

## Introduction

Recent wars and conflicts, such as Operations Desert Shield and Desert Storm, have highlighted the need for the U.S. military to protect its forces from a variety of health threats associated with deployment, including those indirectly related to battle. In this report, the term “deployment” is defined as “A troop movement resulting from a [Joint Chiefs of Staff]/unified command deployment order for 30 continuous days or greater to a land-based location outside the United States that does not have a permanent U.S. military medical treatment facility” (JCS 1998). Following the Persian Gulf War, in which there were few casualties, a large number of unanticipated and still undiagnosed illnesses developed that caused many veterans of that conflict to express concerns about possible exposures to hazardous materials and other potential risk factors associated with their deployment. As a result, a number of task forces and committees, such as the Defense Science Board Task Force on Persian Gulf War Effects, the Office of the Special Assistant for Gulf War Illnesses, and the Presidential Advisory Committee on Gulf War Veterans’ Illnesses, were established and devoted to examining those concerns. The principal focus of those efforts has been on understanding the current health of veterans, ensuring appropriate evaluation and care of veterans’ health concerns, and determining connections between service in the Persian Gulf and specific exposures and the veterans’ current health status.

To help prevent and reduce the number of unanticipated illnesses in future deployments, the Department of Defense (DOD) requested that the National Academy of Sciences (NAS) advise DOD on a long-term strategy for protecting the health of the nation’s military personnel when

deployed to unfamiliar environments. In response to this request, a collaborative effort was established between the Institute of Medicine (IOM) and the National Research Council (NRC) and four tasks were identified as key to addressing DOD's request. These are as follows: (1) develop an analytical framework for assessing health risks to deployed forces; (2) review and evaluate technology and methods for detection and tracking of exposures to potentially harmful chemical and biological agents; (3) review and evaluate technology and methods for physical protection and decontamination, particularly of chemical and biological agents; and (4) review and evaluate medical protection, health consequences management and treatment, and medical record keeping.

The tasks were carried out by principal investigators with the help and guidance of panels of expert advisers and with an understanding of DOD's need to make trade-offs or set acceptable levels of risk. The risk of injury from conventional weapons or nuclear weapons was not considered. The presumed spectrum of conflict in which exposures could occur in the future ranged from peacekeeping to full-scale conflict. The principal investigators collaborated and had the opportunity to attend the meetings and briefings of the other tasks. Separate reports on each task were published concurrently (see NRC 1999a,b and IOM 1999). This report addresses the first task, which is described more fully below.

### **ASSESSING HEALTH RISKS TO DEPLOYED FORCES**

Assessment of the risk of disease and other health outcomes in military personnel requires specific information on potential causative factors, exposure scenarios, dose-response relationships, and types of health responses expected from contact with an agent, mixtures, or sequences of potentially harmful agents. The purpose of this task was to develop an analytical framework that would facilitate the assessment of such risks to deployed forces. The risks that were considered were those incurred from battle injuries, especially from chemical-warfare and biological-warfare agents, and from disease and non-battle injuries (DNBI). DNBI-producing agents include infectious diseases, psychological stress, heat and cold injuries, and unintentional injuries. In developing the analytical framework, information and approaches to addressing the following issues were considered: (1) characterization of sources and releases of specific potentially harmful agents and their transport and fate in all environmental media (air, water, and soil); (2) identification of important routes of exposure (inhalation, dermal absorption, ingestion of liquids, and consumption of food), and concentrations of agents at the point of exposure; (3) determination of exposure scenarios and resulting exposures among populations of military personnel; and (4) identification of the types of

acute and chronic health responses (e.g., neurological effects, immunological effects, reproductive effects, cancer, and infectious disease) under a variety of environmental and physiological conditions (including extreme temperatures and psychological stress) that could be predicted based on toxicological and epidemiological information, exposure-health response relationships, and possible interactions among harmful agents themselves and with administered drugs. Health responses among various sensitive or susceptible subpopulations were also considered.

In addition to developing a health risk-assessment framework, approaches for implementing the framework were considered. Approaches included appropriate use of tools, such as biological markers and other techniques, methods for relating toxicological, toxicokinetic, and toxicodynamic information observed from animal testing and other studies to the prediction of causal relationships in humans, estimation of human exposure levels, use of assumptions when data gaps exist, measures to assess uncertainty, and use of various quantitative methods, such as probabilistic models.

## THE APPROACH TO THE TASK

### Focusing the Task

The request to NAS was to develop an analytical framework for assessing risks from a broad array of threats, including battle injuries, chemical and biological warfare agents, diseases, and non-battle injuries connected with deployment. Included in these threats are the risks of acute and chronic health effects from exposures to chemicals associated with deployment tasks (including prophylactic treatments and protective agents and measures, such as pesticides, that are brought to the theatre by the deployment force itself), as well as those that might be encountered in the deployment environment. How these threats might interact and how physical and psychological stress might affect them are also highly relevant, as is the question of such stresses themselves being threats.

Depending on how this task is defined, the magnitude of the undertaking is potentially enormous. Troops might be sent to many different areas of the world on many different missions, and each deployment will face a different and complex array of threats. The catalog of potential threats is vast, their nature is highly diverse, and the technical approaches needed to address them span a wide array of scientific disciplines. The potential circumstances of exposure are virtually infinite, varying with the setting, the nature of the deployment, and the activities of the troops. It is also critical to acknowledge that, in the military setting, some risks must be borne in furtherance of essential military missions, and so the

question of balancing health and safety risks with the needs of the mission must be part of the approach.

Finally, one could read DOD's charge as calling for a comprehensive review, critique, redesign, and plan for the implementation of the whole body of efforts at DOD touching on the health and safety of troops in and out of combat. In view of this, the first need in the development of a framework for assessing risks is to refine and focus the scope of the task.

Two broad themes—one practical and one conceptual—tie together the analysis of the wide variety of threats to deployed forces. The practical one is that a program to protect the health of deployed troops must strive to consider all sources of potential impact. The assessments of individual sources of risk must in the end come together into a comprehensive risk-management program that includes how to behave in the face of the whole array of threats, avoid or ameliorate those threats, balance some risks against others, and weigh achieving mission objectives without entailing unnecessary risks. Thus, despite the diversity of threats and the different technical approaches that might be appropriate to characterize them, they cannot effectively be managed in isolation from one another. A common framework is needed to provide a basis for comparisons among threats and the integration of results into a well-reasoned program of risk management.

The conceptual theme that ties analysis of diverse threats together is the paradigm of risk analysis. Despite the diversity in the causes and nature of the threats, each threat represents a set of potential degrees of loss that might or might not happen, with the uncertainty in outcome arising not only from incomplete knowledge of the underlying causes but also from the unknown course of future events. Analysis can help characterize the array of the possible degrees of loss and the likelihood of occurrence of each loss. This conceptual paradigm provides a means to achieve the practical need for integration of results referred to above. A deployment risk-assessment framework should also provide a basis for investigating and comparing the potential costs and benefits of alternative decisions and under different scenarios in a way that acknowledges the uncertainties. In this analysis, it is possible to consider the array of potential hazards, the degree of certainty with which those hazards are known and characterized, the potential for additional information to clarify uncertainties, the likelihood that troops will be challenged by the threat in practice, and the possible extent of impact on their health that might result.

Clearly, a framework for assessing risks must also address the goals of the overall enterprise. Risk analysis must include organization, summarization, and presentation of information, done with the motivating questions in mind. Chapter 2 proposes objectives for a risk-assessment framework that emphasize the need not only to characterize recognized

risks, but also to carry out a systematic examination of deployment activities to bring to light heretofore unrecognized threats. This examination should also maintain due diligence toward the responsibility of the military for the health and safety of deployed troops.

The focus of this report is principally on risk assessment—the identification, characterization, and quantitative description of threats and the impacts they may produce—rather than on the means to control or manage those impacts. It must be borne in mind, however, that this assessment occurs within the larger context of the DOD’s activities aimed at enhancing the health and safety of troops while ensuring their military effectiveness, both strategically (through improvement of equipment, doctrine, training, and preparedness) and in actions taken during specific deployments. While the framework does not directly address how to put its characterizations of threats to use in these decision-making contexts, it does attempt to steer the conduct of risk assessment activities so as to provide the most useful and appropriate information while avoiding critical gaps.

Because of the diversity of analyses the framework must cover, it cannot be very specific about any one activity, and it does not try to be a flowchart or decision tree that maps out a process step by step. By “framework,” the present report means an organized context for conducting assessment activities that defines the relationship of the component activities to the achievement of the larger aims of protecting the health of deployed forces. Rather than a prescription of a specific program or a plan for its implementation, the framework is a set of strategies for conducting risk assessment activities so as to be most useful to the military’s needs. Accordingly, stress is put on examining how those needs differ from the more widely familiar context of environmental risk assessment.

In sum, the approach to defining a framework for risk assessment over the broad array of threats should be one that emphasizes a systematic approach to cataloguing and assessing the various kinds and sources of hazard, encourages attention to the question of unrecognized threats, and approaches the analysis of each kind of threat in the commonality paradigm of risk analysis.

## Methods

In developing the framework, a number of factors and trends were examined that bear on the changing context for risk analysis, and the particular challenges faced by the military, which together prompt a closer examination of what the military can and should do to protect the health and safety of deployed forces. In addition, existing frameworks were examined for their usefulness according to a set of stated objectives and the special needs and aspects of U.S. troop deployment.

The development of this framework did not rely solely on following the more traditional structure of focusing on a list of recognized toxic agents, assessing their potencies, describing likely exposure scenarios, characterizing the consequences of these exposures, and investigating what changes in practice might avoid or mitigate the risks. Instead, the approach focused on a framework that examines how the various activities, actions, and settings of deployment come to present threats, how likely it is that threats will be manifested, and how mitigating one risk might raise others.

The task of developing an analytical framework for assessing risks was carried out by a principal investigator with the help and guidance of a panel of 10 advisers, who represented such diverse disciplines as military operations, toxicology, infectious diseases, biomarkers, personal exposure assessment, epidemiology, occupational health, psychiatry, and risk assessment. This panel considered a vast amount of information, including briefings and documentation of current risk assessments provided by DOD, existing risk-assessment paradigms, and six detailed papers commissioned specifically for this task on topics that the principal investigator and advisers identified as needing in-depth analyses. These commissioned papers were presented at a workshop on January 28-29, 1999, in Washington, D.C.: "Approaches for the Collection and Use of Personal Exposure and Human Biological-Marker Information for Assessing Risks to Deployed U.S. Forces," by Morton Lippmann; "Characteristics of the Future Battlefield and Deployment," by Edward Martin; "The Nature of Risk Assessment and its Application to Deployed U.S. Forces," by Joseph Rodricks; "Future Health Assessment and Risk Management Integration for Infectious Diseases and Biological Weapons for Deployed U.S. Forces," by Joan Rose; "Approaches for Using Toxicokinetic Information in Assessing Risks to Deployed U.S. Forces," by Karl Rozman; and "Health Risks and Preventive Research Strategy for Deployed U.S. Forces from Toxicologic Interactions Among Potentially Harmful Agents," by Raymond Yang. See Appendix A of this report for abstracts of the papers and see *Workshop Proceedings on Strategies to Protect the Health of U.S. Deployed Forces: Assessing Health Risks to Deployed U.S. Forces* (NRC 1999c) for the full papers.

It is planned that in 2000 an NRC committee will review this report in conjunction with its sister reports, and a comprehensive analysis will be provided to DOD.

### **What Is Not Covered in the Framework**

This report is not itself a risk assessment but only a proposed framework within which such assessments can usefully be conducted. No attempt has been made to carry out actual assessments of risks.

The report also does not attempt to describe or review established risk-assessment practices; it is not a treatise on the methodologies of risk assessment, a critique of their adequacy, or a prescription for their extension and reform. The field of risk assessment has spent much of the last 20 years debating the challenges to available methods, including extrapolation of animal responses at experimental doses to humans at environmental exposure levels and the ability to accurately describe human exposure levels. Controversies about the ability of risk analysts to provide accurate estimates of exposures and consequent risks, and the difficulties of fully accounting for the complexities and uncertainties in the underlying determinants of these exposures and risks, will continue to exist, and the present report cannot solve them.

This is not to say that the issues do not bear discussion, exploration, and, most especially, examination for their particular role in the assessment of risks to deployed forces. Several of the most important issues are explored in more detail in the set of papers commissioned for this project rather than in the presentation of the framework itself.

Furthermore, although exposures and experiences outside of the deployment context are clearly of concern to the larger question of health and safety protection, this report focuses on the sources of hazard specifically associated with deployment. Moreover, although general categories of threats are discussed and appropriate approaches to assessing them explored, no attempt has been made to create and maintain a comprehensive catalogue of threats that need to be assessed.

This report also does not constitute a review of the current DOD system. Partly by necessity, but mostly by design, the risk-assessment framework proposed in this report is a comprehensive general approach to the problems of assessing sources of threats to the health and safety of deployed troops, unconstrained by reference to particular practices and programs, including those that already exist as part of DOD's current efforts in this arena. Accordingly, omission of reference to existing programs and lack of analysis of how they might fulfill the objectives set out in the framework should not be taken to imply criticism of those programs or judgments about their value.

DOD has in place a wide variety of programs and activities for identifying threats, assessing potential exposures and risks, setting exposure standards, and designing equipment, operating procedures, doctrine, and training to manage risk effectively. Ongoing industrial hygiene procedures are carried out, including sampling and monitoring of exposures. The extensive military health care system tracks the health status of personnel. Collectively, this large set of activities and the planning that ties the components together could be thought of as comprising the current system in place at DOD for the protection of the health and safety of

troops. Although an attempt has been made to acknowledge these activities, there is no attempt to catalogue the activities that are in place or systematically assess their effectiveness, either as individual elements with their particular goals or collectively as a comprehensive system of troop health protection. To do otherwise would require a much more extensive and systematic review of existing practices and programs than would be possible within the current scope and resources of this project and would demand a different array of expertise among the investigators. Similarly, many DOD activities fall under the regulatory authority of various federal regulatory agencies, and the role of such regulation in the arena of health protection of deployed troops is not specifically examined.

Finally, although a good deal of time was spent debating the question of psychological stress as a threat itself, the lack of established ways to assess the risks of such stress was acknowledged. Rather than try to address this issue in the framework proposed here, or to commission a paper on the matter, it was decided to note this as an important but unstudied area that will need broad, continuous attention by DOD. This omission is a shortcoming of the framework, since psychological stress is an issue of major importance to the health of deployed forces and deployment veterans, and any solution to how DOD should approach disorders and unexplained symptoms among veterans must include consideration of the contribution of stress. Further work on this issue is recommended.

## ORGANIZATION OF THE REPORT

This report consists of five chapters. Chapter 2 discusses the factors and trends that should be considered in assessing risk to deployed forces and presents objectives for a deployment health-protection program. Chapter 3 examines existing frameworks for assessing risk and their utility for developing a framework for deployed forces; in addition, special aspects that are relevant to risk analysis for deployed troops are discussed. Chapter 4 describes a proposed framework for assessing risks to deployed forces, and Chapter 5 presents recommendations for strengthening and implementing the framework.