computes the accumulated dose for humans working in radiological environments. The computation is based on timing, distances, shielding, and human activity. The model uses two commercial products, the Interactive Graphical Robot Instruction Program and the Devel/ERGO simulation software, augmented with custom code.[322]

However, there are no models a commander can use to determine how an AEF will perform in LLR. The key problem is that the basic human performance research simply has not been conducted. A useful tool would account for changes in such areas as available manpower, sortie rates, turnaround times, and pilot performance, in a LLR environment. A common assumption is that the acute effect of LLR is negligible. Under such an assumption, a model would use the permissible exposure times (based on chronic effects) to drive work schedules. Unfortunately, applicable policy does not exist. Models that do not use a lethality endpoint, but instead use an "operationally significant" performance decrement, need to be created for LLR environments.[323]

8.5 Responsible Parties

Armed Forces Medical Intelligence Center

Armed Forces Radiobiology Research Institute

Defense Special Weapons Agency

Low-Level Radiation Integrated Concept Team

U.S. Air Force Radiation Assessment Team

U.S. Marine Corps Incident Response Force

8.6 Points of Contact

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9.0 Radiofrequency Radiation

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9.1 Current Threat

As discussed in the previous chapter, the energy of electromagnetic radiation is a measure of the work the radiation can do. This energy usually is measured in eV. High-energy electromagnetic radiation, such as X-rays and gamma rays, contains enough energy — more than about 10 eV — to ionize a molecule in biological tissue. However, lower-energy radiation, called "nonionizing" radiation, contains far less energy than is required to ionize molecules. Nevertheless, the energy imparted on a molecule by nonionizing radiation may be enough to raise electrons to higher orbitals. This action can break chemical bonds (an effect of ultraviolet radiation) or produce heating (an effect of visible light and microwaves). RFR, microwaves, and infrared, visible, and ultraviolet light all are nonionizing types of radiation.

Electromagnetic energy is simply the result of the motion of electric charges through space. As they move, these electric charges create waves of electric and magnetic energy that spread in all directions, somewhat like the waves in a pool into which a stone has been dropped, except that electromagnetic waves move at the speed of light. Electromagnetic energy is characterized by its wavelength and frequency. The frequency is the number of waves that pass a fixed point in space in one second, or "cycles per second"; one cycle per second is a hertz (Hz). Wavelength is defined as the physical distance from one wave peak to the next; it is measured in meters, centimeters, or millimeters. The frequency spectrum of RFR is the range from 3,000 Hz (3 kHz) to 300 billion Hz (300 GHz), and the energy of RFR is about 10^{-6} to 10^{-5} eV. From the perspective of AEF operations, RFR is the most important form of nonionizing radiation. RFR includes radio-, micro-, and millimeter-wave radiation.[324]

The intensity of RFR at a particular place is dependent on the strength of the source of the radiation, on the distance from the source, and on whether the radiation is spread out or focused into a narrow beam. RFR can be measured by various instruments, which usually indicate the amount of power that passes through a given area (the power density). The power density is given in watts per square meter (W/m^2), but for convenience the units usually are stated as milliwatts per square centimeter (mW/cm^2). Field strength is sometimes used to compare types of RFR. A typical way to express field strength is in volts per meter (V/m). In the military, exposure standards for electromagnetic pulse, high-power microwave (HPM), and ultra-wide-band (UWB) radiation, the peak allowable field strength is 100 kV/m (kilovolts per meter).

In addition to frequency, wavelength, and intensity, RFR has other characteristics related to the way the radiation is formed by its transmitter. First, the energy may be produced as continuous-wave radiation, where the radiation is continuously produced by the transmitter. Alternately, the radiation can be "pulsed," with energy varying over time in either amplitude or frequency.

9.1.1 The Biological Effects of RFR

When RFR strikes a human or other biological object, some of the energy reflects, some refracts, and some is absorbed. How much is absorbed — the measure of interest for health and safety purposes — depends on the size and shape of the object and on the electrical characteristics of the tissue concerned. These electrical characteristics are in turn dependent on the amount of water the tissue contains. In general, the closer the physical size of the biological object to the wavelength of radiation, the greater the amount of energy absorbed. The amount of energy absorbed usually is stated in terms of the specific absorption rate and is expressed in power per unit body weight, e.g., watts per kilogram (W/kg).

For every biological object there is a "resonant" frequency — a frequency of radiation at which the object captures the maximum amount of energy. The resonant frequency depends on both the size and the orientation of the object. For the average human body, this resonant frequency is about 70 MHz (megahertz). At this frequency, the specific absorption rate (SAR) can be more than an order of magnitude higher than at nonresonant frequencies. However, the exposure for standing personnel will differ from exposure for personnel lying on the ground.[325]

The internal geometry and tissue electrical properties will cause the SAR to be nonuniform within most biological objects, and the nature of this nonuniformity will vary depending on the properties of the radiation. In general, internal organs and limbs will have higher resonant frequencies than the body as a whole because of their smaller dimensions.[326] Local areas of higher SAR often are referred to as "hot spots." The concepts of SAR, resonance, and hot spots are very important in health and safety considerations and in the development of standards.

The existing exposure standards for human health and safety all relate to thermal effects on biological systems. A specific absorption rate of 4 W/kg has been determined to be a threshold for such thermal effects, and the consensus by standard-setters is that reducing this value by a factor of ten, to 0.4 W/kg, yields a safe permissible-exposure limit. Air Force Occupational Safety and Health Standard 48-9, *Radiofrequency Radiation (RFR) Safety Program*, incorporates this guidance.[327] The standard takes into account a wide range of possible harmful biological effects, including effects on the eyes (e.g., cataracts) and reproductive organs. Limits related to damage from shocks, burns, and induced currents in the human body also are included in the standard.

Historically, the Air Force has been in the forefront of research on the biological effects of RFR, both conducting and funding investigations. In the early 1960s, the Air Force promulgated the first human exposure standard for RFR. Since then, the Air Force has actively participated in most standard-setting and is directly involved in writing the DoD and Air Force instructions on RFR personal protection. However, data are scarce on actual exposures. The many studies in the open literature on RFR effects deal primarily with environmental exposures,[328] and the studies usually have suspect documentation of exposure levels (or no documentation at all). The Air Force and Navy maintain databases of the few reported accidental exposures from radar and other transmitters.[329]

9.1.2 Military Considerations

Besides lasers (which are discussed in a separate chapter), the only nonionizing radiation that presents a meaningful threat to an AEF is RFR, but this threat to AEF resources and personnel could come from multiple sources. This discussion covers only direct threats to personnel, not indirect threats of electronic "spoof" or kill, which are electronic warfare (EW) topics. However, RFR can cause casualties (e.g., by causing an aircraft to crash) if it detonates explosives or disrupts critical electronic components.[330]

9.1.2.1 Weapon Applications of RFR

The HSC defines directed-energy (DE) weapons as "those weapons, or weapon system components, which use nonionizing electromagnetic radiation to detect, locate, disable, or destroy opposing weapons or assets. . . . Regardless of their primary purposes, all directed energy weapons deposit energy into their targets either by intent or as a side effect. This energy deposition results in an increase of the temperature of the target which produces the damaging effect."[331]

The primary target of radiofrequency weapons (RFWs) is electronics.[332] RF DE systems rely on raw power, either average or peak, to either burn out or saturate electronics or sensors in systems. On the other hand, EW systems are tuned to specific frequencies and wavelengths, based upon knowledge of the target construction and operation, in order to fool, or "spoof," the targeted system. Because of the importance of technology in modern AEF operations, almost every function — C^2, communications, maintenance, power generation, medical care, etc. — of an AEF could be vulnerable to DE and EW attack.[333] These attacks could severely disrupt the reachback on which the AEF will rely so heavily.

RFR transmitters usually are pulsed emitters and are distinguished by their high peak powers. The peak powers of this class of transmitters can be tens of gigawatts (thousands of millions of watts), although their average powers can be fairly low. This class of HPM transmitters has been developed only over the past 10 to 20 years. Currently, HPM transmitters are unique to the military. They are used in electronic warfare to burn out the enemy's electronic devices, not just jam or spoof them.

RFR transmitters come in two varieties: HPM and UWB. HPM transmitters emit most of their energy in single "narrow bands" of the frequency spectrum. In general, a narrow-band HPM transmitter will have a pulse width of a few hundred to a few thousand times that of the period of a single oscillation of the pulse. The periods of the narrow-band oscillations are fairly constant (all within a few percent of each other). In contrast, a UWB transmitter will have a pulse width so short that it has only a few oscillations in a single pulse. A UWB pulse sometimes has a very rapid initial rise of electromagnetic energy, reaching an extremely high peak field strength in only a few tenths of a nanosecond. Some UWB sources are able to produce initial radiated-peak electric field strengths that approach one million V/m.

9.1.2.2 Delivery Methods for RFWs

The typical RFW is a fixed or mobile system that fires a beam of energy at a target and can be used repeatedly. When fully "weaponized," this type of RFW may be used for:

- "Fixed or transportable air defense for fixed bases or ships against low-altitude aircraft and missile attack"
- "Mobile systems to protect armor formations against helicopters, missiles, and submunitions"
- "On-board aircraft self-defense systems for protection from missiles"
- "Predetonating mines with helicopter- or vehicle-mounted systems"[334]

A second type of RFW will be contained in a warhead and delivered to the target, where it will produce a single burst of RFR. This type of RFW might be applicable for:

- "Cruise missile systems to disable air defense systems"
- "Scatterable jamming systems"[335]

Because the information is highly classified, the capabilities and limitations of foreign and friendly RFWs will not be presented here. However, the Soviet Union had RFW development programs as long ago as the early 1970s,[336] and China still has an active program.[337] These programs are not likely to produce effective weapons for years. Still, recent demonstrations of the generation of RF pulses with peak powers of a gigawatt or more highlight the potential for future RFWs.[338]

9.1.2.3 Collateral Threat to Personnel

Most RF DE weapons are not targeted at personnel specifically, but personnel who work in or near DE weapons or targets of DE weapons will be exposed to RFR.[339] RFR threats to personnel can come not only from DE systems, but also from aircraft- and ground-based radar, communications, and EW systems.

An aircraft-based radar or DE system can be a health and safety threat to personnel when the emitter is improperly activated by aircrew or maintenance personnel while the aircraft is on the ground. Similarly, ground-based radar and DE systems can be health and safety threats when inadvertently activated during maintenance or if captured by the enemy and purposefully used against personnel. The chief difference between the radar and DE threats is the energy level, with DE emitting at much higher peak power and usually much lower average power. Based on the ranges involved, the threat to AEF personnel from enemy aircraft- and ground-based radar systems and from the secondhand emissions of enemy DE systems is negligible.

Aircraft- and ground-based communications systems can pose health and safety threats similar to those of radar systems, but with less severe effects. Communications transmitters tend to broadcast their RFR in all directions, while radar systems broadcast their RFR in directed beams. Hence, the power density of communications systems decreases much more rapidly than the power density of radar systems. The hazardous zone for a radar system is much larger than that of an equivalent-power communications system. Again, the ranges involved make the threat to AEF personnel from enemy communications systems negligible.

Aircraft- and ground-based EW systems could be health and safety threats with characteristics of both the radar and the communications systems. The level of the threat is likely to lie between the two. According to the ranges involved, the threat to AEF personnel from foreign EW systems is negligible.

The physical effects of high exposures on personnel can be fever and death. The typical symptoms of RFR exposure arise from the heating of tissue:

- “Feeling hot”
- “Heat exhaustion”
- “Surface and subcutaneous burns”
- “Lymphocyte inhibition”
- “Protein denaturization”
- “Cataracts”
- “Destruction of sensitive linings of the stomach and testes”[340]

The reports of effects of RFR on the central nervous system are contradictory, but these symptoms may include “feelings of uneasiness, neurosis, autonomic nervous system disruption, headaches, and grand mal seizures.”[341] Similarly, no consensus exists on the cardiovascular responses, but “bradycardia and tachycardia, hypertension and shock, hypertonia and hypotonia, and both atrial and ventricular dysrythmias have been reported. . . .”[342]

Finally, concern about the possible health consequences from exposure to RFR could have a psychological impact on AEF forces. The popular press has suggested a link between RFR and many dangerous illnesses, such as cancer. Although there is almost no scientific support for these suggestions, the fear of the unknown can affect the performance of some individuals. Education in the validated effects of RFR is the best means to avoid this problem.

9.2 Current Countermeasures

No specific countermeasures, such as RFR-protective suits, exist. Given the current knowledge of the effects of RFR exposure, such countermeasures are not necessary. However, detection of possible threats and treatment of accidental exposures are important today.

9.2.1 Detection

Detection requires appropriate measurement instruments and personnel trained to use them and to interpret the results based on established scientific RFR standards. The Air Force is not currently prepared to detect RFR threats to personnel.

9.2.2 Medical Treatment

Why RFR affects personnel the way it does is not well understood, but it is clear that "different RF weapons in different situations will produce injuries in different organs in different individuals."[343] This disparity in symptoms hampers not only triage and treatment, but also complicates the creation of appropriate regulations and protocols. Currently, no such documents exist.[344]

Part of the difficulty in identifying and treating RFR injuries comes from the similiarity of the symptoms to those of other, non-RFR injuries. For example, heat exhaustion caused by RFR may be blamed on environmental conditions. When there is no known RFR threat, medical personnel will simply treat the symptoms in standard fashion. In fact, because the biological effects of RFR are not understood, such treatment may be the best course of action until appropriate research is conducted.[345]

9.2.3 Medical Support Requirements

The lack of understanding of RFR bioeffects has a significant impact on all aspects of medical support for AEFs. At present, Air Force planners cannot determine the requirements for a number of medical support functions. First, if RFR bioeffects are simply thermal, as is currently assumed, then the current materiel requirements may cover RFR medical support. Planners cannot factor medical evacuation requirements into their airlift equations. Some RFR bioeffects, such as the loss of function of an internal organ, will require the patient's immediate evacuation to CONUS. As long as the number of such casualties is not too high, the usual medical evacuation facilities should suffice. Planners cannot determine the requirements for deployable facilities for treatment of RFR casualties. None of the Services has a medical training program for treatment of RFR casualties. Again, the current medical training may suffice. However, "the potential for internal injuries with few external signs or symptoms, for instance burns of internal organs, will pose special challenges to triage, diagnosis, and treatment. Knowledge that RFR weapons may be deployed and the effects they would produce in the theater of operations would greatly augment the diagnostic awareness of the physician."[346] Programs to provide protection for medical personnel and hardening of medical facilities do not exist.[347]

9.2.4 Research and Development

"Most research and development related to RFWs is classified and is expected to remain so."[348] Most of the available unclassified studies of occupational hazards address the determination of injury thresholds and environmental intensity levels. These intensities are much lower than those that would be expected from RFWs, so these studies have little relevance. The data on accidental injuries from radio and radar sources have some value, but they are not correlated carefully to exposure level.[349]

9.3 Future Threats

In general, the kinds of future nonionizing radiation threats should be similar to the current threats, but the severity and likelihood of occurrence probably will be higher. Also, RFW development programs like those in China and the former Soviet Union could produce field-ready RFWs at some time in the distant future.

9.4 Future Countermeasures

Future countermeasures include detection, casualty care, research, training, and planning.

9.4.1 Detection

There is no known operational impact of nonionizing radiation on the AEF environment. However, the development of countermeasures should focus on measuring nonionizing fields during operations to help prevent damage that might occur indirectly from equipment rendered ineffective by EW.

Detection of a possible threat requires appropriate measurement instruments and personnel trained to use them and to interpret the results appropriately. An AEF should include a person trained in RF field measurement, and the AEF equipment should include a fail-safe overexposure warning device. There is no fielded RFR overexposure warning device, but such a device is in the beginning stages of development by the Air Force.

This device, the Personal Radiofrequency Radiation Dosimeter (PRRD), is a film badge that integrates the RFR exposure of personnel or equipment by changes in slow fluorescence on a polymer-coated plastic film. The detectors are small, and a fielded system will be hardened, inexpensive, and easy to distribute widely in the operational theater. This wide distribution will help trace exposures and identify sources, even after they have been destroyed or removed.

The film is activated to record RFR exposure only when exposed to long-wavelength or near-ultraviolet light. This process is completely passive, and the film can be collected for interpretation at a centrally located solid-state fluorometer. A system enhancement will allow the film to be read remotely with a laser system. The basic dosimeter concept has been reduced to practice and patented by the Air Force. With appropriate funding, a prototype could be produced in FY 00. Such a system would benefit an AEF by detecting HPM and other EW exposures to personnel and equipment.

The next-generation personal dosimeter will sense the nominal wavelength and intensity of the incident RFR. This device will be immune to high temperatures and will have readout devices that are hardened against high-level RFR. As with the PRRD, the device will require no electrical power or maintenance, will be effective in small numbers, and will be unobtrusive when worn by the entire range of AEF personnel. Because of the nature of RFR, personnel exposed to the same attack will have widely different absorption profiles and different affected organs. This sensor will provide a definitive indication of RFR exposure. Therefore, it will greatly speed triage and reduce the diagnostic spectrum for each patient.

Finally, in a Small-Business Innovative Research program, the Air Force is developing a laptop computer-based RF Hazard Assessment Tool that will simplify assessment of potential RFR threats.

9.4.2 Medical Requirements for the RFR Threat

According to the 1996 HSC Study "Treatment of Directed-Energy Casualities Strategic Plan," "the major roadblock to developing a CONOPS for RF casualty care is the uncertainty of the injuries produced by RF weapons."[350] Information on RFWs, such as a CONOPS, should be developed. The material in Section

9.4.2 is taken nearly verbatim from the HSC's 1996 "Treatment of Directed-Energy Casualties Strategic Plan."[351]

9.4.2.1 RFW Medical Threat Study

Because of the classified nature of DE weapon research and development, access to and dissemination of the information needed for medical and air evacuation planning was not available for the HSC report. A classified study to determine the state of knowledge of RFW effects and potential casualties would be useful. A team of critical care, air evacuation, and electromagnetic bioeffects specialists could conduct the study with the participation of the Tri-Service DE laboratories at Brooks AFB and any other laboratories active in DE bioeffects research and weapons development. The scope of the study might include the immediate and future requirements for materials, facilities, and training; the effects of possible injuries on doctrine, materiel, and training requirements for casualty triage, diagnosis, treatment, and evacuation in both the theater and the CONUS; protection of medical assets and patients; and estimates of casualty rates. The study could be the basis for a CONOPS for treatment and air evacuation of DE casualties.

9.4.2.2 Casualty Treatment Development

A possible solution to the uncertainties of RFWs would be the establishment of a Casualty Treatment Development Program. Because DE weapons pose a threat to all Services, the casualty treatment development program would be most effective as a Tri-Service program. The program could monitor the development of DE weapons and, based on their bioeffects, develop casualty treatments for viable threats. The program also could develop training programs for AEF personnel.

9.4.2.3 Casualty Treatment Hotline

A hotline service, similar to the AFMIC hotline, for theater personnel to contact in the event that they learn of potential DE threats would be useful, especially in the event of an unanticipated DE weapon attack. In response to a call, the hotline office could assemble a response team to assess the probable injuries the specific weapon could produce, the necessary medical resources to diagnose and treat the casualties, and the CONUS facilities best suited for receiving evacuated casualties. Using the assessments provided by the response team, the theater medical officer could then select the appropriate equipment, supplies, and protective measures needed for deployment.

9.4.2.4 Protocol for Medical Response to RFW Threats

Until such time that RFW threats and their bioeffects are known to a high level of certainty, it will not be possible to develop either informal or formal doctrine for the treatment of RFW casualties. It is probable that RFW threats will be limited to a few theaters of operations and that their first use may not be anticipated. In the event of a RFW attack, medical service commanders will need access to agencies with the expertise to develop a medical response to the threat or attack. A protocol for responding to known or perceived RFW threats that provides points of contact and resources could provide a short-term solution to the inability to provide a formal doctrine and CONOPS for RF casualty care and evacuation.

9.4.2.5 Casualty Treatment Materiel

A review of existing materiel lists and the correction of any deficiencies would enable deployed and CONUS medical facilities to prepare for treatment of casualties. Knowledge of CONUS facilities capable of treating RFW injuries and the facilities' known capacities is crucial to efficient regulation and air evacuation of casualties. In addition, equipment and facilities required for new treatment methods under development should be identified. Based on existing facilities capabilities and capacities, medical casualty regulating systems for referral of RFW casualties should be updated. Upgrades of CONUS facilities deficiencies should be programmed to conform to the time frames of expected RFW deployments. The development of a rapid-response procurement system to provide supplementary materials and supplies needed to respond to unanticipated attacks also is important.

9.4.2.6 RFW Susceptibility Analysis and Hardening of Medical Equipment and Facilities

Medical facilities and their electronic-dependent assets (monitors, power systems, clinical laboratory devices), while not likely primary targets of RFWs, will be located in close proximity to targets, and collateral damage can be expected. The bioeffects, while secondary, can affect medical personnel and patients, further compromising the mission of medical unit and air evacuation systems. Hardening of medical electronic assets and facilities is, therefore, as necessary as for other military systems, and current assets should be evaluated for their susceptibility to RFW threats. This susceptibility analysis could be done in conjunction with other RF susceptibility test programs.

9.4.2.7 Medical Facility and Personnel Protection

A program to investigate and develop protection of deployed medical personnel, facilities, and patients is needed. Incorporation of lightweight electromagnetic shielding into deployed structures as a means of providing personnel protection and additional protection for medical electronics, computers, and communications appears to be a possible solution. Various conductive materials, such as metal-coated plastic sheeting, fabrics woven of threads containing fine wires, and conductive polymeric coatings, are available. These materials could be used to manufacture tents or could be laminated with tent canvas to make tents into “shielded rooms.” Personnel protection against RFWs could be incorporated into fatigues, flight suits, and NBC individual protective equipment. Solutions that provide partial protection via attenuation of incident fields also are possible. In fact, complete shielding at all frequencies may not be possible, much less practical.

9.4.3 Research

Issues relating to conventional radar and low-level exposure are adequately researched and funded. Still, research is required to assure that HPM and UWB systems, which are likely to be more prevalent on the battlefield, do not produce unexpected acute or chronic health effects.

To rationally develop exposure standards, the expanding biological database must be continuously evaluated. The resulting data must be used to establish permissible exposure levels for occupational situations in the military. For both candidate research systems and operational systems, electromagnetic signals unique to the military (e.g., ultra-short wavelength, fast-rise-time radiation) must be assessed for potential hazardous bioeffects.

Benefits of this health and safety effort will include risk definition for developing systems and fast-response capability. This fast-response capability will answer a wide range of operational concerns related to current electromagnetic radiation threats and modern warfighting scenarios. Data from this effort will affect criteria for new weapon systems, protection criteria for countermeasures, development of realistic guidelines for aircrew protection, and the overall environmental impact of military operations.

9.4.4 Training and Planning

Training and planning for AEF operations should involve personnel sufficiently knowledgeable in the principles of RFR and the associated environmental, health, and safety issues. These personnel can help ensure that legitimate concerns are addressed and that unreasonable fears are minimized. The training could be arranged through the Air Force RFR Consulting Function or could be developed within other AEF training venues. Attention should be given to the development of inexpensive RFR overexposure warning devices. The future of an RFR threat to the AEF depends upon the evolution of DE weapons under development by both the U.S. and other nations.

The first resource for AEFs is Air Force bioenvironmental engineers. To supplement their expertise, preparations for AEF operations should include appropriate Memoranda of Agreement with Air Force RFR consulting and research groups to provide consultation, training, and emergency research, as required.

The requirement to understand the medical environmental and operational impact of RF-emitting devices will not disappear. Readiness must be maintained to respond to both U.S. and foreign emerging RFR weapon technologies. There are limited facilities and expertise available for conducting this type of work, and these resources cannot be easily regenerated on an emergency basis. Thus, the Air Force investment in this area must be preserved.

9.5 Responsible Parties

Bioenvironmental Engineers

Defense Reliance Technology Panel for Directed-Energy Weapons

Institute of Electrical and Electronics Engineers Standards Coordinating Committee for Nonionizing Radiation

NATO General Medical Working Party

Tri-Service Electromagnetic Radiation Panel

U.S. Air Force Office of the Surgeon General

U.S. Air Force Research Laboratory

U.S. Air Force RFR Consulting Function

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10.0 Dangerous Flora and Fauna

James S. Ice and Valerie J. Gawron

10.1 Current Threats

The threat from hostile flora and fauna is very real, although perhaps not as extensive as other threats described in this report. For example, the Joint Task Force in Southwest Asia has experienced 47 cases of injuries associated with hostile fauna since December 1996. Also, there was one shark attack in Mogadishu during Operation Provide Comfort. However, no cases of injury due to hostile flora have been reported in the desert environment. Table I-48 lists hostile flora and fauna that may threaten an AEF.

Table I-48. *Hostile Flora and Fauna*

Hostile Flora	
Poisonous Flora	
	Poison ivy
	Poison oak
	Poison sumac
Thorns	
Hostile Fauna	
Insects	
	Arachnids
	Biting flies
	Cockroaches
	Filth flies
	Fleas
	Lice
	Mites
	Mosquitoes
	Parasites
	Stored-products pests
	Ticks
	Venomous arthropods
Carnivores	

10.2 Current Countermeasures

Countermeasures include avoidance and casualty care.

10.2.1 Hostile Flora Countermeasures

The only countermeasure for hostile flora is to avoid the plants. Deployment and employment training of personnel must include briefings on indigenous hostile flora. Herbicides, which would seem to be a useful countermeasure, may be used only with the permission of the President.

A number of information resources and databases are available for use in planning for deployments and preparing training materials. The Navy Preventive Medicine Information System includes up-to-date

"Disease Risk Assessment Profiles" and "Disease Vector Risk Assessment Profiles" for most countries of the world. In addition, the Defense Pest Management Information Analysis Center publishes "Disease Vector Ecology Profiles." However, the most complete source of information is the MEDIC database, published on CD-ROM by AFMIC.

MEDIC is readily available to the base-level Public Health Officer and Flight Surgeon for use in advising Air Force personnel about health conditions in the countries to which they are deploying. This resource was developed by AFMIC in collaboration with the Services. AFMIC's "Disease Environmental Alert Report" CD-ROM was the vehicle for the preventive medicine information and reference materials agreed upon by the Air Force, Army, Navy, and Coast Guard. The completeness of the information in MEDIC eliminates the old cumbersome process of calling numerous sources of information. Formerly, many Public Health Officers were forced to augment Department of Defense sources with commercial products to help fill information gaps, often with incomplete results. Now, MEDIC provides all the predeployment, medical, and travel information required for the different Air Force missions throughout the world.

10.2.2 Hostile Fauna Countermeasures

The countermeasures to the threat from hostile fauna include preventive measures and medical treatment.

10.2.2.1 Prevention

Just the presence of humans and their facilities and equipment generally is enough to prevent encounters with carnivores. In the few situations in which animals are not deterred by the human presence or actually move into areas populated by humans, education and appropriate public health measures will prevent all but chance encounters. Education about the indigenous shark population would have prevented the shark attack in Mogadishu. In some parts of Alaska and Canada, bears commonly invade human communities, usually in search of food. Careful attention to public health procedures will help prevent these events.

Prevention of hazards caused by insects, vermin, and pests is a more involved process. Again, education and public health procedures are important. For example, the introductory pamphlet issued to all personnel of the 4400th Operations Squadron (Provisional) at Taszár Air Base, Hungary, stresses cleanliness (e.g., no food in tents, no piles of clothes on floors) to avoid rat infestations (and the snakes that follow the rats). This pamphlet also clearly identifies the local venomous snakes and insects.

Ultimately, the use of pesticides may be necessary to control insects, vermin, and pests. Air Force Regulation 91-22, *Aerial Dispersal of Pesticides*; Air Force Instruction 32-1053, *Pest Management Program*; and DoD Instruction 4150.7, *Pest Management*; all provide guidance on the use of pesticides. Table I-49 is a list of standard pesticides available for military use.

Table I-49. *Standard Pesticides for Military Use*

Type	*Composition (Trade Name)*	*Unit Package*	*Unit Cost*	*Using Services*
Algaecide	Copper sulfate, 80.16 percent pentahydrate, crystal (Cuprose)	50-lb bag	NA	Air Force, Army
Fungicide	Wood preservative, copper naphthenate mixture (MIL-W-18142 TYA)	55-gal drum 1-gal can	$1,013.78 $66.69	Army, Navy Air Force, Army, Navy
Fungicide	Methylisothiocyanate (MITC-FUME)	9 tubes/box	NA	All
Herbicide	Borate-bromacil mixture, 94 percent sodium metaborate tetrahydrate, 4 percent bromacil, granular (Borocil IV)	50-lb bag	$116.95	Air Force, Army, Navy
Herbicide	Bromacil, 21.9 percent lithium salt of bromacil, liquid (HYVAR X-L)	Two 2.5-gal cans/box	$226.31	Air Force, Army, Navy
Herbicide	Bromacil, 40.8 percent, water-soluble liquid (Bromax-4L)	5-gal can	$804.44	Air Force, Army, Navy
Herbicide	Bromacil, 80 percent, wettable powder (HYVAR X)	Twelve 4-lb bags/box	$687.50	All
Herbicide	Chlorate-borate mixture, 30 percent sodium chlorate, 68 percent sodium metaborate tetrahydrate, granular (Monobor Chlorate)	50-lb bag	$69.75	Air Force, Army, Navy
Herbicide	Diuron-bromacil mixture, 40 percent diuron, 40 percent bromacil, granular (Krovar I DF)	6-lb bag	$56.72	Air Force, Army, Navy
Insecticide	Cypermethrin (Demon WP)	1-lb jar	$49.00	All

10.2.2.2 Medical Treatment for Injuries From Hostile Fauna

In cases of attacks by carnivores, medical personnel use standard first-aid, emergency, and trauma procedures. The “Infectious Disease and Injury” chapter (see section 12 of this report) covers medical treatment of injuries.

Effective treatment of a bite or sting from a venomous animal or insect usually requires application of the appropriate antivenin. AEF planners must ensure that AEF medical personnel have the antivenins for the local poisonous fauna. MEDIC lists antivenin producers, sorted by region of the world. Table I-50 is a sample list.

Table I-50. *Sample List of Antivenin Producers*[352]

Producer	***Antivenin***	***Known to Be Effective Agent Against***	***Remarks***
AFRICA			
Institut Pasteur d'Algerie Rue du Docteur Laveran Algiers, Algeria Phone: 21-32-672511 Fax: 21-32-672503 Telex: 65627	Antiviperin	*Cerastes cerastes* *Vipera lebetina*	Current as of 1991
Al Algousa Sharea Alvezara Cairo, Egypt Phone: 2022575829	Anti-*Cerastes cerastes* *C. vipera*	*Cerastes cerastes* *C. vipera*	Current as of 1991
Same as above	Polyvalent antivenin	*Naja haje* *Cerastes cerastes* *C. vipera*	Current as of 1991
Institut Pasteur du Maroc 1 Place Charles Nicolle Casablanca, Morocco Prof. Abdellah Benstimane	Purified bivalent antiviperin serum	*Cerastes cerastes* *Vipera lebetina*	Horse serum. Mainly for internal use but can be exported. 100,000 doses (10 ml) available. Unit price is 70.20 dirhams. Liquid form with a shelf-life of 2 years.

10.3 Future Threats

The future threat is the same as the current threat.

10.4 Future Countermeasures

MEDIC is regularly updated and will continue to be the best resource for AEF planners and personnel.

10.5 Responsible Parties

Armed Forces Medical Intelligence Center, Fort Detrick, MD 21701, (301) 663-7511

Armed Forces Pest Management Board

Defense Pest Management Information Analysis Center publishes Disease Vector Ecology Profiles

Navy Environmental Health Center, (757) 444-7575, ext. 456

U.S. Air Force Civil Engineer Support Agency (AFCESA), Tyndall AFB, FL, DSN 523-6465

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In addition, the Services have many points of contact throughout the world for entomological issues. Table I-51 lists them.

Table I-51. *U.S. Military Medical Entomology Points of Contact Overseas*[353]

Country	*Unit/Address*	*Telephone Number*	*Service*
Brazil (Brasilia)	Commander USAMRU-BRASILIA American Embassy — Brasilia APO Miami 34030	055-0610272-4548	Army
Egypt (Cairo)	Commanding Officer NAMRU-3 APO New York 09257	820-727	Navy
Germany (Landstuhl)	Commander 10th Medical Laboratory APO New York 09180	06371-86-8391/7211 DSN 433-1110 Ext. 8391	Army
Germany (Ramstein)	HQ USAFE/DEMO APO New York 09012-5001	06371-47-6846 DSN 480-6846/7306	Air Force
Hawaii (Honolulu)	Tripler Army Medical Center Preventive Medicine Activity Honolulu, HI 96859-5000	808-433-6693/6731 DSN 433-6694/6731	Army
Hawaii (Pearl Harbor)	Officer-in-Charge NEPMU-6 Box 112 Pearl Harbor, HI 96860	808-471-9505 DSN 430-0111 Ext. 471-9505	Navy
Indonesia (Jakarta)	Commanding Officer NAMRU-2 Jakarta Detachment APO San Francisco 96356	62-21-41450	Navy

Country	Unit/Address	Telephone Number	Service
Italy (Naples)	Officer-in-Charge NEPMU-7 Box 41 APO New York 09521	081-724-4468 DSN 625-4468	Navy
Japan (Okinawa)	DET 1 AFOEHL/MEC APO San Francisco 96239-5000	DSN 634-0476	AF
Japan (Okinawa)	Commanding Officer U.S. Naval Hospital Box 244 Attn: Occupational and Preventive Medicine Service FPO Seattle 98778	DSN 634-0105/0228	Navy
Japan (Sagami)	Commander USAPACEHEA — Japan APO San Francisco 96343	DSN 228-4112/4113	Army
Kenya (Nairobi)	Commander USAMRU-K Box 401 APO New York 09675	254-2-722541, Ext. 311	Army
Korea (Yong San)	Commander LA Detachment 5th Preventive Medicine Unit APO San Francisco 96301	DSN 293-8087/8756	Army
Panama (Atlantic side) (Ft. Gulick)	Commander U.S. Army MEDDAC (Panama) Preventive Medicine Services (Atlantic Section — Ft. Gulick) Box 445 APO Miami 34008	83-4701/4774 DSN 283-4701	Army
Panama (Pacific side) (Ft. Clayton)	Commander U.S. Army MEDDAC (Panama) Preventive Medicine Services (Pacific Section) APO Miami 34004	DSN 313-285-5602	Army
Peru (Lima)	Officer-in-Charge NAMRID Lima, Peru APO Miami 34031	011-51-14-52-96-62	Navy
Philippines (Subic Bay)	Officer-in-Charge Branch Clinic, Box 32 U.S. Naval Station APO San Francisco 96651-1612	DSN 884-3669/3730	Navy
Thailand (Bangkok)	Commander U.S. Army Medical Component AFRIMS APO San Francisco 96346	66-2-282-8141 Ext. 283	Army

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Department of Defense, *Pest Management*, DoD Instruction 4150.7, 22 April 1996.

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11.0 Fatigue

Valerie J. Gawron and Jonathan French

11.1 Current Threats

> This is the hour I've been dreading; the hour against which I've tried to steel myself. . . . This will be the worst time of all, this early hour of the second morning—the third morning, it is, since I've slept. . . . My eyes close and stay shut for too many seconds at a time. No mental effort I exert can hold them open. I've lost command over their muscles . . . . I've got to find some way to keep alert. There's no alternative but death and failure.
>
> — Charles Lindbergh, *The Spirit of St. Louis*[354]

Charles Lindbergh's remarkable accomplishment in 1927 — the first successful solo flight across the Atlantic — is well documented in his book. Lindbergh never would have pushed his airplane beyond its design specifications because he was an excellent pilot. However, he made his 36-hour mission far more dangerous than it might have been by depriving himself of sleep for several days before he took off. Future Aerospace Expeditionary Force missions, particularly long-range air-bridge support operations and long-duration bomber missions, may be more dangerous than necessary unless AEF planners treat fatigue as a deadly threat.

> They were dull-eyed, bodily worn and too tired to think connectedly. Even a 30 minute flop on the turf with the stars for a blanket would have doubled the power of the body and quickened the minds of its leaders to ideas which they had blanked out. But no one thought to take that precaution. The U.S. Army is indifferent toward common sense rules by which the energy of men may be conserved in combat. . . . Said Captain Patch . . . "I spoke jerkily, in phrases because I could not remember the thought which had preceded what I said."[355]

There were 70 cases of fatigue in AEF IV from December 1996 to May 1997. These were caused by any of a number of weaknesses in Air Force operational plans and procedures:

- Lack of a Concept of Operations for fatigue management
- Operations planning that does not always try to minimize desynchronosis
- Lack of rest facilities
- Lack of metrics to assess fatigue effects on aircrew performance
- Training that is not performed at the same pace and time of day the mission will be
- Unpredictable duty cycles, which induce fatigue
- Shift work, which decreases vigilance
- MREs that are not the correct food for fitness and alertness

11.1.1 Combat Operations

During the span of combat air operations in Operation Desert Storm (16 January through 28 February 1991), the Air Force flew 67,151 sorties. Given this intense tempo of operations, it is no surprise that fatigue was the most significant and pervasive aircrew problem. Real-time acquisition of intelligence made targeting and retargeting information available more rapidly than in past wars, so crews and aircraft could be turned much more quickly than ever before. Combat air patrol missions of 6 to 8 hours were routine and often were followed immediately by 6- to 8-hour scramble alerts. Heavy air tasking orders, especially at the start of the war, forced significant deviations from normal crew rest and scheduling practices. At some locations, tanker crews worked schedules of 12 hours flying, 12 hours off, and 12 hours alert. Thirty-hour crew duty days existed and crew-rest periods of less than 6 hours were not uncommon. Sleep periods in many locations were interrupted by jet noise and SCUD missile alerts.[356]

Dedicated "day" and "night" squadrons worked well, but some flight surgeons thought line commanders had a poor understanding of the effects of stress and chronic fatigue. Many flight surgeons believed the aircrews were pushed to their limits, and that substantial adverse impact on performance and flying safety would have occurred had the war lasted any longer. In fact, fatigue was a consideration in at least two fatal non-combat mishaps during Operation Desert Storm.

11.1.2 Fundamentals of Fatigue

Fatigue is multifaceted and complex. The effects of fatigue not only overlap the areas of performance, physiology, cognition, and emotion, but also combine with other states, such as boredom or drowsiness.[357] The two general types of fatigue are peripheral (physical) fatigue and central (mental) fatigue.[358] Physical fatigue generally is defined as a reduction in capacity to perform physical work as a function of preceding physical effort. Mental fatigue is inferred from decrements in performance on tasks requiring alertness and the manipulation and retrieval of information stored in memory.[359] Both types of fatigue are known to have influenced aircrew performance since World War II. Figures I-51 and I-52 depict data on navigator errors during night sorties in World War II.[360]

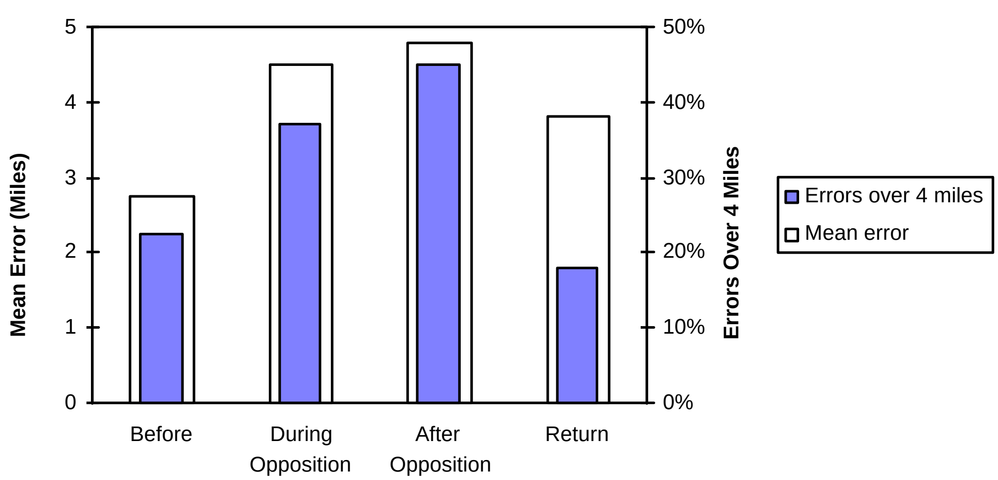

Figure I-50. *WW II Operational Night Sorties: Mean Navigational Errors vs. Enemy Opposition*

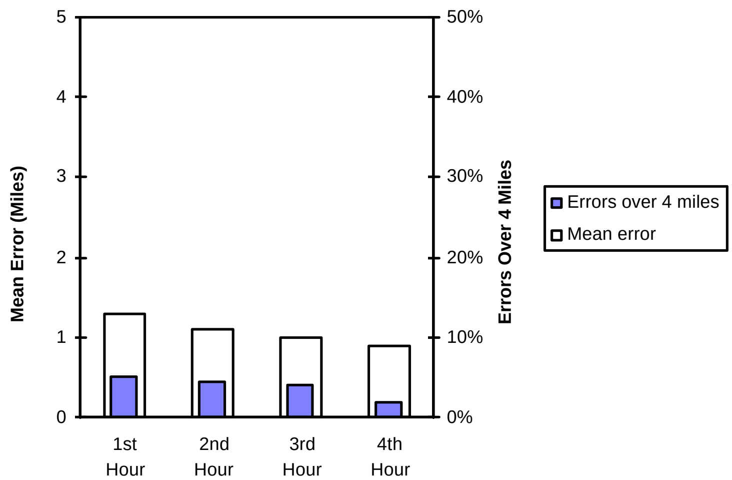

Figure I-51. *WW II Non-Operational Night Sorties: Mean Navigational Errors by Time Into Flight*

The original concept of fatigue was measurable decrements in performance of an activity that are caused by the extended time performing the activity.[361] This definition led to the traditional understanding that as a subject's time on task increases, performance will decrease in a linear fashion.[362] However, a linear relationship between driving time and accident rates has, for example, not been found. Instead, researchers have found a variety of high and low performance rates with different driving durations.[363, 364, 365, 366] From these studies evolved the question of whether the task or some other associated factors create the fatigue.[367]

A 1983 study of naval aviation accidents suggested that the major contributors to fatigue may be the total time spent at work (inclusive of the task) and the time of day at which the work is done.[368] Other researchers also have studied this relationship.[369, 370] In 1996 Stoner used anonymous questionnaires, physiological measurements (mean arterial pressure, pulse, and pulse pressure), the Armed Forces Vision Tester, and hematologic measurements (complete blood count and sedimentation rate) to try to predict early fatigue in 42 Navy EP-3E aircrews. However, none of the physiological or hematologic measurements varied between fatigue and normal states, although 14 percent of personnel did show increased tendencies for visual phorias.[371] In a study of sleep duration, subjects limited to mean sleep durations of 5.2 hours per night for 4 weeks, 4.3 hours per night for 4 nights, and 5.3 hours per night for 18 nights showed no performance decrements in logical reasoning or auditory vigilance, but did show performance decrements in a test of ability to ignore distracting information.[372] In addition to time spent working and time of day, studies of fatigue are confounded by such factors as motivation, coping strategies, and circadian rhythms. These related issues are summarized below.

Landing or takeoff under emergency conditions, dealing with in-flight emergencies, and ingress under fire are difficult circumstances for the most vigilant crews, and burdening crews with fatigue from sleep deprivation can cripple their abilities to deal with emergencies. In fact, the Air Force Safety Center relates that there were 92 Class A incidents — those that involve over a million dollars worth of damage or loss of life — between 1972 and 1995.[373] Sixty percent of these incidents were related to sleep deprivation. Fewer were related to circadian disruption, although these two factors could be quite closely linked for the AEF.

Long transmeridian flights have almost three times the incident rate of shorter flights.[374] The fact that human error or loss of cockpit coordination causes as many as 75 percent of accidents strongly implicates fatigue and circadian disruption.[375] Dramatic deficiencies in operational performance also are easily observed in simulator tests (in commercial airline aircraft simulators, for example).[376]

As crew time in missions becomes longer, overseas staging areas become reduced, and night operations become more important, fatigue will be an increasingly significant threat to mission success.[377] In addition, repetitive missions may lead to chronic fatigue and increase the human cost of long-endurance missions. Frequently, these operations involve multiple days of sustained operations with little sleep or poor sleep between missions.[378] The impairment associated with repetitive, long-duration flights was recently documented during Operations Desert Shield and Desert Storm[379, 380] and in a simulator study.[381] Much can be done to prepare for long-duration activities,[382] and the simulator study showed that appropriate coping strategies help crews reduce fatigue and improve performance during sustained, long-duration air combat missions. Training for long-duration missions now is an important part of operational responsiveness.

Circadian rhythms have a marked effect on performance. For example, the post-lunch and pre-dawn hours are periods of decreased driving ability.[383] Accident data suggest a marked contribution of fatigue to accidents during the night hours.[384] The time of day when sleep is taken also affects fatigue — sleep taken during the day typically is shorter in duration and less restful than night sleep.[385] These factors are discussed in more detail later in this chapter.

11.1.3 Fatigue Factors

Many factors have been identified in past research. These factors are summarized in Table I-52 and discussed in more detail in the subsequent paragraphs.

Table I-52. *Summary of Fatigue Factors*

Factor	***Summary***	***References***
Age	Fatigue-related accidents appear to be related to driver age and time of day.	Summala and Mikkola, 1994 Harris and Mackie, 1972 Smith, 1989
Work-rest schedules	Irregular work-rest scheduling can disrupt circadian rhythms and has been associated with fatigue in driving tasks.	Tilley et al., 1982 Hertz, 1987 Mackie and Miller, 1978
Circadian rhythms	Sleep quality is affected by time and regularity of the sleep period, and this can affect propensity to fatigue-related problems.	Foret and Lantin, 1972 McDonald, 1981 Edmondson and Oldman, 1974
Motivational factors	Experienced truck drivers learn how to cope with fatigue while driving at night. These drivers tend to move to better-run companies.	Hamelin, 1987 McDonald, 1989 Wyckoff, 1982
Coping	Prolonged time at a task leads test participants to favor speed at the expense of accuracy.	Welford, 1968 McFarland, 1953 Brown, Tickner, and Simmons, 1970
Total time spent working	Total time spent working is a major contributor to fatigue.	McDonald, Fuller, and White, 1991 Hamelin, 1981, 1987 Harris and Mackie, 1972

11.1.3.1 Age

Fatigue problems vary with age. Because younger drivers are more sensitive to motivational pressures from peers, they tend to resist or delay taking breaks in spite of fatigue. Younger drivers also take more deliberate risks than older drivers.[386] The tendency of younger drivers to resist fatigue is one factor leading them to drive more at night than older drivers. These younger drivers cause proportionately more accidents by falling asleep at the wheel than older drivers, who tend to avoid prolonged driving at night and take rest breaks.[387] However, older drivers suffer more attention lapses attributable to fatigue during the afternoon hours, especially after lunch.[388] Table I-53 is a breakdown of fatal accidents by age and hour of the day.

Table I-53. *Number of Drivers in Fatal Accidents*[389]

Age (Years)	Time of Day				
	0000-0600	0600-1200	1200-1500	1500-1800	1800-2400
18 – 20	16	3	0	3	8
21 – 35	7	9	7	5	7
36 – 55	5	8	9	8	6
56+	3	2	5	16	3
Total	31	22	21	32	24

$N = 130$, $X^2(12) = 44.0$, $p< 0.001$.

Langlois et al. performed a similar analysis of single-vehicle accidents and found a major diurnal peak from 0100 to 0600 hours and a secondary peak, especially among older drivers, from 1300 to 1700 hours.[390] These peaks appear to follow a general pattern associated with circadian rhythms (discussed in more detail below) and the same hourly distribution of fatigue-related problems in many other activities.[391]

11.1.3.2 Work-Rest Schedules and Sleep Deprivation

Irregular work and rest scheduling, like that experienced by many professional drivers, disrupts normal circadian rhythms. This disruption has been associated with fatigue and performance decrements.[392] For example, professional drivers who use sleeper berths to accumulate rest are three times more likely to be involved in a fatal crash than their counterparts who do not use sleeper berths.[393] This effect has been attributed to Federal regulations that allow drivers to accumulate the required eight hours of off-duty time in two nonconsecutive periods. Drivers with sleeper berths also reported more subjective fatigue than other drivers, and studies of steering, lane tracking, and lane drifting have shown a performance decrement for drivers with sleeper berths.[394]

The effects of shift work on sleep schedules will be important for 24-hour AEF operations, in part because sleep during the day is not equivalent to sleep during the night. A study of train engineers on irregular work schedules showed that subjects who went to sleep after midnight slept for shorter periods of time, and that subjects who slept during the day had a qualitatively different type of sleep than that obtained at night.[395] For professional drivers, shift work poses two problems: maintaining concentration and attention at a time when the circadian rhythm is at a low level, and obtaining enough quality sleep when circadian rhythms and social factors are not favorable for this.[396] Performance measures, obtained in both lab and operational settings, show circadian fluctuations that range from 10 to 190 percent of mean performance, depending primarily on the task. The greatest decrements occur during the circadian trough, which is typically between 0200 and 0700 hours,[397] so working at these hours can be a particular challenge. Lack of sleep will cause more concentration and attentional problems while driving and probably lead to cumulative sleep loss and fatigue. In interviews, nearly all shift-working truck drivers said they suffered from drowsiness at some time while working, and 60 percent suffered from drowsiness very often while working.[398] Finally, night work can lead to health problems, including sleep disorders, gastrointestinal disorders (colitis, gastroduodenitis, peptic ulcers), neuro-psychic disorders (chronic fatigue, depression), and cardiovascular problems (hypertension, ischemic heart disease).[399]

Sleep deprivation can have serious effects on performance and safety, and circadian effects on cognition compound the degradation in performance caused by extended workdays.[400] When sleep debt accumulates, performance degrades linearly — especially on tasks that are low in motivating qualities — while continuing to follow a circadian rhythm. The decline is steeper during the circadian trough than at other times, and this decline seems unaffected by motivation.[401] In subjects with restricted night sleep, Carskadon and Dement (1981) found a striking difference in objective measures of sleepiness with 4 hours versus 5 hours of night sleep. Two nights with 4 hours of sleep each produced "pathological" levels of sleepiness.[402] However, some evidence suggests people can be conditioned to need less sleep. In a limited sample of young adult couples, gradual reduction of sleep to 4.4 to 5.5 hours per night over 6 to 8 months did not result in cognitive performance decrements.[403]

For AEFs, high operational tempos and the associated flight hours must be weighed when assessing the sleep requirements of the crews. A study of the effects of schedule on mood, fatigue, and vigor found that once C-141 crews surpassed the usual 125-hour limit on cumulative flight hours per month, both flight hours and sleep hours obtained in the past 24 and 48 hours affected subjective measures of vigor.[404] A study of two-crew, long-haul, night flight operations[405] concluded that two consecutive night flights and a short layover resulted in ratings of critically high fatigue and brain wave activity indicating low vigilance.

Careful sleep management will be essential in surge operations. Naps can be helpful — 2-hour naps improve performance during sustained operations.[406] The benefits of naps are greatest if they are taken in the first 24 hours of operation. Nevertheless, lack of sleep will affect military operations. For example, infantry soldiers who were totally deprived of sleep for 3 days showed little deterioration in their riflery skills, but their cognitive performance dropped precipitously each day. Then, 4 hours of night sleep on day 4 resulted in large performance improvements *except during the circadian trough*. After obtaining 4 hours of sleep on each of days 4 through 6, performance recovered from approximately 50 percent to 88 percent of control levels.[407]

Recovery sleep periods are essential to returning performance to baseline levels. After 7 days with only 5 hours of sleep each, one full night of sleep followed by a daytime nap returned measures of sleepiness and fatigue to pre-restriction levels.[408] After 40 hours awake, cognitive performance returned to its baseline with 4 hours of night sleep, and after 64 hours awake, with 8 hours of night sleep.[409] Two nights of sleep may be sufficient for full recovery from 3 days of total sleep deprivation and 6 days of partial sleep deprivation (4 hours of sleep per night).[410] However, performance during the circadian trough may be slower to return to baseline levels.

11.1.3.3 Motivational Factors and Coping

The results of laboratory tests cannot necessarily be generalized to real-world performance because personnel may be more motivated in their real-world experiences, which can offset many of the effects of fatigue.[411] Humans also possess a large reservoir of performance capacity that, when called upon, can overcome the effects of fatigue.[412] In an excellent review of fatigue associated with long military engagements, Johnson and Naitoh report that it is difficult to predict the effect of prolonged sleep loss of less than 60 hours on performance in highly motivated military forces.[413] Individuals have many ways of coping with fatigue to allow capable performance. Some of these techniques are increasing the following distance between vehicles,[414] lowering risk thresholds,[415] and increasing effort.[416]

Individuals choose and modify coping strategies and motivational factors based on their fatigue levels and the changing demands of the tasks. This self-monitoring accounts for the fact that critical incidents are rare, even when demanding work requirements stretch an individual's resources to the maximum.[417] For example, professional truck drivers with experience in night driving learn how to cope with fatigue.

Drivers who make these compensations eventually move to safer, better-run companies, and drivers who find it hard to cope leave the occupation.[418, 419, 420] Also, many studies show that prolonged time at a task tends to produce changes in attitude toward the task. Eventually, participants favor speed at the expense of accuracy.[421, 422] In driving situations the frequency of risky overtaking maneuvers by subjects increased with hours driven.[423]

11.1.3.4 Total Time Spent Working

The total time spent working is a more important cause of fatigue than total time on a particular task.[424] In 1985, Transportation Research and Marketing found that 41 percent of heavy truck crashes involved drivers whose total on-duty time was 16 or more consecutive hours. On-duty time includes time spent on any assigned task: driving, waiting for dispatch, loading, unloading, etc.[425] One study showed that drivers with shifts exceeding 14 hours have nearly three times the accident rate of their counterparts on 10-hour shifts. Drivers on 11-hour shifts have twice the accidents of those on shorter shifts.[426, 427] In addition, the accident data for one trucking company showed that the ratio of expected to actual accidents increased between the seventh and tenth hours of driving.[428]

11.1.3.5 Circadian Disruption

The effects of sleep deprivation on reaction time and accuracy are well known.[429] In particular, circadian phase disruption is a debilitating consequence of rapid, transmeridian travel. Physiological functions critical to maintaining vigilance on duty (e.g., sleep inertia, neuroendocrine levels, immune response, gastrointestinal function, and physical strength) are severely disrupted by long-duration travel.[430] Studies of reaction time, logical reasoning, and simulated flight show that complex cognitive abilities are similarly affected.[431]

The deterioration of physical and mental performance associated with circadian desynchrony is well documented in aviation human factors research.[432, 433, 434, 435] Aircrews are at particular risk because they often must take off at night, consequently experiencing altered light and dark cycles. Light exposure can disrupt normal circadian cycles,[436] so recovery from mission-induced fatigue may take longer for crews exposed to unusual light cycles.

Flight has profound effects on sleep.[437] For most individuals, traveling east is more disruptive than traveling west.[438, 439] For example, commercial airline pilots suffer more fragmentation of sleep after eastbound travel, and older aircrew are more sensitive to rapid travel than younger members.[440] The likely cause of this phenomenon is the fact that the period of the circadian rhythm becomes longer than 24 hours. Rapid eastbound travel shortens the geophysical experience (e.g., solar cues).[441]

Circadian rhythm can take longer than a week to fully recover from transmeridian travel. The realignment of rhythm is compounded by the fact that different circadian patterns adjust at different rates.[442, 443] Therefore, the severest symptoms of "jet lag" might not be experienced until the second or third day after arrival, when differential adjustment causes different rhythms to be farther out of phase.

11.2 Current Countermeasures

Non-pharmacological techniques can improve rest during operations, and powerful pharmaceutical agents are available to promote sleep and maintain alertness. Also, a new class of compounds and techniques, chronobiotics, can be used to adjust circadian phase prior to deployment.

11.2.1 Non-Pharmaceutical Techniques

Non-pharmaceutical techniques provide limited but effective fatigue management with careful adherence to crew rest guidelines. Aircrews typically are not trained to be sensitive to their own fatigue levels and instead are expected to overcome fatigue, so fatigue awareness training may be useful. Being more alert to fatigue in themselves and in others may enable crews to better gauge and respond to fatigue-related problems. Also, physical activity and dietary stimulants can temporarily mask fatigue.[444]

Sleep training may be an effective means to reduce stress and promote sleep (by rapidly relaxing large muscle groups). The most effective means to promote and maintain sleep effectiveness are under investigation, but more operationally relevant information is needed. This research is unveiling the most efficient timing of nap and sleep schedules for maximum alertness.[445] Careful attention to sleep environment and duration may permit a few minutes of sleep to provide hours of vigilance. Because sleep latency is reduced at different times of the day, sleep schedules can be designed to maximize crew rest periods, minimize recovery time, and allow safer, extended duty cycles. Also, proper sleep hygiene techniques should be part of routine mission exercises.

Aircrew members report many personal coping strategies: (1) performing tasks one step at a time, (2) holding conversations with other crew members, (3) consuming cold drinks, (4) walking around, (5) being as organized as possible, (6) staying busy and active, (7) keeping the mind busy and active, (8) making extra efforts to fight fatigue, (9) eating, and (10) discussing fatigue symptoms with other crew members.[446] Recommended strategies include preplanned cockpit rests, physical exercise at night, dietary control (eating carbohydrates to induce sleep, eating protein to induce wakefulness), and light therapy.[447] Table I-54 lists sleep-inducement strategies. In addition, institutional support (for example, for protecting sleep periods) is critical to effective transition from daytime to nighttime flying.[448] Other organizational actions include increasing personnel staffing, modifying tasks, dividing workload, cross-training personnel, decreasing aircrew physical load, enhancing physical fitness, providing realistic training, creating night teams, planning rest and sleep discipline, and providing recovery sleep between combat episodes.[449] In addition, Armstrong Laboratory has developed procedures for countering fatigue effects of shift work and long-distance travel. Table I-55 lists these procedures.

Table I-54. *Sleep-Enhancement Strategies for the Flight Surgeon*[450]

Factor	***Strategy***
Quarters	Protect crew rest areas from light, noise, vibration, and temperature extremes. Ensure adequate sleeping quarters with comfortable beds. Quarter together all aircrew flying similar mission schedules. Stress the benefits of 8 to 9 hours of sleep (when possible) and that less sleep will create a sleep debt. Cumulative sleep loss will affect mission performance. Reschedule maid and cleaning services of quarters for after aircrew sleep times.
Diet	Do not use caffeine products within six hours before sleep. Use caffeine upon awakening. Eat high-carbohydrate meals (potatoes, grains, pasta, rice, etc.) before sleep times and high-protein meals (meats, cheese, yogurt, eggs, etc.) upon awakening. Know that alcohol will disrupt sleep patterns. Ensure that 24-hour dining facilities are available to serve meals to help circadian entrainment.
Sleep hygiene	Provide information on relaxation techniques to use prior to sleep (muscle tensing and relaxation techniques, concentration, deep breathing, etc.). Watch for cues of sleep deficiency and sleepiness: eye strain, head nods, yawning, wandering disconnected thoughts, increased alcohol use. Advise commanders about the impact of sleep hygiene techniques on mission success. Discuss the benefit of planned cockpit naps of 30 minutes (3 hours on long-haul flights). Determine the need for circadian rhythm strategies to prevent deployment desynchronosis. Consider crew or squadron isolation prior to long-duration missions. Plan for adequate sleep in the pre-mission phase (2 to 3 days prior to deployment).
Exercise	Promote fitness and regular exercise. Extend hours on gym facilities to accommodate aircrew workouts.
Light	Protect aircrew from light exposure during critical times depending on eastward or westward deployments. Use dark wraparound sunglasses as necessary.
Medications	Consider temazepam use for sleep disturbances associated with transmeridian travel (people over 45 may require higher temazepam doses to induce sleep).

Table I-55. *Shift Work and Travel Fatigue Countermeasures*[451, 452]

Situation	*Countermeasures*
Shift work	Enlist the aid of family members. Make shift meals as healthful as possible. Make lunch the large meal of the day. Keep the work area well lighted. Exercise regularly and work out during the night shift just as in the day shift.
Night shift	Expect to need 6 to 7 days to reverse normal daytime orientation. Sleep for 7 to 8 hours in a darkened room. Avoid early morning daylight — wear sunglasses if necessary. Maintain a nighttime routine even on off-days. Be consistent — if eating immediately after waking is normal, do so no matter what time it is. If night work is occasional, take a 3- to 4-hour nap before a night shift and sleep 3 to 4 hours after it; stay on a normal daytime schedule.
Rotating shifts	Maintain a normal daytime circadian rhythm. After a night shift, sleep only 4 to 5 hours, then do normal daytime activities, then sleep 3 to 4 hours before the shift. For other shifts, sleep at night at consistent times.
Traveling east	Remember that the body clock must advance; the body will not be receptive to sleep at local bedtime. Day 1 at destination: Take a 3- to 4-hour nap between 0900 and 1400 local time. Begin night sleep at 2100 and get up at 0500. Get fresh air, but avoid prolonged (20 minutes) sunlight before 1300 (wear sunglasses). After 1300, sunlight exposure is beneficial. Take a brisk afternoon walk. Day 2 at destination: Take a 30- to 40-minute nap between 1100 and 1300. Go to bed at 2200 and get up at 0600. Avoid prolonged sunlight until after 1300. Take a brisk walk and get fresh air. Days 3+ at destination: Eat and sleep on the local schedule. Take no more than a short nap at lunch time.
Traveling west	Remember that the body clock must delay, but that the body will be receptive to sleep at the local bedtime. Day 1 at destination: If tired, take a 30- to 40-minute nap between 1400 and 1800 local time. Go to bed at 2000 and get up at 0400. Take a morning walk and get fresh air. Avoid sunlight after 1600. Day 2 at destination: Take a short nap between 1200 and 1500. Go to bed at 2200 and get up at 0600. Maintain this schedule for the entire trip. If tired, take walks, fresh air, and short naps as necessary.

11.2.2 Pharmaceutical Agents

Pharmaceutical techniques always have been effective means to promote vigilance or induce sleep, and new compounds are available that are safer (better tolerated) and more efficacious. However, the chronopharmacological and interaction effects with other militarily relevant compounds are important considerations. New, safer "Go" and "No-Go" agents have a great deal of promise for maximizing alertness and enhancing performance.

11.2.2.1 "Go" Agents

Stimulants ranging from amphetamines to caffeine can relieve fatigue. Unlike hypnotic compounds, there are no clear guidelines with regard to substance, dosage, or timing for stimulants. New agents (ergogenic and eugregaric compounds), such as Modafinil may be better tolerated than familiar stimulants, and procedures to use them should be made available.[453] Experience has shown that carefully regulated stimulant administration can be very successful at maintaining vigilance during prolonged operations. Recently, stimulant use by aircrews was banned. However, some research indicates that "the elimination of amphetamine use has put aircrews at increased actual risk for the sake of eliminating theoretical use."[454]

Amphetamines were discovered in the 1930s, and they have been used in every major conflict since then. There still are many militarily relevant questions regarding stimulant use. For example, the number of days that individuals can function effectively on stimulants is not well established, and the most effective dosing regimens over multiple days are not known. Evidence from laboratory studies suggests a continual, but gradual, degradation in performance past 60 hours awake, even with repeated administration of stimulants.[455] However, the physical nature of aircrew and ground crew duties and the stress of conflict may extend the effectiveness of stimulants and delay the degradation of performance. The Air Force has used dextroamphetamine in the past.[456, 457] The use of dextroamphetamine is supported by simulator studies[458, 459] and flight evaluations of UH-60 pilots.[460, 461] In one study, dextroamphetamine caused no clinically detectable adverse effects on six male and six female UH-60 pilots.[462] Nevertheless, methamphetamine might be better for the few days of activity expected of the AEF. Methamphetamine is more centrally active, has a shorter plasma half-life, and causes fewer side effects than dexedrine.[463]

A number of non-amphetamine stimulants have potential for use in AEF operations. Far less is known about Modafinil than amphetamines, but it does seem to have considerable promise for blunting fatigue without the euphoria, hyperactivity, or abuse potential of traditional stimulants. A study of 41 military personnel showed that Modafinil may be a useful alternative to amphetamines in sustained operations.[464] However, Modafinil is not commercially available in the U.S. Pemoline is a newer stimulant that has a fairly long plasma half-life (as much as 12 hours). However, long-duration effects may not be an advantage because they will prevent aircrew members from getting rest if opportunities become available soon after the stimulant is administered. Some evidence suggests that Pemoline may be associated with acute liver toxicity, further lessening its appeal for the AEF. Methylphenidate is a short-acting stimulant, but it lacks the central activity of the amphetamines.

Finally, caffeine is perhaps the oldest and most reliable of the stimulants. Relatively small doses of caffeine (200 mg) improve response times, vigilance, and alertness during periods of sleep deprivation.[465] However, the effects of caffeine on fatigue are not as profound as those of amphetamines. A sustained-release caffeine capsule may be available in the future that would prolong the plasma activity, but, again, long-duration effects may not be an advantage if crew rest becomes available.

11.2.2.2 "No-Go" Agents

Sedatives are available to help overcome circadian rhythm problems. Melatonin is a widely available, non-addictive means to promote sleep. Restoril is currently recommended because its pharmaco-dynamics in Air Force operations are well known. Zolpidem (Ambien) is a newer, shorter-acting sedative compound that is clinically well known; it is an alternative to Restoril that may help overcome sleeplessness caused by the wrong circadian phase. Zolpidem has received much acclaim, and is the world's best-selling sedative.

Zolpidem has been approved for use by Army aviators with command approval, based on laboratory evaluations using 18 Army aviators. The Italian Air Force has found temazepan effective for inducing and maintaining diurnal sleep.[466]

Sedatives do have drawbacks. Idiosyncractic reactions, such as hallucinations, can occur in some people.[467] Beyond a week of use, many sedatives (particularly the older benzodiazepines such as Restoril) begin to interfere with sleep. In fact, with most of the suggested sedatives, "rebound insomnia" can occur after only a few days of use. Short-acting benzodiazepines, such as triazolam (Halcyon), can induce rebound insomnia even on subsequent attempts at sleep, and personality changes have been reported.

11.2.3 Chronobiotics

The unique properties of the pineal hormone melatonin make it extremely appealing as a non-addictive means to promote sleep and perhaps to rapidly shift biological rhythms.[468] The use of melatonin to counteract desynchronosis was demonstrated during an Army training mission to the Middle East.[469] Combinations of melatonin and bright light schedules may provide the most potent means yet to pre-shift the circadian timing system and quickly prepare crews to function at peak performance in a new temporal environment.

Environmental light improves performance degraded by nocturnal circadian effects. The use of bright illumination is possible with existing lighting facilities in most planning, control, and communication environments. Bright light also may be useful in rapidly pre-adjusting circadian phase to night operations. Exposure to bright light at critical times in the early morning seems to quickly regulate circadian phase within a day or two.[470, 471] Laboratory studies have shown that carefully controlled light exposures of a few hours can reverse circadian phase by as much as 12 hours.[472] More information regarding intensity and frequency of light needs to be developed to optimize these recent findings. The timing of light exposure is critical to these effects. Light in the early morning hours before the human's temperature minimum (usually between 0100 and 0400) will delay the circadian phase, while light after the temperature minimum (between 0400 and 0700) will advance the phase. Exposure to light at other times is less likely to affect circadian phase.[473] These results are relatively new, however, and should be tested in field conditions because there are some occasions when reverse effects are possible.[474, 475] Social cues (e.g., naming meals and providing foods typical for that meal, such as breakfast cereal) also have small but demonstrable effects on altering circadian phase, although not as profoundly as bright light or melatonin.[476]

11.2.4 Operational Fatigue Management

For all AEF participants, before and during operations, sleep facilities must be provided away from flight lines, loading areas, or other environments where sleep could be disturbed. In these facilities, proper nutrition, showers, and basic hygiene amenities should be provided. As much as possible, crews should be billeted so that incoming crews do not disturb outgoing crews or crews on different shifts. Quarters that are protected from environmental light, are extremely quiet, and have adequate temperature control are essential. These bivouac areas must be identified well before any national emergency. There are a number of alert facilities on numerous Air Force bases that would serve this purpose well with some modifications. A physician should be available to distribute and regulate the use of "Go" and "No-Go" agents. All participants should be ground-tested in advance for adverse reactions to "Go" and "No-Go" agents and should be thoroughly familiar with their own idiosyncratic responses.

11.2.4.1 Predeployment Procedures

AEFs will be able to attack high-value targets frequently and at unpredictable times. The crews of bombers that attack from bases in the U.S. and U.S. territories and return to the U.S. after each sortie should maintain their normal circadian orientations. This arrangement would allow them to maximize their crew rest at night and better prepare them for subsequent attacks. To maintain high operational tempo, aircrews may need access to “No-Go” agents to facilitate sleep and “Go” agents immediately before and during missions (particularly for the long leg home).

For deploying AEF crews, mission planning should be accomplished in the late morning and late afternoon, when crews are maximally vigilant. The aircrews should receive antifatigue briefings that include sleep hygiene principles. Also, crews should be allowed maximum predeployment crew rest to rid them of any sleep debt that they might have accumulated. Each person should get a minimum of 9 to 10 hours of uninterrupted sleep every day before the deployment if possible. Finally, “No-Go” agents should be used as needed to increase the likelihood of restorative sleep.

11.2.4.2 Deployment Procedures

In the first few days, the most difficult time for the participants will be during their circadian vigilance troughs, approximately 0200 to 0600 local U.S. time. This trough gradually will shift to 0200 to 0600 local target time after several days in country. Night operations forces, including maintainers and other critical support forces, should have separate billeting from day operations forces.

At present, the most effective means to maximize the vigilance of AEF crews during operations has two parts. First, sleep must be as restorative as possible. Crews must be provided the right environment for sleep and adequate time for sleep. As much as possible, crew rest quarters in the target area should be comfortable and protected from noise, light, and temperature extremes. In the event of mission-induced insomnia, crews should have access to “No-Go” agents, but only if absolutely necessary and only if they can be ensured of having 12 hours of crew rest in or near the front lines to clear sedatives from their systems. Second, in the event sleep is ineffective or the conflict prevents sleep, crews should have access to “Go” compounds. After two days of sustained operations using “Go” agents, crews must be allowed extended crew rest if at all possible.

Comperatore, Caldwell, and Caldwell of the Army Aeromedical Research Laboratory and the Army Safety Center jointly developed a *Leader’s Guide to Crew Endurance*. The guide lists indicators of fatigue (see Table I-56), sleep deprivation (Table I-57), and desynchronosis (Table I-58).

Table I-56. *Indicators of Fatigue*[477]

A person suffering from fatigue may
• Have difficulty in attention and concentration
• Appear dull and sluggish
• Attempt to conserve energy by reducing body movements to a minimum
• Sit and stare into space
• Appear careless, irritable, uncoordinated, and confused

Table I-57. *Indicators of Sleep Deprivation*[478]

A person suffering from sleep deprivation may have
• Increased fatigue
• Difficulty concentrating
• Some decrements in the performance of physical tasks
• Increased irritability and unreasonableness
• Psychological and performance deteriorations
• A decrease in mental ability
• Reduced motivation to complete the mission
• Impaired speed and accuracy at skilled tasks
• Occasional visual and tactile hallucinations
• Confusion and disorientation

Table I-58. *Indicators of Desynchronosis*[479]

A person suffering from desynchronosis may
• Have a vacant stare
• Have glazed eyes
• Have pale skin
• Sway when standing
• Walk into objects
• Have degraded personal hygiene
• Lose concentration during briefings
• Slur words when speaking

These authors recommend napping and stimulants to overcome fatigue. They warn that "the use of stimulants requires close coordination by the unit commander, planners, safety officer, and flight surgeon."[480] They also make the following recommendations: (1) pre-adapt soldiers to the operational zone; (2) decrease caffeine consumption 3 to 7 days before deployment; (3) during travel, sleep only at the operational zone time; (4) upon arrival maintain zone time; and (5) use sleep aids. Personnel should take naps according to the following guidelines: (1) naps should be as long as possible, although 2 hours every 24 hours is sufficient; (2) napping is easiest at 0300 and 1300; (3) napping is most difficult at 1500; (4) performance is worst within 5 minutes of waking. Their light exposure guidance is given in Tables I-59 through I-62.

Table I-59. *Light Exposure After Eastward Travel: Daytime Duty**

Time Zones Crossed	Deployment Day	Daylight Exposure		Daylight Avoidance	
		OT	DT	OT	DT
4	Day 1-2	0300-0700	0700-1100	2000-0300	0000-0700
	Day 3		0700-SS		
6	Day 1-3	0300-0700	0900-1300	2000-0300	0200-0900
			0700-SS		
8	Day 1-3	0300-0700	1100-1500	2000-0300	0400-1100
			0700-SS		
10	Day 1-3	0300-0700	1300-1700	2000-0300	0600-1300
	Day 4		0700-SS		

OT = origination time; DT = destination time; SS = sunset

* In the first column, identify the number of time zones to be crossed. The daylight exposure and avoidance schedules are then provided for both the OT zone and the DT zone. This table assumes that the user has been on OT for at least 2 weeks.

Table I-60. *Light Exposure After Eastward Travel: Nighttime Duty (2000-0400 Hours)*

Time Zones Crossed	Deployment Day	Daylight Exposure		Daylight Avoidance	
		OT	DT	OT	DT
4	Day 1-2	0800-SSDT	1200-SS	2000-0300	0000-0700
	Day 3		1200-SS		
8	Day 1-2	0400-SS	1200-SS	2000-0300	0400-BT
	Day 3		1200-SS		

Table I-61. *Light Exposure After Westward Travel: Daytime Duty*

Time Zones Crossed	Deployment Day	Daylight Exposure		Daylight Avoidance	
		OT	DT	OT	DT
4	Day 1-3	2000-0300	1600-2300	0300-0700	2300-0300
	Day 4	1100-SSDT	0700-SS		
6	Day 1-3	2000-0300	1400-2100	0300-0700	2100-0100
	Day 4		0700-SS		
8	Day 1-3	2000-0300	1200-1900	0300-0700	1900-2300
	Day 4		0700-SS		
10	Day 1-3	2000-0300	1000-1700	0300-0700	1700-2100
	Day 4		0700-SS		

Table I-62. *Light Exposure After Westward Travel: Nighttime Duty (2000-0400 Hours)*

Time Zones Crossed	Deployment Day	Daylight Exposure		Daylight Avoidance	
		OT	DT	OT	DT
4	Day 1-2	2000-0300	1600-2300	0300-0700	2300-0300
	Day 3		1200-SS		
8	Day 1-2	2000-0300	1200-1900	0300-0700	1900-2300
	Day 3		1200-SS		

11.3 Future Threats

The future threat is the same as the current threat.

11.4 Future Countermeasures

A number of future countermeasures will be available. The Crew Technology Sustained Operations Branch of Armstrong Laboratory is producing a video on managing the effects of circadian rhythm and is developing a fatigue manual with information on sleep architecture, jet lag, pharmaceuticals, and common fatigue-induced errors. This manual will include software — the Aircrew Fatigue Management System — to develop optimal work/rest cycles. The software is under beta test at Dyess AFB. Also, NASA is producing a fatigue management course. Based on a study of B-1 bomber missions, fatigue management and sleep training are critical to military missions.[481]

11.5 Responsible Parties

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12.0 Infectious Disease and Injury

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12.1 Current Threats

Non-combat disease and injury are key threats to the mission effectiveness of an Aerospace Expeditionary Force. Although chronic conditions will not require care during a short-term operation, disease and injury are likely to place a heavy burden on the medical resources of an AEF. Data provided by Armstrong Laboratory's Epidemiology Services for the Joint Task Force Southwest Asia (AEF IV) illustrate this point (see Table I-63). The data show the numbers of visits for various diagnoses to the on-site clinic from December 1996 to June 1997. Most visits were related to infectious disease; work-related injuries caused the next highest number of visits. The two radiation cases were from exposure that occurred prior to deployment to AEF IV. Toxic-agent visits were predominately smoke inhalation (seven cases) but there was one medical overdose. The weather-related visits included both heat-related illness (primarily dehydration, 39 cases) and cold-related illness (4 cases). Data for Bosnia (maintained by the U.S. Army Center for Health Promotion and Preventive Medicine at Aberdeen Proving Grounds) are similar.

Table I-63. *Number of Clinic Visits in AEF IV*

Diagnosis	*Number of Visits*
Dangerous flora	0
Dangerous fauna	47
Fatigue	70
Infectious disease	1,020
Work-related injury	357
Radiation	2
Toxic agents	7
Weather	43

Data from World War I, World War II, and the Korea conflict further illustrate the magnitude of threat from disease and injury, as shown in Table I-64. One conclusion from these data is that, in each of these combat operations, at least 25 percent of all deaths were not battle deaths. Disease and injury clearly are important threats.

Table I-64. *Medical Statistics for U.S. Forces in World Wars I and II and Korea*[482]

Characteristic	*Number per 1,000 Average Strength*		
	WW I	*WW II*	*Korea*
Total deaths	35.5	11.6	5.5
Battle deaths	17.1	8.6	3.4
Other deaths	18.4	3.0	2.1
Annual non-battle deaths (Army)	15.4	8.0	2.0
Annual non-battle deaths (Navy and Marines)	11.6	2.8	1.9
Annual medical admissions (Army)	978.2	704.4	511.3
Annual medical admissions (Navy and Marines)	1,024.1	553.3	337.3
Person-days lost per day for medical care (Army)	57.7	44.5	25.7
Person-days lost per day for medical care (Navy and Marines)	33.2	31.8	18.5
Wounded who subsequently died (Army)	8.1 %	4.5 %	2.6 %
Wounded who subsequently died (Navy and Marines)	9.0 %	3.2 %	2.2 %

12.1.1 Threat of Infectious Disease

Disease, not armed combat, may be the most deadly threat to personnel involved in military operations. In fact, Spanish influenza killed 43,000 of the 57,000 Americans who died in World War I.[483] The AEF must be prepared to handle all kinds of disease, from routine illnesses to the mostly deadly epidemics. Table I-65 shows the causes of the infectious disease cases reported during AEF IV.

Table I-65. *Infectious Disease Cases in AEF IV*

Infectious Disease	*Number of Cases*
Intestinal infections	147
Other bacterial diseases (primarily strep throat)	27
Viral skin lesions (primarily herpes)	34
Other viral diseases and chlamydiae (primarily warts)	195
Sexually transmitted diseases	3
Other infectious and parasitic diseases	14
Total cases	420

It is impossible for any document involving international travel to remain current on communicable disease threats in the world today. The most up-to-date information on travel-related diseases and recommendations is provided by the Travelers Health Section of the Centers for Disease Control and Prevention (CDC), the AFMIC MEDIC, and Armstrong Laboratory Epidemiology Services (AL/AOES).

Infectious organisms and communicable diseases that AEF forces might encounter in expeditions worldwide are listed below (see Table I-66). The asterisks indicate the most likely biological threats to an AEF. These extensive lists underscore the need for site-specific, predeployment intelligence concerning real-time prevalence in a given area.

Table I-66. *Infectious Organisms of Concern to AEFs*

Bacteria, Rickettsiae, and Chlamydiae	***Viruses***	***Protozoans, Helminths, and Fungi***
* Bacillus anthracis	* Chikungunya	Anisakis
* Bartonella quintana	* Congo-Crimean hemorrhagic fever	Babesia
* Brucella abortus	* Dengue fever	Candida
* Brucella melitensis	* Eastern equine encephalitis	Cryptococcus
* Brucella suis	Ebola	Cryptosporidium
* Burkolderia mollei	* Filoviruses (Marlburg, Ebola)	Giardia lamblia
* Burkolderia pseudormollei	Hantaan	Microsporidia
* Chlamydia psittaci	* Hantaviruses	Plasmodium
* Clostridium botulinum	* Japanese encephalitis	Pneumocystis carinii
* Coxiella burnetii	* Junin	Strongyloides stercoralis
* Francisella tularensis	* Lassa fever	Toxoplasma gondii
* Rickettsia prowazekii	* Lymphocytic choriomeningitis	
* Rickettsia rickettsii	* Machupo	
* Salmonella typhi	Marlburg	
* Shigella dysenteriae	* Monkey pox	
* Vibrio cholerae	* Rift Valley fever	
* Yersinia lestis	* Tick-borne encephalitis	
Aeromonas species	* Variola	
Borrelia burgdorferi	* Venezuelan equine encephalitis	
Campylobacter jejuni	* Western equine encephalitis	
Chlamydia pneumoniae (TWAR strain)	* White pox	
Chlamydia trachomatis	* Yellow fever	
Clostridium difficile	Bovine spongiform encephalopathy (BSE) agent	
Ehrlichia chaffeensis		
Escherichia coli O157:H7	Hepatitis B	
Haemophilus influenzae bio-group aegyptius	Hepatitis C	
Helicobacter pylori	Hepatitis E	
Legionella pneumophila	Human herpes virus 6 (HHV-6)	
Listeria monocytogenes	Human immunodeficiency viruses (HIV-1, HIV-2)	
Mycobacterium tuberculosis		
Staphylococcus aureus	Human papillomavirus B19	
Streptococcus pyogenes (Group A)	Human parvovirus B19	
Vibrio vulnificus	Human T-cell lymphotropic viruses (HTLV-I, HTLV-II)	
	Influenza (Pandemic and Drift)	
	La Crosse and California Group viruses	
	Measles	
	Norwalk and Norwalk-like agents	
	Rabies	
	Ross River	
	Rotavirus	

Another cause of disease that could threaten an AEF is poor public health practices. For example, Harvest Falcon units have been incorrectly fielded, resulting in illness. In addition, a Navy-generated "lesson learned" identifies a danger of illness or infection because no instructions exist for sanitizing the mouthpieces of helicopter emergency egress devices.[484]

12.1.2 Threat of Injury

Medical personnel treat both types of injury — those caused by battle and those that occur during noncombat operations — similarly, so both are included in this chapter. A critical factor in medical treatment is the interval between injury and admission to a medical facility. Figure I-52 shows this interval for Operation Desert Storm; Table I-67 gives medical treatment data for casualties in Danang in the Vietnam War from January to June 1968. In general, if a seriously injured person does not receive medical attention within 1 hour of injury, the person probably will die. This treatment window is called the "golden hour" and many civilian emergency medical services use it as an evaluation criterion. However, the military data below are for admission, which is not likely to be the initial medical treatment an injured person receives, and the triage process ensures that the most serious cases are admitted more quickly than others.

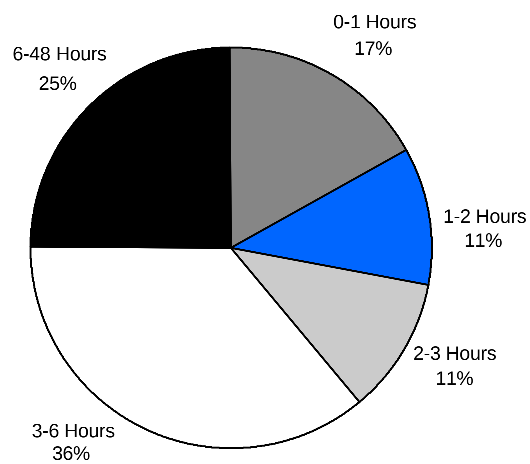

Figure I-52. *Interval From Injury to Admission in Desert Storm*[485]

Table I-67. *Medical Treatment for Combat Casualties in Danang, January to June 1968*[486]

Variable	*Casualty Outcome Group*		
	*Salvageable Deaths**	*Nonsalvageable Deaths*†	*Returned Alive*
Number of cases	42	17	1,962
Average hours from injury to admission	2.83	2.72	4.95
Average units of blood used in initial surgery	11.9	Not applicable	5.6
Average days hospitalization	4.05	1.35	4.38
Cases with penetrating wounds	35	17	404
Cases with non-penetrating wounds	7	0	1,558

* Cases with some possibility of survival.
† Cases with no hope of survival, for which lifesaving care was not provided.

A current deficiency in deployed medical care is blood-banking capability. As shown in the table above, the initial surgery on the most serious casualties required nearly 12 units of blood per case. Current Mobile Field Surgical Teams (MFSTs) have equipment that permits direct transfusion of whole blood (i.e., removal from a person in the field for immediate transfusion into a casualty) but this procedure is for emergency use only. True blood-banking is not available — such a capability with a 30-unit capacity would require one person, a small refrigerator, additional laboratory equipment, and provisions for maintaining temperature control during airlift.

Data on casualties among Marines in Okinawa (April to June 1945) and Korea (February to June 1951) give an indication of the possible patient loads that AEF medical forces could expect in a high-intensity combat operation. The maximum disease and non-battle injury (DNBI), wounded-in-action (WIA), and killed-in-action (KIA) rates shown in Table I-68 might be comparable to those experienced in an operation in which an airbase came under enemy attack.

Table I-68. *Daily Casualty Rates for Marines in Okinawa and Korea*[487]

Characteristic	Okinawa Apr-Jun 1945		Korea Feb-Jun 1951	
	Combat Troops	Support Troops	Combat Troops	Support Troops
	Per 1,000 Strength per Day			
Maximum daily DNBI rate	14.25	6.00	13.25	2.25
Maximum daily WIA rate	32	5	73	1
Maximum daily KIA rate	6.4	1.4	7.0	0.5

Injuries that are not combat related may be a significant portion of the patient load of the AEF medical force. Table I-69 shows the work-related injuries reported during AEF IV.

Table I-69. *Work-Related Injuries in AEF IV*

Type of Injury	Cases
Fracture	14
Dislocation	2
Sprain and strain	67
Head trauma	2
Internal injury	0
Open wound	8
Superficial injury	35
Bruise/hematoma	32
Crushing injury	3
Foreign body	6
Burn	17
Unspecified trauma	6
Poisoning	0
Unspecified cause (including heat, cold, radiation)	3
Complication of medical care (e.g., needlestick)	92
Total cases	287

Fatalities due to noncombat mishaps in an AEF forward operating location could be predicted in a manner similar to that used by civilian authorities to predict automobile accident fatalities. A model developed by Mitretek uses accident notification time (the time between the accident and notification of emergency medical services) to predict the number of fatalities. The model uses the equations shown in Table I-70.

Table I-70. *Roadway Fatality Equations*

Location	Equation and Parameters
Freeway[488]	ln (NF) = -2.47 +1.06 ln (M) + 2.33 ln (S) + 0.64 ln (AC) + 0.53 ln (YA) + 0.27 ln (T) -1.17 ln (I) + 3.81 NF is the number of fatalities M is the vehicle miles traveled S is the mean vehicle speed AC is the alcohol consumption YA is the fraction of miles traveled by young and aged drivers T is the accident notification time I is the per capita income
Rural area[489]	ln (NF) = 5.27 +0.48 ln (MRI) + 0.62 ln (MRA) + 0.03 ln (MRL) + 0.32 ln (AC) + 0.11 ln (YA) + 0.14 ln (T) -0.93 ln (I) + 0.66 MRI is miles traveled on rural interstates MRA is miles traveled on rural arterials and connectors MRL is miles traveled on rural local roads

The Air Force Safety Center collects data on mishaps among Air Force maintenance personnel. Of the mishaps reported from 1992 until July 1997, 81 percent (2,136) occurred during the day (between 0700 and 2059 hours), and 19 percent (490) occurred during the night (2100 to 0659 hours). There also was a statistically significant difference ($p < 0.001$ in Chi-square tests) in the types of mishaps that occurred in the two periods. For strains, the percentage occurring during the day (42 percent of 2,136) was larger than the percentage occurring at night (33 percent of 490). However, the percent of daytime falls (23 percent) was less than the percent of falls reported at night (31 percent). Nevertheless, if the Caught, Strain, and Fall categories are combined to form a Musculoskeletal category, the percentages of mishaps in this category are equal for day and night (81 percent). Figure I-53 shows the frequency of mishaps by category and period.

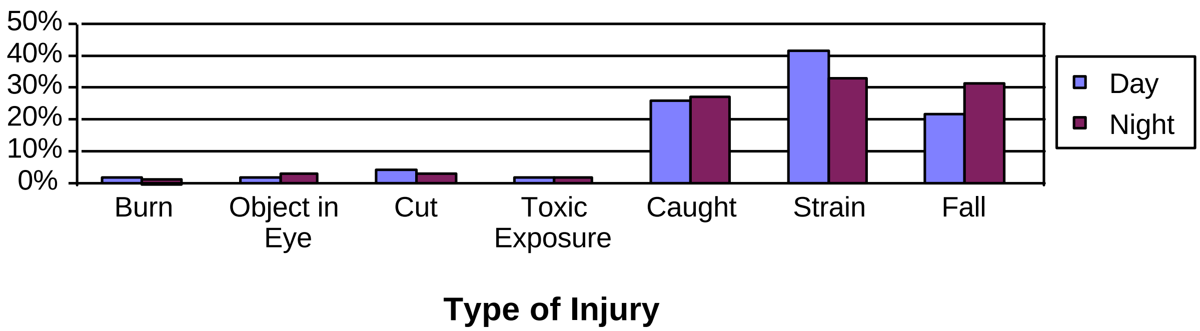

Figure I-53. *Day and Night Mishap Frequency for Air Force Maintenance Personnel*

12.2 Current Countermeasures

Countermeasures are described in two sections: (1) infections disease and (2) injury.

12.2.1 Infectious Disease Countermeasures

Infectious disease countermeasures include epidemiological teams, medical environment disease intelligence and countermeasures, and infectious disease prevention.

12.2.1.1 Epidemiological Teams

The Concept of Operations for an Air Force Medical Epidemiological Team is based on Air Staff and Major Command recommendations. The CONOPS helps assure the availability of a capable epidemiological/preventive medicine team. This team deploys to support AEF deployments and to provide on-site field assistance for contingency operations at the request of respective theater command surgeons.

Historically in military operations, more person-days have been lost from DNBIs than from combat injuries. Outbreaks of disease can quickly degrade unit effectiveness, decrease the morale of units, result in large numbers of illness and death, and become “war stoppers.” With the current worldwide Air Force deployment responsibilities (including peacekeeping and humanitarian relief efforts, in addition to wartime contingencies), the relative impact of DNBIs on mission achievement is likely to continue and, as forces become leaner, perhaps increase.

When disease outbreaks have exceeded the capabilities or technical expertise of on-site medical forces, the Air Force Epidemiology Division has provided critical preventive medicine consultation and disease outbreak investigation to the Theater Commander, upon the request of the Theater Surgeon and Commander. This continues to be a critical peacetime and wartime mission of the Air Force Epidemiologic Research Division.[490] The recent disbanding of in-theater “Epidemiology Flights” at Wiesbaden AFB, Germany (USAFE), and at Clark AFB, Philippines (PACAF), has significantly reduced the availability of in-theater preventive medicine specialists.

The CONOPS outlines the purpose and scope of the Epidemiology Team. The team supports Air Force Component Command Surgeons, who are responsible for deployed and forward-based Air Force personnel. Formal establishment of the team enhances the availability, preparedness, and deployability of Air Force epidemiology/preventive medicine specialists. The Epidemiology Teams are deployed in addition to the normally deployed medical assets (e.g., Air-Transportable Hospitals/Clinics, Squadron Medical Elements). The teams procure, maintain, and deploy with their own equipment. They provide in-theater, technical specialty assistance for communicable disease and biological warfare prevention and control and environmental disease prevention. Upon deployment, the team is assigned to the Air Component Commander Surgeon’s staff. The team provides epidemiological monitoring and, at the request of the local medical treatment facility or line commander, on-site consultation for communicable and environmental disease prevention and control. When not providing field assistance, the team provides epidemiologic monitoring for the Air Component Commander Surgeon’s staff.

The Air Force requires two complete Epidemiology Teams. Table I-71 gives the composition of each team, and each team should have a primary and an alternate member for each position. All members of the team must be physically qualified for worldwide duty and capable of functioning under strenuous field conditions. They must have a minimum of secret security clearances, although top secret is highly recommended. All members of Epidemiology Teams must have the levels of education and training appropriate to their respective specialties. They must comply with the medical mobility training requirements as specified in AFI 41-106, *Medical Readiness Planning and Training*, including periodic (at least annual) team training; small arms weapons training; and NBC defense training.[491] Completion of other courses, such as Global Medicine, biological warfare, and Introduction to Medical Intelligence, is desired.

Table I-71. *Epidemiology Team Staffing*

Number	Specialty	Air Force Specialty Code
1	Board-Certified/Qualified Preventive Medicine Physician (generally will be the Team Chief)	48P3/4
1	Public Health Officer with epidemiological training (MPH or Ph.D., with Board Certification)	43H3/4
1	Public Health Craftsman* (or Aerospace Medicine Craftsman*)	4EO71 (4FO71)
1	Medical Entomologist	43M3/4
1	Laboratory Officer* (or Clinical Laboratory Craftsman*)	4TO3/4 (4TO71)
1	Bioenvironmental Engineering Craftsman* (or Bioenvironmental Engineer*)	4BO71 (43E3/4)

* In some cases, these team members may be provided from in-theater sources.

Note: Team size may be reduced or composition adjusted to meet specific needs of the Theater Command Surgeon.

The Air Force Epidemiology Research Division routinely provides off-site assessments and consultations, using medical resources already in-theater whenever possible. Disease outbreaks at deployed sites could exceed the preventive medicine capabilities of deployed medical units; the tasking of an Epidemiology Team will be based on the requirements to respond to actual and expected disease outbreaks. Teams will deploy to the theater only as needed, and some taskings may require response times of 24 to 72 hours. Epidemiology Teams maintain a state of deployment readiness to permit rapid deployment in these cases.

Theater medical planners (e.g., European Command/USAFE) and Functional Unified Command planners (e.g., U.S. Space Command/Air Force Space Command) are responsible for including anticipated requirements for use of the Epidemiology Teams in their respective planning documents. The teams will respond to validated requirements in both peacetime and wartime. In all cases, routine support services, such as billeting, food services, laundry, sewage and waste disposal, transportation, and communications will be provided by base support organizations. On deployment, the Epidemiology Team works through the Theater Command Surgeon's Office, but it may be redeployed in-theater to fulfill mission requirements. Upon completion of the team's specific mission, the team members are released by the theater commander or surgeon as soon as is practical.

12.2.1.2 Medical Environmental Disease Intelligence and Countermeasures

Specific disease countermeasures, vaccine requirements, and drug availability are posted by the CDC, AFMIC MEDIC, and Armstrong Laboratory (AL/AOES). MEDIC, in particular, is a tool that is readily available (on CD-ROM) to the base-level Public Health Officer and Flight Surgeon for use in advising Air Force personnel about health conditions in the countries to which they are deploying. MEDIC is a single source for the medical and public health information required for a deployment.

MEDIC was developed by AFMIC in collaboration with the Services. AFMIC's "Disease Environmental Alert Report" CD-ROM was the vehicle for the preventive medicine information and reference materials agreed upon by the Air Force, Army, Navy, and Coast Guard. The completeness of the information in MEDIC eliminates the old cumbersome process of calling numerous sources of information. Formerly, many Public Health Officers were forced to augment Department of Defense sources with commercial products to help fill information gaps, often with incomplete results. Now, MEDIC provides all the predeployment, medical, and travel information required for the different Air Force missions throughout the world.

12.2.1.3 Other Provisions for Infectious Disease Prevention

AEFs must use a comprehensive system of countermeasures to neutralize the infectious disease threat. A key element is a predeployment health screen, including medical profile status, prescription medications, dental health, fitness status, health questionnaire, and a serum (DNA and HIV) sample. Other important elements are prophylactic medications (e.g., antimalarials) and personal protective equipment (e.g., mosquito netting).

12.2.2 Injury Countermeasures

Injury countermeasures include organizations, telemedicine, and casualty care.

12.2.2.1 Organizational Roles

Many organizations play roles in injury countermeasures for AEFs. The Air Force Surgeon General establishes policy and provides guidance for medical support to AEF operations. The higher-headquarters planning cells that determine requirements for medical assets include medical representatives and get input from the wing level on airlift, expected need, and local limiting factors. Armstrong Laboratory's Aircrew Performance Enhancement branch (AL/CFBS) is responsible for developing the technology to support aeromedical evacuation.

The Air Force attempts to prevent injuries by maintaining a healthy, fit force, and it provides interventions to decrease DNBIs. To provide medical care, the Air Force employs a cadre of highly qualified personnel. All medical providers, nurses, and technicians assigned to emergency medicine sections are fully trained in emergency care. Medical members of the Fast Action Support Team receive Advanced Trauma Life Support (ATLS) training. In addition, there is an initiative at Air Force Headquarters to train all medical providers on mobility status in ATLS. In the Squadron Medical Elements, senior technicians attend the Independent Medical Technician course. All fire department rescue personnel are National Registered Emergency Medical Technicians. Finally, all active duty personnel receive self-aid and buddy-care training annually.[492]

12.2.2.2 Telemedicine

A key element of medical support for AEFs will be telemedicine. Telemedicine is a reachback concept, in which as many medical tasks as possible (from planning to management to diagnosis to patient tracking) are conducted via data links among deployed medical units, regional medical centers, and medical facilities and personnel in CONUS. In recent deployments, U.S. military forces have begun to implement components of a complete telemedicine system (see the "Future Countermeasures" section).

For example, the Army installed the Patient Accounting and Reporting Realtime Tracking System (PARRTS) at Walter Reed Hospital in Washington, DC. This database "contains complete medical histories of all military personnel authorized to go into combat zones."[493] PARRTS was used by medical personnel in Bosnia to consult with CONUS experts in diagnosing and treating patients at in-theater aid stations. The in-theater medical personnel transmitted photos and X-rays over conventional military communications satellites and commercial telecommunications links to provide their CONUS counterparts with case-specific information.

12.2.2.3 Casualty Care

For casualty care, the Air Force provides aeromedical evacuation. Only aeromedical evacuation has unique AEF requirements, so it is the only topic discussed at length here. For AEF deployments, there is no build-up phase or operational pause, so airlift is at premium during the entire operation. Essential care must be given in-theater to reduce the time to reach trauma care and to provide early surgical therapy. Stabilized patients are evacuated. To accommodate this approach to medical treatment, the AEF medical response must be a pyramid of component therapy and modular resources, as shown in Figure I-54.[494]

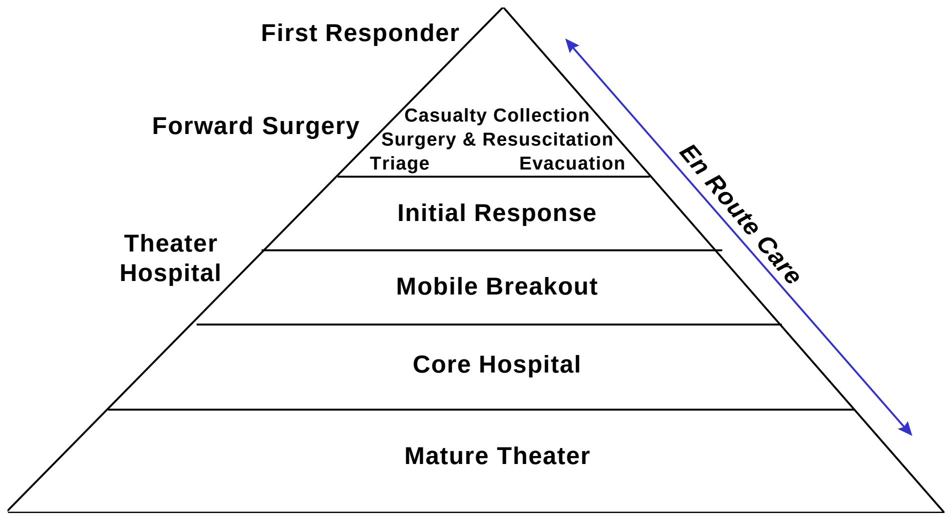

Figure I-54. *Pyramid Response to Injury Care*[495]

The AEF has no requirement to provide medical care for chronic conditions. All personnel who deploy with an AEF must be qualified for worldwide duty in accordance with Air Force Instruction 48-123, *Medical Examination and Standards*. A medical provider in the mobility processing line evaluates all personnel with acute medical conditions at the time of deployment.

Casualty care is provided by one of the five air-transportable medical assets described in Table I-72: Air-Transportable Clinic (ATC), Air-Transportable Trauma Center (ATTC), Coronet Bandage, and 25- and 50-bed Air-Transportable Hospitals (ATHs). The 366th Wing at Mountain Home AFB has selected the ATTC for use in its deployments. The ATTC is a mobile, light, versatile medical care facility that is manned by 51 people and supports 1,000 to 1,500 deployed personnel. It is equipped with emergency, surgery, and dental facilities and is stocked with 30 days of supplies. The ATTC can be launched within 24 hours and carried on one C-141. Upon arrival at the operating location, it can be ready to receive patients within 8 hours. The AEF Battlelab is validating the ATTC for use in all AEF operations.[496]

Table I-72. *Air-Transportable Medical Assets*[497]

	ATC	*ATTC*	*Coronet*	*ATH/25*	*ATH/50*
Beds	0	10	14	25	50
Personnel	6	51	49	96	128
Ambulances	0	0	1	2	3
Forklift	No	No	Yes	Yes	Yes
Emergency room	No	Yes	Yes	Yes	Yes
Surgery	No	Yes	No	Yes	Yes
Dental	No	Yes	Yes	Yes	Yes
Days of supply	30	30	10	20	30
Total pallets	1	11	26	41	52
C-141 equivalent	<1	1	4	6	7

A Deployable Aeromedical Readiness Team is a modular unit composed of three Critical Care Aeromedical Transport Teams (CCATTs), five MFSTs, and one Aeromedical Evacuation Liaison Team. The CCATT conducts aeromedical evacuation and is composed of (1) a critical care physician trained in anesthesia, emergency medicine, pulmonary medicine, and surgery; (2) a critical care nurse; and (3) a respiratory therapist. The team's equipment includes an impact ventilator, a Propaq 160 EL Intensive Care Unit (ICU) monitor, airway equipment, intravenous access materials, ICU medications (such as pressors, sedatives, and paralytics), and a portable lab.[498]

The MFST is a mobile, rapid-response team that provides emergency operative and nonoperative trauma care. The team is designed to integrate with the ramp-up, sustainment, and ramp-down phases (and surge operations, if necessary) of a classic deployment. MFSTs can provide triage, therapy, and salvage surgery at the airhead; additional surgical capability within the aeromedical evacuation system; mobile forward surgery; and surge augmentation of existing facilities. The teams also are prepared to respond to civilian disasters and support Special Operations Forces.[499]

The MFST fills the need for a combat casualty-care team that is immediately available for deployment and employment, lightweight (with minimal airlift requirements), proficient in state-of-the-art trauma care, and operationally flexible (able to function in a variety of environments). The MFST is built around five members and portable equipment that allows the team to perform initial trauma care and salvage surgical procedures. The personnel are a general surgeon, an orthopedic surgeon, an emergency medicine physician, an anesthesiologist, and an operating room nurse/technician. The equipment includes surgical equipment in five backpacks (see Tables A9 though A15 in the Annex), a generator, two folding litters, and personal gear. The total equipment weight is approximately 600 pounds.[500]

The MFST carries enough supplies in its core package to provide non-operative trauma resuscitation for 20 casualties or to perform trauma surgical procedures for 10 casualties. The team can definitively treat injuries of the thorax, abdomen, extremities, and head. The salvage and stabilization procedures will control hemorrhage, arrest ongoing contamination, stabilize fractures, and address other injuries to stabilize patients for transportation. Endurance of the core package is limited by weight considerations, but the team can be supplemented by prestocked modules that add operative supplies, fluid supplies, and post-operative care capability. The team uses any shelter of opportunity; to set up a field operating theater, the team requires space equivalent to about half of a medium general-purpose tent. The MFST has no organic transportation, shelter, security, or food and water supplies, so it depends on host-unit support in these areas.[501]

12.3 Future Threats

Future threats are described in two sections: (1) infectious disease and (2) injury.

12.3.1 Future Threat of Infectious Disease

The future threat is the same as the current threat, although some consideration must be given to the growing number of antibiotic-resistant bacteria. Infectious disease will continue to be a major threat to deployed forces. Endemic infectious disease rates will remain high or even increase; Tables I-73, I-74, and I-75 list the most important emerging viral, bacterial, and parasitic infections. Many operations involve close contact with indigenous populations, many will involve multinational task forces, and many will rely heavily on host-nation support.[502] All these factors will contribute to the threat of infectious disease.

Table I-73. *Emerging Viral Infections*[503]

Disease	*Causes of Emergence*	*Mode of Transmission*	*Symptoms*	*Treatment/Prevention*

Dengue	Poor mosquito control; increased urbanization in tropics; increased air travel.	Bite of infected mosquito (primarily *Aedes aegypti*).	Hemorrhagic fever; eruptions similar to measles.	No specific treatment; analgesic and sedative agents; mosquito control.
Filoviruses (Ebola, Marburg)	Natural host still unknown.*	Direct contact with infected blood, organs, secretions, and semen.	Sudden fever, diarrhea, vomiting, massive hemorrhaging.	No specific therapy, but convalescent serum may be helpful. No cure.
Hantaviruses	Environmental changes increasing exposure to rodent hosts.	Inhalation of aerosolized rodent urine and feces.	Abdominal pain, hemorrhagic fever, kidney failure.	No specific therapy; ribavirin (an antiviral drug) may help.
Hepatitis B	Probably increased sexual activity and intravenous drug abuse; transfusion (before 1978).	Contact with saliva, semen, blood, or vaginal fluids of an infected person; mode of transmission to children not known.	Nausea, vomiting, jaundice; chronic infection leads to hepatocellular carcinoma and cirrhosis.	A vaccine for use in preventing hepatitis B was licensed in the United States in 1981.
Hepatitis C	Recognition through molecular virology applications; blood transfusion practices following World War II.	Exposure to contaminated blood or plasma; sexual contact.	Nausea, vomiting, jaundice; chronic infection leads to hepatocellular carcinoma and cirrhosis.	The drug interferon alpha-2b used to treat chronic hepatitis C. Only 10 to 15 percent of patients experience long-term remission.
Human Immuno-Deficiency Virus (HIV—AIDS)	Travel, migration to cities. Sexual contact, use of contaminated needles, transfusions.	Sexual contact with or exposure to blood or tissues of an infected person.	AIDS; severe immune system dysfunction, opportunistic infections.	Several antiviral drugs can slow progression; other drugs are used to treat opportunistic infections from immunosuppression.
Influenza	Natural hosts, such as pigs and ducks, may facilitate rapid genetic changes, causing periodic epidemics.	Airborne, highly contagious, especially in crowded, enclosed spaces.	Sore throat, fever, headache, cough, malaise.	Immunization; rest and liquids usually are adequate; some drugs such as amantadine can shorten illness.
Lassa fever	Rapid urbanization in squalid conditions bringing humans in contact with rodent hosts.	Contact with urine or feces of infected rodents.	Fever, malaise, headache, sometimes shock, seizures.	No specific therapy is known. Ribavarin, ventilation, and dialysis sometimes needed.
Measles	Deterioration of public health infrastructure supporting immunization.	Airborne; direct contact with respiratory secretions of infected persons.	Fever, conjunctivitis, cough, red blotchy rash.	Children who have not had measles should be immunized with live attenuated measles vaccine at 12 months of age. Inactivated vaccine produces short-lived protection.
Rift Valley fever	Dam construction, irrigation, facilitating spread of mosquito vector (carrier); importation of infected mosquitoes or animals.	Bite of an infective mosquito.	Abrupt onset of fever, severe fever complications in survivors, with visual and nerve damage.	Mosquito control and vaccination.
Rotavirus	Increased recognition; infects 90 percent of humans by age 3, regardless of hygiene standards.	Handshaking, drinking from an infected person's glass, playing with toys that are contaminated.	Diarrhea, vomiting, dehydration, and low-grade fever.	Replace fluids with a substance that contains both water and salt. There is no medication to cure it. Vaccines under development.
Yellow fever	Lack of effective mosquito control and widespread vaccination; urbanization in tropics; increased air travel.	Bite of an infective mosquito (*Aedes aegypti*).	Fever, headache, muscle pain, nausea, vomiting.	No specific therapy. Absolute rest; cool, well-ventilated room; liquid diet; vitamin K and calcium gluconate for hemorrhagic tendency; analgesics for pain.

* Studies are under way in forests of Cote D'Ivoire to identify the reservoir in which the Ebola virus hides; in Europe and the United States, the disease comes from virus-infected monkeys that have been shipped by air from developing countries.

Table I-74. *Emerging Bacterial Infections*[504]

Disease	*Causes of Emergence*	*Mode of Transmission*	*Symptoms*	*Treatment/ Prevention*

Cholera	Recent epidemic in South America introduced from Asia by ship; spread by travel and inadequate water chlorination; poor sanitation.	Ingestion of water contaminated with feces of infected persons; ingestion of food exposed to contaminated water.	Severe diarrhea, rapid dehydration.	Recent strains resistant to several antibiotics.
Escherichia Coli 0157:H7 (*E. coli*)	Contamination of meat during butchering process; spread by poor handling and inadequate cooking. Likely due to development of new pathogen.	Ingestion of contaminated food, especially undercooked beef and raw milk.	Hemolytic uremic syndrome, hemorrhagic colitis.	Oral or intravenous replacement of fluids.
Legionnaires' Disease (Legionella)	Legionella bacterium widely distributed in environment; found in creeks and ponds, hot and cold water taps, hot water tanks, and air-conditioning systems.	Air-cooling systems, water supplies.	Fever, headache, confusion, pneumonia.	Antibiotics such as erythromycin and rifampicin appear to be effective.
Lyme Disease	Increase in deer and human populations in wooded areas.	Bite of infective deer (Ixodes) tick.	Fatigue, headache, rash, fever, arthritis, neurologic and cardiac abnormalities.	Oral or intravenous antibiotics.
Streptococcus infections (Group A)	Change in virulence of the bacteria; possibly mutation.	Direct contact with infected persons or carriers; sometimes ingestion of contaminated foods.	Necrotizing fasciitis, streptococcal toxic shock.	Antibiotics.
Tuberculosis	Increase in immunosuppressed population, improper treatment exposing more people to disease.	Exposure to sputum droplets exhaled through a cough or sneeze of a person with active disease.	Cough, weight loss, lung lesions; infection can spread beyond lungs to other organs.	Combination of antibiotics for at least six months.
Typhoid	Spread of typhoid bacillus.	Infected water or milk supplies. Human carriers, particularly food handlers, may be responsible for spread of infection.	Fever, headache, abdominal pain.	General care, isolation, disinfection of all discharges. Inoculation with vaccine containing killed *Salmonella typhi*.

Table I-75. *Emerging Parasitic Infections*[505]

Disease	*Causes of Emergence*	*Mode of Transmission*	*Symptoms*	*Treatment / Prevention*
Cryptosporidium and other waterborne pathogens	Protozoan-contaminated surface water; development near watershed areas; immunosuppression.	Fecal-oral, person-to-person.	Diarrhea, vomiting, usually lasts less than 30 days.	Fluid/electrolyte replacement.
Malaria	Migration and travel to mosquito-infested areas; urbanization; changing parasite biology; environmental changes; drug resistance.	Bite of infective *Anopheles* mosquito.	Fever, headache, can cause respiratory and renal failure.	Chloroquine, but some forms may be resistant to most drugs.

12.3.2 Future Threat of Injury

Biological, chemical, directed-energy, and laser weapons are likely to cause injuries in future AEF deployments. In addition, currently unknown dangerous flora and fauna and infectious diseases will be encountered. Each of these threats is described in greater detail elsewhere in this report. Finally, increased all-weather and night operations could contribute to a higher frequency of injury.

12.4 Future Countermeasures

Future countermeasures against disease and injury are described in the following sections.

12.4.1 Future Infectious Disease Countermeasures

The essential countermeasures are fairly simple. Training is available through the Biological and Chemical Warfare Course at Aberdeen Proving Grounds. AEF personnel also must receive medical intelligence briefings before, during, and after deployment in areas of interest.

Naturally, immunizations play a critical role in preventing outbreaks of disease among AEF personnel. With careful planning, all deployable personnel can keep their immunizations current to ensure that they are ready to respond rapidly to a call for AEF deployment. Disease detection and monitoring will complement immunizations in a complete infectious disease countermeasures program, so the appropriate disease detection and monitoring equipment must be developed and made available to AEFs.

AEF units require direction from and coordination with higher headquarters to determine exactly which immunizations will be provided to deploying personnel. Each unit's Public Health Officer receives general requirements and then researches MEDIC and CDC guidelines for specific, nonroutine immunizations and prophylactics (e.g., for malaria). Table I-76 lists the immunizations all AEF personnel should have, and Table I-77 lists additional immunizations for personnel in "disease-susceptible" jobs and those personnel who receive animal bites.

Table I-76. *Immunization Recommendations for All Personnel*

Immunization/Chemoprophylaxis	*Dose Volume*	*Number of Doses*	*Frequency*
Hepatitis A	1.0 cc (IM in deltoid)	2 (no. 2 6-12 months after no. 1)	Shot no. 1 at least 14 days before departure
*Alternate (IG, ISG, GG)	2 ml — last 3 months (IM) 5 cc — last 5 months	1	Before deployment
Influenza	0.5 ml	1 every year	Before deployment
Japanese encephalitis	1.0 ml	3 (days 0, 7, and 30)	Before deployment
Typhoid	0.5 ml (injected) Oral dose	2 (weeks 0 and 4) 4 (days 0, 2, 4, and 6)	Before deployment
Meningoccocal meningitis	0.5 ml	1	Before deployment
Tetanus diphtheria	0.5 ml	Booster every 10 years; immediately after an animal bite or needlestick	Before deployment
Yellow fever	0.5 ml	1 every 10 years	Before deployment
Polio (oral or IM)	2 gtts	1	Before deployment

IM = Intramuscular

Table I-77. *Immunization Recommendations for Selected Personnel**

Immunization/Chemoprophylaxis	*Dose Volume*	*Number of Doses*	*Frequency*
Hepatitis B	1 ml	3 (months 0, 1, and 6)	Before or during deployment
HRIG (rabies)	20 IU/kg (half near the bite, half IM)	1	As soon as possible after bite
HDCV (rabies)	1.0 ml (IM in deltoid)	5 (days 7, 14, and 28-30)	As soon as possible after bite

* These recommendations are for personnel at risk for blood and body fluid contact and those individuals who are bitten or scratched by any animal.

The Air Force Reserve and Air National Guard are working toward the development of software to track immunizations for the entire Air Force, active duty forces included. The program would be mainframe-based, and user access would be similar to Internet access. This system would

- Allow an immunization technician to access an individual's record and immediately identify which immunizations are required
- Prepare an information sheet for an individual, listing the vaccines given, side effects, and dates for boosters
- Given a deployment location, identify all additional immunizations, medications, and laboratory tests required by an individual before deployment
- Produce a country-specific predeployment Health Assessment Questionnaire and, based upon the results of the questionnaire, identify recommended medical action for an individual
- Prepare a country-specific information package to be given to all deploying personnel
- Accomplish similar post-deployment actions
- Permit identification and monitoring of health trends and post-deployment health problems

The international community also is preparing to tackle the problem of infectious disease. The G-7 group of industrial nations (the U.S., Britain, Canada, France, Germany, Italy, and Japan) and Russia will establish a senior working group to "develop a global disease surveillance network, coordinate international responses to disease outbreaks, and coordinate efforts of the eight governments to increase their individual capacities to cope with infectious diseases."[506]

12.4.2 Future Injury Countermeasures

To implement this new strategy, a process of "Medical Readiness Reengineering" is under way. The key components of future medical readiness will be modularity, with a flexible mix of modules, augmentation of the ATH and aeromedical evacuation systems, time-based responsiveness to patients, interoperability of medical units, and appropriate movement of stabilized patients. The future medical units will be lighter, smaller, and more capable. The "visioning" phase and the requirements and feasibility phase of this process are complete. The current implementation phase, including Operational Test and Evaluation in FY 97 and upcoming membership in an Air Force Battlelab, is expected to be complete in FY 02.[507]

12.4.2.1 Medical Readiness Reengineering

The old medical strategy focused on treating a large number of WIA cases, providing care in large facilities, continuing treatment until patients were stable, and returning treated personnel to duty in-theater. Now, Air Force medical units are preparing for future operations that feature short, intense periods of treatment of WIA and DNBI cases; ATHs and modular deployment; stabilization — but not complete recovery — of wounded personnel in theater; and evacuation of wounded personnel with replacement by new personnel.[508]

12.4.2.2 Telemedicine

As implemented to date, telemedicine has not reached its full potential. Successful telemedicine relies on in-theater communications, Tri-Service integration, scale-up and scale-down capability, and modularity. In CONUS, the system must have both traditional and telemedicine referral centers, a network operations center, an image and data repository, and analysis and integration of data from the theater. Nearly all the necessary technology is available today, and telemedicine has been tested to some extent in Bosnia.[509]

The Air Force Mobile Composite Health Care System (CHCS) is one in-theater component of a complete telemedicine system. The brain of CHCS is a MEDSITE deployable computer room, which incorporates a workstation, climate control, and an uninterruptible power supply in a single shelter. The software includes an open operating system, the primary CHCS program, network systems, and a drug information package. There are 64 megabytes of random-access memory, 20 gigabytes of disk storage capacity, and additional tape and disk backup.[510]

Another telemedicine concept is the Southwest Asia Medical Informatics (SWAMI) package, a system initiated in 1996 by the Air Combat Command "to enhance force protection and capture vital medical information in-theater."[511] SWAMI is a small, lightweight, low-bandwidth system that incorporates command and control capabilities, voice communications, real-time video teleconsultation, data collection and processing, and World Wide Web access. The package melds commercial off-the-shelf technology with Medical Surveillance Theater (which captures data from medical locations) and runs on a high-end personal computer.

To be truly effective, the medical care infrastructure must include a comprehensive medical surveillance system. This system would make telemedicine truly seamless. The medical surveillance system should have an electronic medical record that links exposure information (for all threats, including disease, NBC, and occupational hazard agents) to health outcomes. The electronic medical record also should be linked to the in-theater personnel and unit record systems so that movements to different locations can be documented. One result of successful implementation of the surveillance systems would be complete exposure histories for individuals and units.

12.4.2.3 Laser Medical Pac

The Laser Medical Pac, under in-house development by Phillips Laboratory, is a compact device that provides the field paramedic or physician with a portable, battery-operated laser capability. The laser cuts like a scalpel, coagulates blood, and closes wounds. This system will be particularly useful for advanced trauma care on the battlefield. Because of its simplicity, the Laser Medical Pac can be used by anyone with a requirement to provide treatment of trauma cases, including special operations and pararescue personnel, medical technicians, and flight surgeons. This device is a significant advance over current laser-cauterization equipment. A 2W argon laser now takes about l0 seconds to stop a bleeding artery; however, this argon laser is roughly half the size of an office desk and requires alternating current. In comparison, the Medical Pac laser is about the size of a masonry brick, delivers l0 watts, and uses battery power.

The system is a self-contained unit (7 inches by 3 inches by 2.5 inches) that fits inside a beltpack. Laser energy is delivered to the instrument by a fiber-optic cable, which provides a very high power density (one kilowatt per square centimeter) at the tip of the instrument. The development team is working on different disposable-tip designs that can be applied directly to wounds. The output wavelength, which ranges from visible red to mid-infrared, can be tuned to provide different tissue interactions. The Pac is powered by two 2-volt batteries for the laser and one 9-volt battery for its electronics. The capability to operate from common camcorder batteries is in development. These 12-volt batteries would provide two amp-hours of power and would be quickly removable.

12.4.2.4 Other Concepts

Other concepts for future medical care requirements are the use of Common Air Transport to provide aeromedical evacuation; self-contained “flying hospitals”; and delivery of medical assets by unmanned aerial vehicles. There also is potential for integrated ground modules that serve as hospitals, crew quarters, water-purification stations, ground security, and NBC protection.

The Patient Loading System (PLS) is a new effort designed to make the Civil Reserve Air Fleet (CRAF) compatible with military requirements for aeromedical evacuation. The systems to provide commercial 767 aircraft with the capability to evacuate mass casualties — Aeromedical Evacuation Ship Sets — already are fielded. However, casualties on CRAF aircraft would have to embark and disembark through doorways 13 to 15 feet above the ground, and overseas and CONUS airbases do not have the necessary jetways. This long-standing aeromedical evacuation deficiency will be corrected by the PLS. In the near term, the PLS will be a modular ramp. In the far term, the PLS will be a complete system for rapid loading and unloading of ambulatory and nonambulatory patients, as well as carry-on medical equipment and supplies. The complete PLS will not be fielded until FY 98 at the earliest.[512]

12.5 Responsible Parties

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Centers for Disease Control and Prevention, 1600 Clifton Rd., NE, Atlanta, GA 30333, (404) 639-3311

Defense Advanced Research Projects Agency

Department of Agriculture, Washington, DC

Electronic Systems Center, Hanscom AFB, MA

Medical Advanced Technology Management Office

Medical Defense Performance Review

Medical Readiness Organizations at Air Force Base, Command, and Air Force levels

National Institutes of Health, Bethesda, MD 20892

Pan American Health Organization, Washington, DC

Theater Medical Information Program

U.S. Air Force Civil Engineering Support Agency, Tyndall AFB, FL

U.S. Air Force Medical Logistics Office

U.S. Air Force Research Laboratory

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13.0 Night

Valerie J. Gawron and James E. Priest

13.1 Current Threats

The AEF attributes of rapid response and awareness require deployment and defense at any time of day or night. Night operations, however, are associated with decreased performance because of decreased visual acuity. There are two countermeasures for this threat: selecting personnel with excellent night vision and using night vision goggles (NVGs). Identifying personnel with excellent night vision is difficult because the tests to measure this ability may not be diagnostic.[513]

NVGs are not wholly satisfactory either. Most NVGs (e.g., the Pilot's Night Vision System on the AH-64A) restrict the field of view (FOV) and do not provide daylight acuity.[514] In addition, NVGs are not compatible with aircraft lighting systems, as illustrated by the following reports from the Automated Lessons Learned Capture and Retrieval System.

> Night vision goggles are worn by crew members during covert operations and night search and rescue missions. The NVGs amplify visible and infrared (IR) light emitted from the aircraft lighting systems. This is accomplished by utilizing a light frequency band in aircraft lighting systems that is compatible with NVGs. Minimum lighting levels are desired for low detectability during unique operational requirements. The request for proposals for existing helicopter systems did not identify NVG design requirements. It becomes cost and design prohibitive to modify lighting systems, new avionics display face plates, instrumentation lights, and aircraft lighting systems after procurement of a weapons system.[515]
>
> Location of external lighting produces glare shadows that can severely degrade the pilot's night vision. The refueling probe light on the F-18 is positioned such that the shadow cast by the refueling drogue gradually covers the tanker aircraft, until the tanker is completely blanked at the later stages of the rendezvous. At this point the pilot must flyoff the drogue with no visual cues from the tanker aircraft. Turbulent air could move the drogue basket enough to make a successful hook-up very difficult. Furthermore, after the probe has been inserted into the drogue, the light reflects off the drogue back into the cockpit. At this point the pilot cannot see the tanker aircraft. This condition could easily lead to a midair collision. Also, after the refueling has been completed, the pilot must readapt his night vision. This adversely affects the pilot's safety and effectiveness.[516]
>
> Inadequate NVG compatible exterior lighting can lead to a midair collision. . . . Several helicopter aircrews were required to configure their exterior lights to allow formation flight using NVGs. The reduced lighting was sufficient for formation separation, but provided insufficient visual cues for aircraft outside the formation. Another type helicopter participating in the same operation failed to see the lead helicopter in the formation and collided with it. Both aircraft and aircrew were lost. Inadequate exterior lighting compatible with NVGs was identified as a cause of the mishap.[517]

Other problems with NVGs include incompatibility with current crew stations (for example, any bright light in the cockpit will cause blooming in the NVG) and no integration with laser eye protection. The fundamental problem, though, is that targets and threats simply are difficult to see with NVGs.

In addition, the NVG hardware has serious shortcomings. The lithium batteries needed to use these NVGs also can be a problem, as they are easily short-circuited. Short-circuiting can result in excessive heat build-up, release of toxic fumes, or explosion. Also, spare parts frequently are not compatible with the original hardware.

> A pilot signed for NVG, power pack, and two lithium batteries prior to briefing for a night launch. He installed the batteries for an operational check of the NVG. After receiving a go indication, he removed the batteries and put them in the sleeve pocket of his flight suit along with a keychain. Hours later, after brief, preflight, and launch, he removed the batteries from his pocket to install them in the NVG power pack. One of the batteries was so hot he could not hold it in his hand. The use of lithium batteries in NVG poses a handling problem which could escalate and endanger aircrew safety.[518]

> The inability to procure replacement aircraft hardware which is compatible with existing night vision retrofit components can result in degradation of mission capability. . . . A cargo helicopter retrofitted with NVG cockpit compatible lighting has experienced a problem with NVG filter lenses that do not fit replacement utility lights received from the Federal Supply System. The units displayed the same National Stock Number as the original lights, but exhibited different physical dimensions, forcing the squadron to attach the lenses with tape when converting to night vision. An inventory of seven aircraft in another squadron revealed three different sizes of cockpit utility lights.[519]

Also, other night operation equipment is not operationally effective.

> The MX-991 flashlight contains one each red, blue, white, and clear diffuser lens. . . . Night vision equipment (spotting scopes, rifle scopes, and goggles) basically view the infrared spectrum. The flashlight lens with the red, blue, or clear diffuser emits a strong infrared spectrum signal that is easily detected with night vision equipment. Thus, anyone using a flashlight with one of these filters can instantly become a visible target. These lenses give the soldier a false sense of security that could be lethal.[520]

Finally, pararescue personnel report that they need a more effective, more compact night vision scope to perform their missions.[521]

13.2 Current Countermeasures

Current countermeasures include various forms of night vision equipment.

13.2.1 Human Vision

Acuity at night can be enhanced with night vision equipment (NVE). This equipment can be combined with other sensors or displays to present an overall picture to the crew member. The purpose of the NVE is to provide the crew member with an artificially amplified view of the immediate surroundings in conditions where the unaided eye can see little or nothing. The eye presents an image to the brain by focusing it onto the retina, which contains cone- and rod-shaped cells called photoreceptors (Figure I-55). These cells convert sensed light to electrical impulses, which in turn are transmitted to the brain via the optic nerve. The cones are concentrated in a small area (i.e., perimetric angle of less than 10 degrees) at the center of the retina called the fovea. The rods dominate the remaining area of the retina and are most prevalent about 20 degrees from its center. A blind spot exists in an area about 15 degrees from the center of the retina, where the optic nerve is connected.

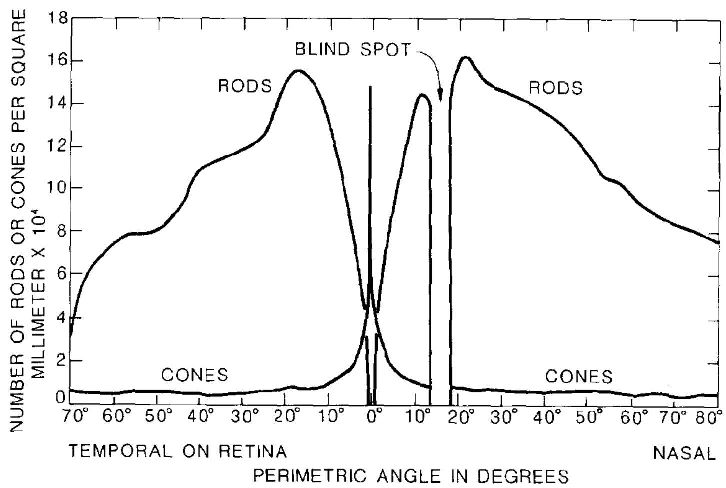


Figure I-55. *Distribution of Rods and Cones in the Retina*[522]

The three classifications of human vision are photopic, mesopic, and scotopic (Figure I-56). Photopic vision yields good acuity and color vision (mediated predominately by retinal cones) and is characterized by normal light-adapted vision in daylight. Alternatively, scotopic vision yields poor acuity and no color vision (mediated predominately by retinal rods) and is characterized by dark-adapted vision at night. Mesopic vision occurs between photopic and scotopic vision. The cone threshold is approximately 10^{-4} millilamberts (3.2 x 10^{-4} candelas/m^2), which is equivalent to the illuminance of white paper in starlight. Photopic vision is generally thought to begin at luminance levels above 1 millilambert (3.2 candelas/m^2), which is equivalent to the illuminance of white paper 1 foot from a standard candle.

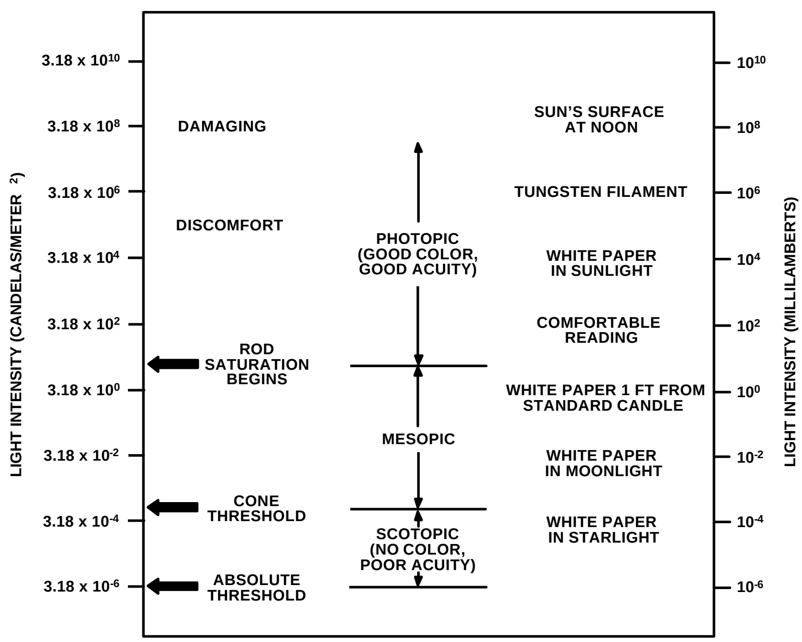


Figure I-56. *Light Intensity Bands*[523]

Visual acuity typically is measured as a ratio between what the subject can discern and what a perfect eye would see at 20 feet. To date, the best visual acuity that image-intensification technology can achieve is 20/40. This level of acuity corresponds to mesopic vision.

Studies examining recognition accuracy in the near-visual periphery as a function of foveal cognitive load reveal that aviators have larger effective visual fields than nonaviators. Figure I-57 shows how different experience levels have a direct effect on the amount and type of peripheral task decrement.[524]

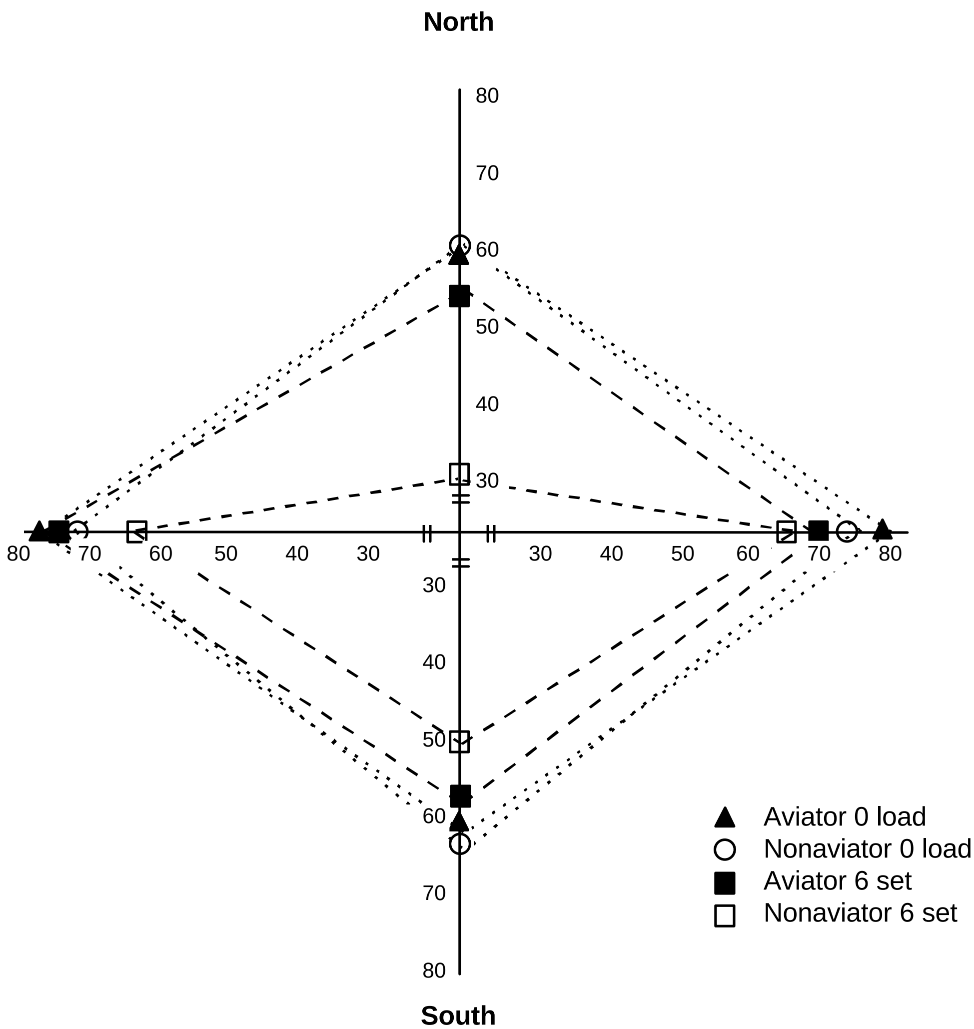


Figure I-57. *Peripheral Recognition Accuracy in Aviators and Nonaviators for 0 Load and 6-Set (High) Load at Each of the Four Meridians*[525]

13.2.2 Night Vision Equipment

NVE is used to amplify the ambient scene through image intensification and thereby provide the user with a higher-acuity (photopic) view of the surroundings. The image-intensification tubes (IITs) evolved through three distinct generations (Figure I-58). The Generation One (Gen I) IIT uses three stages to amplify the sensed ambient light and display it to the operator. Generation Two (Gen II) IITs adopted fiber-optic technology and a tri-alkalide photocathode to amplify the image. The Generation III (Gen III) IITs use a silicon-arsenic photocathode. These systems use high vacuum to electronically amplify the illuminated images.

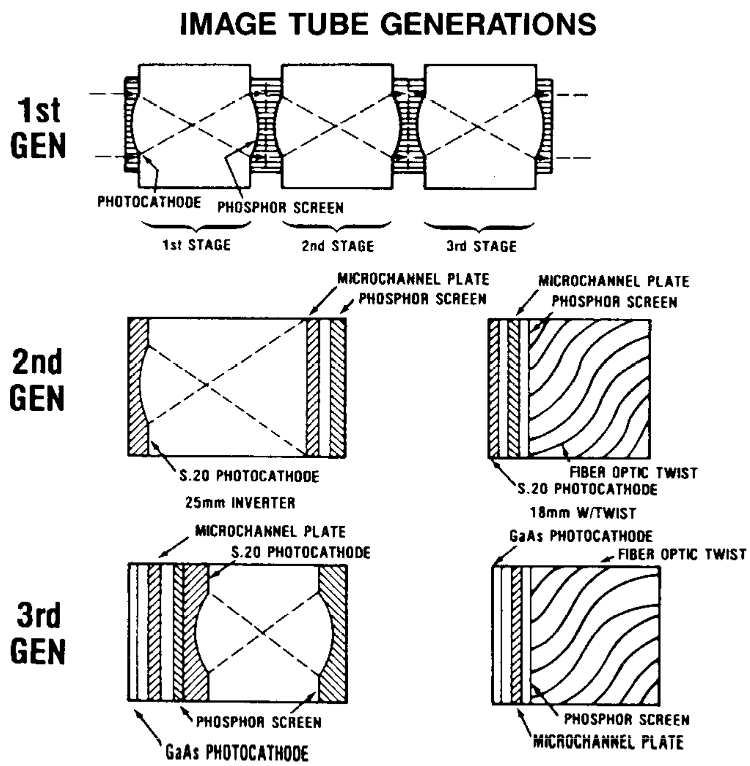


Figure I-58. *Image Tube Cross Section by Generation*[526]

Each tube generation provides distinct advantages in both weight and system performance. System gain, signal-to-noise ratio (SNR), and resolution all have been improved dramatically through this evolution. Because of its limited capability and higher weight, NVE using Gen I technology has limited use. The mean-time-to-failure of Gen II tubes (2,000 hours) has been improved significantly in Gen III (7,500 hours). System gains have increased from 800 for Gen II technology to 2,000 for Gen III. SNRs of 16.5 for Gen III tubes (up from 4.5 for Gen II) now are achievable. Resolution has increased from 25 linepairs per millimeter (lp/mm) for Gen II tubes to 36 lp/mm for Gen III.

The IIT has three major components, the photocathode, the microchannel plate (MCP), and the phosphor screen (Figure I-59). An inverted image is focused on the input window by the objective lens. The image then is amplified by the MCP and projected on the phosphor screen. The visible phosphor image is erected by a fiber-optic bundle installed with a 180-degree twist. Then the image is viewed through the eyepiece lens (in direct-view NVGs) or passed through the collimating lens in projected-view systems.

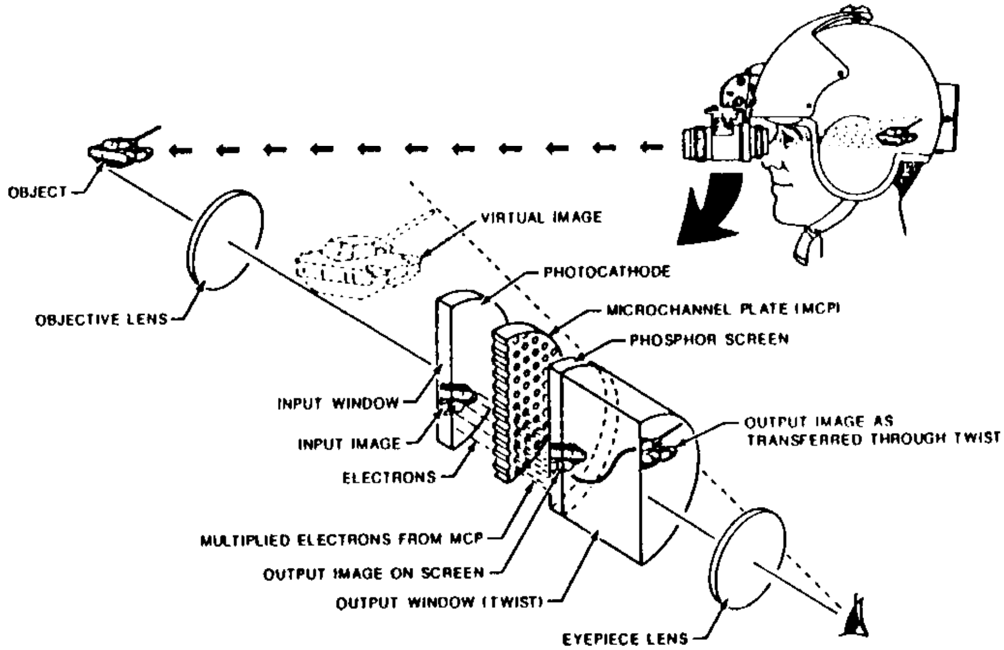


Figure I-59. *Night Vision Goggle Components*[527]

The photocathode converts photons (visible or infrared light energy particles) into electrons (Figure I-60). These electrons then bombard the MCP, which has more than one million channels. The channels have excess electrons because of a high negative voltage across the MCP (approximately 1,000 volts). The electrons emitted from the photocathode release the MCP electrons to travel out the channels. This significantly amplifies the incident light. Finally, the phosphor screen converts the electrons into a visible monochrome image. Typically, a green monochromatic phosphor is used because the human eye is very sensitive to green.

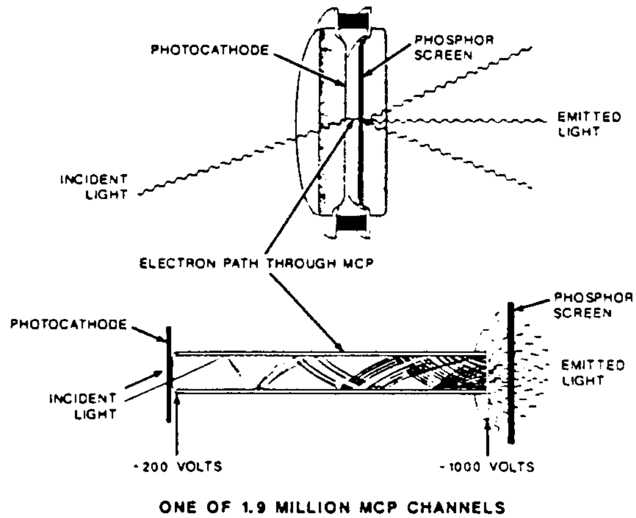
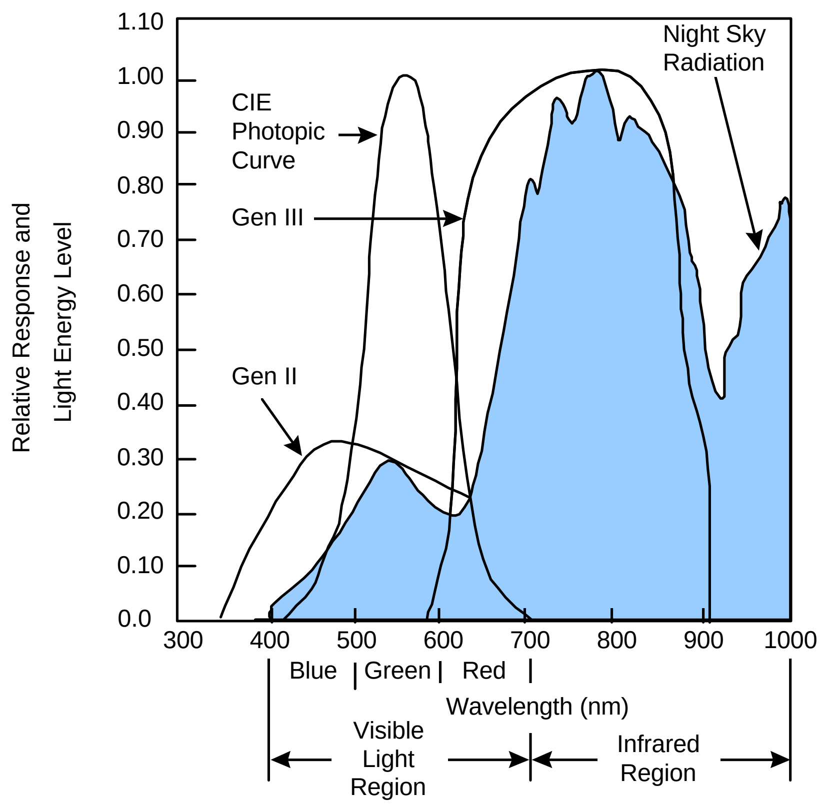


Figure I-60. *Image Intensifier Cross Section*[528]

The human eye perceives stimuli in the visual spectrum, which extends from about 400 nanometers (nm) to 700 nm (0.4 to 0.7 micrometers). As illustrated by the Commission Internationale de l'Eclairage (CIE) photopic curve (Figure I-61), the greatest sensitivity occurs in the visible green band, which is the peak wavelength of sunlight (approximately 550 nm). At the longer wavelengths found in typical night sky radiation (greater than 600 nm), the eye is not able to resolve fine detail and color. The peak night sky radiation occurs in the near-IR region (wavelengths between 600 and 900 nm). Unfortunately, Gen II ITTs sense light best in the visible region and have only limited performance in the near-IR region. Gen III IITs correct this limitation. Their peak performance occurs in the near-IR region, exploiting the characteristics of typical night sky radiation. Another advantage of Gen III IITs is that they filter shorter-wavelength visible light (wavelengths < 625 nm), making green-blue cockpit light effectively invisible to the IIT.



) LJXUH,□□□□□ *Image Intensifier Response Curves*[529]

With NVGs, two factors can contribute to perceptual problems: a narrow FOV and reduced visual acuity. In laboratory studies measuring judgments that involve depth perception, results indicate that NVGs cause objects to appear closer than with unaided vision. Also, any underestimates of distance increased as the distance estimated decreased.[530]

13.2.3 Direct-View NVE Configurations

The use of NVGs has allowed military personnel to operate in conditions of reduced visibility and at night with little reduction in mission capability. The first fielded version of NVG, designated Army-Navy/Personal Visible-Light Detection Series 5 (AN/PVS5), was designed primarily for ground personnel use. The advantages of such a system were immediately recognized and prompted implementation of a helmet-mountable version for airborne weapon systems. The AN/PVS5 and the follow-on AN/PVS7 used a single second- or third-generation IIT, providing a view of the scene through a single objective lens (Figure I-62). The image was optically split and presented to the eyes through two eyepieces. This approach did not provide true stereopsis and, therefore, proved inadequate for the demanding airborne environment.

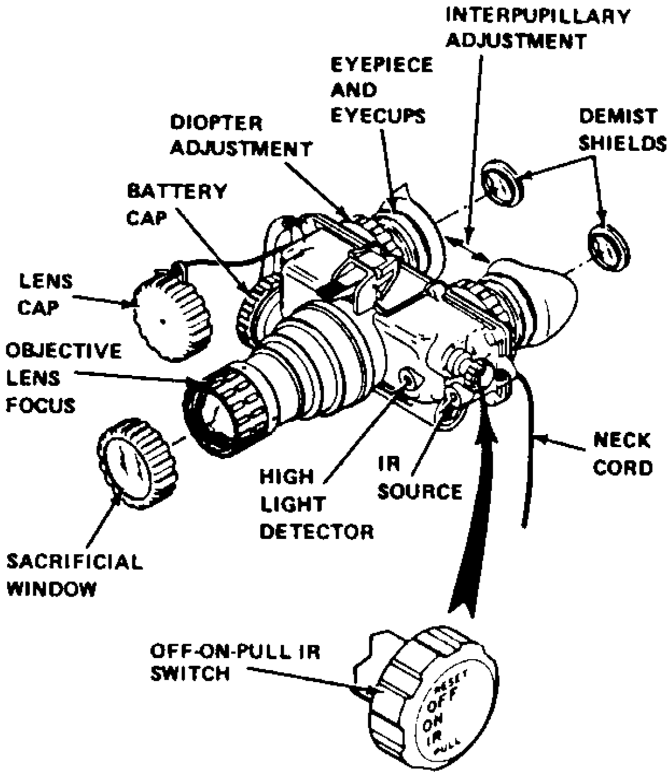


Figure I-62. *Monocular NVG*[531]

Airborne NVGs were first fielded in rotary-wing aircraft. That first configuration, the Aviator's Night Vision Imaging System (ANVIS), used two IITs, one placed directly in front of each eye (Figure I-63). This corrected numerous problems associated with single-tube goggles. The crew member now had a true stereoscopic view and gained the requisite improvement in depth perception. The two-tube configuration provided adequate redundancy should a single tube fail. The NVG also provided an essential backup to a fixed FLIR sensor by allowing an all-aspect "look-around" capability. This increased the crew member's total field of regard with a display of the outside scene comparable to the FLIR's.

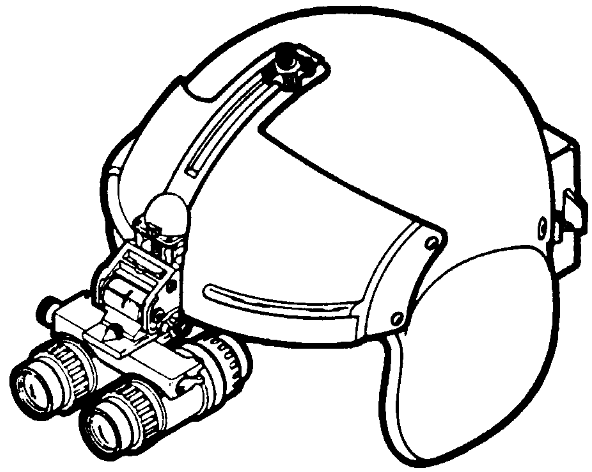


Figure I-63. *Binocular ANVIS NVG*[532]

Direct-view NVGs have numerous limitations. Eye relief (the distance from the eyepiece to the eye) must be sufficient to allow the user to look under the tubes to view the crew station and in some cases wear corrective glasses. However, most of the crew station still is obscured by the tubes. Problems with viewing head-up displays through the IIT delayed the implementation of NVGs in fixed-wing fighter aircraft. This problem is amplified when the crewmember views FLIR imagery superimposed on the HUD. The projected FLIR imagery typically is reduced by as much as 50 percent because of a decrease in goggle resolution and worsening of chromatic aberrations because of the inability of the objective lens to compensate when focusing the image on the flat plate of the photocathode.

The characteristics of the HUD itself cause additional problems. The HUD is optimized for the green phosphor of the cathode-ray tube (CRT). Only this visible light is focused at infinity. The “red tail” sensed by the NVG may not be focused at infinity. Additionally, decollimation of the HUD changes the focal point to allow correlation to the out-the-canopy view. The NVG is affected by the canopy decollimation differently because the longer-wavelength light transmitted by the NVG is refracted differently than the visible light. The NVG is not decollimated, and, therefore, the HUD display is at a different focus than the outside world (i.e., the HUD is not focused at infinity when viewed through the NVG).

The advent of wide-FOV HUDs caused even greater complications. These HUDs present the correctly defracted holographic image to a very limited eye box. The NVG IIT objective lens typically is 4 to 5 inches in front of the design eye point. Consequently, the HUD is viewed at the forward edge of or outside the eye box. Additionally, the accurate image is visible only over a very narrow band with the peak in the center of the visible light region. Although in some cases the HUD is visible to the NVG, this display is a sideband of the peak and may be degraded and inaccurate.

FOV of the direct-view system is a trade-off between eye relief, exit pupil (the diameter of the display projected to the eye), and the size of the collimating lens. The eye relief must be sufficient to allow the crew member to wear corrective spectacles, since they would be necessary for viewing both the HUD and the intensified image. The collimating lens size must be kept to a minimum to control the weight of the optics. The exit pupil must be sufficient to allow for misalignment of the combiner eyepiece from normal shifting during wear. Figure I-64 shows how the designer must balance these conflicting design goals. For a given FOV (a_1), the eye relief can be reduced (x_2 to x_1) to reduce the size of the collimating lens (d_2 to d_1) and thereby reduce weight. However, this will reduce the exit pupil accordingly. For a given eye relief (x_1) the size of the collimating lens must be increased (d_1 to d_2) to increase the FOV (a_1 to a_2). Again, the exit pupil will change accordingly.

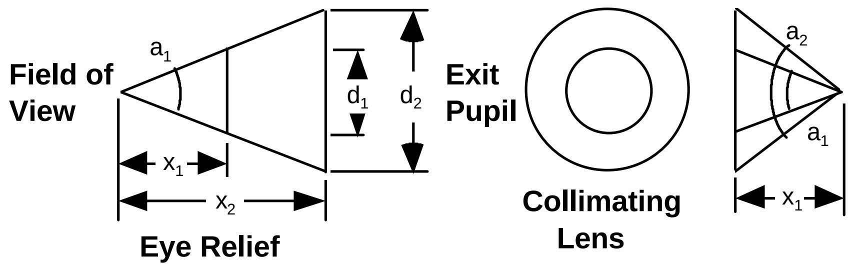


Figure I-64. *FOV Trade-offs*[533]

Ideally, the FOV would be equivalent to that of the eye itself (roughly 120 degrees vertically by 200 degrees horizontally, binocular). This FOV would allow the crew member to use all normal peripheral cues. Critical among these cues is attitude recognition. The minimum FOV required for flight is not clearly understood. However, any reduction in FOV degrades the crew member's ability to sense orientation, because information in the peripheral retina is reduced. This retinal area normally mediates visual information regarding orientation. More concentration is required to acquire orientation from central (foveal) vision. This renders the crew member susceptible to spatial disorientation in situations where primary attention is diverted to other crew station duties. Studies indicate that the crew member's ability to maintain orientation is proportional to FOV and is degraded with increasing workload.[534]

The FOV also can affect the resolution and object detection range. The resolution ultimately is limited by the resolution of the IIT itself. Gen III tube resolution is approximately 36 lp/mm. For a given tube resolution, reducing the FOV increases the overall resolution at the expense of peripheral cues. Generally, reducing FOV improves detection range. Another advantage of reducing FOV is reduction in the haloing effect. The halo is caused by bright ambient lights. Since the light occupies less angular area in the FOV, the halo will be reduced. However, in a recent experiment, decreasing the FOV (to 80 degrees, 60 degrees, and 40 degrees) resulted in the most errors, the lowest number of targets detected, and the longest search times at the lowest resolution (20/120, 20/80, and 20/40, respectively).[535]

13.2.4 Projected-View NVE Configurations

The introduction in 1989 of projected-view NVE using a combiner eyepiece circumvented many of the problems associated with direct-view NVGs (Figure I-65). These configurations typically mounted the IITs above and ahead of the crew member's line of sight, allowing room for combiner eyepiece mounting on the aft end of the tubes. Unfortunately, this forced the movement of the IITs farther forward to allow the necessary eye relief. The weight of the package increased with the addition of the required optics and forced tradeoffs with FOV to reduce weight. To afford ejection seat safety, the assembly had to be removable. Removal could be accomplished either automatically or manually prior to ejection. Neither solution was desirable. If using a manual quick-disconnect, the crew member was forced to accomplish another task at the critical time prior to ejection. An automatic system relieved the crew member of the disconnect task, but introduced a foreign object into the crew station, causing a potential safety hazard.

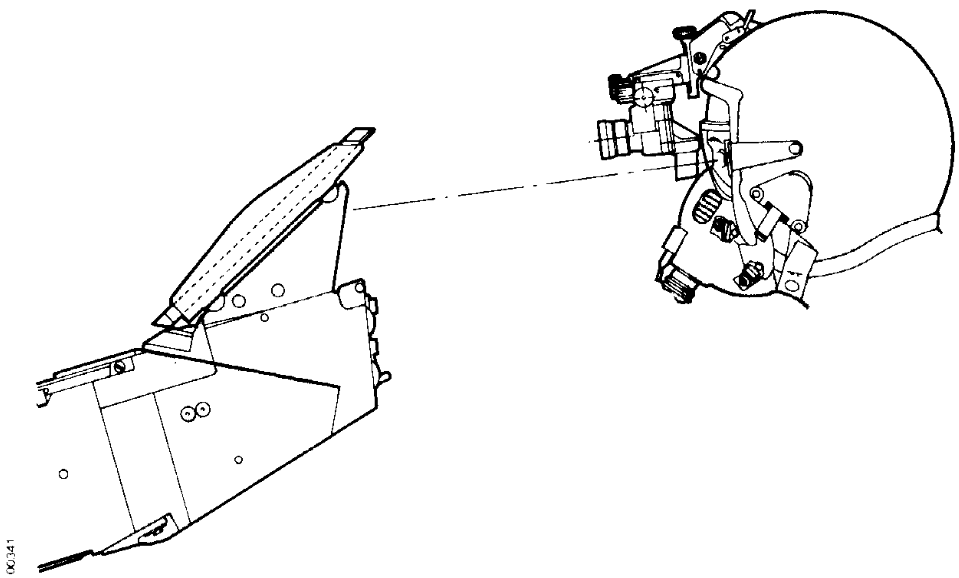


Figure I-65. *Cat Eyes NVG*[536]

The projected-view NVE allowed the crew member to look directly at the crew station instruments, the HUD, or the actual outside scene. Minus-blue filtering in conjunction with compatible blue-green cockpit lighting made the crew station lights and HUD invisible to the IITs. The crew member thus would receive an intensified image of the outside scene only. The view of the HUD was correctly decollimated and focused. The view inside the crew station was nearly unobstructed, since the crew member no longer had to look around direct-mounted IITs.

Subsequent integrated projected-view configurations correct many of the shortcomings associated with the early helmet-mounted types (Figure I-66). The IITs are part of the flight helmet. Weight and balance are improved by removal of the mass of the goggle assembly mount in front of the head. The line of sight of the IITs now is closer to the crew member's eyes and is not obstructed by the HUD combiner or canopy bow. The ejection conflict is essentially removed because the integrated system can remain safely attached to the crew member. However, the added weight and additional components do introduce a somewhat higher risk of injury than in ejection with the flight helmet alone.

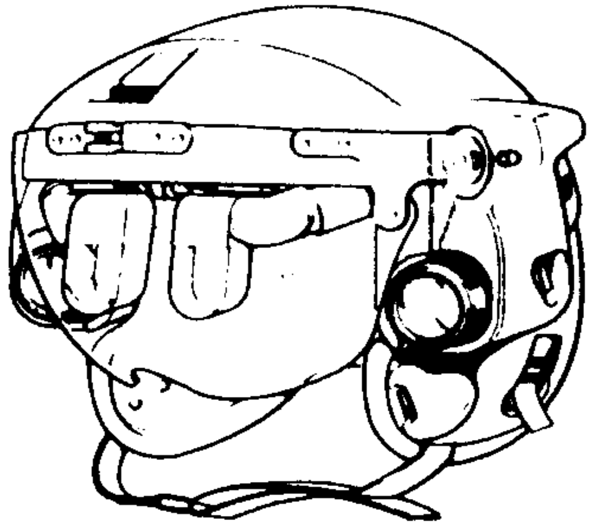


Figure I-66. *Integrated Night Vision Helmet*[537]

Viewing the actual scene combined with an intensified image of the scene improves the crew member's view outside the crew station. The IIT automatically adjusts its gain when it senses bright objects. This adjustment causes the entire scene to disappear until the object is outside the FOV of the IIT and the gain increases. If this bright object were viewed using direct-view NVGs, the crew member would be temporarily blinded. However, with the projected-view configuration, highlighted features not visible to the IIT can be viewed directly.

The overall brightness gain of the projected system (IIT combined with the associated optics) is lower because the combiner eyepiece must both reflect and transmit light in order to provide both views. Brightness gain is the ratio of intensified image brightness to actual image brightness, typically 25,000 for this configuration. Contributors to brightness gain include (1) f-number (the ratio of focal length to lens diameter), (2) objective lens transmission, (3) IIT gain, and (4) eyepiece transmission.

High brightness gain corresponds to low transmission of the direct view (outside scene, HUD, or crew station instruments), because most of this light reflects off the combiner eyepiece. The transmittance and reflectance are inversely proportional and controlled by the manufacturer through the design of the combining glass. The combining glass is semitransparent, so some loss in the intensified image occurs due to transmittance. Conversely, the loss in the direct-view image is due to reflectance. Figure I-67 illustrates this phenomenon. The intensified image reflects off the combiner glass and is displayed to the crew member. Concurrently, the direct view through the combiner glass also is viewed. A balance is reached to allow both images to be viewed with reasonable brightness.

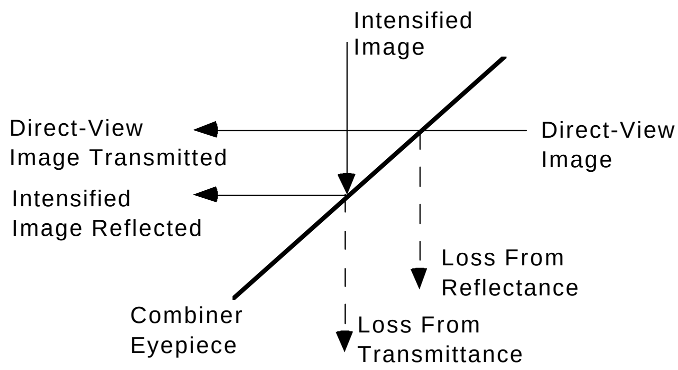


Figure I-67. *Combiner Eyepiece Characteristics*[538]

Because the combiner glass has finite thickness, incident light is refracted (Figure I-68). The intensified image reflects off the surface of the glass and is displayed to the crew member. The direct-view image is refracted as it passes through the glass. Consequently, the intensified and direct-view scene are slightly misregistered. The amount of misalignment depends on the refractive index of the combiner glass and the angle it makes with eye. Typically, the combiner eyepiece is placed at a 45-degree angle. This arrangement allows the intensified image to be bent through a 90-degree angle.

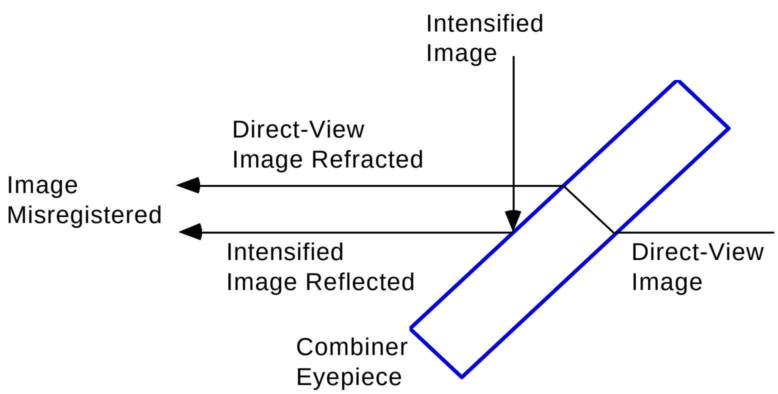


Figure I-68. *Combiner Eyepiece Image Misalignment*[539]

Combiner eyepiece transmittance and refraction both combine to cause difficulties when used with a HUD. The losses in the direct-view image caused by low transmittance reduce the HUD contrast, making it less compelling. Additionally, if the HUD is visible to the IITs, the misalignment due to refraction causes a double image to be presented to the crew member. Both these effects are undesirable, and, to alleviate them, designers have resorted to blanking algorithms. A sensor is used to detect movement of the crew member's head. When the crew member is looking at the HUD, the intensified image is blanked, alleviating any conflicts. Unfortunately, the intensified image is removed from the quadrant where it is most useful (i.e., along the flightpath).

13.2.5 NVG Performance

Armstrong Laboratory developed the NVG Resolution Chart for testing preflight NVG performance under specific lighting conditions.[540] The NVG Resolution Chart consists of nine randomly placed square-wave gratings with 95 percent contrast. Grating bar widths range from 20/35 to 20/100 Snellen when viewed from 20 feet. Aircrew members who use the NVG Resolution Chart to adjust their NVGs have significantly better acuity.[541] Because of the increased resolution afforded by the current NVG, F4949, the resolution charts have been modified to 20/20. Typical F4949 performance is 20/25.

Three factors are critical to NVG performance: experience, alignment, and focus. Aircrew members with more than 2 years of NVG experience have significantly better acuity (20/50.8) than aircrew members with fewer than 2 years (20/54.8).[542] Aircrew members who received an NVG Adjustment Procedures class had the best goggle acuity (20/37.5).[543] The Night Imaging and Threat Evaluation (NITE) Laboratory provides training in several types of alignment and focusing procedures, which enable NVG users to quantify and maximize NVG performance before each flight test. These procedures are conducted with NITE Lab visual acuity/resolution charts under controlled, calibrated illumination conditions.

A variety of other factors affect NVG performance. Hypoxia has an impact because visual acuity with ANVIS is degraded to 4,300 meters after 30 minutes at an altitude.[544] Furthermore, the inverse relationship between FOV and visual acuity must be considered.[545] Specifically, "an increase in field-of-view is accomplished by providing higher magnification of the image intensifier tube. However, since the image intensifier tube has a fixed linear resolution at its output screen, increased magnification means that the 'picture elements' (pixels) will subtend a larger angle with respect to the eye, thus leading to lower visual acuity when viewing through the NVGs."[546] Visual acuity also is degraded by an increase in the SNR of NVGs. The effect can be predicted using empirical equations:[547]

- Visual Acuity = 0.2328 – 1.2966/SNR (at 0.01 illumination, 20 percent contrast)
- Visual Acuity = 0.3024 – 0.9572/SNR (at 0.01 illumination, 95 percent contrast)
- Visual Acuity = 0.3234 – 0.8630/SNR (at 0.25 illumination, 20 percent contrast)
- Visual Acuity = 0.4836 – 1.4387/SNR (at 0.25 illumination, 95 percent contrast)

Finally, the type of goggle is important. There are three types: monocular, biocular, and binocular. The Army compared off-road walking performance of NVG-trained National Guard troops wearing monocular AN/AVS-6s with the left tube assemblies removed, biocular AN/PVS-7Bs, and binocular AN/AVS-6s.[548] In a high-moon illumination condition (average light level 0.0057 foot-candles) and a low-moon illumination condition (average light level 0.000961 foot-candles), subjects made significantly fewer errors (contact with hazard, marked decrease in walking pace, request for assistance, stop, and stumble) while wearing the binocular goggle than while wearing either of the other two goggles. Similarly, in the low-moon condition, participants completed the course faster with the binocular goggles than with the other two goggles. (However, this difference did not occur for the high-moon condition.) The rating data indicated that the binocular goggle provided better warning and less visual discomfort, and subjects preferred the binocular goggle to the other two goggles. In an expanded study that required NVG wearers to scan for targets, the binocular goggle again yielded better performance and was preferred to either the biocular or monocular goggle.[549]

Comfort is another consideration for NVGs. In a recent comparison of the comfort of head-mounted monocular and biocular goggles, male Army National Guard members used the goggles to traverse a 2-km course in full- and no-moon conditions. The only statistically significant difference between the goggles was more discomfort due to tight neck muscles when wearing the biocular goggles, which weigh 180 grams more than the monocular goggles. Finally, all reported headaches were attributable to the head harness.[550]

Military specification MIL-L-85762A establishes performance, general configuration, test, and acceptance requirements for aircraft interior lighting that is compatible with night vision imaging systems (NVISs).[551] The specification is applicable to all systems, subsystems, and component equipment that provide the lighting environment in aircraft crew stations and compartments where NVE is used. The specification covers both types and classes of image intensification. Table I-78 shows which NVE are compatible with which crew station, and Figures I-70 and I-71 provide the specifications for objective lens filters. Military specification-compliant lighting is essential if NVE is employed. Some important compliance issues exist:

- Green light is not necessarily compliant (if it contains IR energy).
- Any incompatible light sensed by the NVE will cause a reduction in gain.
- Incompatible lights cannot be turned down enough to be compatible.
- Decreased NVE performance is rarely perceptible to the human eye.
- Thin stroke (10:1), noncondensed, well-spaced lettering is easily read at low luminance.
- A windscreen and HUD combiner can degrade NVG capability.[552]

Table I-78. *NVE-Compatible Crew Station Types and Classes*[553]

Crew Station	*Compatible NVE*
Type I	Any direct-view NVE using Gen III image intensification
Type II	Any projected-image NVE using Gen III image intensification
Class A	Any NVE using 625 nm minus-blue objective lens filters (Figure I-69)
Class B	Any NVE using 665 nm minus-blue objective lens filters (Figure I-70)

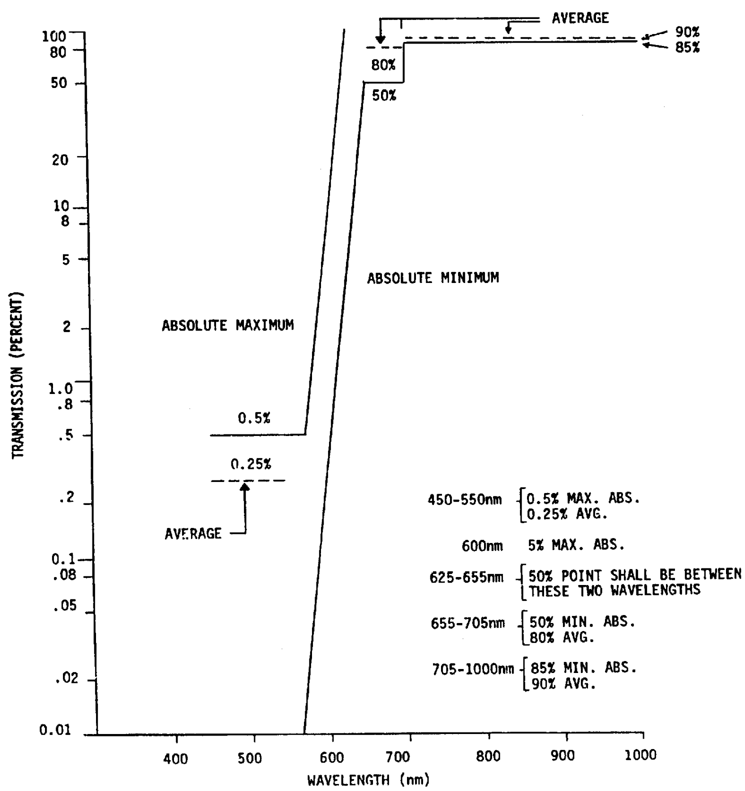


Figure I-69. *Class A 625-nm Minus-Blue Filter Specification*[554]

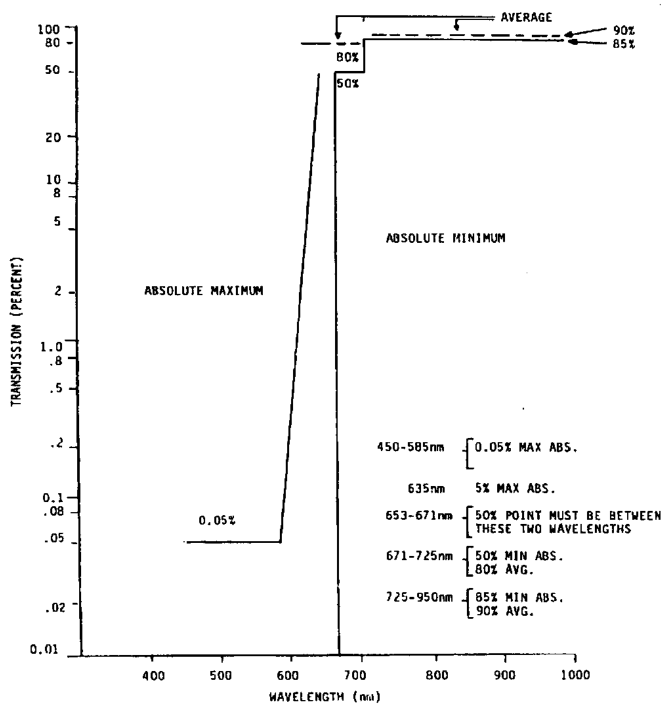


Figure I-70. *Class B 665 nm Minus-Blue Filter Specification*[555]

13.2.6 Vision Problems With NVGs

Use of NVGs can adversely impact human vision. NVGs can cause eye strain and other side effects, and these effects must be monitored constantly to avoid undue hazard to the test subjects. Setup errors in the focus, interpupilary distance, diopter, or mount alignment can cause eye strain and reduce the effectiveness of the NVE. In addition, defects in current-technology (Gen III) IITs and related assemblies can cause visual anomalies.[556] The magnitude of the anomaly is the deciding factor for NVG flightworthiness. The crew member should inspect the NVG for 10 potential defects:

- **Shading.** Each IIT should present a perfect circle. If shading is present, this circle will be distorted and have a dark edge. Shading always begins on the edge and moves inward. *Do not* fly if shading is present (see Figure I-71).
- **Edge Glow.** Edge glow is a bright area (sometimes sparkling) in the outer portion of the viewing area. To check for edge glow, block all light by cupping a hand over the lens. If the image tube is displaying edge glow, the bright area will still show up. *Do not* fly if edge glow is present (see Figure I-71).
- **Emission Point.** An emission point is a steady or fluctuating pinpoint of bright light in the image area. The position of an emission point within the image area does not move. To check for emission points, block all light by cupping a hand over the lens. If the image intensifier tube is displaying emission points, the bright spot will still show up. *Do not* fly if the emission point is brighter than the background scintillation (see Figure I-71).

- **Black Spot.** This is a cosmetic blemish in the image intensifier or dirt or debris between the lenses. *Do not* fly if the black spots mask the intensified image enough to preclude safe mission accomplishment (see Figure I-71).
- **Bright Spot.** This defect is caused by a flaw in the film on the MCP. A bright spot is a small, nonuniform, bright area that may flicker or appear constant. To check for bright spots, block all light by cupping a hand over the lens. If the image tube is displaying bright spots, the bright area will still show up. *Do not* fly if the bright spot is present. If the bright spot goes away when the light is blocked, it is a cosmetic defect that is signal induced, and the NVE is still usable (see Figure I-71).
- **Fixed-Pattern Noise (Honeycomb).** This is usually a cosmetic blemish characterized by a faint hexagonal pattern throughout the viewing area that most often occurs at high light levels or when viewing very bright lights. This pattern is present in all IITs when the light level is bright enough. *Do not* fly if the honeycomb masks the intensified image enough to preclude safe mission accomplishment or if it remains in low-light conditions (see Figure I-71).
- **Chicken Wire.** An irregular pattern of dark, thin lines in the FOV in parts or all of the image area. In the worst case, these lines will form a hexagonal or square-wave pattern. These lines are caused by defective fibers that do not transmit light at the boundaries of fiber bundles in the output optic of the image intensifier. *Do not* fly if the chicken wire masks the intensified image enough to preclude safe mission accomplishment (see Figure I-71).
- **Image Distortion.** Proximity-focused image intensifiers exhibit various kinds of image distortion as a result of the characteristics of the fiber-optic faceplate. Gross distortion and shear distortion are inherent in the basic fused fiber-optic material. Imperfect image rotation and S-distortion are more common in fiber-optic image rotators or inverters. *Do not* fly if the intensified image is distorted enough to preclude safe mission accomplishment.
  - **Gross distortion** is a result of nonuniformities in the fiber-optic block processing. It is characterized by the straightness with which a line is transferred from one surface to the other. Because of the nonuniform nature of the fiber-optic fiber matrix and variances in the manufacturing process, this characteristic cannot be eliminated (see Figure I-71).
  - **S-distortion** is a result of the twisting operation and is caused by fibers moving differently in different regions of the fiber-optic bundle as the twisting operation is performed. S-distortion is identified by viewing a diametrical line through the center of the image. The line will have an “S” shape and will pass through the center of the FOV (axis of rotation of the twist). The maximum deviation from a straight line is usually not more than 60 to 80 micrometers on Gen III IITs. The effects of S-distortion and gross distortion are additive and consequently are difficult to separate (see Figure I-71).
  - **Shear distortion** is a dislocation in the output image caused by slippage of a few fibers or fiber rows relative to adjacent fibers (see Figure I-71).
  - **Incomplete image rotation** occurs when the fiber optic twist is not exactly 180 degrees. For typical Gen III optic inverters, the twist angle is 178 to 182 degrees. Again, it is difficult to separate imperfect twist from the other types of distortion.
- **Flashing, Flickering, or Intermittent Operation.** The image may appear to flicker or flash. This can occur in either one or both monoculars. If the flicker occurs repeatedly, check for loose wires or power interruptions. *Do not* fly if this condition exists.

- **Image Disparity.** This condition exists when there is a difference in performance between the two image-intensifier assemblies. The disparity is usually evident as a difference in brightness between the two images. *Do not* fly if this condition masks the intensified image enough to preclude safe mission accomplishment.

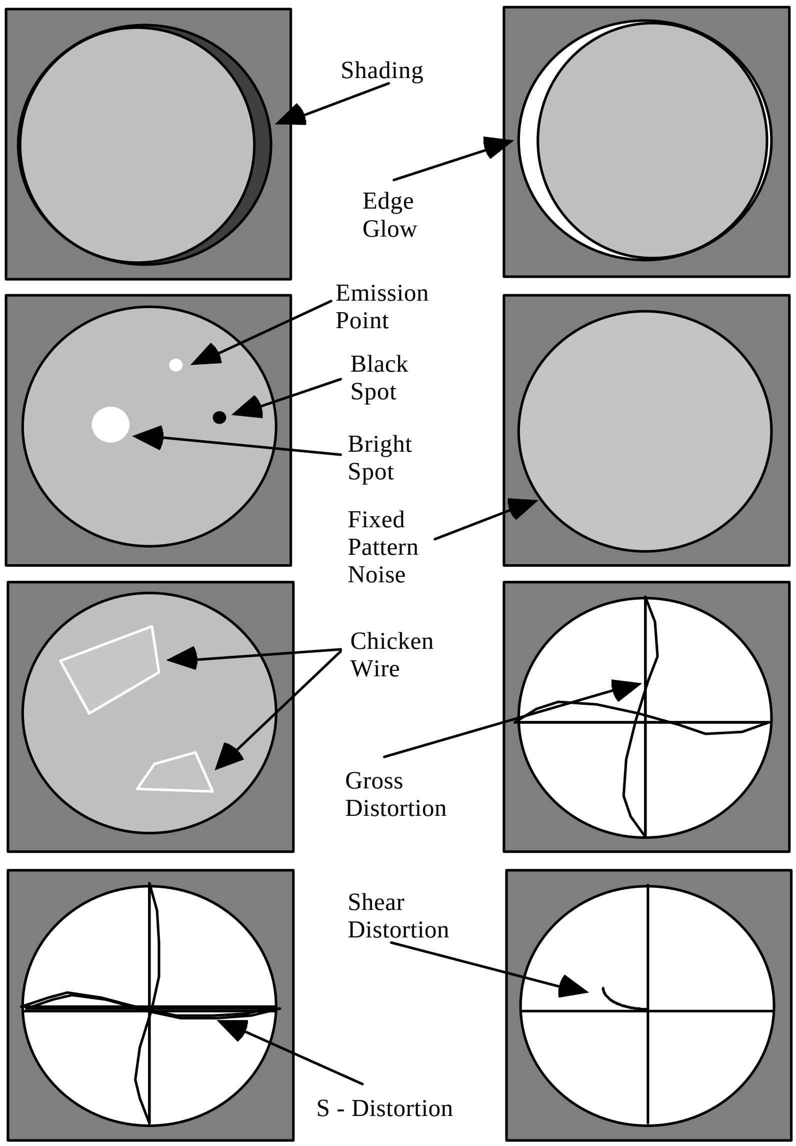


Figure I-71. *Image-Intensifier Tube and Assembly Defects*[557]

13.3 Future Threats

The future threat is the same as the current threat.

13.4 Future Countermeasures

Future countermeasures include enhanced goggles and displays.

13.4.1 Panoramic Night Vision Goggle

The most important future countermeasure is the Panoramic Night Vision Goggle (PNVG). The PNVG is a revolutionary change to traditional image intensifier–based night vision devices. The initial focus of the project was to develop an enhanced-capability NVG. The primary parameter to be improved was the FOV, with secondary enhancements to resolution, weight, center of gravity, and the integrated display symbology overlay.

The conceptual working model displayed a 100-degree (horizontal) by 40-degree (vertical) intensified FOV. This FOV increased the intensified image seen by the warfighter by 160 percent compared to the currently fielded 40-degree circular FOV systems. The larger FOV was achieved by using four off-the-shelf IITs to produce four ocular channels. Two channels were used to produce a full 30-degree by 40-degree binocular FOV, and the other two were used to produce monocular left and right eye channels of about 35 degrees by 40 degrees. The PNVG's folded optical system resulted in a much better center of gravity compared to the currently fielded AN/AVS-6- and AN/AVS-9-type NVG configuration. Even with the added IITs and associated optics, the overall weight of the device was comparable to currently fielded NVGs. Figures I-73 and I-74 illustrate the difference in view between current NVGs and PNVGs.

Figure I-72. *Simulated Scene Viewed Through Current NVGs*

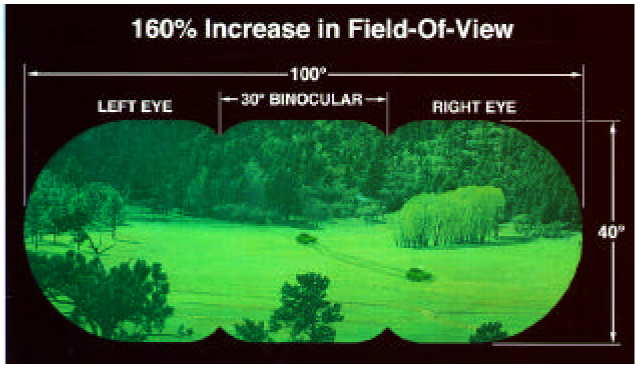


Figure I-73. *Simulated Scene Viewed Through Panoramic NVG*

The large, panoramic FOV and better center of gravity should reduce fatigue effects during long missions and improve operational performance and safety. Applications such as low-level turnpoint identification, terrain avoidance, objective area acquisition, tanker/receiver operations, and force protection will be greatly enhanced. Additionally, this unique approach potentially permits the PNVG in fighter/bomber platforms to be retained upon ejection for use in evasion, escape, and rescue.

13.4.2 Visually Coupled Acquisition and Targeting System (VCATS)

VCATS is an advanced Helmet-Mounted Tracker and Display (HMT/D) that provides the pilot with targeting information and flight symbology throughout the full, head-out-of-the-cockpit field of regard. VCATS incorporates a high-speed head/helmet tracker to determine the pilot's line of sight, a collimated display to present symbology and imagery to the pilot, and a miniature helmet camera for mission recording and debrief. The system eliminates the operational and safety deficiencies of existing systems that were identified in the Vista Sabre II Operational Utility Evaluation. The baseline VCATS is implemented with EM&D-quality hardware. It provides a 20-degree circular FOV and incorporates a 240-Hz AC magnetic head tracker, the new high-brightness "Hot Tube" CRT, and the standardized Helmet-Vehicle Interface. An expanded up-look version will add Upper Aiming Reticles that provide a 45-degree targeting advantage in "within visual range" air-to-air engagements. Other refinements will include a reduced system latency upgrade, improved symbology stabilization, and the ability to support symbology overlay/imagery insertion on the PNVG head-up display. VCATS will be flown on three F-15Cs at Nellis AFB and an F-15D at Edwards AFB.

VCATS will improve mission effectiveness, increase survivability, and exploit the capabilities of new weapons for air-to-air and air-to-ground missions. The system will allow U.S. forces to maintain air superiority and allow multiple kills per pass against air-to-ground targets. VCATS is being used as the baseline design for the Air Force/Navy Joint Helmet-Mounted Cueing System program, which is developing a common HMT/D for the F-15, F/A-18, F-16, and F-22. This program, however, is currently experiencing both technical and cost difficulties.

13.5 Responsible Parties

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14.0 Weather and Climate

Susan A. Woods, Duane E. Stevens, and Valerie J. Gawron

14.1 Current Threats

"Weather" is the day-to-day, minute-to-minute natural atmospheric environment. Weather varies both spatially (i.e., geographically) and temporally (i.e., with time) through a large range of scales. The prediction of weather is steadily improving as observation systems evolve in type, quality, and quantity; as computer hardware and software improve in speed, power, and distribution; and as our theoretical understanding of natural phenomena increases. However, humans are not likely to be able to deterministically and significantly modify the weather in the near future.

"Climate" typically refers to statistical averages, such as monthly and seasonal means, that comprise many weather events. The focus of climate is on historical data. Technology development has significantly improved the availability of climate information to planners and logisticians and, therefore, has contributed to the accuracy and reliability of planning in both the military and civilian sectors. For the overall conduct of hostile military operations, it is important that the U.S. military maintain an advantage in knowledge and information about weather and climate.

14.1.1 Planning the Operation

Theater air forces need current, accurate, and dependable weather information to support operations. The AEF concept includes very distant secure bases (global scale); partially secure, temporary forward bases for flight operations (e.g., 1,000 miles distant); and remote target locations. By its nature, the AEF precludes the application of theater-based, subjective (human) weather forecasts for which the target is "close enough" that the forecaster has a "feel" for the local weather based on personal experience. As a result, planners, logisticians, and operators will have to depend more on machine-based forecasts, particularly in the earliest stages of an operation. Higher technology, weather-sensitive weapons, aircraft, and other delivery systems will demand greater accuracy and precision in future weather forecasts with longer lead times.

The AEF needs information on conventional weather parameters (e.g., wind, temperature, and humidity), aviation hazards (e.g., icing, turbulence, and thunderstorms), and mission-impacting human environmental factors (e.g., visibility, ceiling, and cloud fields). The AEF would benefit greatly from an accurate "nowcast" for the present and the next 6 to 12 hours at specific locations, such as target domains and forward bases with areas of approximately 10 square miles. In addition, forecasts should be sufficiently accurate and detailed for forward mission planning of at least 24 to 48 hours. Ultimately, weather forecast guidance is demanded for overall operational planning for three to seven days, although forecasts are inherently less accurate for extended lead times. Forecast users must be made aware continually of the increase in uncertainty as the lead time increases.

Because of the turbulent and chaotic nature of atmospheric flows, and the nonlinear behavior of atmospheric processes, every weather prediction model has limited ability to accurately forecast weather changes, even with perfectly known initial and boundary conditions. This limitation on predictability is inherent in the physics of the phenomena and exists regardless of computer speed or observational detail.

Present state-of-the-art, research-quality mesoscale (smaller scale) prediction models (with horizontal grid resolution of 1 to 25 km) are imperfect and limited in their ability to accurately forecast weather changes.

These shortcomings are due to uncertainties in current knowledge of physical processes and the imperfections in representing scale-interactive, nonlinear phenomena — the so-called parameterization problem. By the nature of turbulent fluid flow, practical predictability is imperfect and time limited.

Clearly, initial and boundary conditions are inexact because of observational and analytical uncertainties. Focused observation and analysis systems cannot be applied everywhere on earth simultaneously, even from satellite platforms. With lead times as short as 24 hours, war planners cannot possibly acquire perfect information on current weather, let alone on future weather developments. Warfighters must contend with weather uncertainty in the initial phases of any operation.

14.1.2 Protecting the Human

14.1.2.1 Heat Stress

Temperature regulation is vitally important because it affects the rates of a variety of biochemical reactions that underlie all physiological processes. Any significant increase or decrease in body temperature affects these processes and potentially can affect human performance. Skin temperature and core temperature — which is the temperature in the abdominal region, thoracic region, and central nervous system — are indications of the body's total heat content. The body must maintain its temperature within narrow limits: the normal core temperature is about 37°C, and the recommended maximum core temperature is 38°C. To maintain stability, the body must make compensating adjustments to balance heat loss and heat gain. Depending on the situation, either heat production must decrease or heat loss must increase.[558]

Generally, heat stress develops from one or more of the following factors: environmental conditions, clothing, and work load. In AEF operations, all of these factors exist. AEF operations are likely to be conducted in very hot areas of the world, where the environmental conditions are perfect for heat stress. Flightline personnel often work outdoors or in spaces without thermal control. These personnel are affected by metabolic rate and air velocity, as shown in Table I-79. For the aircrew member, crew station environmental conditions are significant, and a variety of factors influence aircraft temperature. Some of the important factors are whether the canopy, doors, or hatches are opened or closed, whether avionics or lights are on or off, whether the aircraft is in direct sunlight, and whether ground cooling equipment is in use. Although many aircraft have an environmental control systems (ECS), heat stress remains a threat because the ECS may function optimally only in flight. Taxiing and sitting on the flight line in hot conditions only exacerbate the problem. Aircrew members must work in hot conditions to prepare their aircraft for flight and often enter a heat-soaked aircraft or cockpit. Hot-weather flying increases skin temperature, with core temperature reaching 38°C.[559] This increase appears small; however, even mild heat stress may be significant because flying tasks require peak mental performance. Table I-80 lists the maximum recorded temperatures by aircraft.

Table I-79. *Body Core Temperature as a Function of Air Velocity and Metabolic (Basal and Activity) Rate*[560]

Metabolic Rate	*Low Air Velocity (< 1.5 m/s)*	*High Air Velocity (‡ 1.5 m/s)*
Light (< 230)	30.0°C	32.0°C
Moderate (230-350)	27.8°C	30.5°C
Heavy (> 350)	26.0°C	28.9°C

Table I-80. *Maximum Recorded Temperatures by Aircraft*

Aircraft	Body Temperature (°C)	Skin Temperature (°C)	Crewstation Wet-Bulb Temperature (°C)
Harrier	38.0	37.4	31.0
Buccaneer	38.2	36.3	25.0
Phantom	37.8	36.6	not measured
Gazelle	37.6	37.1	26.0
Scout	not measured	37.0	23.0
Jaguar	38.0	37.2	36.0
Mohawk	38.0	37.2	30.0
F-15	37.5	38.9	36.4
F-111A	not measured	38.9	not measured

According to Automated Lessons Learned Capture and Retrieval System (ALLCARS) Lesson Learned No. 225, aircrews operating in the Persian Gulf routinely encountered cabin temperatures of 150°F and higher. These temperatures brought on premature heat exhaustion and fatigue during flights. In some cases, hoisting operations had to be stopped to allow aircrew members time to cool and recover from dizziness. All aircrews reported that their standard flight suits, survival vests, and helmets prevented cooling through sweat evaporation or airflow around the body core. The ALLCARS conclusion is that the very devices issued to protect aircrew members from environmental exposure cause physiological problems because of their unsuitability for high-temperature use.[561]

When IPE is worn, heat storage by the body increases, with a corresponding decrease in tolerance of higher temperatures. The harder a person works, the more heat is generated, so flightline personnel performing strenuous tasks in IPE are likely to experience this intolerance. Furthermore, aircrew members often must wear IPE designed to protect against chemicals, infection, *g*-loads, and hypoxia. This IPE provides unwanted insulation in hot conditions, impeding heat exchange between the body and the environment (see Figure I-74).

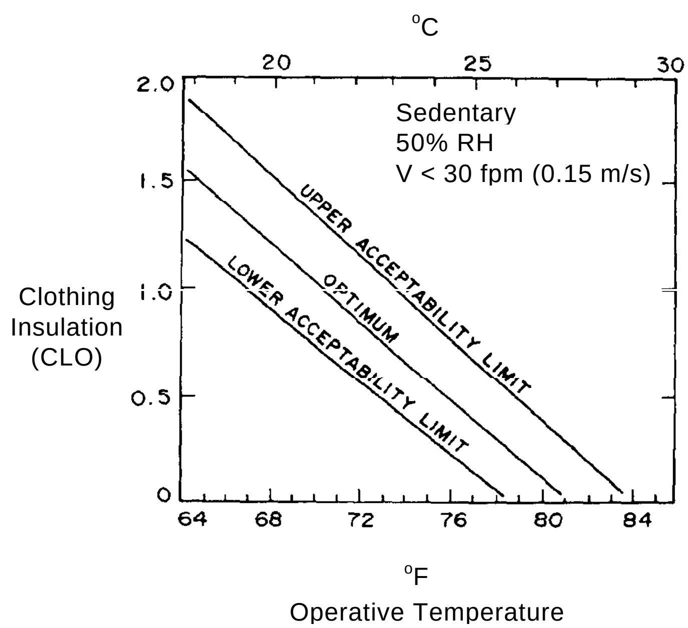

Figure I-74. *User Acceptability as a Function of Clothing Insulation and Temperature*[562]

During AEF IV, 39 people suffered from heat-related illness (e.g., dehydration), and 4 suffered from cold-related illnesses. Table I-81 lists the gear currently issued to U.S. personnel deployed to Bosnia.

Table I-81. *Standard Cold-Weather Gear*

Item	*Quantity*
M-40 protective mask	1 each
Duffel bag or kit bag	2 each
Barracks bag	1 each
Waterproof bag	2 each
Entrenching tool	1 each
Entrenching-tool carrier	1 each
Shelter	1 each
Personal armor ground troop helmet	1 each
Camo helmet cover	1 each
Cold-weather camo parka	1 each
Wet-weather parka	1 each
Cold-weather liner	1 each
Wet-weather trousers	1 pair
Extreme-cold camo Gortex trousers	1 pair
Wet-weather poncho	1 each
Trouser suspenders	1 set
Individual equipment suspenders	1 set
Extreme-cold-weather sleeping bag	1 each
Protective frag. body armor vest	1 each
Intermediate cold/wet boot	2 pair
Black rubber cold-weather boot	1 pair
Poly-knit cold-weather shirt	2 each
Brown cold-weather undershirt	3 each
Extreme-cold-weather drawers	3 each
Wool sweater	2 each
Plastic canteen	2 each
Water canteen cover	2 each
Water canteen cup	2 each
Vinyl overshoe	1 pair
Cold-weather glove shell	1 pair
Cold-weather glove insert	2 pair
Leather work glove	1 pair
Individual equipment belt	1 each
Mitten shell (trigger finger)	1 pair
Mitten insert (trigger finger)	2 pair
Wool blanket	1 each
Mattress pad	1 each
Field pack frame	1 each
Nylon field pack	1 each
First-aid dressing	1 case
Ammunition pouch	2 case

Humans exchange heat with the environment by four means: conduction, convection, radiation, and evaporation. Conduction occurs when heat exchanges between two objects in contact with one another, but conduction usually does not play a large role in human temperature regulation. Convection occurs when a fluid (a liquid or gas) at one temperature flows over a surface at a different temperature. Heat is transferred to the cooler of the two surfaces. The rate of heat transfer depends on the temperature difference and the rate of fluid flow. Liquids transfer heat more effectively than gases, so convection is especially important when a body is immersed in water. In radiative heat transfer, a hot object transfers heat to a cooler object, but contact between the two objects is not required. The rate of heat transfer depends on the difference in the fourth powers of the temperatures of two surfaces. Hot surfaces, such as those in a heated cockpit, radiate heat to any cooler object, such as the pilot. Finally, in evaporation, heat energy is dissipated as liquid is transformed into vapor. In humans, sweat evaporates from the surface of the skin, carrying away heat. Evaporation is the body's main cooling mechanism.

When air temperature is equal to or higher than skin temperature, as in a hot environment, evaporative cooling through sweat is the only means available to the body for heat dissipation. Each liter of evaporated water removes 580 kilocalories of heat.[563] Unfortunately, sweating causes a significant loss of water, often as much as 1 to 2 liters per hour in individuals working hard in a hot environment (for example, ground crews and security police).[564] The water lost while sweating at these rates cannot be completely replaced by drinking water because the body cannot absorb water fast enough. To keep up with the water loss, an individual must take a break and continue drinking water. If this type of preventive measure is not taken, dehydration can occur. In general, the thirst mechanism lags the body's need for water, and a person can lose 1 to 2 percent in body weight before becoming thirsty. Eventually, depletion of body water will affect performance. A 2 to 3 percent body weight decrease drives core temperature and heart rate up and reduces saliva production. Further dehydration impairs physical and mental capability, causes discomfort, and creates disturbances of the central nervous system.

For aircrew members, dehydration can be deadly. A person who is 3 percent dehydrated experiences a decrease in both aerobic and anaerobic capacity. The decrease in anaerobic capacity is extremely important because the anti-*g* straining maneuver is anaerobically intensive. The dehydration also increases errors of omission, mechanical mistakes, fatigue, and susceptibility to motion sickness. Although the obvious threat is dehydration, the significance is its effect on performance.

Environmental and crew station temperatures also can affect performance, depending on exposure time and the actual temperature. For reaction time and mental tasks, increases in either temperature or exposure time are associated with degraded performance, as shown in Figure I-75. For tracking, vigilance, and complex tasks, an increase in temperature is associated with greater degradation in performance than is an increase in exposure time (see Figure I-76). The longer the exposure, the greater the performance degradation, but the degradation levels off at about 3 hours of exposure (Figure I-77).

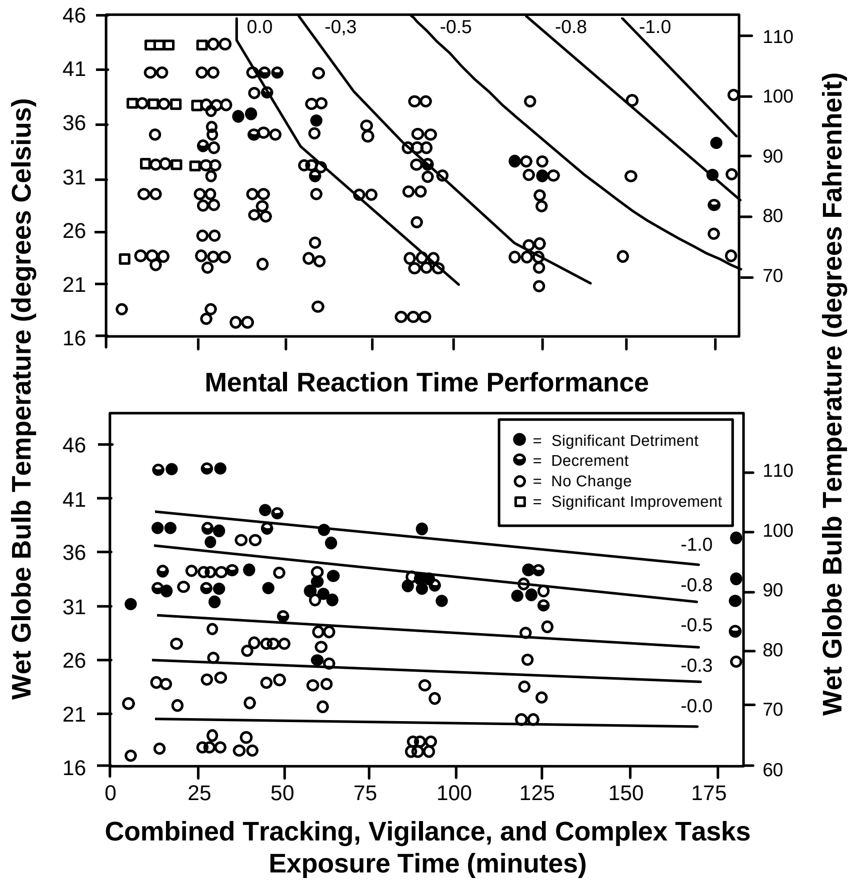

Figure I-75. *Performance as a Function of Task, Temperature, and Exposure*[565]

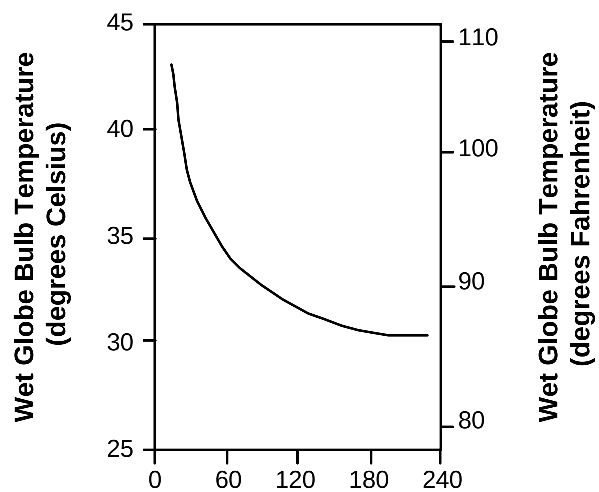

Figure I-76. *Performance as a Function of Temperature and Exposure*[566]

Other heat-related illnesses can develop. Heat exhaustion due to dehydration or excessive electrolyte loss may occur without a marked increase in core temperature. Heat stroke is another possibility. In this case, core temperature can be as high as 42°C, and the body's heat control mechanism stops functioning properly. Personnel working at strenuous tasks in hot environments are at risk for these types of illnesses if precautionary measures are not taken.

14.1.2.2 Humidity

Absolute humidity is the amount of water vapor contained in a unit volume of air. Saturated air is air that has absorbed the maximum amount of water vapor possible. The saturation amount is a function of air temperature, and warm air can absorb more water vapor than cool air. Relative humidity (RH) is the ratio (expressed as a percentage) of the actual amount of water vapor in a sample of air to the amount that sample could hold at saturation. Saturated air is, therefore, at 100 percent relative humidity. If air temperature increases, but no water vapor is added, relative humidity decreases. Because air with low relative humidity has capacity to take on more water, evaporative cooling takes place more readily. High humidity impedes the evaporation of sweat, causing discomfort and dehydration. Therefore, individuals working in a hot environment with high humidity are at greater risk for heat stress. Decrements in performance and risk of heat illness are likely to increase in this situation.

14.1.2.3 Cold Stress

The body does not handle cold stress as effectively as heat stress. When heat conservation and production mechanisms fail to maintain core temperature, the effects of cold stress become evident. Discomfort, loss of manual dexterity, and shivering may occur. These effects degrade performance and cause local tissue damage and hypothermia (i.e., reduced metabolism of critical tissues and organs).

The body's defense mechanism against heat loss is vasoconstriction. In essence, the body attempts to keep the core warm by maintaining blood supply in the core area at the expense of the periphery. Thus, the core temperature can be maintained, while the periphery of the body suffers from the cold temperatures. In particular, the hands, feet, nose, and ears are susceptible to damage. These body parts have high surface-to-volume ratios, vasoconstrict quickly, and are difficult to protect without compromising their usefulness. Manual dexterity decreases as hand temperature falls below 15°C, and numbness occurs at 8°C. The freezing point of skin is -1.5°C. Frostnip (reversible freezing with no permanent damage) can develop at this temperature.[567] Frostbite (actual tissue damage due to freezing) also may occur. As heat loss persists to the point that vasoconstriction is ineffective, the body increases heat production through muscle tensing or shivering. Shivering, however, provides only limited protection. Once core temperature drops below 35°C, clinically significant hypothermia occurs, characterized by depressed reflexes and slowed mental capacity. As the core temperature decreases below 34°C, the central nervous system becomes depressed. Severe hypothermia results below 31°C, and all physiological functions slow.[568] Hypothermia can develop quickly in individuals exposed to constant cold rain or spray.

Just as AEF operations are likely to take place in hot environments, they also may occur in cold locations. Proper clothing, such as gloves, hats, and parkas, provide protection against the cold, but in some instances this protection can hinder task performance. Maintenance personnel who must do specific tasks with their hands may find it difficult to work with bulky clothing and gloves. There may be a temptation to remove the gloves. Ultimately, however, stiff, numb hands are the result, causing reduced dexterity, pain, and impaired performance. Conversely, individuals performing hard physical work in the cold while wearing layers of clothing for protection are in danger of overheating. Overheating, with its associated sweating, must be avoided because most clothing fabrics have little or no insulating effect when wet. Lack of insulation or other protection can lead to frostnip or frostbite, which makes performing even simple tasks difficult. Finally, hypothermia severe enough to depress the central nervous system and affect mental processes can increase errors of omission and decision times.

14.1.2.4 Other Information

Temperature and moisture requirements are specified in MIL-STD-1472D, Section 5.8. The following paragraphs identify particular requirements of that standard. Refer to the standard itself for detailed requirements and clarification.[569]

- **Ambient crew station temperature** must be kept between 50°F and 85°F (paragraphs 5.8.1.1 and 5.8.1.3).
- **Head/foot differential** (temperature difference between floor level and head level) must not exceed 10°F (paragraph 5.8.1.5).
- **Surface temperature** limits (upper and lower) for both momentary and prolonged contact are specified in paragraph 5.13.4.6. Temperatures induced by climatic environment, such as direct sunlight, are exempt from these requirements, however.
- **Mean calf skin temperature** must not exceed 35°C when the crew station is in full sunlight, avionics are on, and the aircrew are in clothing appropriate for their mission.
- **Upper body temperature** must not exceed 36°C.
- **Foot and leg temperature** must not exceed 29°C.
- **Auditory canal temperature** must not exceed 38.3°C for flights shorter than 3 hours and 37.7°C for flights longer than 3 hours or for repeated sorties totaling more than 3 hours.
- **Water vapor pressure** must not exceed 20 torr.
- **Crew station relative humidity** should be approximately 45 percent at 70°F, with the specified relative humidity decreasing as temperature increases (paragraph 5.8.1.4).
- **Air velocity** must be no lower than 0.5 m/s and no higher than 3.0 m/s.

Also, the procuring activity of a system, generally the System Program Office, may impose additional requirements or more stringent requirements than those contained in MIL-STD-1472D. These requirements must be specified contractually and should be in the Prime-Item Development Specification for the system.

Although individual temperature tolerances vary, Figure I-77, adapted from NASA-STD-3000, provides guidelines for maximum exposure time as a function of temperature.[570]

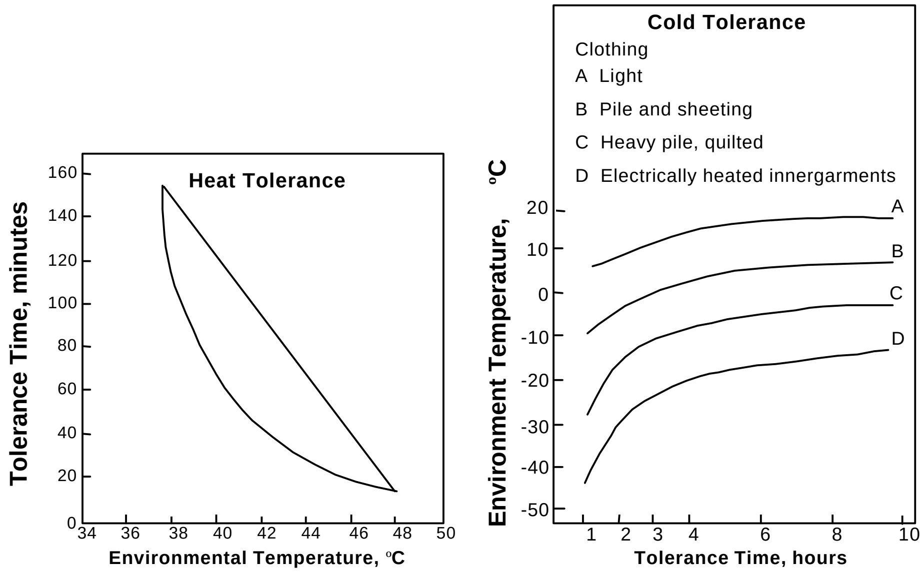

Figure I-77. *Recommended Heat and Cold Exposure Limits*

A summary of the effects of temperature, relative humidity, and time on human performance is presented in Table I-82.

Table I-82. *Weather and Climate*

Authors	*Temp. (°F)*	*RH (%)*	*Time (min)*	*Comments*
A. Reaction Time (RT)				
Grether et al. (1971)	72	Ambient	95	Possible decrement in choice RT at 120°F
	120	Ambient	95	
Lovingood et al. (1967)	74	30	60, 120, 180	Improved simple RT at 126°F
	126	30	60, 120, 180	
Ramsey, Dayal, and Ghahramani (1975)	99	42	120	Possible increase in simple RT at 120°F
	110	44	90	
	120	47	45	
B. Sensory				
Kibrick, Johnson, and McMenemy (1988)	55, 95	35, 60	120	Phoria and contrast sensitivity impaired at 95°F in chemical protective clothing
Hohnsbein et al. (1984)	84	40	180	Visual acuity impaired at 101°F and above
	101	65	180	
	122	10	180	
Russell (1957)	68	47	73	Best tactile sensitivity at 85°F
	85	33	73	
	103	30	73	
C. Vigilance				
Arees (1963)	55	40	80	Visual task; different temperature/performance relationships among different subjects
	75	40	80	
	105	40	80	
Colquhoun (1969)	75	59	120	No difference in visual vigilance performance
	90	65	120	
	120	24	120	
Colquhoun and Goldman (1972)	75	41	120	0, 10, 20, or 30 min walk before visual vigilance test. No difference
	103	68	120	
Mackworth (1946a)	75	59	120	Visual search best at 85°F; decrements occur above and below 85°F; acclimatized subjects

	85	63	120	
	95	66	120	
	105	69	120	
Mortagy and Ramsey (1973)	80	50	180	Visual vigilance; decrements at 120°F increasing with work level and work-rest ratio
	92	50	180	
	102	50	180	
Pepler (1958)	75	59	120	Decrements in visual vigilance above and below 90°F
	90	65	120	
	120	24	120	
Poulton and Edwards (1974b)	68	72	90	Visual vigilance; fewer correct detections at 100°F
	100	74	90	
Poulton, Edwards, and Colquhoun (1974)	68	72	90	Auditory vigilance; fewer correct detections at 100°F
	100	74	90	
D. Psychomotor				
Johnson and Kobrick	70, 95	30, 60	360	Poorer rifle marksmanship, less steadiness, and better dexterity at 95°F

Table I-82. *Weather and Climate (continued)*

Authors	*Temp. (°F)*	*RH (%)*	*Time (min)*	*Comments*
Lovingood et al. (1967)	74	30	60, 120, 180	Better in aptitude classification and steadiness at 126°F
	126	20	60, 120, 180	
Mackworth (1945)	85	63	180	Poorer pointer alignment above 90°F
	90	65	180	
	95	66	180	
	100	68	180	
	105	69	180	
E. Tracking				
Grether et al. (1971)	72	Ambient	95	No change in compensatory tracking
	120	Ambient	95	
Pepler (1953a)	75	59	160	Poorer pointer alignment at 85°F, increased with higher temperature; acclimatized subjects
	85	63	160	
	93	66	160	
	100	68	160	
Pepler (1958) (study 3)	85	63	150	Best manual tracking at 90°F. Poorer manual tracking above and below 90°F; acclimatized subjects
	90	65	150	
	95	67	150	
	100	68	150	
Pepler (1959a)	116	70	30	Poorer pointer alignment at 116°F
Pepler (1959b)	69	77	30	Poorer pointer alignment at 100°F
	100	68	30	
Pepler (1960)	69	77	40	Poorer pointer alignment at 100°F
	100	68	40	
Russell (1957)	68	47	73	No difference in tracking tasks
	85	33	73	
	103	30	73	
F. Concurrent Tasks				
Bell (1978)	72	45	33	Primary task-pursuit rotor; second task number processing. Decrement in second task at 95°F
	84	45	33	
	95	45	33	
Dean and McGlothlen (1965)	70	40	20	Very short exposures; no difference in tracking radar monitoring
	80	41	20	
	90	44	20	
	100	48	20	
	110	50	20	
Lampeitro et al. (1972)	77	45	50	Decrements in some simulated fight at 110°F and 140°F
	110	22	50	
	140	11	50	
Mackie and O'Hanlon	66		540	More steering adjustments, less brightness discrimination, more drive errors at 90°F
	90		540	
Provins and Bell (1970)	68	59	175	Training unstated; no difference in vigilance
G. Memory, Cognition, and Perception				
Bartlett and Gronow (1953)	60 to 70	-	60	No difference in performance on a cognitive game
	80	61	60	
	90	65	60	
	100	68	60	

Table I-82. *Weather and Climate (continued)*

Authors	Temp. (°F)	RH (%)	Time (min)	Comments
Fine and Kobrick (1978)	70	35	420	Improved performance at 3rd hour; significant decrements thereafter
	95	88	420	
Fine and Kobrick (1987)	55	35	420	Cognitive performance and work rate lower after 4 to 5 hours in heat/MOPP-4; mainly errors of omission
	70	35	420	
	91	61	420	
Fine et al. (1960)	70	30	390	No difference in performance of anagram and auditory discrimination tasks
	70	90	390	
	95	28	390	
	95	89		
Grether et al. (1971)	72	Ambient	95	No difference in performance on short-term memory
	120	Ambient	95	
Johnson and Sleeper (1985)	55, 91	35, 61	420	Poorer speech intelligibility at 91°F in chemical protective clothing
Kobrick, Johnson, and McMenemy (1988)	55, 95	36, 60	120	Better speech intelligibility at 95°F/60 percent RH in chemical protective clothing
Kobrick and Sleeper (1986)	55, 91	35, 61	420	Impaired peripheral visual signal detection at 91°F in chemical protective clothing
Lovingood et al. (1967)	74	30	60, 120, 180	Better mental arithmetic at 126°F
	126	30	60, 120, 180	
Mackworth (1946a)	85	63	180	Lower Morse code reception above 90°F; acclimatized subjects
	90	65	180	
	95	66	180	
	100	68	180	
	105	69	180	
Pepler (1959b)	69	77	50	Serial choice worse at 100°F
	100	68	50	
Pepler and Warner (1968)	62	45	180	Greater effort, errors and performance in programmed learning above and below 80°F. Performance best at 80°F
	68	45	180	
	74	45	180	
	80	45	180	
	86	45	180	
	92	45	180	
Poulton and Edwards (1974a)	68	72	60	No change on 5-choice task
	100	74	60	
Poulton et al. (1974)	68	72	60	More gaps and errors on 5-choice task at 100°F
	100	74	60	
Ramsey et al. (1975)	99	42	120	Decrements in arithmetic task in heat
	110	44	90	
	120	47	45	
Reilly and Parker (1968)	75	40	360	Of 16 tasks, 6 better, 2 worse, 8 same at 100°F
	100	42	360	
Wing and Touchstone (1965)	80	38	60	Poorer short-term memory at 120°F
	110	30	60	
	120	28	60	

14.2 Current Countermeasures

Current countermeasures include planning the operation and protecting the human.

14.2.1 Planning the Operation

The accuracy of a forecast depends on the quality of the information processors (models) used and the quality of the data fed to the models. The input data, in turn, depend on the accuracy and resolution in space and time of weather observations. Forecasts today are based on data from instruments on satellites, rawinsondes, and ground radars, plus cooperative-source reporting (e.g., from aircraft in the area). Each of these data sources has limits. Satellites cover the globe, but they have relatively coarse observational resolutions and limited ability to penetrate clouds. Rawinsondes typically are launched no more than twice daily, again at fairly widely separated points (200 nmi in the U.S. and even wider distances in much of the world), but the information is available only from those launched within friendly territory. Ground Doppler radar is inexpensive but sees only precipitation and major scatterers, such as intense storms. Cooperative-source reports are sporadic and obviously unreliable over denied territory. Finally, meteorology officers attached to Air Force wings provide personalized and subjective forecasts to the operators, based on objective guidance products provided by the Air Force Global Weather Center (AFGWC).

Global-scale numerical weather prediction recently has been reassigned from AFGWC to the Navy in Monterey, CA. AFGWC now focuses on tailoring products derived from the Navy-model forecast for use by Air Force operators and meteorologists. AFGWC also operates the MM5 regional mesoscale model, developed at the National Center for Atmospheric Research, for theater-level forecasts nested within the global Navy model. Output of MM5 forecasts is used as weather parameter input to specialized applications models being developed and tested by Phillips Laboratory.

Unfortunately, mesoscale meteorological models (such as the MM5) are not actively used in the operational Air Force today, primarily because the technology is in active research and development in the universities and Government laboratories. In the future, these models will be capable of efficient in-theater execution using local observations derived from local assets.

The Atmospheric Sciences group of Phillips Laboratory (PL/GP) is working on “First-In Weather Support.” The goal of this program is to anticipate and exploit weather information in combat through three steps:

- Observe, understand, and predict weather.
- Apply information to precision-guided missile and surveillance systems.
- Deliver and display the information to the warfighter.

Weather Impact Decision Aids (WIDA) for mission planning and execution are being designed to predict the impact of forecast weather on specific weapon and navigation sensors for mission planning and execution. Current WIDA products under development include infrared target-scene simulation, target acquisition, NVG operations, and automated mission planning.

14.2.2 Protecting the Human

The human must be protected against heat, humidity, and cold.

14.2.2.1 Heat Threat

A wide variety of countermeasures — personal behaviors, clothing, and equipment — are available for use against heat threats. Individuals can minimize exposure to the hot environment, if and when the mission allows it. Prehydration (drinking ahead of any scheduled activity) is a technique to prevent dehydration. Drinking cool water during an activity also is essential for replacing water loss. AEF commanders should provide personnel with the opportunity to adjust to the environment (acclimatization). Performing 2 hours per day of stressful work in the heat helps the body adapt to the hot environment: sweat rate increases, heart rate decreases, skin and core temperature remain low, and electrolyte loss decreases. Complete acclimatization takes 10 days, but an individual can partially adapt in 2 to 3 days. Maintaining a good exercise regimen, something that is important to all personnel regardless of thermal threat, can have a similar effect. Aerobic exercise increases core temperature in the same manner as working in a hot environment, causing similar adaptation to occur.

Clothing that protects against heat, including air-ventilated and liquid-cooled suits, also is valuable. The ventilated suit can distribute cold air over the skin through a duct system or a spacer garment, promoting evaporative cooling and convection. Liquid-cooled garments come as whole body suits, vests, or head systems. They contain small-bore plastic tubing sewn into the material. Cool water circulates through the tubing, picks up body heat, and passes through a heat-removing device.

The ECS is the primary control for the internal aircraft environment. One drawback of the ECS is that the engines must be running for the system to function efficiently. The system cannot handle completely the thermal load of radiant heating from the sun, and the problem is compounded by the complex clothing assemblies worn by aircrew. Therefore, the ECS must be backed up by ground air-conditioning equipment, which can pump cool air into the cockpit while aircrew prepare their aircraft for flight.

Relief from heat is essential for limiting physical effort and thermal exposure. A common source of relief is an air-conditioned building located near the work site. If no building is nearby, a vehicle with adequate cooling can be used. Such vehicles are especially important for transporting the aircrew to and from their aircraft. For aircraft parked in the open, sun shades and thermal blankets will minimize cockpit heating. Finally, flying missions helps thermal control and relates well to wartime tactics.

14.2.2.2 Humidity

In addition to using many of the countermeasures for heat stress, individuals must be vigilant where humidity is concerned. Drinking cool water throughout the day, especially while working, is essential because high humidity will impede the effectiveness of the sweating mechanism.

14.2.2.3 Cold Threat

Cold-threat countermeasures are very similar to those available for heat threats. Personnel should minimize exposure to the elements and wear the proper clothing. Cold-weather clothing, such as boots with thick insulation, gloves, mittens, and hats, is designed to insulate and to exclude rain and wind. Layered clothing is best because it traps air pockets, which provide insulation. Layering also allows a person to add or remove clothing as necessary, depending on the work rate. Electrically heated gloves, socks, and suits have electrical elements woven into the fabric. Air-ventilated and liquid-heated suits also are possibilities. Hats and helmets are important because a significant amount of resting metabolic heat is lost through the head of an unprotected person. Maintenance personnel who wear thin contact gloves should carefully balance cold protection against the need for sensitivity and dexterity. In aircraft operations, the ECS is efficient at heating the cockpit, and the ground conditioning equipment can keep the cockpit warm while aircrew are doing preflight tasks. Using a heated form of transportation to minimize exposure to cold also is important.

Finally, the U.S. Atlantic Command has established a Joint Preparation and Onward Movement Center at Fort Benning, GA, to provide cold-weather training. The SECDEF and Joint Chiefs of Staff direct this center to establish joint training and indoctrination for individuals destined for multinational staffs, as specified by the support CINC.

14.3 Future Threats

Future threats are categorized as planning the operation and protecting the human.

14.3.1 Planning the Operation

Threats to the operation have three components: (1) data acquisition, (2) model development, and (3) forecast credibility.

14.3.1.1 Data Acquisition

In a rapidly changing, hostile environment, AEFs are likely to be denied access to *in situ* weather data in enemy-controlled geographic regions. These forces also may lose observational capability because of hostile acts and experience loss of data through enemy attacks on communication lines. Since every weather prediction depends crucially on initial data, forecasting the weather over denied territory can be a significant problem when observations are difficult or impossible.

14.3.1.2 Model Development

The Air Force is very close to losing the organizational and personnel infrastructure necessary to assure future weather forecasting capabilities for flight operations and weapons guidance and delivery. The atmospheric sciences applicable to weather forecasting have suffered frequent and continuing threats from upper management. Air Force planners and operators seem unconcerned about the certain, deleterious impacts of eliminating research and development programs, despite a history of success and service since the 1950s. For example, the Air Force's lack of commitment virtually guaranteed the loss of its global-scale weather forecasting to the Navy.

14.3.1.3 Forecast Credibility

Perhaps of equal concern for future operations is the relative confidence or disdain that pilots and planners display toward weather forecasts. From Gulf War reports, pilots and commanders (operators) are known to ignore (partially or even totally) weather forecasts and rely more on personal observation and verbal communication. Experience in past wars may validate such distrust. But with advances in numerical weather modeling and observational technology, nowcasts and forecasts are becoming significantly more reliable. The practice of ignoring short-term weather forecasts could well be asset- and life-threatening for the warfighter.

14.3.2 Protecting the Human

Cold, heat, and humidity threats always will be present. As the Air Force expands its role throughout the world, these threats will only increase. Short-notice deployments to areas without permanent facilities and operations in less-than-optimal environments with only essential equipment may make thermal comfort a luxury in some circumstances. Additionally, as flying operations become more complex and challenging, the effects of thermal stress on performance will become more apparent.

14.4 Future Countermeasures

Future countermeasures include planning the operation and protecting the human.

14.4.1 Planning the Operation

Planning the operation includes data acquisition, model development, and forecast credibility.

14.4.1.1 Data Acquisition

Satellite-based observations will provide crucial but limited input for weather forecasting. A UAV system with a variety of onboard (*in situ)* and dropsonde sensor packages could supplement existing conventional data sources, resulting in weather observations that are highly accurate, complete, current, and densely spaced. Such an observational breakthrough might enable the more stringent forecasting requirements demanded by highly sensitive precision weapons of the future.

Large clusters of low-cost, expendable UAVs could be seeded over enemy territory. By their small size and high flight altitude, they would be relatively stealthy and expensive for the enemy to remove. At greater expense and vulnerability, remote-sensing systems on larger UAVs could contribute not only weather information, but also military intelligence. However, implementation of much of this technology will likely be long range because these systems are in very early development and require substantial investment.

Such a networked observation system also would have the great advantage of mobility. Since future weather may be primarily influenced by weather events (such as fronts) propagating from different directions at different times, the flexibility to physically move the airborne sensors to different locations on command is likely to be especially useful in extending the duration of forecast skill.

As a benchmark, an accurate12- to 24-hour forecast typically requires data on the evolution of weather from a large area over the preceding 2 to 3 days and accurate current observations in the mesoscale region of interest. Virtually all forecasting uses three-dimensional, gridded models of atmospheric dynamics. The primary time-dependent parameters to be fed to a model are (1) temperature, (2) dew point or relative humidity, (3) barometric pressure, (4) wind speed, and (5) wind direction. Other factors are ice cover, water vapor in the troposphere, vegetation, and atmospheric chemicals, but these are not as critical and can be estimated or measured less frequently.

Instruments for *in situ* measurements are conventional thermometers and barometers, usually delivered in a balloon-lifted rawinsonde. Wind is measured by tracking the balloon. For remote sensing from UAVs, four types of sensors are of primary interest: (1) lidar for wind, visibility, temperature, and cloud-top measurements in clear air (under some circumstances, it is possible to infer atmospheric pressure from the data); (2) passive microwave radiometer for temperature and water vapor determination; (3) passive infrared radiometer, also for temperature and water vapor sensing; and (4) Doppler radar for measuring cloud dimensions and movements.

14.4.1.2 Model Development

Mesoscale models still are rather primitive and untested. Significant development and testing of these models is absolutely essential, along with specialized application to specific weapon systems and flight operations associated with the Air Force. The recent selection of the MM5 mesoscale model for a range of Air Force forecasting requirements is a good sign. Testing and evaluation of dynamic weather models for different purposes, different space and time scales, and different geographical locations is absolutely vital.

The Gulf War demonstrated the necessity to validate climate data sets in regions of possible deployment. A very large proportion of weather-induced failures occurred early in the air war, before Air Force forecasters gained personal experience with local weather. In a future operation, the war may be lost within the first week if the AEF is not prepared to apply available climate knowledge in locations where the enemy has years of subjective local experience.

14.4.1.3 Forecast Credibility

Further pilot training and especially much-improved communication between meteorologist and pilot are needed to take advantage of increased forecasting skill. Skilled, trained, and educated meteorologists are required to use the latest advances in science and technology. These meteorologists must have the confidence of their commanders and operating customers. Unfortunately, the Air Force and other Government agencies tend to reduce their expertise in critical but non-core technical areas when budgets are tight. Specifically, the Air Force has chosen to significantly decrease its expenditure levels in the atmospheric sciences. It is no accident that the Air Force no longer makes global-scale forecasts, having lost that task to a better prepared Navy.

Finally, current weather information (analyzed observations) and future weather prediction are aspects of information warfare that can be denied to the enemy, providing a significant advantage for flight operations.

14.4.2 Protecting the Human

There is no “magic” technological solution in development to eliminate thermal threats. As new aircraft are conceived, new versions of thermal countermeasures — fundamentally the same as earlier versions — are designed and developed for those aircraft. Additional future countermeasures include improved ECS designs that take into account radiant heating and aircrew clothing ensembles. Clothing designs that provide thermal protection without inhibiting performance are another area for improvement.

14.4.2.1 Acoustic-Cycle Mobile Heat Pump (ACMHP)

One new development is the ACMHP. The Air Base Technology Branch of Wright Laboratory (WL/FIVC) is responsible for this system, which will enhance the 6,000-nmi, 24-hour AEF deployment capability. During field testing, the rapidly maturing prototype maintained ORD-specified shelter heating loads at ambient, exterior temperatures below 0^{o}F, more than 35^{o}F beyond the capability of current environmental control unit (ECU) systems. This improvement in capacity may enable the AEF to expand its geographical domain of operations.

The lightweight ACMHP uses an ECU with significant environmental and operational benefits: (1) it uses no ozone-depleting refrigerants; (2) it weighs 250 to 300 pounds less than current systems; and (3) it draws 2 to 4 fewer kilowatts of power per unit. The helium refrigerant is nontoxic, inexpensive, and easy to use, and it does not have the lubricant in compatibility or decomposition problems that afflict current refrigerants. Typical Harvest Falcon deployment kits fielding 240 ACMHPs have a reduced total deployment weight of 60,000 to 72,000 pounds per kit — the equivalent of two C-141 loads.

As one of five essential infrastructure elements, bare-base ECUs protect personnel in harsh climates, yet they are still based on inefficient 1960s technology. Current AEF ECUs draw 40 percent of all generated power and account for 10 percent or more of the total bare-base deployment weight, placing a further burden on a limited fleet of transport aircraft. By using a high-efficiency, single-phase refrigerant, the revolutionary ACMHP pulse-tube provides unparalleled ECU weight and power-load reductions by eliminating the need for conventional evaporators and condensers. The ACMHP pulse tube is a simple, linear design with fewer moving parts, which reduces logistics support requirements.

14.4.2.2 Electrohydrodynamic Enhanced Heat Transfer

WL/FIVC also is leading the development of electrohydrodynamic (EHD) enhanced heat transfer. This technology will be used in ECUs. EHD will reduce the weight and size of heat-transfer units by more than 35 percent, which may allow the AEF to move more quickly. The technology can be used in any heat transfer equipment, so it can benefit many weapon systems. For example, the F-22 has 18 heat exchangers for oil, hydraulic fluids, and electronic-equipment cooling. The volumes and weights of the heat exchangers can be reduced by more than half to allow the plane to carry more munitions or loiter longer over a target area.

EHD heat transfer uses a strong electric field to augment fluid velocity fields in various heat-transfer equipment. Conventional EHD technology is in the final development stages. WL/FIVC has a prototype, and experimental increases in heat transfer coefficient have reached 850 percent. The prototype uses tubes surrounded by electrodes, but this arrangement requires a support structure, causes high pressure drops, and does not allow miniaturization of heat exchangers. To offset these drawbacks, WL/FIVC is working on a new approach that uses embedded electrodes. With immediate funding, a prototype for the embedded electrode technology can be available by the end of CY 99.

14.5 Responsible Parties

ACC/DOW, Weather

ACC/DOXC, AEF planning

AF/XOW

ETAC (Scott AFB)

U.S. Air Force Civil Engineer Support Agency

U.S. Air Force Global Weather Center

U.S. Air Force Research Laboratory

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15.0 Glossary

absorbed dose Concentration of energy absorbed into the tissue; energy per unit mass of tissue; measured in grays.

acute exposure Exposure to a single dose of radiation or a series of doses over a short period of time; opposite of chronic.

binocular goggle Goggle with two objective lenses, two image-intensifier tubes, and two eyepieces that create two distinct image-intensified views of the world from two horizontally separated viewpoints.

biocular goggle Goggle with one objective lens, one image-intensifier tube, and two eyepieces that create two identical two-dimensional intensified images of the scene with no depth cues provided by binocular disparity.

biological warfare The use, for military or terrorist purposes, of living organisms or material derived from them, that are intended to cause death or incapacitation in man, animals, or plants (OSD, 1996).

blister agent A chemical agent that can cause blistering of the skin and extreme irritation of the eyes and lungs; although primarily an incapacitant, it can cause death in large doses. Examples are sulfer mustard, nitrogen mustard, and lewisite (OSD, 1996).

blood agent A chemical agent that acts on hemoglobin in blood cells, thus preventing oxygen from reaching cells. Examples are hydrogen cyanide and cyanogen chloride (OSD, 1996).

brightness gain The ratio of the intensified scene image as viewed by the eye, divided by the actual brightness of the scene itself; it is affected by the f-number of the objective lens, the transmission of the objective lens, the image-intensifier tube gain, and the transmissivity of the eyepiece.

chemical warfare The military use of toxic substances such that their chemical effects on exposed personnel result in incapacitation or death (OSD, 1996).

choking agent A chemical agent that is typically a nonpersistent, heavy gas. It irritates the eyes and throat and, when inhaled, can lead to pulmonary edema, resulting in death from lack of oxygen. Examples are chlorine and phosgene (OSD, 1996).

chromatic aberration Distortion of light transmitted through a lens, caused by the focusing of different wavelengths at different points, which is a result of variations in refractive index of the lens with wavelength.

chronic exposure Continuous dose or a series of doses of radiation over a long period of time.

collimation The orientation of light rays into parallel paths.

combiner eyepiece An optic component that combines to the viewer a direct view and projected view as shown in Figure I-78.

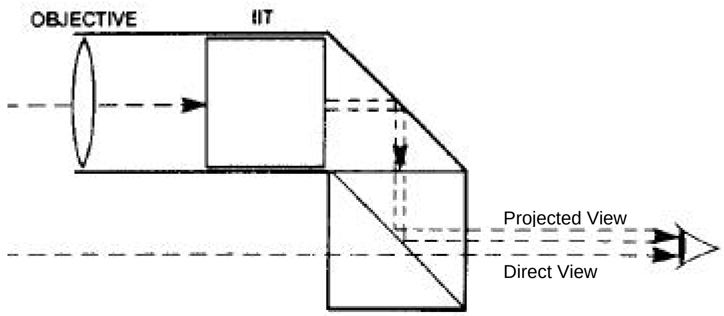

Figure I-78. *Combiner Eyepiece*

cone photoreceptors Cone-shaped cells concentrated in the foveal region of the retina that convert sensed light to electrical impulses, which are transmitted to the brain via the optic nerve; these are the predominant mediators of color vision.

detection Chemical warfare defense activities that include collecting background information and threat agent samples; analyzing samples; determining the presence of potential threat agents; quantifying specific threat agents; confirming the identification of the threat agent; and providing information reports, alarms and all-clear notices.[571]

diffraction Spreading of light waves around an obstacle into the not-directly-exposed region behind the obstacle.

diopter A measure of the power of a lens; one diopter is equal to the power of a lens with a focal length of one meter.

dose equivalent Absorbed dose weighted by the relative biological effectiveness; measured in sieverts.

dose rate Rate at which absorbed dose is accumulated; dose absorbed per unit time; measured in cGy/hr or equivalent units.

exit pupil Diameter of an image exiting an objective lens.

eye box Region in space from which a display must be viewed by the eye to ensure that the entire display can be seen.

eye relief Distance from a lens to the eye.

field of regard Area visible with both eyes with movement and scanning.

field of view (FOV) Area visible with one eye without movement or scanning.

fovea Central region of the retina (perimetric angle less than 10 degrees) composed primarily of cone photoreceptors.

gray (Gy) International unit for absorbed dose; equal to one joule of energy deposited in one kilogram of tissue; one centigray is equivalent to one rad.

half-life Time required for one-half of a given quantity of radioactive material to decay into stable material and stop emitting radioactive particles.

holographic image Three-dimensional image generated by multipathing light beams.

infectious Capable of producing disease in a susceptible host (OSD, 1996).

infrared Electromagnetic energy with wavelength between 1 and 20 micrometers.

interpupilary distance Distance between an individual's pupils; interpupilary distance is set on direct-view night-vision goggles to ensure that the entire exit pupil is visible.

K (severity) level DOS term to categorize attack-vehicle speed. K4 includes speeds from 28.0 to 37.9 mph; K8, 38.0 to 46.9 mph; and K12, 47.0 to 56.9 mph.

legal perimeter Boundary of an airbase that encompasses all territory owned or legally controlled by the air base authorities.

L (protection) level DOS term to categorize the distance that an attack vehicle penetrates a compound. L1.0 includes distance from 20 to 50 feet; L2.0, 3 to 20 feet; and L3.0, 0 to 3 feet.

mean lethal dose (LD_{50}) Lethal dose is denoted LD_x, where x is the percentage of exposed people who will die within 60 days without medical intervention; LD_{50} — the standard reference — is the dose at which 50 percent of exposed people would die and is approximately 450 cGy.

mesopic vision Vision between photopic and scotopic vision.

microchannel plate High-voltage plate containing 1.9 million channels, which amplify incident light by releasing charged electrons when struck by photocathode-released electrons.

minus-blue filter Filter used on most Gen III night-vision equipment; it filters wavelengths less than 625 nm (blue-green) to help make crew station lighting invisible.

Mission-Oriented Protective Postures (MOPP) Levels of preparedness and use of chemical and biological warfare individual protective equipment, ranging from 0 (equipment is prepared for use and readily available) to 4 (all equipment items are worn).[572]

monochrome display Display that presents an image in the visible region at a single wavelength; green is the typical color for night-vision equipment because the eye is most sensitive to the green wavelength (550 nm).

monocular goggle Goggle with one objective lens, one intensifier tube, and one eyepiece; observer sees an intensified view in one eye and an unaided view in the other eye.

MOPP 0 Individual protective equipment (IPE) is issued to personnel, inspected, prepared for use (the overgarment should remain sealed in its vapor bag until needed), and kept readily available (accessible within 5 minutes). Use MOPP 0 during periods of increased alert when the enemy has a CB employment capability but CB warfare has not begun and there is no indication of its use in the immediate future. The time needed to don the equipment is about eight minutes (AFMAN 32-4005 Attachment 4, 1 October 1995, paragraph A4.1).

MOPP 1 The overgarment and helmet are worn; the web belt and filled canteen may be worn or kept at hand if desired; other IPE items are carried or kept at hand. Contact lenses must be removed at MOPP 1.

Personnel needing vision correction must revert to glasses and the appropriate spectacle inserts for the mask worn. Use MOPP 1 when CB attack is possible (e.g., NATO threat level low). Personnel should automatically assume MOPP 1 during Alarm Yellow unless directed otherwise. Time to achieve complete CB protection is reduced by half — from 8 to 4 minutes (AFMAN 32-4005 Attachment 4, 1 October 1995, paragraph A4.2).

MOPP 2 The overgarment, helmet, and footwear covers are worn; the web belt and canteen may be worn if desired. Carry or keep remaining IPE at hand. Use MOPP 2 when CB attack is probable (e.g., NATO threat level medium) unless otherwise directed. Mobility is reduced, but personnel can go to a higher MOPP in seconds (AFMAN 32-4005 Attachment 4, 1 October 1995, paragraph A4.3).

MOPP 3 All IPE items except gloves are worn; the overgarment and hood openings are closed. Carry or keep gloves at hand. MOPP 3 has very limited application. Personnel who need increased dexterity while performing essential tasks should use MOPP 3 when contamination is present. MOPP 3 should not be used if liquid agent contact is possible or blister agent vapors are present (AFMAN 32-4005 Attachment 4, 1 October 1995, paragraph A4.4).

MOPP 4 All IPE items are worn; the overgarment and hood openings are closed. Automatically assume MOPP 4 when CB attack is imminent or in progress (e.g., NATO threat level high), when Alarm Red is declared, or as directed (A.4.5.2). In MOPP 4, protection is complete, but efficiency will decrease rapidly. Vision and communications are restricted and there is a greater risk of heat stress. Providing personnel with enough drinking water and appropriate rest and relief periods becomes a primary concern (AFMAN 32-4005 Attachment 4, 1 October 1995, paragraph A4.5).

nerve agent A chemical agent that acts by disrupting the normal functioning of the nervous system (OSD, 1996).

objective lens A lens that collects available incident light and focuses it on an image-intensifier tube input window; an objective lens normally contains a minus-blue filter.

persistence A measure of the duration for which a chemical agent is effective. This property is relative, however, and varies by agent, by method of dissemination, and by environmental conditions such as weather and terrain (OSD, 1996).

photocathode A negatively charged electron emitter that emits electrons when struck by incident light; the emitted electrons then strike the microchannel plate.

photopic vision Vision that begins at luminance levels above 1 millilambert (3.2 candelas/meter^2), which is equivalent to the illuminance of white paper 1 foot from a standard candle; normal light-adapted vision in daylight.

reflectance The ratio of the amount of light reflected off the combining lens to the amount of light originally striking it.

refraction The bending of light by the combiner eyepiece as the light passes through it; depends on the physical properties of the combiner eyepiece and the incident angle.

relative biological effectiveness The ratio of absorbed dose of a particular type of radiation required to produce a given biological effect to the absorbed dose of gamma radiation required to produce the same effect; related to how the radioactive particles distribute energy along their paths through tissue.

retina The innermost interior lining of the eye, which contains the rod- and cone-shaped photoreceptors.

rod photoreceptors Rod-shaped cells concentrated outside the foveal region of the retina that convert sensed light to electrical impulses, which are transmitted to the brain via the optic nerve; used for dark-adapted vision and spatial orientation; they yield poor acuity and no color vision.

scotopic vision Vision mediated predominantly by rod photoreceptors; characterized by poor acuity and no color vision; dark-adapted vision at night.

sievert (Sv) The international unit for dose equivalent; product of the absorbed dose (in grays) and the relative biological effectiveness of the radiation type; typically expressed in thousandths or millisieverts (mSv); one millisievert is equivalent to 0.10 rem.

signal-to-noise ratio Measure of equipment performance.

stereopsis The generation of a three-dimensional image by the brain using the disparity in the separate images of the eyes.

Threat, Level I Small-scale operations conducted by agents, sympathizers, partisans, or terrorist groups.[573]

Threat, Level II Includes long-range reconnaissance, intelligence gathering, and sabotage operations conducted by special-purpose forces, guerrilla forces, unconventional forces, or small tactical units.[574]

Threat, Level III Airborne, ground-based, and amphibious attacks, including major attacks by aircraft and theater missiles armed with conventional, nuclear, biological, or chemical weapons.[575]

total dose equivalent Sum of the products of the dose equivalents received by specified body tissues and the appropriate weighting factors reflecting differential tissue sensitivities; often referred to as whole body dose.

toxicity A measure of the harmful effect produced by a given substance on a living organism (OSD, 1996).

toxins Poisonous substances produced by living organisms (OSD, 1996).

transmittance The ratio of the amount of light transmitted by a lens to the amount of light originally striking it.

vaccine A substance administered to induce immunity in the recipient (OSD, 1996).

virus A submicroscopic infectious agent that is characterized by a total dependence on living cells for reproduction and that lacks independent metabolism (OSD, 1996).

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Annex 1 to Appendix I

Index

The following items are provided in this Annex:

Table A-1. *Deployment Preparation Checklist*[576]

1. Identify potential victims by category and prepare your A and B lists of possible targets. Categories include
   a. Specifically selected victims
   b. Targeted groups of victims
   c. Personnel who may be involved in a random attack.
2. Plan your antiterrorism personnel security.
   a. Identify high-risk personnel.
   b. Develop your countermeasures.
   c. Harden targets where possible.
   d. Prepare your crisis management and location files.
3. Set up an awareness and education program.
   a. Emphasize the current threat according to your threat assessment and statement.
   b. Stress prevention aspects.
   c. Include information on
      (1) Foot surveillance
      (2) Vehicle surveillance
      (3) Fixed surveillance.
4. Arrange victim survival training to include
   a. Attacks by terrorists
   b. Bombings
   c. Kidnap or hostage situations
   d. Letter and package bomb recognition.
5. Regard protective details.
   a. Select personnel for these details and ensure that they receive the proper training.
   b. Brief principals on how to work with their assigned details.
6. Observe security measures while traveling.
   a. To help you evaluate the threat
      (1) Contact the U.S. Department of State for current information and periodical updates.
      (2) Review the DOs and DON'Ts listed in this chapter.
   b. When preparing to travel in low-intensity conflict areas, plan separately for each phase:
      (1) Predeployment
      (2) Deployment
      (3) Employment.

Table A-2. *Intelligence Implementation Checklist*[577]

1. Establish your terrorism incident database.
   a. Determine the sources of your data.
   b. Evaluate the reliability and validity of the information available from those sources.
   c. Assign responsibility for this activity to a "terrorism specialist."
2. Consider measures to counter terrorist intelligence collection methods.
   a. Open-source information
   b. Human intelligence collection
   c. Signal intelligence collection
   d. Surveillance of the target
   e. Photographic intelligence collection.
3. Review the criteria for terrorist target selection. How many of these apply to your assets and what can you do to counter these threats?
4. Develop a localized threat indicator checklist and assign responsibility for conducting a threat assessment using this checklist to a member of the threat management committee.
5. Develop your vulnerability-determination checklist using the following information as models:
   a. Terrorist target selection criteria
   b. Installation vulnerability assessment.
6. Review the scenarios you have developed.
   a. Develop additional scenarios using your creativity rather than previous incidents as the basis. If you were a terrorist, how would you attack your installation?
   b. Compare your scenarios to your threat indicators and vulnerability-determining systems.
7. Validate your scenarios and countermeasures through
   a. Desktop exercises
   b. Field training exercises
   c. Review by consultants
   d. Penetration teams.
8. Prepare a threat condition-level format with required responses at each level.

Table A-3. *Unit Vulnerability Assessment*[578]

1. GENERAL ASSESSMENT
   A. Unit mission sensitivity
      ___ National security mission, highly publicized (6 points)
      ___ Sensitive mission, limited to medium publicity (3-5 points)
      ___ Covert or unpublicized mission (2 points)
   B. VIPs
      ___ One point for each CEO or star (6 points maximum)
      ___ Diplomats or politicians (3 points)
   C. Current threat analysis by intelligence agency or U.S. Department of State
      ___ Available (0 points)
      ___ Unavailable (3 points)
   D. World attitude toward mission
      ___ General agreement (0 points)
      ___ General disagreement (3 points)
      ___ Add 1 point for stated disagreement by each of the following:
      Cuba
      North Korea
      Iran
      Libya
      Syria (6 points maximum)
   E. Status of unit training
      ___ No terrorism security plan, no terrorism counteraction trained personnel (6 points)
      ___ Comprehensive security plans, terrorism counteraction trained personnel and teams (0 points)
   F. Unity of security effort
      ___ Single unit or group with terrorism counteraction plan and organization (0 points)
      ___ Multiple groups or units. No coordinated plan (3 points)

2. REGIONAL ASSESSMENT
   A. Area of deployment
      ___ Europe, Middle East, Central/South America, the Philippines (6 points)
      ___ Caribbean (4 points)
      ___ Other locations outside the continental United States (3 points)
   B. Country team guidance
      ___ Good intelligence, security advice or assistance, no conflicting mission (0 points)
      ___ No intelligence or security advice, conflicting mission (3 points)
   C. Coordinated assistance from law enforcement or military agency
      ___ Assistance immediately available (0 points)
      ___ Assistance available within one hour (2 points)
      ___ Assistance not available (3 points)

Table A-3. *Unit Vulnerability Assessment*[579] *(continued)*

3. SPECIFIC LOCATION ASSESSMENT

A. Availability of military, security, or law enforcement assistance

___ On site (1 point)
___ Thirty-minute reaction time (2 points)
___ One-hour reaction time (3 points)

B. Location (separate assessment for each subunit separately located)

___ Urban undefended (8 points)
___ Urban semidefended (law enforcement or military) (4 points)
___ Urban defended (perimeter fence, etc.) (2 points)
___ Rural undefended, close country (6 points)
___ Rural undefended, open country (4 points)
___ Rural defended (perimeter fence, etc.) (2 points)

C. Access to location

___ Roads (3 points for freeways to 1 point for secondary roads) (3 points maximum)
___ Airfields (3 points for high-performance aircraft to 1 point for small aircraft) (3 points maximum)
___ Waterways (2 points for navigable to 1 point for nonnavigable (2 points maximum)

D. Personnel/vehicle access

___ Free access to area (6 points)
___ Access controlled by host nation (4 points)
___ Access controlled by your organization (2 points)
___ No unauthorized access allowed (0 points)

E. Communications

___ No outside communications (4 points)
___ Communication with higher, lateral, and lower elements (0 points)
___ Landline: 2 points for nondedicated, 0 points for secure dedicated (2 points maximum)
___ Radio: 2 points for nondedicated, 0 points for semidedicated (2 points maximum)

F. Tactical limitations of law enforcement, military, or security personnel (rules of engagement)

___ No live ammunition (6 points)
___ No magazines in weapons (2 points)
___ No outside patrols/operations/intelligence gathering (4 points)
___ No barricades or other methods of building hardening (6 points)
___ Enforced stereotyped patterns of life (4 points)

Table A-4. *Installation Vulnerability-Determining System*[580]

INSTALLATION CHARACTERISTICS AND SENSITIVITY (18 POINTS)
___Very important persons (1 point per U.S. dignitary or star, 3 points for foreign dignitary) (6 points maximum) ___Mission sensitivity (6 points maximum) ___Nuclear, chemical, or law enforcement facility (6 points) ___Research and development facility (5 points) ___International corporation or activity (4 points) ___Domestic corporation or activity (2 points) ___Current threat analysis conducted by law enforcement, military, or security professionals (available, 0 points, unavailable, 3 points) ___Open access to facility (2 points), limited access (1 point), totally controlled access (0 points) ___Symbolic value (shrine, museum, etc.) (1 point)
COMMENT: All facilities should be capable of establishing and maintaining barrier integrity, especially in emergency situations. THREAT CONSIDERATIONS: __________ __________ __________ __________
STATUS OF TRAINING (12 POINTS)
___ No operational emergency operations center (EOC) and no counterterrorism-trained tactical team available (12 points) ___ Operational EOC, but no counterterrorism tactical team available (9 points) ___ Operational EOC, tactical team available, but they do not have appropriate counterterrorism equipment or training (6 points) ___ Operational EOC, tactical team trained and equipped for counterterrorism operations (3 points) ___ Operational EOC, tactical team trained and equipped for counterterrorism operations and the system is tested at least every six months (0 points) COMMENTS: Consideration must be given to establishing, equipping, maintaining, and testing of the EOC. The tactical team may be available for local law enforcement, security, or military assets. THREAT CONSIDERATIONS: __________ __________ __________ __________

Table A-4. *Installation Vulnerability-Determining System*[581] *(continued)*

AVAILABLE COMMUNICATIONS (10 POINTS)

___ Communications with lower elements only (4 points)
___ Communications with lower and lateral elements (3 points)
___ Communications with high, lower, and lateral units (0 points)

Land-Line Communications

___ Nondedicated (4 points)
___ Dedicated point-to-point (2 points)
___ Secure dedicated (0 points)

Radio

___ Nondedicated (2 points)
___ Dedicated (1 point)
___ Secure dedicated (0 points)

COMMENTS: Consideration should be given to security of lines of communication and the communications terminals at this facility. Secure radio communications are an important consideration for law enforcement, security, and military assets.

THREAT CONSIDERATIONS:

____
____
____
____

AVAILABILITY OF LAW ENFORCEMENT RESOURCES (8 POINTS)

	RESPONSE TIME			
	1 hr	2 hr	3 hr	3+ hr
Trained, federal and local	1	2	3	4
Trained federal	2	3	4	5
Trained local	3	4	5	6
Nontrained local	4	5	6	7
Unavailable	8	8	8	8

COMMENTS: Consideration should be given to the determination of which law enforcement agencies are available, their resources, training status, and response times. Note that the term “federal” refers to U.S. and host country agencies.

THREAT CONSIDERATIONS:

____
____
____
____

Table A-4. *Installation Vulnerability-Determining System*[582] *(continued)*

TIME AND DISTANCE FROM OTHER FACILITIES OR INSTALLATIONS ABLE TO LEND ASSISTANCE (7 POINTS)

TIME (hr)	DISTANCE (miles) 0-29	30-59	60-90	90+
1.5	0	1	2	3
2.0	1	2	3	4
2.5	2	3	4	5
3.0	3	4	5	6
3.0+	4	5	6	7

COMMENT: Coordination should be made with the closest facility capable of providing assistance.

THREAT CONSIDERATIONS:

TIME AND DISTANCE FROM URBAN AREAS (7 POINTS)

TIME (hr)	DISTANCE (miles) 0-59	60-89	90-120	120+
1	0	1	2	3
2	1	2	3	4
3	2	3	4	5
4	3	4	5	6
4+	4	5	6	7

COMMENTS: For purposes of this matrix, an urban area has a population in excess of 100,000 people. Because of their size and the opportunity for the terrorists to blend into the population, urban areas offer the terrorist a safe haven for conducting operations.

THREAT CONSIDERATIONS:

Table A-4. *Installation Vulnerability-Determining System[583] (continued)*

GEOGRAPHIC REGION (8 POINTS)

___ West Coast/Florida/outside the continental U.S. (8 points)
___ Eastern U.S. (6 points)
___ Southwest (4 points)
___ South, Northwest, Central, Northeast, and Mid-Atlantic (2 points)

COMMENTS: Points are awarded based on historical data gathered on terrorist activity by geographic region. This classification scheme must be modified according to the recent activities in your area.

THREAT CONSIDERATIONS:

____
____
____
____

POPULATION DENSITY OF THE FACILITY OR INSTALLATION (8 POINTS)

POPULATION	AREA (square miles) 10-100	101-200	200+
50-500	3	2	1
500-2,500	6	5	4
2,500-5,000	8	7	6
5,000+	8	8	8

CONSIDERATIONS: For a facility located in an office complex, industrial park, etc., consider the population density for the entire immediate area.

THREAT CONSIDERATIONS:

____
____
____
____

Table A-4. *Installation Vulnerability-Determining System*[584] *(continued)*

PROXIMITY TO FOREIGN BORDERS (8 POINTS)
Mexican Border ___ 0-100 miles (8 points) ___ 101-500 miles (6 points) ___ More than 500 miles (2 points) **Canadian Border** ___ 0-100 miles (6 points) ___ 101-500 miles (4 points) ___ More than 500 miles (2 points) COMMENT: If you are located outside the U.S., assess the maximum point value.
THREAT CONSIDERATIONS: ______________________________ ______________________________ ______________________________ ______________________________
ACCESS TO THE FACILITY (8 POINTS)
Roads ___ Freeways or Interstate highways (3 points) ___ Improved roads (2 points) ___ Secondary roads (1 point) **Airfields** ___ Usable by high-performance (jet) aircraft (3 points) ___ Usable by low-performance (prop) aircraft (2 points) ___ Usable by small fixed-wing/rotary-wing aircraft (1 point) **Waterways** ___ Navigable (2 points ___ Nonnavigable (1 point) ___ None (0 points) COMMENTS: Consideration should be given to these three methods of entering or exiting the facility both from the terrorists' point of view and from that of a law enforcement agency rendering assistance. THREAT CONSIDERATIONS: ______________________________ ______________________________ ______________________________ ______________________________

Table A-4. *Installation Vulnerability-Determining System*[585] *(continued)*

TERRAIN (5 POINTS)		
___ Built-up areas (5 points) ___ Mountainous, forested, or conducive to concealment (4 points) ___ Open areas (2 points) COMMENTS: Terrain should be analyzed in conjunction with a review of facility sensitivity, adequacy of barrier fencing, and route of access and egress. THREAT CONSIDERATIONS: ____ ____ ____ ____ Total points for all 11 categories and compare your facility's total to the scale below. This will give you an idea of your overall vulnerability.		
	POINT TOTAL	
	0-10	Very low
	11-30	Low
	31-60	Medium
	61-80	High
	81-100	Very high

Table A-5. *Personnel Crisis Management File*[586]

A separate crisis management file should be maintained on each person who is listed on your "A" list of potential personnel security risks. Files must be updated annually. The file should include photographs and/or videotapes of each person's residence, vacation house, and office area.

Date: ____________________

Employer: ____________________

Employee's Position: ____________________

	Name	*Profile*	*Photo*	*Fingerprints*	*Writing Samples*	*Voice Tapes*
Employee:	______	______	______	______	______	______
Spouse:	______	______	______	______	______	______
Children:	______	______	______	______	______	______

Other family members living with employee:

Relationship:

______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______

Other Information:

	Sketches	*Photographs*
Residence:	______	______
Second Residence:	______	______
Vehicle #1	______	______
#2	______	______

INDIVIDUAL PROFILE

Today's Date: ____________________

Name: ____________________
Last First Middle

Nickname(s): ____________________

Social Security Number: ____________________

Driver's License: State: __________ Number: ____________________

Birth: Place: ____________________ Date: ____________________

Address: #1 ____________________

____

____

____

Address: #2 ____________________

____

____

____

Physical Description:

Height: ____________________ Weight: ____________________

Hair: ____________________ Eyes: ____________________

Eyeglasses: ____________________ Hearing Aid: ____________________ Other: _____

Scars or Identifying Marks:

____

____

Table A-5. *Personnel Crisis Management File*[587] *(continued)*

Special Medication Requirements: ______________________________

	Name	*Address*	*Telephone*
Physician:	________	________	________
Dentist:	________	________	________
Pharmacist:	________	________	________

Name: ______________________________

Profile of:

Clubs or Organizations: ______________________________

Hobbies: ______________________________

Other Activities: ______________________________

Routine Events:

Sunday: ______________________________

Monday: ______________________________

Tuesday: ______________________________

Wednesday: ______________________________

Thursday: ______________________________

Friday: ______________________________

Saturday: ______________________________

Bank(s): ______________________________

Savings & Loan Association(s): ______________________________

Credit Cards:

	Company	*Number*
1.	________	________
2.	________	________
3.	________	________
4.	________	________
5.	________	________
6.	________	________
7.	________	________

Comments:

Table A-5. *Personnel Crisis Management File[588] (continued)*

Fingerprints:

____________ ____________
Thumb Index
Right Hand

Staple
Photograph
Here

____________ ____________
Thumb Index
Left Hand

Writing Sample: Please write the following sentence and sign using your regular signature.

“I feel good and am looking forward to tomorrow.”

Sequence on Voice Tape: Number ___________________

Table A-6. *Physical Security Plan*[589]

1. PURPOSE

   State purpose of the plan.

2. AREA SECURITY

   Define the areas, building, and other structures considered critical, and establish priorities for their protection.

3. CONTROL MEASURES

   Define and establish restrictions on access to and movement into critical areas. These restrictions can be categorized as personnel, materials, and vehicles.

   a. *Personnel Access*. Establish control pertinent to each area or structure.
      - (1) Authority for access
      - (2) Access criteria for unit personnel, visitors, maintenance or support personnel, contractor personnel, and local police/armed forces
      - (3) Identification and control
        - (a) Description of the system to be used in each area. With a badge system, a complete description should be used to disseminate requirements for identification and control of personnel who conduct business on the installation.
        - (b) Application of the system for unit personnel, visitors to restricted or administrative areas, vendors, tradesmen, contractor personnel, and maintenance or support personnel.

   b. *Material Control*
      - (1) Incoming
        - (a) Requirements for admission of material and supplies
        - (b) Inspection of material for possible sabotage hazards
        - (c) Special controls on delivery of supplies and/or personnel shipments in restricted areas
      - (2) Outgoing
        - (a) Documentation required
        - (b) Controls, as outlined above for incoming material control
        - (c) Classified shipments

   c. *Vehicle Control*
      - (1) Policy on registration of vehicles
      - (2) Policy on search of military and privately owned vehicles
      - (3) Parking regulations
      - (4) Controls for entering restricted and administrative areas
        - (a) Privately owned vehicles
        - (b) Military vehicles
        - (c) Emergency vehicles

Table A-6. *Physical Security Plan*[590] *(continued)*

4. AIDS TO SECURITY

Indicate the manner in which the following aids to security will be implemented on the installation

a. *Protective Barriers*
   - (1) Definition
   - (2) Clear zones
     - (a) Criteria
     - (b) Maintenance
   - (3) Signs
     - (a) Types
     - (b) Posting
   - (4) Gates
     - (a) Hours of operation
     - (b) Security requirements
     - (c) Lock security

b. *Protective Lighting System*
   - (1) Use and control
   - (2) Inspection
   - (3) Pointing inward or outward
   - (4) Action to be taken during a commercial power failure
   - (5) Action to be taken during an alternate source of power failure
   - (6) Emergency lighting systems
     - (a) Stationary
     - (b) Portable

c. *Intrusion-Detection Systems*
   - (1) Security classification
   - (2) Inspection
   - (3) Use and monitoring
   - (4) Action to be taken in event of alarm conditions
   - (5) Maintenance
   - (6) Alarm logs or registers
   - (7) Sensitivity settings
   - (8) Fail-safe and tamperproof provisions
   - (9) Monitor panel location

d. *Communications*
   - (1) Locations
   - (2) Use
   - (3) Tests
   - (4) Authentication

Table A-6. *Physical Security Plan*[591] *(continued)*

5. INTERIOR GUARD PROCEDURES

Include general instructions that apply to all interior guard personnel (fixed and mobile). Detailed instructions such as special orders and SOPs should be attached as annexes. Ensure that randomness is incorporated in guard procedures.

a. *Composition and Organization*
b. *Tour of Duty*
c. *Essential Posts and Routes*
d. *Weapons and Equipment.* Live ammunition? Magazines on weapons? Round in the chamber?
e. *Training*
f. *Use of Sentry/Patrol Dogs*
g. *Method of Challenging With Sign and Countersign*
h. *Rules of Engagement*
i. *Alert Force*
   (1) Locations
   (2) Use
   (3) Tests
   (4) Authentication
   (5) Deployment concept

6. CONTINGENCY PLANS

Indicate required actions in response to various emergency situations. Detailed plans such as counterterrorism, bomb threats, hostage negotiation, disaster, and fire should be attached as annexes.

a. *Individual Actions*
b. *Alert Force Actions*
c. *Security Alert Status*

7. SECURITY ALERT STATUS

8. USE OF AIR SURVEILLANCE

9. COORDINATING INSTRUCTIONS

a. *Integration With Plans of Host or Nearby Military Installations*
b. *Liaison and Coordination*
   (1) Local civil authorities
   (2) Federal agencies
   (3) Military organizations

Table A7 is a form for recording a bomb threat — essentially the same as Air Force Form 440, "Bomb Threat Aid"; Table A8 is a form for conducting the investigation after a bomb threat.

Table A-7. *Bomb Threat Form*[592, 593]

Time and date reported: ______________________

How reported: ______________________

Exact words of caller: ______________________

____

Questions to ask: ______________________

1. When is bomb going to explode? ______________________
2. Where is bomb going to explode? ______________________
3. What kind of bomb is it? ______________________
4. What does it look like? ______________________
5. Why did you place the bomb? ______________________
6. Where are you calling from? ______________________

Description of caller's voice: ______________________

Male _____ Female _____ Young _____ Middle-aged _____ Old _____ Accent __________

Tone of voice _____ Background noise _____ Is voice familiar? _____

If so, whom did it sound like? ______________________

____

Other voice characteristics: ______________________

Time caller hung up: ___________ Remarks: ______________________

____

Name, address, telephone number of recipient: ______________________

____

RECORD:

1. Date ____________________ and time ____________________ of call.
2. Exact words spoken: ______________________

____

____

3. ☐ Male ☐ Female
   ☐ Adult ☐ Child
   Estimated age: ____________________ Race: ______________________
4. Speech (check applicable boxes)
   ☐ Slow ☐ Excited ☐ Disguised
   ☐ Rapid ☐ Loud ☐ Broken
   ☐ Normal ☐ Normal ☐ Sincere
   Accent: ______________________
5. Background noises: ______________________

____

____

6. Name of person receiving the call: ______________________

Table A-8. *Bomb Threat Investigation Form*[594, 595]

Type of Complainant:
☐ School ☐ Hospital ☐ Industrial manufacturing company
☐ Business ☐ Other
Business name of complainant ______
Business address ______
Business telephone ______
Name of person reporting complaint ______
Telephone number that call was received on ______
Date and time of call ______
Exact words said by caller ______
Background noises (street sounds, baby crying, etc.) ______
Information about caller: Age _____ Sex _____ Race ______ Accent ______Education level _________
Speech impediments (drunk, lisp, etc.) ______
Attitude (calm, excited, etc.) ______
Any suspects? ☐ Yes ☐ No
Have previous calls been received? If yes, approximately how many?
☐ Yes ☐ No ______
Has the telephone company security department been notified?
☐ Yes ☐ No
Was any incendiary or explosive device found?
☐ Yes ☐ No
Number of threats received thus far during calendar year ______

Table A-9. *MFST Inventory List: Operating Room Element (Pack 1)*

Location	***Item***	***Quantity***
Top flap:	Leather work gloves	1 pair
	Trauma scissors	1 pair
	Laminated inventory cards	1 set
	Surgical floor (plastic tarp)	1
Main:	Protective eye wear	1 pair
	Surgical apron, vinyl	1
	Petzl headlight with batteries	1
	C batteries, alkaline	3 batteries
	Headlight bulb	1 bulb
	Impervious split sheets	2 drapes
	Suture pack	1 pack
	Surgical sleeves	10 sleeves (single)
	GIA staplers (75 mm)	2 staplers
	Stapler reloads	10 reloads
	Chest tube/trach set	1 set (2nd set in Pack 4)
	Suction machine, with case	1 machine
	Vascular Balfour retractor	1
	Basic OR instrument set*	1 set (2nd set in Pack 2)
	Lap sponges	5 packs
	Impervious split sheets	10 sheets
Bottom:	Sterile gloves, size 7½	10 pair
	Sterile gloves, size 8	10 pair
	Yankhauer suction tips	15 suction tips
	Suction tubing	4 packages
	ACE bandages (4-inch)	6 rolls
	Nonsterile gloves	1 box (in bag)
	Kerlix rolls	10 rolls
	Field dressing (large)	5 dressings
	Field cravats	5 cravats
	Connectors (5-in-1), sterile	5 connectors
Left side:	Betadine solution	1 bottle (1-qt size)
	3 percent NaCl, 500 cc	2 bags
	Hespan, 500 cc	3 bags
Right side:	Bovie tips	10 tips
	Bovie handles	5 handles
	Eye patches	5 patches
	Fox eye shield	5 eye shields
	Eye shield garters	5
	A-33 disinfectant agent	20 packets
	Scrub brush, heavy	2 brushes
	Hespan, 500 cc	1 bag

* Detailed list for Bone Set is in Table A-15

Table A-10. *MFST Inventory List: General Surgery Element (Pack 2)*

Location	***Item***	***Quantity***
Top flap:	Leather work gloves	1 pair
	Trauma scissors	1 pair
	Laminated inventory cards	1 set
	MFST op records	20 records
Main:	Protective eye wear	1 pair
	Surgical apron, vinyl	1
	Petzl headlight	1
	C batteries, alkaline	3 batteries
	Surgical sleeves	10 sleeves
	Finochetto rib spreader	1 retractor
	Propaq, with case	1
	Propaq adapter	1
	Propaq BP cuff	1
	Propaq monitor wires	set, as below
	BP tubing	1
	A-line transducer	1
	EKG leads	1 set
	oximeter probe and wire	1
	Sterile gloves, size 7½	10 pair
	Sterile gloves, size 8	10 pair
	Suction tubing	3 packages
	Basic OR instruments*	1 set (2nd set in Pack 1)
	Suture pack	1 pack
	Vicryl mesh, large	2 sheets
Bottom:	Steel basin (deep)	2 basins
	4-inch x 4-inch nonsterile gauze	1 large package
	Surgical razor	6 razors
	Ampicillin/sulbactam	2 boxes (20 vials)
	Gentamicin, 80-mg vials	2 boxes (50 vials)
	Bacitracin ointment	5 tubes
	Genoptic ointment	5 tubes
	Pen lights	6 lights
	Impervious split sheets	10 sheets
	Gigli saw blades	6 blades
	Sulfadiazine cream	1 jar
Left side:	Lap sponges	5 packages
	Rubber bands	1 bag
	Safety pins	1 bag
	Pens, black, ball-point	4 pens
	Markers, black, impervious	4 markers
Right side:	Face masks	30 masks (1 bag)
	Handwash lotion, Calstat	6 bottles

* Detailed list for Bone Set is in Table A-15

Table A-11. *MFST Inventory List: Orthopedic Surgery Element (Pack 3)*

Location	***Item***	***Quantity***
Top flap:	Leather work gloves	1 pair
	Trauma scissors	1 pair
	Laminated inventory cards	1 set
Main:	Protective eye wear	1 pair
	Surgical apron, vinyl	4
	Petzl headlight	1
	C batteries, alkaline	3 batteries
	External fixation sets	7 sets
	Each set contains	
	Pins (5 mm x 50 mm x 180 mm, Howmedica)	4 pins (28 total), sterile
	Frames (AD trauma fixators, pins removed)	1 frame (7 total), nonsterile
	Clamps (bar-to-bar Fernandez clamps)	4 clamps (28 total), nonsterile
	Surgical wrench for Fernandez clamps	1 wrench (7 total), nonsterile
	Pleurevac Autotransfuser (bag)	4 bags
	Pleurevac Autotransfuser (frame)	1 frame
	Kerlix rolls	10 rolls
	Bone set*	1
	Leibzke knife	1
	Mallet	1
	Hudson drill set†	1 set
	(with 5-mm brace adapter, Howmedica)	
	Impervious split sheets	10 sheets
Bottom:	Steel basin (deep)	1 basin
	2-inch silk tape	10 rolls
	Bulb syringes	5 syringes
	Lap sponges	10 packages
	Field dressings, large	5 dressings
	Plastic bags, large (garbage)	20 bags
	Plastic bags, 1 gallon (Ziploc)	10 bags
	Space blankets (small)	10
Left side:	3 percent NaCl, 500 cc	2 bags
	Pressure bags	2 bags
	Hespan	4 bags (500-cc bags)
Right side:	Surgical sleeves	10 single
	Betadine solution	1 bottle (1-qt size)

* Detailed list for Bone Set is in Table A-15

† Detailed list for Hudson Drill Set is in Table A-15

Table A-12. *MFST Inventory List: Emergency Medicine Element (Pack 4)*

Location	***Item***	***Quantity***
Top flap:	Leather work gloves	1 pair
	Trauma scissors	1 pair
	Laminated inventory cards	1 set
Main:	Protective eye wear	1 pair
	Surgical apron	1
	Petzl headlight	1
	C batteries, alkaline	3 batteries
	Chest tube/tracheostomy set	1 set (2nd set in Pack 1)
	Clipboard	1
	Fogarty catheters, No. 3	3 catheters
	Bovie unit, with case	1 unit
	Power cord, 3 sockets	1 cord
	Surgical sleeves	10 single sleeves
	E.M. “Ready” pack (in trauma vest)	See Table A-13
Bottom:	Foley collection bags	5 bags
	Bovie pads	10 pads
	Chest tubes, 36 Fr straight	10 tubes
	Foley catheters, 18 Fr	12 catheters
	Chest tube connectors (5-in-1)	5 connectors
	3 percent NaCl	4 bags (500-cc bags)
	Hespan	4 bags (500-cc bags)
	Nonsterile gloves, large	1 box
Left side:	Heimlich valves	10 valves
	Hespan	4 bags (500-cc bags)
Right side:	3 percent NaCl, 500 cc	2 bags
	Penrose drains, 0.5-inch	10 drains
	Vascular shunts	
	Sundt, large, heparin bonded	5 shunts
	G.U. tubing	2 tubes
	Vascular grafts	
	PTFE, 8 mm	2 grafts
	Hepatic graft, large, Argyle	1 graft

Table A-13. *MFST Inventory List: Trauma Vest (Travels in Pack 4)*

Location	***Item***	***Quantity***
Right large pocket:	Laryngoscope handle	1
	Laryngoscope blades	
	Miller	2
	Mac	2
	AA batteries	4
	Laryngoscope bulbs	2
	MacGill forceps	1
	Crile, 5-inch	2
	Kelly, 9-inch	2
	Scalpels	
	No. 10	3
	No. 11	3
	Stylet	2
	Endotracheal tubes	
	6.0	1
	7.0	5
	Heimlich valve	4
	0 Silk, on Keith needle	4
Right velcro pocket:	Protective eye wear	1
Right center pocket:	Surgilube packets	15
	Oral airway	4
	Nasal airway	4
Right breast pocket:	BP cuff	1
	Stethoscope	1
Left lower pocket:	Betadine pads	20
	Alcohol prep pads	20
	IV tubing	2
	Lidocaine 1 percent	1 50-cc vial
	Epinephrine 1:1,000	1 30-cc vial
	Atropine 0.4 mg/cc	1 20-cc vial
	Syringe, 5-cc	5
	Syringe, 1-cc	5
	Needle, 18-ga	10
	Heparin lock cap	5
Left middle pocket:	IV tubing	2
	0.9 percent saline, 250-cc bag	1
Left upper pocket:	IV angiocath, 14-ga	10
	IV angiocath, 18-ga	10
	4-0 silk, on Keith needle	2
Left lower small pocket:	4-inch ACE wrap	
Right inside lower pocket:	4-inch x 4-inch gauze pad	10
	ABD dressing	2
	Petrolatum gauze	2

Table A-13. *MFST Inventory List: Trauma Vest (Travels in Pack 4) (continued)*

Location	*Item*	*Quantity*
Right inside upper pocket:	Cravat	4
Right inside lining compartment:	Chest tube, 36 Fr	2
Left inside lower pocket:	Sterile gloves, size 7½	4 pair
Left inside upper pocket:	Disposable gloves	10 pair
Fanny pack, central compartment:	Ambu bag, mask	
Fanny pack, left pocket:	Vecuronium, 10-mg vial with diluent	5
	Succinylcholine Flowpak	1 (1-g vial)
	NS, 50-cc bag	1
Fanny pack, right pocket:	Ketamine, 100 mg/5 cc	5

Table A-14. *MFST Inventory List: Anesthesia Element (Pack 5)*

Location	***Item***	***Quantity***
Top flap:	Personal gear	
	Anesthesia records	25
	Air Force Form 600	15
Main:	Ohmeda Universal PAC with instructions and accessories. Self-inflating bag is packed in top of compartment and vaporizer is wrapped in foam eggcrate	
	Anesthesia masks	
	Adult-sized mask (w/vaporizer)	1
	Nondisposable black rubber mask (size 3)	1
	Nondisposable black rubber mask (size 4)	1
	Ambu self-inflating bag and valve	1
	Pulse oximeter, w/ case	1
	Y-type blood tubing with hand pump	15
	(sets of 5, packed in each of 4 zip-lock bags)	
	Blood pressure cuff, extra large (thigh cuff)	1
	Nelcor pulse oximeter probes (disposable)	5/90
	EKG pads	60
	Nelcor End Tidal CO_2 Detector	10/96
	Syringes	
	30-cc	5
	10-cc	15
	60-cc catheter tipped syringe	2
	1-cc syringe with 25-ga, 0.0625-inch needle	10
	Needles	
	18-ga	50
	22-ga “B” bevel	10
	Spinal needles, 22-ga	10
	Airway Supplies	
	6.0 ET tube (cuffed)	5
	7.0 (cuffed)	10
	8.0 (cuffed)	10
	Mallinckrodt “satin slip” intubating stylet	1
	Stubby-handle laryngoscope	1
	(with 2 AA batteries, pack w/ batteries not installed)	
	Miller, size 3	1
	Mac, size 3	1
	IV Supplies	
	IV extension set with stop cock	20
	Alcohol pads	60
	Penrose tourniquets	3
	14-ga, short	20
	14-ga, long	10
	16-ga	5
	18-ga	10
	CPDA-1 single-use blood bags	1 pkg. of 12

Table A-14. *MFST Inventory List: Anesthesia Element (Pack 5) (continued)*

Location	***Item***	***Quantity***
	Metal Tubex syringe holder	1
	Laryngoscope bulbs	2
	AA batteries (pulse ox, laryngoscope extras)	10
	1-inch tape	6
	Airlife oxygen tubing (7-ft., vinyl tipped)	2
	Green “Xmas tree” oxygen tubing connector	2
	White “football” oxygen tubing connector	2
	Pen light	2
	Tongue depressors	20
	Oral airway	
	size 90 mm	2
	size 100 mm	2
	Salem sump tube (18 Fr)	10
	Yankhauer suction tip (disposable)	3
	Endotracheal suction catheter (18 Fr)	5
	Disposable latex gloves	40/100
	Black ink pens	3
	Black felt tip marker	1
	Gauze 4-inch x 4-inch (unsterile)	1 pkg.
	Isoflurane, 100 cc bottles	6
	Induction Agents	
	Ketamine 100 mg/cc, 5-cc vials	5
	Scopolamine	5
	Relaxants	
	Succinylcholine powder, 1,000 mg	3
	Normal saline, 50 cc bags	3
	Vecuronium 10 mg with sterile water 10 cc	5
	Reversal agents	
	Neostigmine, 10-mg vials	3
	Glycopyrrolate, 1-mg vials	10
	Local anesthetics	
	Lidocaine 2 percent MDV, 20 cc vials	4
	Emergency drugs	
	Atropine .4 mg/cc, 20 cc MDV	2
	Epinephrine 1:1,000 1 mg/cc, 30 cc MDV	1
	Other drugs	
	Droperidol 12.5-mg/5-cc ampule	2
	Sterile water, 20-cc multidose vials (plastic)	10
	Zantac 25-mg/cc, 6-cc MDV	3
	Reglan 10-mg/2-cc	10
	Heparin, 1,000 U/cc, 10-cc MDV	1
	Benadryl 50-mg/cc, 10-cc MDV	1
	Albuterol inhaler	1
	Decadron 20-mg vials	3/25
	Contained in black padded nylon box	
	Haloperidol, 5-mg/cc ampules	5/25
	Naloxone, .4-mg/cc ampules	5/25

Table A-14. *MFST Inventory List: Anesthesia Element (Pack 5) (continued)*

Location	***Item***	***Quantity***
	Ephedrine, 50-mg ampules	5/25
	Neosynephrine, 10-mg ampules	5/25
	Levophed, 1-mg/cc in 4-cc ampule	1
	Toradol 60-mg tubex syringes	10
	Spinal marcaine .75 percent hyperbaric ampules	5
	Bupivicaine .5%, 50-cc vials (for nerve blocks)	5
	Miscellaneous drugs	
	2 percent xylocaine jelly	1
	Tincture of Benzoin	1 pt
	Surgilube	40 packs
Bottom:	Petzl headlight	1
	C batteries, alkaline	3
	Narcotics and controlled drugs These are stored in the narcotics vault in the pharmacy and must be checked out from the pharmacy at the time of deployment. The exception will be rapid on-call deployment. In that event the 4th ASF will bring narcotics along with packs.	
	Morphine, 10-mg/1-cc vials	50
	Fentanyl, 5-cc ampules	10
	Versed, 5-mg ampules	10
	Sodium pentothal (500-mg kit)	5
	Auto-injectors for MFST These drugs are disbursed to the team. The narcotics go in two padded boxes labeled MFST 1-of-2 and 2-of-2.	
	2-Pam CL	15
	Atropine	15
	Diazepam	5
	Pyridostigmine blister packs	5
Right:	Y-type blood tubing with hand pump	5
	(sets of 5, packed in each of 4 zip-lock bags)	
	Hespan, 500-cc bags	2
	Leather work gloves	1 pair
	Laminated inventory cards	1 set
Left:	*Left pocket contains Quick Start setup, to begin first case*	
	Trauma scissors	1 pair
	Stubby-handle laryngoscope	1
	(pack w/ 2 AA batteries not installed)	
	Miller, size 2	1
	Mac, size 4	1
	ET tube, size 8.0	1
	Mallinckrodt “satin slip” intubating stylet	1
	IV start set	
	Alcohol pads	15
	Penrose tourniquet	1
	16 g angiocath	1
	18 g angiocath	3

Table A-14. *MFST Inventory List: Anesthesia Element (Pack 5) (continued)*

Location	***Item***	***Quantity***
	Penrose tourniquet	1
	Hespan, 500 cc	1
	Y blood tubing	1
	Succinylcholine Flowpak, 1,000 mg	1
	Atropine, 20-cc vial	1
	Ketamine, 100-mg/cc, 5-cc vial	1
	NS, 50 cc	1
	Stethoscope	1
	Skin temp. stickers	10
	Precordial stethoscope (medium)	1
	Precordial stickers	12/100
	Foam ear piece	2/100
	Three-way stop cock	2
	Mini-Stim II nerve stimulator (w/ 9-V battery) (include balls for nerve stimulator)	1
	Spare battery (9-V transistor)	1
	Small bandage scissors	1
	Drug labels	15
	Oral airway, 100 mm	1
	Nasal trumpets	
	size 7	1
	size 8	1
	size 9	1
	Tongue depressors	2
	MacGill forceps	1
	Bulb syringe (Yankhauer tip)	1

Table A-15. *MFST Inventory List: Additional Equipment*

Item	***Quantity***
Packed in Surgeon's Bag (Bag 2)	
Propak 106EL	
Blood pressure cuff and cable	1
Temperature cable	1
Pulse oximeter cable	1
Nondisposable pulse oximeter probe	1
EKG lead wires	1 set
Charger	1
Basic Instrument Tray, General Surgery (2 sets per team, located in Packs 1 and 2)	
String on instrument fork	
Curved Mayo scissors	1
7-inch Stevens scissors	1
7-inch curved Metzenbaum scissors	1
9-inch curved Metzenbaum scissors	1
12-inch curved Metzenbaum scissors	1
7-inch Mayo needle holders	2
9-inch DeBakey needle holder	1
9-inch straight coarctation clamp	1
10-inch curved Glover	1
8-inch curved DeBakey clamp	1
9-inch Schnidts	2
7-inch right-angle clamp	1
9-inch right-angle clamp	1
12-inch right-angle clamp	1
7.5-inch tonsil clamps	2
6-inch Alice clamps	2
10-inch Alice clamps	2
8-inch Babcock clamps	2
5-inch curved Crile clamps	4
6-inch curved Kelly clamps	6
9-inch curved Kelly clamps	4
No. 3 knife handle, standard	1
No. 3 knife handle, long	1
7-inch DeBakey pickups	2
12-inch DeBakey pickups	2
5-inch rat-tooth forceps	2
Bonnie forceps	1
Adsons with teeth	2
Gigli saw handles	2 (1 pair)
DeBakey bulldog vascular clamps	2
Bottom of pan	
Small malleable retractor	1
Medium malleable retractor	1

Table A-15. *MFST Inventory List: Additional Equipment (continued)*

Item	*Quantity*
Large malleable retractor	1
Small Richardson retractor	1
Large Richardson retractor	1
Wheitlander self-retaining retractor	2
Orthopedic Instrument Tray (1 set, located in Pack 3)	
Gigli saw handles	2 (1 pair)
Freer elevator	1
Key elevator	1
No. 3 curette	1
No. 5 curette	1
Pliers	1
Kleintert-Kuntz rongeur	1
No. 3 knife handle	1
5-inch rat-tooth forceps	2
Chest Tube/Tracheostomy Set (2 sets, located in Packs 1 and 4)	
Sarot clamp (Miltex)	1
5-inch Crile clamp	1
7-inch Metzenbaum scissors	1
5-inch rat-tooth forceps	1
7-inch Mayo Haeger needle holder	1
No. 3 knife handle	1
No. 10 blade	1
Hudson Drill Set (1 set, located in Pack 3)	
Hudson brace drill	1
Jacobs chuck	1
Jacobs chuck key	1
Hudson extension	1
Skull perforator bits (oval and round, 1 ea.)	2
Wheitlander (Codman 50-1220)	1
Key elevator	1
No. 3 knife handle	1
No. 10 blade	1
Other Sterile Instruments	
Vascular Balfour (Pack 1)	1
Finochetto retractor (Pack 2)	1
Liebzke knife (Pack 3)	1
Mallet (Pack 3)	1

Table A-15. *MFST Inventory List: Additional Equipment (continued)*

Item	***Quantity***
Suture Pack (2 sets, located in Packs 1 and 2)	
Suture organizer	1
No. 2 Prolene, TP-1	25
3-0 Prolene, double armed, SH	5
5-0 Prolene, double armed, RB-1	5
0 silk pop-offs, T-12	20 packs (5/pack)
3-0 silk pop-offs, T-5	15 packs (5/pack)
0 silk free ties, 30-inch	20 packs (10/pack)
3-0 silk free ties, 30-inch	20 packs (10/pack)
0 Chromic, BP-1	10 sutures
2-0 nylon, FSL	10 sutures
2-0 Vicryl	10 sutures
Cardiac Teflon pledgets	5 packs
Surgicel, small package	20
Vessel loops, blue maxis	10 packs (2/pack)
No. 10 blades	30 blades

Annex 2 to Appendix I

List of Acronyms and Abbreviations

AARS	Advanced Airborne RADIAC System
ABL	Airborne Laser
ABPBD	Air Base/Port Biological Detection
ACADA	Automatic Chemical Agent Detector and Alarm
ACC	Air Combat Command
ACE	Aircrew Chemical Ensemble
ACMHP	acoustic-cycle mobile heat pump
ACP	Air Commander's Pointer
ACTD	advanced concept technology demonstration
AE	aeromedical evacuation
AEF	Aerospace Expeditionary Force
AERP	Aircrew Eye/Respiratory Protection
AF/IL	Air Force/Installations and Logistics
AFCESA	Air Force Civil Engineer Support Agency
AFFTC	Air Force Flight Test Center
AFGWC	Air Force Global Weather Center
AFIWC	Air Force Information Warfare Center
AFMIC	Armed Forces Medical Intelligence Center
AFMS	Air Force Medical Service
AFR	Air Force Reserves
AFRAT	Air Force Radiation Assessment Team
AFRL	Air Force Research Laboratory
AFRRI	Armed Forces Radiobiology Research Institute
AGARD	Advisory Group for Aerospace Research and Development
AICPS	Advanced Integrated Collective Protective System
AL	Armstrong Laboratory
AL/OEA	Armstrong Laboratory Analytic Services branch
ALAD	Automatic Liquid Agent Detector
ALEP	aircrew laser eye protection
ALLCARS	Automated Lessons Learned Capture and Retrieval System
AMC	Air Mobility Command
AN/PVS	Army-Navy Personal Visible-Light Detection Series
ANG	Air National Guard
ANSI	American National Standards Institute
ANVIS	Aviator's Night Vision Imaging System
ARS	acute radiation syndrome
ASC	Aeronautical Systems Center
ASD	Aeronautical Systems Division
ASM	air-to-surface missile
ASTAMIDS	Airborne Stand-Off Minefield Detection System
ASUBM	antisubmarine missile

ATC	Air-Transportable Clinic
ATD	Advanced Technology Demonstration
ATH	Air-Transportable Hospital
ATLS	advanced trauma life support
ATSD(NCB)	Assistant to the Secretary of Defense for Nuclear, Chemical and Biological Defense Programs
ATTC	Air-Transportable Trauma Center
AUIB	Aircrew Uniform Integrated Battlefield
AW	Air Warrior
BEIR	biological effects of ionizing radiation
BIDS	Biological Integrated Detection System
BM	ballistic missile
BM	battle management
BP	blood pressure
BW	biological warfare
C^2	command and control
C^3I	command, control, communications, and intelligence
C^3ISR	command, control, communications, intelligence, surveillance, and reconnaissance
C^4I	command, control, communications, computers, and intelligence
CAF	Combat Air Force
CAM	Chemical Agent Monitor
CB	chemical or biological
CBD	chemical/ biological defense
CBDCOM	Chemical and Biological Defense Command
CBIAC	Chemical and Biological Defense Information Analysis Center
CBW	chemical and biological warfare
CCA	contamination control area
CCATT	critical care aeromedical transport team
CCATT	Critical Care Air Transport Team
CDC	Centers for Disease Control and Prevention
CENTCOM	Central Command
CFM	contractor-furnished materiel
cGy	centigray
CHCS	Composite Health Care System
CHPPM	Center for Health Promotion and Preventive Maintenance
CIE	clothing and individual equipment
CIE	Commission Internationale de l’Eclairage
CM	cruise missile
COI	critical operational issue
CONOPS	concept of operations
CONUS	continental United States
CPE	collective protective equipment
CRAF	Civil Reserve Air Fleet
CRT	cathode ray tube
CW	chemical warfare
DARPA	Defense Advanced Research Projects Agency
dB	decibels

DDFP	Deployable Defensive Fighting Positions
DE	directed energy
DLA	Defense Logistics Agency
DNBI	disease and nonbattle injury
DoS	Department of State
DST	dielectric stack technology
DSWA	Defense Special Weapons Agency
DTPA	diethylenetriamine-pentaacetic acid
DTUG	Deployment Toxicology Users Group
DU	depleted uranium
DUSD(ES)	Deputy Undersecretary of Defense for Environmental Security
ECS	environmental control system
ECU	environmental control unit
EDTA	ethylenediaminetetraacetic acid
EHD	electrohydrodynamic
ELISA	enzyme-linked, immuno-sorbent array
EM&D	engineering, manufacturing, and development
EMPP	Expedient/Modular Physical Protection
EOC	emergency operations center
ERDEC	Edgewood Research, Development, and Engineering Center
ES/C	expandable shelter/container
ESAH	environmental, safety, and health
ESAI	Expanded Situation Awareness Insertion
eV	electron volts
EW	electronic warfare
FAST	Fast Action Support Team
FBI	Federal Bureau of Investigation
FLIR	forward-looking infrared
FOL	forward operating location
FOV	field of view
GAO	General Accounting Office
GHz	gigahertz
GPS	Global Positioning System
GSTAMIDS	Ground Stand-Off Minefield Detection System
HE	high explosive
HF	hemorrhagic fever
HHV	human herpes virus
HIV	human immunodeficiency virus
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HMT/D	helmet-mounted tracker and display
HPM	high-power microwave
HPSLT	high-power semiconductor laser technology
HSC	Human Systems Center
HSC/XRE	Human Systems Center/Environmental Planning Directorate
HSC/YA	Human Systems Center/Human Systems Program Office
HSC/YAC	Human Systems Center/Life Support Systems Division
HSTAMIDS	Hand-Held Stand-Off Mine Detection System
HTLV	human T-cell lymphotropic virus

HUD	head-up display
Hz	hertz
ICT	integrated concept team
ICU	intensive care unit
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IIT	image-intensification tube
IL	installations and logistics
IM	intramuscular
IOT&E	initial operational test & evaluation
IPE	individual protective equipment
IPT	integrated product team
IR	infrared
IRBM	intermediate-range ballistic missile
ITAP	Improved Toxicological Agent Protective
IU	illuminator unit
J/cm^2	joules per square centimeter
JBPDS	Joint Biological Point Detection System
JCAD	Joint Miniature Chemical Agent Detector
JCBAWM	Joint Chemical/Biological Agent Water Monitor
JFACC	Joint Forces Air Component Commander
JMCAD	Joint Miniature Chemical Agent Detector
JORD	Joint Operational Requirements Document
JSAM	Joint-Service Aircrew Mask
JSAWM	Joint-Service Agent Water Monitor
JSGPM	Joint-Service General-Purpose Mask
JSIG	Joint-Service Integration Group
JS-LIST	Joint-Service Lightweight Integrated Suit Technology
JSLSCAD	Joint-Service Lightweight Stand-Off Chemical Agent Detector
JSMG	Joint-Service Materiel Group
JSSAMP	Joint-Service Small Arms Master Plan
JSTARS	Joint Surveillance, Target, and Attack Radar System
JVAP	Joint Vaccine Acquisition Program
JWARN	Joint Warning and Reporting Network
keV	kiloelectron volts
kHz	kilohertz
KIA	killed in action
kV/m	kilovolts per meter
KW	Kiowa Warrior
LANTIRN	Low-Altitude Navigation, Targeting, and Infrared for Night
LASED	Laser Aircrew Safety and Education Demonstrator
LD	lethal dose
LEP	laser eye protection
LET	linear energy transfer
LHA	liquid hazard area
LLR	low-level radiation
LNBCRS	Light NBC Reconnaissance System
lp/mm	linepairs per millimeter

LRBSDS	Long-Range Biological Stand-Off Detection System
LSCAD	Lightweight Stand-Off Chemical Agent Detector
LTAS	Laser Threat Analysis System
LW	Land Warrior
m/s	meters per second
MAIS	Major Automated Information System
MCP	microchannel plate
MCPS	Mobile Collective Protection Shelter
MDAP	Major Defense Acquisition Program
MEDIC	Medical Environmental Disease Intelligence and Countermeasures
MeV	mega-electron volt
MFST	Mobile Field Surgical Team
$mg/min/m^3$	milligrams per minute per cubic meter
MHz	megahertz
MICAD	Multipurpose Integrated Chemical Agent Detector
MIDAP	Minefield Detection Algorithm and Processor
MNS	Mission Need Statement
MOPP	Mission-Oriented Protective Posture
MREs	meals ready to eat
mSv	millisievert
mW	milliwatt
MW	Mounted Warrior
mW/cm^2	milliwatts per square centimeter
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, and chemical
NCRP	National Council on Radiation Protection and Measurements
NDI	nondevelopment item
NIR	near-infrared
NITE Lab	Night Imaging and Threat Evaluation Laboratory
nm	nanometers
nmi	nautical miles
NMRI	Naval Medical Research Institute
NSWC	Naval Surface Warfare Center
NVE	night vision equipment
NVGs	night vision goggles
NVIS	night vision imaging system
OCSW	Objective Crew-Served Weapon
OICW	Objective Individual Combat Weapon
OMRI	Open Media Research Institute
OR	operating room
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OSLR	operationally significant-level radiation
PACAF	Pacific Air Force
PAM	Preventive Aerospace Medical
PARRTS	Patient Accounting and Reporting Realtime Tracking System
PBA	Professional Bodyguards Assn.
PHO	Public Health Officer

PJs	pararescue jet personnel
PL	Phillips Laboratory
PLS	Patient Loading System
PNVG	panoramic night vision goggles
Prime BEEF	Prime Base Engineering Emergency Force
PRRD	Personal Radiofrequency Radiation Dosimeter
PSPS	Portable Sampling and Processing System
R&R	remove and replace
RAF	Royal Air Force
RBE	relative biological effectiveness
RD&A	research, development, and acquisition
RDW	radiological dispersion weapon
RF	radiofrequency
RFR	radiofrequency radiation
RFW	radiofrequency weapons
RH	relative humidity
RT	reaction time
SAB	Scientific Advisory Board
SAF/AQ	Assistant Secretary of the Air Force, Acquisition
SAM	surface-to-air missile
SAR	search and rescue
SAR	specific absorption rate
SDS	sorbent decontamination system
SEB	staphylococcus enterotoxin B
SECDEF	Secretary of Defense
SEP	Soldier Enhancement Program
SFG	Security Forces Group
SNR	signal-to-noise ratio
SON	Statement of Operational Need
SP	Security Police
SRBM	short-range ballistic missile
SRL	Systems Research Laboratories
SSM	surface-to-surface missile
STANAG	(NATO) Standardization Agreement
SWAMI	Southwest Asia Medical Informatics
TAF	Tactical Air Forces
TAML	Theater Army Medical Laboratory
TAP	Toxicological Agent Protective
TASS	Tactical Automated Security System
TBD	to be determined
TBM	theater ballistic missile
TCPS	transportable collective protective system
TDM	theater-defense missile
TEMPER	expandable, modular personnel tent
TERP	Tri-Service Electromagnetic Radiation Panel
TFA	toxic-free area
TIH	toxic industrial hazards
TPDEW	Technology Panel for Directed-Energy Weapons

TTU	triggering transmitter unit
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UK	United Kingdom
USAARL	Army Aeromedical Research Laboratory
USAFE	U.S. Air Forces in Europe
USAMRD	U.S. Army Medical Research Detachment
UWB	ultra-wide-band
V/m	volts per meter
VCATS	Visually Coupled Acquisition and Targeting System
VHA	vapor hazard area
VMMD	Vehicular-Mounted Mine Detector
W/kg	watts per kilogram
W/m^2	watts per square meter
WIA	wounded in action
WIDA	weather impact decision aids
WIN	Western Intelligence
WL	Wright Laboratory
WL/FIVC	Wright Laboratory Air Base Technology Branch

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Annex A to Volume 3

Executive Summary From Volume 1

When the Chief of Staff and the Secretary of the Air Force tasked the Air Force Scientific Advisory Board to

> *". . . conduct an intense examination of Air Expeditionary Force operations and to recommend to the Air Force opportunities and options for enabling the Air Force to fulfill the training, deployment, sustainment and employment performance it requires to conduct air expeditionary operations . . ."*

they foresaw the possibility of the Air Force offering increased and valuable military options to the United States. Current Air Force core competencies and near-term technological advances provide the foundation for significant enhancements in both operational capability and responsiveness. This report provides a roadmap to fielding new options for Air Force expeditionary operations.

The Scientific Advisory Board Committee defined *Aerospace Expeditionary Forces* (AEFs) as follows:

> ***Aerospace Expeditionary Forces are tailorable and rapidly employable air and space assets that provide the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations.***

In the course of this study, the Committee visited personnel ranging from crew chiefs to commanders, from Mountain Home Air Force Base, Idaho to Tazar, Hungary, and gathered information that leads to the belief, relative to today, that an AEF can

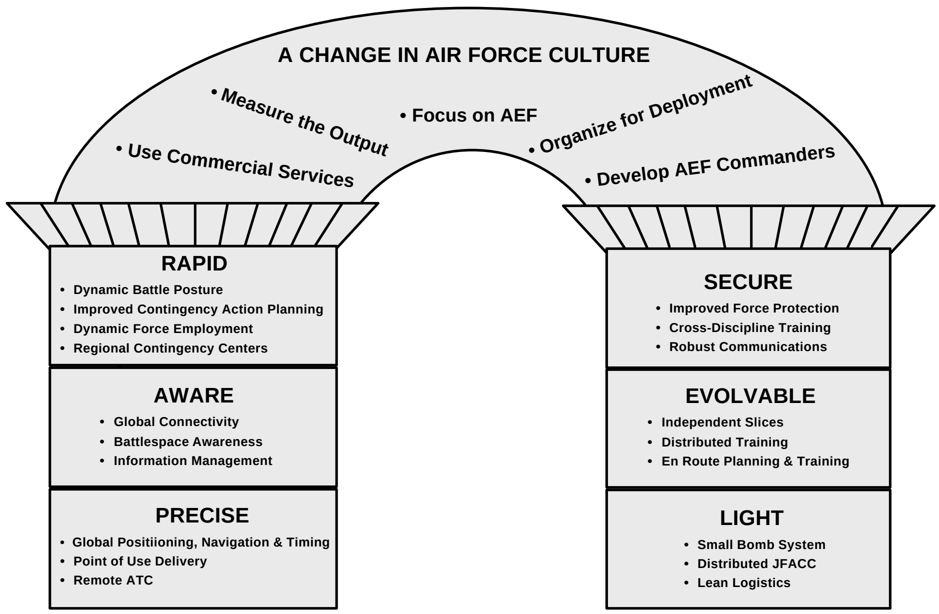
- Respond in less than half the time currently needed, with less than half the airlift, with less than one-third the people forward, to unprepared locations throughout the world
- Operate about an order-of-magnitude more effectively, consistent with other commander-in-chief (CINC) requirements, and with relatively small marginal cost to the current Air Force program and in the near future

Fielding the envisioned AEF will require that the Air Force adopt new operational concepts, new organizational structures, new approaches to training, and new equipment. But most importantly, the AEF is a different culture and the Air Force will have to make the appropriate cultural changes to be successful in this venture.

Taken together, the new approaches will allow the AEF to control the operating tempo of the battlespace by consistently operating with shorter time cycles than the adversary, proactively preparing the battlespace for operations, creating windows of opportunity for AEF exploitation, and inflicting surprise and shock on the adversary. The anticipated result will be a quicker, more efficient achievement of the AEF's objectives with smaller size forces, less support forward, and fewer casualties.

The tremendous leverage created by rapid response to virtually any situation expands the capability of decision makers to influence situations worldwide. Deterrence will be accomplished, in many cases, simply because an AEF exists and the world knows the U.S. has the capability to deliver substantial firepower anywhere in the world within 24 hours. The ability of the AEF to reduce employment timelines to a little more than the flight time from the U.S. to the area of operations provides flexibility to decision makers that has never existed in the past.

The AEF is a giant step forward from today's expeditionary operations, yet it stems from the same core competencies of the Air Force: air and space superiority, global attack, rapid global mobility, precision engagement, information superiority, and agile combat support. The AEF has the potential to provide both a new military capability to the U.S. and a revalidation of the historical basic strengths of the Air Force. The AEF will succeed primarily through fundamental cultural changes in the way the Air Force is organized, trained and equipped.



Keys to the AEF Vision

The essential cultural changes necessary to make an AEF successful include focusing decisions within the Air Force on AEF capabilities, developing commanders who can effectively lead the diverse components of an AEF, organizing the Air Force for rapid deployment, relying upon commercial services (particularly communications), and establishing a continuous self-measurement system based upon desired outcomes.

This new Air Force culture will be technologically enabled by advances in speed of response; understanding of the environment via better use of sensors and connectivity; clear understanding of friendly, enemy and neutral locations and the ability to deliver to precise locations; minimal forward equipment; improved security of forces; and the capability to rapidly assemble and evolve into the right force at the right time. Because the AEF will be used in a variety of scenarios, the Committee identified a spanning set of possible scenarios and subjectively tested the concept against this set. The scenarios used are

- Combat operations mission similar to AEF IV
- Separate combatants mission similar to Bosnia
- Show-of-force mission similar to F-15 fly-overs in Korea
- Counterproliferation mission similar to the Israeli raid on the Iraqi nuclear facility
- Humanitarian relief mission similar to Rwanda
- Battlespace awareness mission

In every scenario and by every relevant measure, the Committee believes the new AEF provides greater (or occasionally equal) capability compared to today's force. One feature of the AEF is that it is easy to test. After a plan is developed to implement the AEF, the Air Force Chief of Staff and the CINCs can and should regularly use no-notice exercises to validate and test the effectiveness of the concept.

To enable this operational vision of Aerospace Expeditionary Forces, the Committee believes AEF implementation needs to be joint and must be integrated appropriately across the other U.S. Military Services, defense-related agencies, and with allies of the U.S. Full implementation of the specific recommendations below will result in a tailorable and rapidly employable Air Force that provides the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or coalition combat operations.

Recommendation Relating to the Joint Approach to AEF Implementation

- The Air Force should ensure that requirements are incorporated for an improved AEF capability into national readiness source documents such as DoD Strategic Guidance, Defense Planning Guidance, Joint Chiefs of Staff Strategic Planning and Operational Requirements documents (e.g., Vision 2010), and CINC Integrated Priority documents and joint operational plans.

Recommendations Relating to Operational Characteristics

- The Air Force should organize, train, and equip for deployment and employment of slices (small independent packages) of fighter, bomber, unmanned air vehicle (UAV), tanker, intelligence, surveillance and reconnaissance (ISR), airlift forces, and compatible support slices with an Initial Operating Capability in two years.
- The Air Force should fund the development of munitions with more effectiveness per round and requiring less airlift, such as the Small Bomb System and Low Cost Autonomous Attack System (LOCASS); integrate them on current and planned bombers, fighters, and UAVs; and procure sufficient numbers of the munitions.
- The Air Force should develop the means to do rapid planning, execute employ/deploy mission profiles,[1] and support operational forces from distributed locations, with minimal forward forces, using en route planning, a distributed command center for the Joint Force Air Component Commander, and demand-pull logistics. This concept must be consistent with a minimum forward footprint (people and materiel).
- The Air Force should establish Regional Contingency Centers, implement lean logistics, implement the AEF "Minimum Flight Essential Maintenance" concept, and complete the development and deployment of common operational logistics planning software such as Logisticians' Contingency Assessment Tools (LOGCAT).
- The Air Combat Command (ACC) should be the Air Force lead to work with all relevant DoD and Civil agencies and the Force Protection Battlelab to develop and field effective, highly deployable detection, protection (including nonlethal systems), and decontamination systems for biological, chemical, and laser threats.

[1] "Employ/deploy mission profiles" means that the deploying aircraft (and/or UAVs) conduct a mission at the end of their deployment before landing at their recovery base(s).

Recommendations Involving Information as a Key Enabler

- The Air Force must develop and integrate affordable command and control (C^2) and information systems necessary to find, fix, track, target, and engage any target of interest in the world. This entails establishment of the following:
  - Global Grid system
  - Information management, control, and distribution system
  - Dynamic battle planning tools and systems
  - Geospatial and temporal reference battlespace integration into all AEF platforms, sensors, and weapon systems
  - Maximum integration of commercial systems into AEF-relevant information systems

Recommendations Relating to Instilling a New Air Force Culture

- The Air Education and Training Command (AETC) should provide education and training from the classroom to the field that inculcates the AEF philosophy in all members of the Air Force.

- The Air Force should develop, adopt, and continuously track metrics on AEF performance. Furthermore, Air Force inspections must be revised to reflect the AEF concept and scoring must be consistent with these AEF metrics.

Recommendations Relating to Research and Development, Experiments, and Demonstrations

- The Air Force should perform experiments, both field and Advanced Concept Technology Demonstrations (ACTDs), in command, control, and information, lean sustainment, and force protection as discussed in Chapter 4 of this report.

- The Air Force Materiel Command (AFMC) should ensure that, as part of the SAB annual Science and Technology (S&T) quality review of the Air Force Research Laboratory (AFRL), investments are made that underwrite the AEF concepts described herein.

- The Air Force should place high priority on Research and Development (R&D), particularly in the following areas:

  Near to Mid Term

  - Anti-jam and differential Global Positioning System (GPS) (on-orbit and in user equipment)
  - Information management, access, and distribution
  - Network access management (communications)
  - Remote air traffic control (GPS related)
  - Engine reliability and maintainability (e.g., high cycle fatigue)
  - Embedded diagnostics for engines and avionics with inflight reporting
  - Improved chem/bio masks and detection systems
  - Reachback expertise for medical and maintenance diagnoses (telemedicine, telemaintenance)
  - Communication systems to ensure all forms of "in-transit visibility"
  - Affordable integration of military and commercial satellite systems
  - Distributed and embedded training

  Mid to Far Term

  - Lasers and high power microwave weapons and defensive systems
  - Hypersonics (engines, endothermic fuels, materials, etc.)
  - Space structures (e.g., lightweight structures, deformable optics)
  - Reusable launch vehicles

Realizing the New AEF

The Committee envisions Aerospace Expeditionary Forces to be tailorable and rapidly employable air and space forces that provide the NCA and the CINC with the option to produce the desired outcomes for a range of possible missions the country may be called upon to undertake. The full realization of this AEF depends upon the synergistic combination of the many changes to people, systems, and concepts described throughout this report. However, many advances (particularly organizational, planning, and training) can be made relatively rapidly and inexpensively in the near term. The Air Force should undertake these improvements immediately. The Air Force should assure that funding priorities appropriately consider program/system contributions to making the force more expeditionary.

In its travels and meetings, the Committee developed a renewed appreciation for the creativity, initiative, and enthusiasm of the operational Air Force — a group many of the Committee had previously had little opportunity to investigate and understand. While several key recommendations of this report revolve around cultural changes — and cultural changes are often the most difficult ones to effect — the AEF concept is one the people of the Air Force want to make happen. *They* can succeed in providing this new and valuable military capability to the U.S.

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Annex B to Volume 3

Terms of Reference

USAF Scientific Advisory Board 1997 Study on
United States Air Force Expeditionary Forces

11 February 1997

BACKGROUND: The majority of U.S. Air Force and other DoD operations since the end of the Cold War have been limited-objective, non-Major Regional Conflict (MRC) activities (Operation Desert Storm being the primary exception). There have been many of them and they typically lasted a long time, with infrastructure often at a premium. The number of simultaneous operations precluded any one of them being able to count on all the support services the Air Force has for that single event. The likelihood of having months to organize, plan, and deploy has grown increasingly smaller. The need to conduct operations quickly, in austere environments, with a minimum of support and support infrastructure has become the norm.

For more than forty years the Air Force operated out of a robust peacetime infrastructure at home and, most importantly, abroad. This has changed significantly since the breakup of the Soviet Union. The capability to quickly deploy and fight "lean and mean," while a strength of the Air Force in the past, must be "reengineered" today. At the Fall CORONA in October 1996, General Fogleman and his senior Air Force leaders developed a strategic vision for the Air Force. The strategic vision, *Global Engagement: A Vision for the 21st Century Air Force*, charts a path into the next century as an Air Force team within the joint team. Global Engagement is based on six core competencies: *air and space superiority, global attack, rapid global mobility, precision engagement, information superiority,* and *agile combat support.* One aspect of the *global attack* core competency is described as follows:

> "The Air Force has developed and demonstrated the concept of an Air Expeditionary Force (AEF) rapidly deployable from the United States. This expeditionary force can be tailored to meet the needs of the Joint Force Commander, both for lethal and non-lethal applications, and can launch and be ready to fight in less than three days. The Air Force will develop new ways of doing mobility, force deployment, protection, and sustainability in support of the expeditionary concept."

> "Air Force power projection and presence capabilities today are a complementary mix of long-range and theater aircraft, based in the United States and forward-based. The Air Force has relied heavily in the past on the elements of that mix that were permanently forward-based overseas. Currently, the Air Force is increasing the role of expeditionary forces to maintain its global engagement capability. In the future, capabilities based in the continental United States will likely become the primary means for crisis response and power projection as long-range air and space-based assets increasingly fill the requirements of the Global Attack core competency."

STUDY PRODUCTS: Briefing to AF/CC and SAF/OS in October 1997. Report completion by December 1997.

STUDY CHARTER: The goal of the 1997 SAB Summer Study is to conduct an intense examination of AEF operations and to recommend to the Air Force opportunities and options for enabling the Air Force to fulfill the training, deployment, sustainment, and employment performance it requires to conduct air expeditionary operations. Specifically, this study will examine/suggest

- Likely context/constraints for the warfighting elements (e.g., deploy to a specified set of scenarios, meet an operational tasking within a specified time, sustain the tasking with stream resupply for the necessary time, or operate in a specified environment [such as chemical and biological])
- Interoperability and joint service compatibility requirements
- Minimum warfighting elements that need to be forward deployed and deployed infrastructure requirements
- Minimum support facilities required for what length of time
- Minimum system support required, including Battle Management (BM)/C^3ISR
- Concept of operations for logistics, supplies, and support (such as information systems)
- Core expeditionary forces and scenario-dependent supplemental forces
- Recommended investments to support force capabilities
- Security and security system requirements
- Training and training system requirements

SUGGESTED PANEL STRUCTURE

Operational Context and Training Panel. Identify relevant scenarios, describe operational concepts, determine system requirements for deployment and operations, define shortfalls, establish minimum force structure. Define infrastructure for the AEF Battlelab. Define potential organizational structures for AEF.

Technology Thrusts Panel. Identify current technology applications that support expeditionary operations. Establish linkage between shortfalls and technology developments. Identify high-leverage technology investments. Develop investment recommendations and associated costs.

Lean Sustainment Panel. Establish logistics and maintenance concepts (building on AF/ILX concepts) such as reach-back that allow the tasks to be performed at a fraction of the current deployment cube. Define shortfalls and recommend solutions.

Environment (Chemical and Biological and Force Protection) Panel. Identify human factor requirements such as protective gear and operational alternatives for conducting operations in a chemical and biological environment. Define force protection and security concepts. Define potential organizational changes, investment options, and other factors required to accomplish this portion of the AEF mission.

Command, Control, and Information Panel. Tailor top-level BM/command, control, communications, and intelligence (C^3I) architectures (building on the SAB C^2 Vision Study) to support ops concepts.

Identify shortfalls in current systems (in deployability, latency, interoperability, targeting, mission planning, currency, capability, opsec, etc.) and recommend solutions to identified shortfalls.

Integration and Cost Assessment Panel. Integrate and coordinate other panel efforts to develop a coherent program. Identify costs of current and alternative AEF concepts. Establish an affordable approach to the AEF mission.

STUDY MEMBERSHIP

Study Chair	Dr. Ronald P. Fuchs
Senior Advisor to Study Chair	General Michael P.C. Carns, USAF (Ret)
Operational Context and Training Panel Chair	Maj Gen John A. Corder, USAF (Ret)
Command, Control, and Information Panel Chair	General James P. McCarthy, USAF (Ret)
Technology Thrusts Panel Chair	Dr. Robert R. Rankine, Jr., Maj Gen, USAF (Ret)
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Lean Sustainment Panel Chair	Dr. John M. Borky
Integration and Cost Assessment Panel Chair	Dr. William C. Miller
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Initial Distribution

Headquarters Air Force

SAF/OS	Secretary of the Air Force
AF/CC	Chief of Staff
AF/CV	Vice Chief of Staff
AF/CVA	Assistant Vice Chief of Staff
AF/HO	Historian
AF/ST	Chief Scientist
AF/SC	Communications and Information
AF/SG	Surgeon General
AF/SF	Security Forces
AF/TE	Test and Evaluation

Assistant Secretary for Acquisition

SAF/AQ	Assistant Secretary for Acquisition
SAF/AQ	Military Director, USAF Scientific Advisory Board
SAF/AQI	Information Dominance
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SAF/AQQ	Global Reach
SAF/AQR	Science, Technology and Engineering
SAF/AQS	Space and Nuclear Deterrence
SAF/AQX	Management Policy and Program Integration

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AF/ILX	Plans and Integration

Deputy Chief of Staff, Plans and Programs

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AF/XPM	Manpower, Organization and Quality
AF/XPP	Programs
AF/XPX	Strategic Planning
AF/XPY	Analysis

Initial Distribution (continued)

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AF/DP	DCS, Personnel

Office of the Secretary of Defense

USD (A&T)	Under Secretary for Acquisition and Technology
USD (A&T)/DSB	Defense Science Board
DARPA	Defense Advanced Research Projects Agency
DISA	Defense Information Systems Agency
DIA	Defense Intelligence Agency
BMDO	Ballistic Missile Defense Organization

Other Air Force Organizations

AFMC	Air Force Materiel Command
– CC	- Commander, Air Force Materiel Command
– EN	- Directorate of Engineering and Technical Management
– AFRL	- Air Force Research Laboratory
– SMC	- Space and Missile Systems Center
– ESC	- Electronic Systems Center
– ASC	- Aeronautics Systems Center
– HSC	- Human Systems Center
– AFOSR	- Air Force Office of Scientific Research
ACC	Air Combat Command
– CC	- Commander, Air Combat Command
– ASC^2A	- Air and Space Command and Control Agency
– 366^{th} Wing	- 366^{th} Wing at Mountain Home Air Force Base
AMC	Air Mobility Command
AFSPC	Air Force Space Command
PACAF	Pacific Air Forces
USAFE	U.S. Air Forces Europe
AETC	Air Education and Training Command
– AU	- Air University
AFOTEC	Air Force Test and Evaluation Center
AFSOC	Air Force Special Operations Command
AIA	Air Intelligence Agency
NAIC	National Air Intelligence Center
USAFA	U.S. Air Force Academy
NGB/CF	National Guard Bureau
AFSAA	Air Force Studies and Analysis Agency

U.S. Army

ASB	Army Science Board

Initial Distribution (continued)

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NRAC	Naval Research Advisory Committee

U.S. Marine Corps

DC/S (A)	Deputy Chief of Staff for Aviation

Joint Staff

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J3	Operations
J4	Logistics
J5	Strategic Plans and Policies
J6	Command, Control, Communications & Computer Systems
J7	Operational Plans and Interoperability
J8	Force Structure, Resources and Assessment

Other

Study Participants
Aerospace Corporation
ANSER
Mitre
RAND
Naval Studies Board
Royal Air Force/Headquarters Strike Command, United Kingdom
Permanent Joint Headquarters, United Kingdom

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