Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats

Committee for an Assessment of Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats, National Research Council

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Naval Studies Board

Division on Engineering and Physical Sciences

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Preface

In support of the national security strategy, U.S. naval forces remain deployed throughout the world, engaged in or ready to support operations ranging from peacekeeping and peace enforcement, to crisis intervention, to combat. To conduct these operations successfully, the naval forces must be prepared to respond to a broad array of threats. In recent years, preparations to meet chemical and biological warfare threats have taken on increased importance. The number of countries capable of producing and delivering a wide range of chemical and biological weapons is increasing. The proliferation of associated technologies (such as delivery vehicles and weapons, navigation systems, and chemical and biological agents) and their availability to potential adversarial nation-states and transnational groups challenge U.S. peacekeeping, intelligence, and warfighting capabilities.

In response to this changing situation and reflecting its dissatisfaction over the individual Services' fielding of chemical or biological defensive materiel, the U.S. Congress included in the National Defense Authorization Act for Fiscal Year 1994 (Public Law No. 103-160) a mandated consolidation of the Department of Defense (DOD) chemical and biological defense programs and associated procurement funds. On the basis of DOD history in this area, the Secretary of the Army was designated executive agent for joint Service research, development, testing, evaluation, and acquisition for medical and non-medical chemical and biological defense. Recent studies[1] of the DOD's chemical and biological

[1]See, for example, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June.

defense research and development (R&D) efforts have recommended improvements in the process; for example, the connection between R&D goals and military requirements needs to be strengthened. The department is responding to these recommendations by reassigning responsibilities within the DOD Joint Chemical and Biological Defense (CBD) Program and the Office of the Secretary of Defense (OSD).

In the context of the Joint CBD Program, one of the issues affecting the Department of the Navy is the extent to which the capabilities receiving priority and being developed meet naval-specific needs. For example, naval forces must quickly sense and analyze the presence of chemical and biological agents, withstand or avoid exposure to such agents (through effective protection or countermeasures), deal with contamination, and sustain operations in a broad—and largely unique—set of maritime environments. Forward-deployed, distributed naval forces will continue to provide adversaries with highly visible targets, particularly in port and in the littorals of forward operational areas, and must be equipped with effective chemical and biological defensive capabilities for both warfighting and support personnel.

The focus of the Joint CBD Program and of this report, as requested by the Chief of Naval Operations, is on passive defense. The Committee for an Assessment of Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats recognizes, however, that a robust approach must include active measures as well, in order for the Department of the Navy to achieve a fully integrated capability for addressing the threat posed by chemical or biological weapons.[2] Passive defense includes capabilities for contamination avoidance (detection, warning, and agent identification); force protection (individual protection, collective protection, and medical support); and decontamination. The Joint CBD Program considers its current R&D to be predominantly low risk and aimed at improvements to existing systems or technologies or at technologies developed in other communities—the intelligence community, the Defense Advanced Research Projects Agency (DARPA), the Department of Energy, or the private sector. DARPA has invested significant funds in biodefense, focused on higher-risk, potentially high-payoff technologies, most notably in multiagent medical therapeutics and countermeasures and in miniature mass spectrometry.

[2]DOD's Counterproliferation Program, which includes passive defense as one of its elements, is also developing capabilities for active defense and counterforce to detect, identify, destroy, and neutralize chemical and biological warheads or production and storage facilities while minimizing collateral damage. DOD's Missile Defense Program includes capabilities to intercept missiles armed with chemical or biological warheads. The Navy's ships on station for theater missile defense will not only have to intercept the missiles, but will also have to predict incoming threats and give adequate warning.

TERMS OF REFERENCE

At the request of the Chief of Naval Operations, the Naval Studies Board of the National Research Council has conducted an assessment of naval forces' defense capabilities against chemical and biological warfare threats. At issue for the Department of the Navy are these questions—to what extent are capabilities being developed that will enable the naval forces to quickly sense and analyze the presence of chemical and biological agents, withstand or avoid exposure to such agents (through effective protection or countermeasures), and deal with contamination under a broad spectrum of operational conditions; and over what time frame will these capabilities be realized? The tasks of this assessment were as follows:

- Evaluate present and projected chemical and biological warfare threats to naval force operations in littoral regions and deep-ocean regions of the world. Explicit consideration should be given to potential adversaries' capabilities to deliver chemical and biological weapons in littoral settings.
- Examine the current state of technologies, tactics, and procedures involved in chemical and biological defense, accounting for the efforts of the other Services, the OSD, and other government agencies. Project (out to the year 2015) the future state of the technologies involved.
- Evaluate current and projected R&D programs aimed at providing naval forces with new and improved capabilities. Recommend R&D priorities, accounting for the potential operational interactions among naval and other Service elements of the joint forces.
- Evaluate existing and planned testing and evaluation procedures (in conjunction with training procedures) for ensuring operationally effective capabilities.

The issues listed above should be addressed over three specific time frames—near term (to 2005), mid-term (to 2010), and far term (to 2015).

SPECIAL TASKING FROM THE CHIEF OF NAVAL OPERATIONS

In a letter to the president of the National Academy of Sciences on June 28, 2001, after the terms of reference for the study had been agreed upon (and notably, before September 11), the Chief of Naval Operations added special directions for the committee:

> I am especially pleased that the Board is now about to initiate a study of naval force defense capabilities against chemical and biological warfare threats. Recent world events demonstrate that forward-deployed naval forces are constantly at risk even in today's relatively peaceful world. I look forward to supporting this study and receiving the conclusions on issues with direct operational implications such as **developing concepts of naval operations to deal with emerging terrorist threats.** [Emphasis added.]

These special directions added to the original terms of reference broadened the scope of the study to include not just deep-ocean and littoral operations but also any credible part of naval operations at risk for terrorist attacks. Although this study was initiated after September 11, 2001, it should be noted that the committee did not expand its charter to consider the roles for the Navy in homeland defense, with the exception of the ties of its continental United States (CONUS) force protection mission requirements in relation to U.S. naval bases' neighboring civilian communities.

Finally, as the committee was completing its work, there was a rapidly changing picture of activity by the U.S. government relating to chemical and biological defense—notably, the establishment of the Department of Homeland Security; the major involvement of the National Institutes of Health in vaccine development, drug discovery and development, pathogenesis, and some diagnostics; and the deployment of military forces in preparation for what was then considered a possible war in the Middle East. Throughout this period of change, the committee attempted to keep abreast of information relevant to the topic of this study. While its recommendations were formulated on the basis of impressions gained before these developments, the committee believes that these recommendations continue to be applicable to the chemical and biological defense problem at the time this report is issued. Any activity by the Department of the Navy in response to the report's recommendations, however, should follow closely and leverage these new developments as much as possible.

COMMITTEE MEETINGS

The Committee for an Assessment of Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats first convened in September 2001 and held further meetings and site visits over a period of 6 months:

- *September 18-19, 2001, in Washington, D.C. (plenary session). Organizational meeting.* Deputy Assistant to the Secretary of Defense for Chemical and Biological Defense: briefing on Department of Defense Joint CBD Program; Office of the Chief of Naval Operations: briefing on current Navy chemical and biological counterproliferation efforts; Office of Naval Intelligence: briefing on chemical and biological defense threats; Defense Advanced Research Projects Agency: briefing on the Unconventional Pathogen Countermeasures Program and defense capabilities against chemical and biological warfare threats; and Office of Naval Research: briefing on chemical and biological defense science and technology.
- *October 16-17, 2001, in Washington, D.C. (plenary session).* Deputy Assistant Secretary of the Navy for Expeditionary Forces Programs: briefing on naval forces' defense capabilities in a chemical and biological warfare environment; Marine Corps Systems Command (MARCORSYSCOM): briefing on the

MARCORSYSCOM perspective on chemical and biological defense; Office of the Chief of Naval Operations: briefing on current Navy chemical and biological counterproliferation efforts; Marine Corps Combat Development Command: briefing on the Fourth Marine Expeditionary Brigade (Anti-Terrorism); Naval Sea Systems Command: briefing on the Navy and the Joint CBD Program; Joint Service Materiel Group: briefing on coordinating and integrating Department of the Navy research, development, acquisition, and logistics; Headquarters, U.S. Marine Corps (HQMC) Security and Law Enforcement Branch: briefing on HQMC perspective on chemical and biological defense; U.S. Army Medical Research and Materiel Command: briefing on medical science and technology commodity areas; U.S. Army Soldier Biological Chemical Command: briefing on non-medical science and technology business areas; and U.S. Army Medical Research Institute of Chemical Defense and U.S. Army Medical Research Institute of Infectious Diseases: briefing on medical defense against chemical warfare threats.

- *November 14-16, 2001, in Norfolk, Virginia (plenary session).* Site visit to Naval Amphibious Base, Little Creek, Virginia, U.S. Navy Atlantic Fleet Command, Headquarters, Marine Forces Atlantic, and U.S. Joint Forces Command to discuss operational readiness issues—fleet, bases, ports, Marine Corps warfighting—and joint doctrine training, tactics, and procedure development.
- *December 18-19, 2001, in Washington, D.C. (plenary session).* Chemical and Biological Incident Response Force (CBIRF): briefing on CBIRF organization and capabilities; U.S. Air Force Directorate of Nuclear and Counterproliferation: briefing on the Air Force perspective on chemical and biological defense; Office of the Chief of Naval Operations: briefings on the status of the Joint CBD Program and maritime roles for homeland security; Center for Naval Analyses Corporation (CNAC): briefings on the following CNAC reports:

Navy Implications of NBC Proliferation: Final Report (1999);
Shipboard Biological Hoax (2001);
Biological Attack on a Pier (2001);
Shipboard Biological Contamination Scenarios (2000);
The NBC Warfight: Concepts from the COMUSNAVCENT Experience (2001);
MC00/FBE-H Biological Warfare Limited Objective Experiment (2001);
Preparing a Forward Fixed Site for Chemical, Biological, and Radiological Defense: The COMUSNAVCENT Experience (2000);
Operation Desert Thunder Quicklook: Chemical and Biological Defense (1998);
Operation Desert Fox: CBR Defense (1999); and
Navy Role in Homeland Defense Against Asymmetric Threats (2001).

Office of the Deputy Assistant to the Secretary of Defense for Chemical and Biological Defense: briefing on DOD counterproliferation efforts; Marine Corps Combat Development Command: briefing on U.S. Marine Corps land mine war-

fare requirements; Naval Sea Systems Command: briefing on Navy sea mines; and Defense Advanced Research Projects Agency: briefing on mine warfare technology efforts.

- *January 14-15, 2002, in Washington, D.C. (Medical Science and Technology Panel and Operating Forces/Shore Establishment Panel).* Joint Program Office for Biological Defense (JPO-BD): briefings on JPO Navy Medical Coordination and Medical Requirements Program; Joint Vaccine Acquisition Program Project Management Office: briefing on technologies for current, next-generation, and future vaccines for biodefense; Office of the Chief of Naval Operations: briefings on Navy medical chemical and biological defense coordination and programs and shore installation preparedness; Navy Medical Research Center (NMRC): briefing on NMRC overview and diagnostics; U.S. Army Medical Research Institute of Infectious Diseases: briefing on Aero-medical Isolation Team and Containment Care; Pennsylvania National Guard: briefing on Third Weapons of Mass Destruction Civil Support Team; and Institute for Defense Analyses: briefing on restoration of operations.
- *January 16, 2002, in Washington, D.C. (plenary session).* Office of Naval Research and Naval Research Laboratory: briefing on the Department of the Navy's science and technology regarding chemical and biological defense; Operational Test and Evaluation Force and Office of the Chief of Naval Operations: briefings on Navy chemical and biological defense technology assessment, testing, and evaluation; and Navy Warfare Development Command (NWDC): briefing on NWDC activities related to chemical and biological defense.
- *January 17-18, 2002, in Aberdeen, Maryland (Non-Medical Science and Technology Panel).* Small-group site visit to Edgewood Chemical and Biological Command for briefings on detection and identification devices, dispersion models, and decontamination.
- *February 18-22, 2002, in Irvine, California (plenary session).* Committee deliberations and report drafting.

The months between the last committee meeting and publication of this report were spent preparing the draft manuscript, gathering additional information, reviewing and responding to external review comments, editing the report, and conducting the required security review to produce a public report.

ORGANIZATION OF THE REPORT

The committee's first priority was to answer the request of the Chief of Naval Operations to address the operational implications for naval forces of dealing with chemical and biological threats. After an executive summary, the first three chapters of the report focus on these issues. Historical background, discussion of the nature and size of the threat, and arguments for and against how seriously it should

be taken are offered in Chapter 1. The committee's assessment of the operational chemical warfare and biological warfare defense posture of naval forces is given in Chapter 2, along with general recommendations for improvement. Chapter 3 provides more specific recommendations for improving operations.

The next two chapters present specific findings and recommendations related to the equipment, materiel, and skills required for effective chemical or biological defense. Chapter 4 deals with non-medical science and technology and Chapter 5 with medical chemical and biological countermeasures. Both near- and longer-term research and development efforts are addressed.

Because the report contains multiple levels of findings and recommendations, Chapters 2 through 5 begin with an introduction to their major points, followed by separate sections that elaborate on each point, presenting findings and recommendations. In addition, the findings and recommendations of each of these chapters are collected in abbreviated form in a box at the end of the respective chapters.

Chapter 6 closes the report emphasizing the essential role of leadership to sustain an improved posture—the threat is unlikely to stagnate, so neither can the approaches for dealing with it. Appendixes B and C offer greater detail on chemical and biological warfare agents and the technologies for dealing with them. Biographies of the committee and staff are also presented (Appendix A), and a list of acronyms is provided (Appendix D).

A supplement to this report contains information that the U.S. government and the National Academies have determined is not releasable to the public. Requests for the supplement shall be made to the Office of Naval Research (ONR).

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Alexander H. Flax, Potomac, Maryland,
David R. Franz, Southern Research Institute,
Kenneth H. Keller, University of Minnesota,
Bruce B. Knutson, Tucson, Arizona,
Richard A. Nelson, Silverdale, Washington,
William S. Rees, Jr., Georgia Institute of Technology,
Harrison Shull,[1] Monterey, California, and
Robert H. Wertheim, Science Applications International Corporation.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommen-

[1]Deceased.

dations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert A. Frosch, Senior Research Fellow, John F. Kennedy School of Government, Harvard University. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

In Memoriam

David W. McCall

December 1, 1928–June 5, 2002

The committee members wish to honor the contributions of their colleague Dave McCall, who—in spite of his terminal illness—dedicated his exceptional talents to helping create this report.

Prologue

There are two central themes in this report: the first is the belief of the authoring committee in a serious potential threat to U.S. naval forces from chemical or biological weapons; the second is the fact that the Department of the Navy needs to establish a more robust defensive posture against these threats. The following brief chronologies drive these themes home.

AUM SHINRIKYO

- *1994.* Members of the Japanese cult Aum Shinrikyo attack a hotel in Matsumoto, Japan, with sarin gas, and succeed in killing a targeted judge (among others).
- *March 1995.* The sarin attack on the Tokyo subway system kills 12 people and sends hundreds to the hospital.
- *1990 to 1995.* Cult members conduct as many as a dozen attacks in the Tokyo metropolitan area with anthrax and botulinum toxin, with the intent each time to kill millions. Included are multiple attacks on U.S. naval bases in Japan. For technical reasons related to agent purity, these attacks fail. The Navy was apparently not aware of these attacks. Nor was it apprised of them even in the wake of courtroom testimony in the prosecution of cult members.[1]

[1]WuDunn, Sheryl, Judith Miller, and William J. Broad. 1998. "Sowing Death, A Special Report: How Japan Germ Terror Alerted World," *New York Times,* May 26, p. A-1. See also Kaplan, David E., and Andrew Marshall. 1996. *The Cult at the End of the World: The Terrifying Story of the Aum Doomsday Cult from the Subways of Tokyo to the Nuclear Arsenals of Russia,* Crown Publishers, New York.

AL QAEDA

• *1998.* Osama bin Laden issues an edict, a "fatwa," for holy war against the United States and calls for attacks on U.S. military and civilian personnel around the world. He calls it a "holy duty" of Muslims to acquire weapons of mass destruction for the "fight against Jews and Crusaders" in order to "terrorize the enemies of God." In well-planned and well-executed operations, al Qaeda forces attack U.S. embassies in Africa.[2]

• *October 2000.* A second successful attack on U.S. assets outside the continental United States is executed—this time against the USS *Cole* in Yemen.

• *September 11, 2001.* Al Qaeda brings the reality of its holy war to the U.S. homeland with attacks on the World Trade Center and the Pentagon.

• *2002.* Director of the Central Intelligence Agency George Tenet testifies that "al Qaeda was working to acquire some of the most dangerous chemical agents and toxins."[3] Documents recovered from al Qaeda facilities in Afghanistan show that bin Laden was pursuing a biological weapons research program. According to Bush administration and intelligence reports, much of the al Qaeda leadership remains at large.[4]

DEPARTMENT OF DEFENSE

• *December 1993.* Secretary of Defense Les Aspin announces the Defense Counterproliferation Initiative aimed at improving the ability of U.S. power projection forces to project into and prevail in hostile environments where weapons of mass destruction are present.

• *1994.* According to *Defense Planning Guidance,* "chemical and biological weapons are a likely condition of warfare."[5]

• *1996.* The General Accounting Office concludes that the military Services "face many of the same problems they confronted during the Persian Gulf conflict in 1990 and 1991."[6]

• *2001.* According to the *Quadrennial Defense Review Report*, "The new defense strategy identifies key operational goals for deterring conflict and con-

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[2]Bodansky, Yossef. 2001. *Bin Laden: The Man Who Declared War on America,* Prima Publishing, Roseville, Calif.

[3]Statement by George J. Tenet, Director of the Central Intelligence Agency. 2002. "Worldwide Threat: Converging Dangers in a Post 9/11 World," Senate Select Committee on Intelligence, February 6.

[4]Bodansky, Yossef. 2001. *Bin Laden: The Man Who Declared War on America*, Prima Publishing, Roseville, Calif.

[5]Department of Defense. 1994. *Defense Planning Guidance*, Washington, D.C. (classified).

[6]U.S. General Accounting Office. 1996. *Chemical and Biological Defense: Emphasis Remains Insufficient to Resolve Continuing Problems*, GAO/NSIAD-96-103, Washington, D.C., March.

ducting military operations. . . . Number 3 [of these goals is to] project and sustain U.S. forces in distant anti-access and area-denial environments. . . . [This requires] ensuring U.S. forces can sustain operations under chemical or biological attack."[7]

• *2001.* Assessments by the General Accounting Office indicate improvements are needed by the DOD and the Services in inventory management and risk assessment procedures, in addition to addressing the treatment of chemical and biological (CB) casualties.[8]

[7]Rumsfeld, Donald H., Secretary of Defense. 2001. *Quadrennial Defense Review Report,* Washington, D.C., September 30. Available online at <www.defenselink.mil/pubs/qdr2001.pdf>.

[8]U.S. General Accounting Office. 2001. *Chemical and Biological Defense, Improved Risk Assessment and Inventory Management Are Needed,* GAO-01-667, Washington, D.C., September; U.S. General Accounting Office. 2001. *Chemical and Biological Defense, DOD Needs to Clarify Expectation for Medical Readiness,* GAO-02-38, Washington, D.C., October.

Executive Summary

At the request of the Chief of Naval Operations (CNO), the Naval Studies Board, under the auspices of the National Research Council, established a committee to assess the defensive capabilities of both the U.S. Navy and U.S. Marine Corps against chemical and biological warfare threats. In response to the terms of reference and the special tasking from the CNO for this study,[1] the Committee for an Assessment of Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats devoted its attention to evaluating the current operational posture of naval forces with regard to defending against chemical and biological weapons across the entirety of its operations and to identifying the opportunities for improvement afforded by operational and technical advances. The attacks of September 11, 2001, and the subsequent anthrax attacks significantly raised awareness of chemical and biological threats, providing additional impetus to this study. In that context, the committee developed a consensus of concern that the nation's naval forces—with a few notable exceptions in the Marine Corps and the Fifth Fleet operating area, which includes the Persian Gulf—are not as prepared as they could be and should be to deal with such

[1]In a letter dated June 28, 2001, to the president of the National Academy of Sciences, the CNO wrote: "I am especially pleased that the [Naval Studies] Board is now about to initiate a study of naval force defense capabilities against chemical and biological warfare threats. Recent world events demonstrate that forward-deployed naval forces are constantly at risk even in today's relatively peaceful world. I look forward to supporting this study and receiving the conclusions on issues with direct operational implications such as developing concepts of naval operations to deal with emerging terrorist threats."

threats, and it formulated recommendations for improving operational capabilities in the near as well as far term. The committee's findings and recommendations highlight these areas:

- The seriousness of the threat;
- An approach to dealing with the threat focused on mission success and based on risk management principles, as opposed to the prevailing (and largely unachievable) philosophy of avoiding contamination;
- The critical role of naval leadership in ensuring readiness throughout the force and in sustaining improvements in posture;
- The need for consistent requirements and supporting systems in training and reporting to ensure readiness; and
- The contributions that technology can—and cannot—make for both medical and non-medical defense.

CHEMICAL AND BIOLOGICAL WEAPONS— A REAL AND PRESENT THREAT TO NAVAL FORCES

While the committee is convinced that naval forces face a real and present threat, Navy leadership presented a wide range of views about the reality, importance, and practicality of defending against chemical or biological weapons. With a few exceptions, most notably the Fifth Fleet, the Navy needs to improve its preparedness for today's chemical or biological threats. In particular, more attention should be paid to address threats in port, at shore installations, and throughout the logistics trains, either in the continental United States (CONUS) or outside the continental United States (OCONUS). The Fifth Fleet's attention to the chemical warfare (CW) and biological warfare (BW) problem is undoubtedly due to its recognition of a threat and vulnerabilities in its operating area of responsibility, especially in the commercial ports and foreign bases on which it depends. The Marine Corps, in contrast to the Navy, seems to have paid much more attention to the problem, although it too has opportunities for improvement—especially at many of its bases.

Both the chemical and the biological threats of today are characterized by wide availability of agents and a variety of delivery methods, from simple to complex. The threats posed by various agents and delivery methods are real today almost everywhere the Navy operates—on the open ocean and in the littorals, and especially in port and at shore installations. Because of the Navy's dependence on foreign ports and its growing emphasis on warfighting in the littorals, the committee believes that the Navy should, in fact, be more concerned about limited, asymmetric attacks in such environments than about more massive, open-ocean encounters on which its defensive posture has been historically based.

GUIDING PRINCIPLES TO MITIGATE THE PROBLEM

The committee found that effective approaches to chemical and biological warfare defense are based on a few important principles:

- *Recognize that chemical weapons and biological weapons constitute different threats.* Chemical and biological weapons, and ways to deal with them, are often discussed together, and indeed some equipment and procedures for defense work for both. These weapons differ, however, in the effects that each produces; thus, there are unique requirements for dealing with each and even more specific requirements for various classes of agents within either category. In general, chemical warfare is better understood than biological warfare, and defensive measures for chemical warfare are more mature (largely because of the use of CW in World War I and the years of development of both offensive and defensive capability since then; biological warfare was not as seriously studied until World War II). Chemical warfare is expected to be a threat at the tactical or operational level because of the immediacy and localization of chemical agent effects. Biological warfare is more likely a theater- or strategic-level threat because of the delay in the onset of symptoms and effects, which may be widely dispersed, especially with contagious agents.
- *Manage to risk, not to threat alone.* Threat alone should not form the basis for developing a defense, as it can drive requirements to unrealistically expensive levels in addressing the full scope of potential scenarios, especially when considering the nearly unlimited possibilities that can arise with asymmetric adversaries. (The Department of Defense (DOD) has recognized this issue and is shifting from threat-based to capabilities-based planning.[2]) Instead of managing to threat alone, balanced risk assessments should form the basis for deciding "how much (capability) is enough." Such assessments should combine a broad view of adversary intent and force vulnerabilities with an analysis of the operational consequences of adversary actions and defensive countermeasures to these (passive and active), to understand the impact on accomplishing a mission and on overall campaign success. (Chapter 1 provides a simple example, created by the committee, of the comparative risk—defined as vulnerability × consequences—to operations in an environment of chemical or biological threat from nations and terrorist enemies with capability and intent to attack.)
- *Adopt a reasoned view of chemical and biological weapons exposure environments.* In the Cold War, massive attack scenarios led to requirements for chemical and biological defense for the Services on the basis of exposures at the point of release (i.e., the highest level). The risk-based approach recommended by the committee ties levels of protection not to the worst case, but to an accep-

[2]Rumsfeld, Donald H., Secretary of Defense. 2001. *Quadrennial Defense Review Report,* Washington, D.C., September 30. Available online at <www.defenselink.mil/pubs/qdr2001.pdf>.

tance of casualties in the scenario or environment of operations that are consistent with those expected from conventional weapons. Equipment design requirements can then be based on exposures expected for almost all (but not 100 percent) of environments, and the temptation to categorize the problem as "too hard to solve" can be avoided.

GENERAL FINDINGS AND RECOMMENDATIONS

In developing operational and technical findings and recommendations as directed by this study's terms of reference, the committee observed that two general themes emerged. Both are foundational and must be addressed for achieving the improvements in defensive posture needed. They are (1) leadership for lasting improvements and (2) the approach for getting started:

1. *Naval leadership for chemical and biological warfare defense*. In spite of both the general military and the naval-specific concerns and guidance regarding preparedness for chemical and biological warfare defense articulated for more than a decade, little improvement in the Navy's posture could be found. The Navy's senior leadership should commit to strengthening and integrating chemical and biological defense throughout all Navy functions in order to achieve both near-term and sustained improvements. Leadership within the Marine Corps has been more visible and sustained, but gaps in preparedness remain. For both Services, especially the Navy, this includes having a much higher profile in the Joint Chemical and Biological Defense (CBD) Program to ensure that naval-specific requirements are being adequately addressed. (See also the discussion in the section below and in Chapter 4 on non-medical science and technology.)

2. *Getting started with operational net assessments.* Chemical or biological warfare defense alone will never be perfect, nor are there single robust elements within any defensive approach. Consequently, a defense-in-depth strategy—that is, a layered defense that exploits the synergies among individual components in order to have the strongest possible performance of the overall system—should form the basis for the future. Models for developing defensive capabilities can be found in the Fifth Fleet, with selected Marine base commands, with most commercial fleet operators, with the British Royal Navy, and with the U.S. Air Force. The Navy and Marine Corps should get started with an operational net assessment, particularized to each combat or supporting commander's operating environment.

OPERATIONS: SPECIFIC FINDINGS AND RECOMMENDATIONS

This section provides specific findings and recommendations on operational issues related to naval chemical and biological warfare defense.

• *Operational requirements.* The committee found that the Navy—and in some respects the Marines—has not defined the chemical or biological warfare defense operational requirements for mission success. The committee recommends that this situation be remedied throughout the entire force by defining a comprehensive concept of operations (CONOPS) with supporting policies and practices. This CONOPS should address all dimensions of naval operations that go into sustaining a mission: how to prevent an attack, how to recover from and minimize the impact of an attack, how to restore naval operations after an attack, and, above all, how to achieve mission goals. How U.S. naval forces plan to operate and fight in a chemical or biological warfare environment should then drive naval priorities in doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF), as well as in research and development (R&D) and acquisition.

• *Focal point for CONOPS.* The Navy appears to lack a focal point for the development of policy, concepts of operations, and doctrine for chemical or biological warfare defense; the Marine Corps appears to place greater emphasis on the problem. The committee recommends that the Navy Warfare Development Command (NWDC) and the Marine Corps Combat Development Command (MCCDC) be clearly designated as the primary authorities and given the requisite resources for the development of policy, concepts of operations, and doctrine for chemical and biological warfare defense issues.

While NWDC has contributed nuclear, biological, and chemical (NBC) defense guidance in publications on tactics, techniques, and procedures (TTPs), its alignment role and capabilities should be strengthened through realistic experimentation and testing and in promulgating CONOPS and supporting policies for how naval forces will execute their warfighting and base support missions in an environment that may be or has been contaminated with chemical or biological agents.[3] The Marine Corps should build on the work already under way at MCCDC, which has been active as a focal point in joint efforts, and on the experiences with the Corps's Chemical and Biological Incident Response Force (CBIRF), and the Navy should leverage that work. In particular, NWDC and MCCDC should assess the technical basis for assumptions defining their own doctrine and undertake tests of these assumptions in field experiments in relevant naval operating environments.

• *Readiness.* Navy readiness for chemical and biological warfare defense needs improvement. Sustained improvements toward remedying these deficien-

[3]Effective October 1, 2001, the CNO assigned the Commander, U.S. Atlantic Fleet, concurrent duties of Commander, Fleet Forces Command (CFFC). The CFFC is responsible for coordinating, establishing, and implementing integrated requirements and policies for manning, equipping, and training Atlantic and Pacific fleet units during the interdeployment training cycle. NWDC will report to the CFFC as its immediate superior in command for purposes of warfare innovation, concept development, fleet and joint experimentation, and the synchronization and dissemination of doctrine.

cies require establishing standards for readiness, training and exercising to those standards, and developing a reporting system attuned to this area. Special urgency should be given to bases and shore installations and to the logistics chain. *In fact, if the Navy chooses to implement only one recommendation from this report, it should be that of committing to dramatically improve readiness.*

More specifically, the Navy should institute a system of exercises, training, assessment, and reporting aimed at meeting higher standards of chemical and biological warfare readiness. Central to this effort is to define appropriate standards of readiness in each of its mission areas—standards derived from the operational requirements generated by the net assessment recommended in the preceding section, "General Findings and Recommendations," and refined through the efforts of NWDC (and MCCDC as needed for the U.S. Marine Corps). The Marine Corps's Marine Expeditionary Units (Special Operations Capable) (MEU(SOC)s) are a good example to follow, since they have established readiness standards for themselves that are being extended throughout the Marine Corps.

SCIENCE AND TECHNOLOGY: SPECIFIC FINDINGS AND RECOMMENDATIONS

All of the research, development, and acquisition for chemical and biological warfare defense is carried out through the legislatively mandated Joint CBD Program and is organized around two principal areas—(1) Non-Medical Science and Technology and (2) Medical Defense. Although the committee was tasked to make R&D projections in specific time frames—to 2005 (near term), to 2010 (mid-term), and to 2015 (far term)—it found this practically impossible for two reasons:

1. The establishment of the Department of Homeland Security and the significantly increased investment by the National Institutes of Health (NIH) in medical countermeasures and vaccines are leading to increased activities in these areas, which should in turn impact the Joint CBD Program. The committee believes, however, that its recommendations remain applicable. The Department of the Navy should follow closely and leverage any such future activities to accelerate developments appropriately in the Joint CBD Program.
2. The Joint CBD Program has been undergoing substantial reorganization and reassignment of responsibilities that should affect current near-, mid-, and far-term plans. The Navy is urged to engage more actively with the program to influence those changes.

However, the committee does offer observations on activities in the context of the near, mid-, and far term based on the technical or development difficulties associated with a particular area.

Non-Medical Science and Technology

The Non-Medical Science and Technology part of the Joint CBD Program is organized in five "commodity" areas: contamination avoidance, individual protection, collective protection, decontamination, and modeling and simulation. Detailed findings and recommendations for each commodity area are presented in Chapter 4 of this report and are summarized in Box 4.1; more detailed descriptions of the technologies appear in Appendix C. The findings and recommendations regarding the Joint CBD Program in the Non-Medical Science and Technology area and the Navy's relationship to it are given below.

• *Joint CBD Program: Non-Medical Science and Technology.* Two aspects of this part of the Joint CBD Program appear not to serve naval needs well and can be ameliorated with appropriate attention by the Navy:

—The first of these is that this part of the program has been and remains dominated by a philosophy of "contamination avoidance," a laudable goal indeed, but one that the committee believes is unrealistic as the driving force, considering the broad range of possible asymmetric attacks. Such a philosophy requires early detection to facilitate avoidance and the identification of a threat agent as early as possible, which in turn drives investments heavily toward sensor systems for both standoff and point detection to provide rapid early warning. *The committee recommends that the Navy champion a fundamental change in philosophy in this part of the Joint CBD Program—one that moves toward a risk management approach which assumes that contamination will happen and focuses on managing the response*. Such a shift should result in a more balanced investment portfolio, to also include detection capabilities to support decontamination and diagnostics; characterization of agent fate on exposed surfaces; protective equipment in consonance with tactics, techniques, and procedures that better facilitate operating through an exposure; and rapid and "friendly" decontamination techniques and procedures.

—A second observation is that the requirements and acquisition processes of the entire Joint CBD Program have pushed acquisition schedules out far too long into the future for providing capabilities that could significantly improve the current operational posture. Those processes are undergoing revision, with reassignment of responsibilities within the Joint CBD Program and the Office of the Secretary of Defense (OSD). The committee recommends that the Navy seize the opportunity to ensure that processes are truly revamped to accelerate the introduction of improvements into the fleet.

• *Navy participation*. Achieving the changes in the Joint CBD Program recommended above would be challenging enough if the Navy were fully engaged in the joint process. But in fact the Navy has been the least aggressive of the Services in its participation. Personnel from the Naval Sea Systems Command (NAVSEA), the Office of Naval Research (ONR), and the Commander,

Fleet Forces Command (CFFC), assigned to represent naval interests are well informed and committed to their assignments; however, they do not have sufficient support from senior Navy leadership and commands to analyze joint requirements in the naval context and, if need be, to influence the program for it to address Navy-unique needs. It was not clear to the committee how serious an issue this might be. Lacking a robust, independent assessment on its own, the Navy is captive to equipment and accompanying operational procedures derived largely from the more stressing requirements of environments expected for ground forces in combat, based on conditions at or near the point of agent release.

The recommendation in the section "Operations," above, that NWDC develop and promulgate a carefully analyzed and gamed concept of operations would go a long way toward addressing this issue. Knowledgeable personnel at NWDC could also provide to naval personnel involved in the Joint CBD Program sorely needed support and expertise for ensuring that naval needs are adequately defined. In carrying out this recommendation, the Navy should make good use of Naval Research Laboratory (NRL) personnel who have well-established reputations in the chemical and biological science and technology (S&T) community.

- *Testing and evaluation.* The maritime environment introduces unique factors that should be explicitly considered for accepting equipment from the Joint CBD Program and developing procedures for its use. The Navy's research, development, testing, and evaluation (RDT&E) community is limited in its capabilities to make such assessments. The committee recommends that a much more serious and comprehensive program in testing and evaluation be undertaken by the Navy, to include both modeling and simulation and realistic test environments for chemical and biological warfare defense. The committee, in fact, recommends that the Navy consider dedicating a ship to chemical and biological simulant testing in a fashion analogous to the use of the ex-LSD *Shadwell* for fire research.

Medical Defense

Medical defense against chemical and biological warfare agents is critically important in preserving combat effectiveness of naval forces. Medical defense has great commonality across all of the Services—the affected asset in all cases is the individual Service member, not a weapon system or a logistics facility. While the level of threat may differ, individuals' medical defense needs are the same whether personnel are stationed on a forward-deployed aircraft carrier, at an airbase, or at a home port. Medical defense reemphasizes the need to differentiate clearly between the response to chemical agents and the response required to wage an effective medical defense against biological agents. Exposure to chemical agents is quickly detectable because the effects are rapid; there are also specific medical responses available for some of the agents. In contrast, biological attacks will most certainly be silent and will not present an immediate, concentrated mass casualty situation. Biological warfare defense is clearly the most

challenging from a medical perspective, and, not surprisingly, the committee has found the greatest gaps between that threat and our capacity to manage the consequences of an attack.

The findings and recommendations for medical defense, especially as they relate to the Navy, can be grouped in three general areas:

1. *Medical training.* Medical training remains a critical determinant of success in medical defense and an area in which senior leadership can be most effectively applied. It is also an area in which Navy medical personnel are significantly lagging behind their counterparts in other Services. *Enhanced training of naval personnel, medical and—as noted for operations—non-medical, represents the highest-payoff, near-term investment that can be made by the naval Services, and the committee urges that it be done now.* Training is not without costs, but the costs are relatively low. Moreover, without better training, the equipment and medical countermeasures provided by the technology developers cannot provide the levels of effectiveness for which they are designed.

2. *Technical and operational shortfalls.* Many of the technical and some of the operational shortfalls in naval medical capabilities are the result of overreliance on the Joint CBD Program.[4] The committee's leading recommendation for addressing these issues is to define the nature of the shortfalls in terms of naval-specific requirements. This analysis involves the full range of developmental activities, as discussed for operations: doctrine, organization, training, materiel, leadership, personnel, and facilities (commonly referred to as "DOTMLPF" analysis). This kind of analysis and formalization of naval requirements should be undertaken by the naval Services doctrine and warfare development centers, NWDC and MCCDC, informed and supported by qualified medical personnel.

There is, in fact, a finite number of drugs, vaccines, and antidotes available to support medical CW or BW defense. Vaccines could provide the most comprehensive defense against BW agents, but the Department of the Navy should be under no illusions that there will be a stream of effective approved vaccines (besides those for smallpox and anthrax) available in the near term to mid-term based on DOD priorities alone.[5] In the absence of adequate supplies of effective vaccines, casualties must be anticipated, but observant sailors, corpsmen, clinicians, and commanders, in combination with modern diagnostic tools, will allow early medical interventions to save lives, minimize contamination and further

[4]Due to their expanded scope of chemical and biological defense associated with the war on terrorism, the Department of Homeland Security and the Department of Health and Human Services, especially in the area of vaccines, may impact the Joint CBD Program. The committee believes, however, that its recommendations remain applicable, although the Department of the Navy should follow closely and leverage these activities as much as possible.

[5]The Department of Homeland Security may choose to accelerate some programs, but it is far too soon to assess if and when vaccines important to the military will be included.

exposures, and preserve warfighting strength. The committee recommends (1) that recognition of symptoms and pre-incident intelligence should be the earliest input into an efficient distributed disease reporting and analysis system, and (2) that such a system should be developed and deployed to allow effective and timely medical defensive measures to be taken. (Detailed medical defense S&T assessments and recommendations are presented in Chapter 5 and summarized in Box 5.3.)

3. *Medical policy issues.* Embedded in the acquisition programs of DOD and the Joint CBD Program for both vaccines and laboratory diagnostics is the requirement for Food and Drug Administration (FDA) certification of drugs, devices, and vaccines. According to current DOD policy, the FDA provides the standards for the safety and efficacy of systems that are used to protect military personnel. FDA certification for BW and CW medical systems is problematic because objective clinical trials involving humans cannot be conducted on the diseases or injuries produced by CW or BW agents. The committee noted two major shortfalls in the development programs of the Services and the medical defense part of the Joint CBD Program: (1) the certification of critical laboratory reagents and (2) the slow progress toward certification of drugs and vaccines against BW pathogens. These shortfalls continue despite evidence that the FDA commissioner has shown increasing willingness to modify the certification systems unique to BW and CW. He has recently provided relief from some of the documentation requirements on "orphan" drugs or vaccines that are only effective against BW pathogens.[6] The commissioner has also recently signed a letter authorizing the use of adequate animal studies to meet the efficacy rule. Yet the Joint CBD Program has been slow to act on those "openings" to shorten development and approval times. Liaison and cooperation between the Department of Health and Human Services and the Department of Defense must be continuously exercised to facilitate ways of establishing safety and efficacy in systems designed for military use. This kind of dialogue cannot be assumed to represent the Navy's interests or needs. The committee recommends that the Secretary of the Navy champion those issues within which large gaps in capabilities expose sailors and Marines to unnecessary risk.

CONCLUSION—LEADERSHIP TO SUSTAIN THE COMMITMENT

A strategy to implement the committee's recommendations can pay dividends over the short term, mid-term, and long term. In the short term, it can produce dramatic improvements to force readiness and overall situational aware-

[6]U.S. Food and Drug Administration. 2002. "FDA Amends Its Regulations to Provide for Approval of Certain New Pharmaceutical Products Based on Animal Efficacy Data," *FDA News,* P02-17, Department of Health and Human Services, May 30. Available online at <http://www.fda.gov/bbs/topics/NEWS/2002/NEW00811.html>.

ness. In the mid-term, technical enhancements can contribute significantly to a reduction in operational vulnerabilities. In the long term, naval forces should find themselves well prepared to cope with adversaries willing and able to exploit CW or BW in campaigns of asymmetric warfare aimed at gaining operational and strategic leverage.

In the short term and mid-term, the Navy and Marine Corps can make good progress but need to accelerate the improvement of their capability to successfully sustain operations—across the full spectrum of missions—in the face of robust adversary use of chemical or biological weapons. The current "business as usual" approach will not suffice.

There is critical need for increasing the priority that Navy and Marine Corps leadership assigns to protecting naval forces against CW and BW threats. The lessons from the post-Gulf War era, during which the Navy's attention to CW and BW defense fell off dramatically, suggest a serious leadership challenge for the long term—namely, sustaining institutional commitment to improving the operational posture of naval forces with regard to defending against chemical and biological weapons as the threat evolves to ever more capable levels. Guided by sound risk management practices, naval forces can go far toward reducing the dangers—and therefore, the threat—of any chemical or biological attack.

1

The Chemical and Biological Threat to Naval Forces

Over the course of this study, the committee discovered a considerable mismatch between its view of the chemical and biological warfare threat to naval forces and what should be done about it, compared with the view of the Navy on these same issues. The latter, in fact, presented itself in many different ways. These varying views within the Navy should be reconciled and the elements of a path forward should be defined at the outset. This introductory chapter attempts to lay groundwork for that process by describing both the problem and the principles of a solution.

The committee found a more consistent and appropriately serious view of the threat among most organizations in the Marine Corps that were consulted during this study. As a result, the emphasis in this chapter and throughout the report tends to be on actions to be taken by the Navy, although areas for attention by the Marine Corps are noted when appropriate.

FRAMING THE PROBLEM

A Clear and Present Threat

To set the context for the findings, conclusions, and recommendations presented in Chapters 2 through 5, the committee first evaluates the present and projected threat of chemical and biological weapons to naval force operations in littoral and open-ocean regions.

In the committee's assessment, there is a serious threat to naval forces from chemical and biological weapons today, and it is likely to grow with time. Because of the viability of short-range, land-based, or airborne-delivery systems, the littorals present a higher-risk environment than does the open ocean (which was the Cold War focus for chemical and biological weapons defense). But the committee believes that the threats could be even greater in ports, logistics chains, and military installations, where simple delivery methods can be utilized and reliance on commercial and/or foreign suppliers is the rule. As key technologies become more mature and widely available, adversaries armed with chemical or biological weapons can be expected to gain increased technical sophistication and operational capability. Taking into account the types of events listed in the prologue, this assessment of the chemical and biological threat to naval forces derives from the following principal factors:

1. Today, chemical and biological weapons and/or weapons development programs can be found worldwide in every region where the possibility of interstate war exists. The programs of concern stretch in a virtually unbroken arc from Northern Africa through Southwest Asia, into South and Central Asia, up to Northeast Asia.[1] Thus, in any theater where a major war is a planning imperative for U.S. military forces, chemical and biological threats are present.

2. Moreover, among terrorist groups there is a rising interest in causing mass casualties and a parallel rising interest in the use of both chemical and biological weapons. Although many terrorists seem to regard the use of such weapons as unnecessary or counterproductive, the Japanese cult Aum Shinrikyo did acquire and use them for many purposes, including attacks on U.S. naval forces.[2] Al Qaeda is said to have established the acquisition of chemical and biological weapons as a "holy duty" for Muslims in its war with the United States and its secular allies.[3] Given the proclivity of terrorists for making broader use of techniques whose effectiveness has been demonstrated (as in the well-known examples of skyjacking and suicide bombings), precedents for and any encouragement of the use of chemical and biological weapons are a source of particular concern.

The term "asymmetric strategy" has come into vogue to describe the kinds of approaches that regional powers and nonstate actors must pursue in confronting a country such as the United States that is militarily superior by any index of conven-

[1]Cohen, William S., Secretary of Defense. 2001. *Proliferation: Threat and Response*, Washington, D.C. Available online at <http://www.defenselink.mil/pubs/ptr20010110.pdf>.

[2]WuDunn, Sheryl, Judith Miller, and William J. Broad. 1998. "Sowing Death, A Special Report: How Japan Germ Terror Alerted World," *New York Times,* May 26, p. A-1.

[3]Yusufzai, Rahimulla. 1999. "Conversation with Terror," Interview with Osama bin Laden, *Time*, Vol. 153, No. 1, p. 38.

tional and nuclear power. The logic of asymmetric conflict suggests that U.S. adversaries will target vulnerabilities in a military theater and in the homeland as a way to generate fear, induce "conflict fatigue," and by coercion keep the United States from defending certain interests that the aggressor is challenging. For the bold and well-armed adversary willing to try by asymmetric means to inflict operational defeat on U.S. forces across an entire theater, chemical or biological weapons may seem more destructive than conventional weapons, but, if employed in a targeted and controlled fashion, perhaps less likely than nuclear weapons to provoke unleashing of the full brunt of U.S. power. Compared with nuclear weapons, chemical or biological weapons are also more accessible and their use less easily attributed.

How might chemical or biological weapons actually be used in asymmetric conflicts? Among the possibilities are threatened use, perhaps to dissuade the United States from attempting to reverse an act of aggression, to deter other nations from joining a U.S.-led coalition, or perhaps to coerce U.S. acceptance of tolerating the survival of a regime if its aggression is stopped. They further compound retaliatory strategies through diffuse operations, including those in and amongst civilians to achieve goals such as disruption or financial chaos. Such weapons might also be used in overt or covert attacks to slow the arrival of U.S. power projection forces or even to defeat coalition forces in theater, for example, or to cause widespread disruption and hardship in retaliatory attacks on the United States during or after a war.[4]

The Navy's Current Views of the Threat

Based on its collective experience and knowledge gained prior to and throughout this study, the committee observed that the Navy appears to lack a unified view of the threat posed by chemical or biological weapons. Some in the Navy do share the committee's view of a clear and present threat and seek further insights into the threat's precise character so as to be able to focus naval defense strategies. Among these taking the initiative to improve capabilities, however, some have tended to focus on the better-known approaches to countering chemical weapons, such as the Marine Corps' Chemical and Biological Incident Response Force (CBIRF), sometimes mislabeling their efforts as constituting both a chemical *and* a biological defense. Others perceive both chemical and biological threats but see them as too hard to address and seem paralyzed about taking further steps. Still others simply do not recognize a problem and see no reason to dwell on the matter further. And some focus on both the improbability of an attack and the difficulty of a solution in order to rationalize placing attention and

[4]For more on weapons of choice in asymmetric warfare, see Roberts, Bradley. 1998. *Biological Weapons in Major Theater War,* Institute for Defense Analyses, Alexandria, Va., November; and Roberts, Bradley. 2000. *Asymmetric Conflict 2010,* Institute for Defense Analyses, Alexandria, Va., November.

resources elsewhere. Examples of each of these views exist within individual commands and/or among individuals within a given command.

To help address these disparate views and get past this potential stumbling block to progress in improving overall naval defensive posture, the committee offers the discussion below.

• *Too hard?* Many who regard defense against chemical and especially biological weapons as being too hard focus on the potential for their use to kill huge numbers of people and to cripple military operations. A recent study conducted jointly by the Defense Science Board (DSB) and the Threat Reduction Advisory Committee (TRAC) concluded that biological weapons are potentially "comparable to nuclear weapons" in the scale of damage they might do.[5] If the problem posed by chemical or biological weapons is viewed as indeed overwhelming, then it seems to some that there is little that a military official might do to reduce the operational or political impact of such weapons used in a strategic role.

The potential for massively destructive uses of chemical and biological weapons is real.[6] But uses on that scale seem highly unlikely in the absence of a peer competitor actively concerned with the possibility of extinguishing U.S. society and institutions. National leadership appears to be assuming that the United States faces no such peer competitor in the foreseeable security environment because it has framed a defense strategy that describes instead a world in which a handful of regional powers and transnational terrorist organizations are acquiring weapons of mass destruction to gain regional dominance and to confound U.S. power projection strategies. The uses that such adversaries might make of chemical or biological weapons are unlikely to be "apocalyptic," but rather "asymmetric," as described above.

In the committee's view, the potentially catastrophic nature of chemical warfare (CW) or biological warfare (BW) and the potential utility of nuclear threats in deterring these most devastating types of attacks[7] represent a very limited perspective of the threat that is now apparent. There are many other uses

[5]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June, p. v.

[6]As both intelligence sources and a highly placed defector have stated, the Soviet Union intended to follow an initial intercontinental nuclear exchange with a salvo of biologically tipped missiles on American cities—missiles filled with biological agents engineered to reduce or eliminate the efficacy of antibiotic treatments that survivors might have used to treat the victims. See Alibek, Ken, and Stephen Handelman (contributor). 1999. *Biohazard: The Chilling True Story of the Largest Covert Biological Weapons Program in the World Told from the Inside by the Man Who Ran It,* Random House, New York.

[7]Adversaries may well dismiss such U.S. threats as not being credible, given that their asymmetric tactics seem not to require retaliation with overwhelming force.

that could be operationally and/or politically advantageous for the adversary—and for which nuclear deterrence is irrelevant. Thus, reducing U.S. vulnerabilities is essential.

Another part of the argument that CW or BW defense is too hard is based on the long-standing Department of Defense (DOD) emphasis on contamination avoidance, that is, driving to zero any direct exposure to the effects of chemical or biological weapons. This zero-risk approach is at odds with the fact that robust warning to avoid exposure remains a goal yet to be achieved, especially for BW, despite years of investment in developing technologies and systems for that purpose. The committee believes that such a philosophy must be reassessed in this era of asymmetric threats. A more prudent approach that accepts some level of risk and shifts investments to a balance among warning and response capabilities (e.g., decontamination, medical therapeutics, and countermeasures) is called for.

• *Not a problem?* Among those who do not believe that there *is* a problem the reasons are varied. One argument is that U.S. adversaries simply would not dare to use chemical or biological weapons because of the extreme punishment that the United States could and would inflict, whether military or political. The logic of asymmetric conflict, as described above, diminishes this argument. Adversaries may well believe that the threatened or actual use of chemical or biological weapons promises some benefits, at what is judged to be a reasonable risk. Some adversaries may even desire such punishment in the belief that it would be criticized as excessive and thus discredit the United States.

A second argument for there being "no problem" follows from the lack of historical precedent for widespread military use of chemical and biological weapons. The United States did indeed relinquish both chemical and biological weapons, but not on the argument that they lack military utility. In fact, the U.S. weapons development program clearly demonstrated the tactical, operational, and strategic value of biological weapons. Their potential high utility and the relative ease of acquiring a biological weapons capability as opposed to a nuclear weapons capability were primary motivators of the Nixon administration's decision to renounce biological weapons. The hope was that creating a norm and treaty regime against biological weapons would inhibit their proliferation to additional states and persuade states with existing programs to disarm.[8]

Lethal chemical weapons, with their more rapid lethal effects and limited area coverage (for individual bombs or artillery shells), were categorized as tactical weapons. While the United States had a no-first-use policy for chemical weapons, a defensive-only chemical capability would have placed the United States (and the North Atlantic Treaty Organization (NATO)) at a disadvantage

[8]For further discussion of the U.S. decision to renounce biological weapons, see Tucker, Jonathan. 2002. "A Farewell to Germs: The U.S. Renunciation of Biological and Toxin Weapons, 1969-1970," *International Security,* Vol. 27, No. 1, June, pp. 107-149.

(i.e., due to the debilitating effects of defensive gear). Thus, the United States did retain offensive chemical weapons until chemical arms control agreements could be negotiated.[9] In addition, the United States committed a significant level of effort to fashioning an ability to fight and survive against Warsaw Pact use of chemical weapons in spite of most other NATO members' recalcitrance about doing the same.

Any remaining doubts about how potential enemies might view the utility of such weapons ought to be set to rest by the revelations over the past decade of the biological weapons activities of Iraq, South Africa, and the Soviet Union/Russia—all of which exceeded assessments in both scale and sophistication.

The third argument for the position that neither CW nor BW presents a serious problem is that naval forces are essentially invulnerable to whatever the threat may be, given their ability to maneuver away from toxic releases and the ability to close up and wash down many vessels. The committee believes that this argument fails to see the Navy as a whole. The majority of U.S. naval personnel are not at sea. Operations at sea depend on an extensive port and shore infrastructure system. Operations in theater depend not just on ports but also on host nation support, contractors, ready access to safe food and water, and the like. Even at sea the Navy is sometimes restricted in its ability to maneuver, especially if engaged close to shore. Moreover, to maneuver around a dispersed cloud of agent, naval forces must have a robust means to sense the presence of that cloud—a capability not now in existence. Furthermore, covert use of chemical and biological weapons does not require a technique for highly precise delivery, since dispersion downwind can make up for delivery shortfalls if the dispersion is modestly predictable. In the committee's assessment, as the Navy transitions from being a deep-water force to a theater-support force engaged in littoral operations, it will face a more formidable challenge from both CW and BW.

Limitations to What Intelligence Can Provide

A further argument against the seriousness of a chemical or biological threat to naval forces is that the intelligence community has not made a strong case for type of biological threat. This committee is similarly unimpressed by threat assessments that focus on technical descriptions of chemical or biological warfare agents and do not address operational issues from both adversarial and U.S.

[9]On November 25, 1969, U.S. President Richard Nixon declared that the United States would unilaterally renounce the first use of lethal or incapacitating chemical weapons and would unconditionally renounce all methods of biological warfare. The U.S. biological program would be confined strictly to research on defensive measures such as communication. The President further instructed the Department of Defense to draw up a plan for the disposal of existing stocks of biological agents and weapons.

perspectives. On the basis of the information presented to the committee, the Office of Naval Intelligence's (ONI's) own characterization of the threat appeared to be deficient, for reasons elaborated below, but it is important for skeptics to understand some of the reasons why the picture drawn by the intelligence community is not more compelling.

CW and BW development programs are inherently difficult for the intelligence community to assess. Many such programs are embedded in dual-use capabilities: that is, they have both legitimate commercial and military as well as terrorist purposes. Also, the "footprint" for acquiring a capability (e.g., production, storage, delivery) is inherently small, compounding the detection challenge. Moreover, proliferators have been able to study Iraqi, Soviet, and other's techniques of concealment and deception to make such targets more difficult to identify and characterize. The difficulty of accurately characterizing adversary capabilities is well illustrated by the revelations of the last decade about undetected weapons development in South Africa and elsewhere.[10]

The intelligence community has been harshly criticized for not doing well enough with the information that is available.[11] The standard approach of the intelligence community characterizes the CW or BW threat in technical as opposed to operational terms. For example, threat agents and their technical characteristics are described and countries of concern are listed, but trends in the proliferation of delivery systems are not generally linked with weapon configurations to provide insight into overall capabilities. Insights into adversaries' strategies and tactics and thus concepts of operations are rare. The result is an assessment that conveys little about the operational implications of adversaries' possession and use of chemical or biological weapons. Threat briefings by the intelligence community have done a poor job of informing the military decision maker's understanding of how an adversary might employ chemical or biological weapons to achieve specific objectives with resulting consequences for U.S. missions and plans. As the recent DSB/TRAC study concluded, in order to avoid future BW surprise, the intelligence community must completely reengineer its focus, process, and product, enlisting expertise that it does not currently have with respect to biological weapons

[10]Burgess, Steven F., and Helen E. Purkitt. 2001. *The Rollback of South Africa's Chemical and Biological Warfare Program,* U.S. Air Force Counterproliferation Center, Air War College, Maxwell Air Force Base, Ala. See also Kay, David A. 1995. "Denial and Deception Practices of WMD Proliferators: Iraq and Beyond," *Washington Quarterly,* Vol. 18, No. 1 (Winter), p. 83.

[11]Concern about the community's ability to track and interpret available information has been regularly flagged by independent studies and analyses and is a regular topic of congressional discussion as the hearings after September 11 illustrate. Earlier documented concerns can be found in the following: Office of the Under Secretary of Defense for Acquisition and Technology. 1997. *Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Final Report*, Vol. 1, Washington, D.C., October.

and assessing a much broader range of information sources, *most especially human intelligence.*[12]

Having more and better information about adversaries' CW or BW capabilities and intentions would undoubtedly be useful. To the extent that new approaches by the intelligence community can provide that information, Navy leadership should support them. It is important to recognize, however, that such information may not simply be lying somewhere in secret, awaiting discovery by the right means; the complexities of attribution may make the task of capturing such intelligence impossible, since hard information about when, where, why, and how chemical and biological weapons will be used may not in fact exist until a time of crisis or war and may therefore not be possible to ferret out ahead of time.

What Is Known Today

The committee recognizes that debating the nature of the CW or BW threat tends to distract attention from the simple fact that a great deal is already known. A number of states have been confirmed as having chemical and/or biological weapons and the means to deliver them. An additional number of states are suspected of being well along in one or more of these areas. Still others are known to have the technical capability to move to a weapons program whenever a decision is made to do so. Transnational terrorist organizations have shown both interest and some competency in chemical and biological weapons. States sometimes collaborate with terrorists, and the known state sponsors of terrorism are also the known possessors of banned weapons. These facts ought to be clear enough to persuade any military planner of the importance of being prepared to operate in a CW or BW environment.[13]

STEPS TOWARD IMPLEMENTING A SOLUTION

Subsequent chapters of this report present general and specific recommendations in a variety of topical areas. The committee's purpose in the remainder of this chapter is to elaborate three basic principles upon which the recommendations of this report are built.

To focus its response strategies effectively, the Navy should emphasize these three key principles:

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[12]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June, pp. 74-78.

[13]DOD has identified Libya, Sudan, Syria, Iraq, Iran, Pakistan, India, China, North Korea, and Russia as countries of concern with respect to nuclear, biological, and chemical weapons capability. See Office of the Secretary of Defense. 2001. *Proliferation: Threat and Response,* 3rd ed., Washington, D.C., January. Available online at <http://www.defenselink.mil/pubs/ptr20010110.pdf>.

1. *Recognize that chemical weapons and biological weapons constitute different threats.* Each has a set of unique requirements for achieving an acceptable defensive posture.

2. *Manage to risk, not to threat alone.* There should be use of risk assessments that combine a broad view of adversary intent and force vulnerabilities with an analysis of the operational consequences of adversary actions and defensive countermeasures to these (passive and active), to understand the impact on accomplishing a mission and on overall campaign success.

3. *Adopt a reasoned view of chemical and biological weapons exposure environments—not simply worst-case scenarios—to prioritize investments of people, time, and dollars.* Requirements for defense against chemical and biological weapons should be based on operationally realistic exposure environments; levels of protection should be established to accept casualties that are consistent with those expected from conventional operations spanning similar time and spatial domains.

Each of these principles is elaborated below and then tied to the emphasis on capabilities-based planning in the most recent Quadrennial Defense Review (QDR).[14]

Recognizing That Chemical and Biological Weapons Pose Different Threats

A first and fundamental principle is that the threats posed by chemical and biological weapons are similar but not identical. Many in naval leadership positions tend to lump chemical and biological defense together and to link such defense closely with protection against nuclear, radiological, and other types of unconventional attack. Lost in the process is an appreciation of the essential distinctions between and the defenses needed against chemical and biological weapons. Throughout this report, the committee attempts to note how responses to chemical risks can be similar to and different from responses to biological risks, both technically and operationally.

Chemical and biological warfare agents have different technical characteristics that require appropriate operational responses. Chemical weapons are poisons whose direct physiological effects are generally well characterized. They incapacitate or kill by damaging the exterior of the human body (e.g., the burns of mustard agent) or its interior processes (e.g., interference with the processing of gases in the blood and/or the flow of nerve impulses throughout the nervous system). The effectiveness of deployed chemical weapons may be temporary or

[14]Rumsfeld, Donald H., Secretary of Defense. 2001. *Quadrennial Defense Review Report,* Washington, D.C., September 30. Available online at <www.defenselink.mil/pubs/qdr2001.pdf>.

persistent. Some chemical agents have both short- and long-term toxic and genetic effects. (Toxins, although of biological origin, behave similarly to and should be understood technically and operationally as chemical agents.) Generally, chemical agents are considered tactical weapons: Their effects on forces are immediate or nearly so and their practical employment range limited. Their strategic value would come largely from inducing fear or by degrading the overall effectiveness of naval forces by placing them in a continuous protective posture. (Appendix B lists various chemical agents and their effects, including effective doses and rates of action.)

Biological weapons contain microbes that harm or kill through replication in the infected body. They are neither dermally active nor volatile as compared with chemical agents. Because the microbial agent can replicate, extremely low-level exposures can infect an individual and may lead to contamination of many more people than were first exposed, if the agent is transmissible (e.g., smallpox). Biological weapons are vulnerable to meteorological factors in ways that chemical weapons are not: for example, exposure to sunlight may quickly kill some types. Other agents, such as anthrax, are more persistent in the environment. BW agents are not generally used for tactical advantage since the onset of their effects occurs in hours or days, not minutes. However, an infected naval unit can be out of action for extended periods once an agent starts to cause symptoms. (Appendix B also lists biological agents and some of their properties, including effective doses and onset times. The reader is also referred to the DSB/TRAC report for a more detailed primer on biological weapons and their effects.[15])

Given the technical differences between chemical and biological weapons, means of employment and targets will probably differ for the two weapon types, with different operational implications for U.S. forces. A chemical attack could be delivered either by standard military ordnance on target or by covert means, though the latter approach would likely reduce the quantity of agent deliverable and limit the possibility of sustained re-attack. Chemical attacks could also include toxic industrial chemicals (TICs). A biological attack may be delivered by standard ordnance, but because the necessary quantities to achieve target coverage are so small when compared to those for chemical agents, unconventional delivery becomes more attractive, as the anthrax attacks conducted through the mail demonstrated in the fall of 2001. In contrast to chemical attacks, biological attacks may go undetected until illness begins to present itself, hours, days, or even weeks later. Attack with a biological agent is not simply another version of "getting slimed," as with a chemical agent, and the differences point to different requirements for defense posture.

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[15]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June, pp. 13-29.

As with other forms of warfare, there is a "learning curve" associated with acquiring an effective CW or BW capability. At the low end of the curve are initial research and development (R&D) and the production of traditional threat agents. A bit higher up the curve are improved technical solutions to the challenges of effective weaponization and closer integration of the R&D and operator communities. Higher up the curve is an understanding of an opponent's vulnerabilities and a focused effort to exploit those vulnerabilities with tailored agents and delivery systems. Higher yet is an exploitation of advancing technologies to enhance the potency, specificity, and survivability of both chemical and biological agents. Circumventing any of these steps in the learning curve is possible (e.g., through buying a capability outright), and lower levels of capability can still cause significant damage. But the Navy should recognize that a determined adversary committed for the long term will make steady progress with time and experience—with the potential to create an ever more formidable threat.

As intelligence community leaders repeatedly emphasize, nation-state proliferator programs are climbing this curve.[16] Proliferator programs are becoming more sophisticated, and the resulting capabilities are being integrated into the different states' military systems and postures. Although terrorist success in mastering these capabilities has been limited, it was reported in the late 1990s that both Aum Shinrikyo and al Qaeda had made significant investments and were at work assembling potentially effective capabilities.[17] In the CW realm, those states that have dabbled in entry-level capabilities with first- and second-generation chemical warfare agents appear to be moving on to third- and fourth-generation agents.[18] In the BW realm, there is sharply rising concern about the impact of the biotechnology revolution on the BW threat. As the recent DSB/TRAC study emphasizes, the likely impact of this revolution on the threat over the coming decade could be a dramatic transformation in the threat: "Time is short. Modern molecular biology has not yet been effectively applied to biological warfare, but when and if it is, a defense against the resulting weapon will be very difficult. It is critical to stop the development of biological weapons."[19] A

[16]Roberts, Bradley. 1998. *Biological Weapons in Major Theater War,* D-2234, Institute for Defense Analyses, Alexandria, Va., November, pp. 5-6.

[17]See Kaplan, David, and Andrew Marshall. 1996. *The Cult at the End of the World: The Terrifying Story of the Aum Doomsday Cult from the Subways of Tokyo to the Nuclear Arsenals of Russia,* Crown Publishers, New York; and Lifton, Robert J. 1999. *Destroying the World to Save It: Aum Shinrikyo, Apocalyptic Violence, and the New Global Terrorism,* Henry Holt, New York.

[18]Director, Central Intelligence Agency. 2003. *Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions, 1 July Through 31 December 2001,* Washington, D.C., January 7. Available online at <http://www.cia.gov/cia/publications/bian/bian_jan_2003.htm>.

[19]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Major Findings, Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June, p. 1.

recent study by the JASONs[20] similarly underscored the potential impact of genetic modification techniques on the threat.[21] Proliferators also appear increasingly capable of engineering work-arounds to U.S. defenses, which are evolving slowly.

Managing to Risk, Not to Threat Alone

In developing strategies to address the CW or BW threat, it is important to understand that the threat will present itself differently to different parts of the naval force. Ships operating in deep water face one set of risks. Ships operating close to shore face another. Ports, shore installations, and bases have their own vulnerabilities, both outside and within the continental United States. The logistics infrastructure presents its own problems in the face of CW or BW threats. And Marine operations have their own special vulnerabilities, as do activities associated with special operations forces.

This fundamental understanding is not, however, reflected in the current Joint CBD Program, which is crafted on a philosophy of contamination avoidance in all situations, in spite of Joint Staff guidance to the contrary.[22] More realistic and practical is a risk management approach which assumes that contamination will happen and balances avoidance with managing the response. With an understanding of the threat as described above, it is possible to take the next step, to characterize risk.

As a first step to characterize risk, Tables 1.1 and 1.2 should be completed by the Navy in order to provide a notional comparative assessment of the vulnerability of different types of naval assets to attack with different types of weapons and the expected consequences. To help manage the situation requires that risk then, represents the combination of the threat, vulnerability, and consequence in the judgment of the decision maker. When completed, Table 1.1 would offer a summary of such risks to U.S. naval forces in time of war against a nation-state armed with chemical or biological weapons, and Table 1.2 would offer analogous risks

[20]JASON is a rotating group of the nation's foremost scientists who have, since the late 1950s, devoted extensive time and energy to problems of national security.

[21]Block, Steven M., et al. 1997. *Living Nightmares: Biological Threats Enabled by Molecular Biology*, JASON (MITRE Corporation), McLean, Va., (classified). For an unclassified summary, see Steven Block's chapter in Drell, Sidney D., Abraham D. Sofaer, and George D. Wilson (eds.). 1999. *The New Terror: Facing the Threat of Biological and Chemical Weapons,* Hoover Institution Press, Stanford, Calif., pp. 5-38.

[22]"Chemical Warfare (CW) Agent Exposure Planning Guidance," Joint Staff memorandum MCM-0026-02, April 29, 2002, Office of the Chairman, Joint Chiefs of Staff, states: "In the execution of the force's mission, all commanders should conduct a risk assessment, balancing exposure to contamination and other risks in light of joint task force priorities. This is essential to operational risk management."

TABLE 1.1 Nation-state Attack in Time of War—Notional Assessment of Vulnerability/Operational Consequences for Naval Assets

	Vulnerability to/Operational Consequences of Attack by:			
Targets	Chemical Agents	Biological Agents	Explosives	Industrial Chemicals
Ships at sea				
Ships in littoral waters				
Ships in commercial ports				
CONUS military installations				
CONUS/OCONUS logistics				

TABLE 1.2 Terrorist (or Asymmetric) Attack—Notional Assessment of Vulnerability/Operational Consequences for Naval Assets

	Vulnerability to/Operational Consequences of Attack by:			
Targets	Chemical Agents	Biological Agents	Explosives	Industrial Chemicals
Ships at sea				
Ships in littoral waters				
Ships in commercial ports				
CONUS military installations				
CONUS/OCONUS logistics				

posed by terrorists. In summary, the tables are provided as an illustration of the type of analyses that the Navy ought to conduct in each command with a view to particularizing the risk management plan.

With this perspective on the risk of chemical or biological attacks to naval forces, it is possible to draw some conclusions about the Navy's present focus. In this committee's assessment, the Navy has paid too much attention to certain types of risks and too little attention to others. It has paid too much attention to the risk that ships at sea will have to cope with—namely, the types of high-density attacks that were a serious risk to land forces in the event of U.S.–Soviet war. It has paid too little attention to the risks to ports, bases, and logistic infrastructure and to operations in littoral waters. The changing role of the Navy in the post-Cold War security environment obliges it to come to terms with missions in which it cannot readily steam away and use the open ocean as a refuge. These include operations in littoral waters, visits to foreign ports, reliance on foreign port logistic support, and close shore support of Marine forces, all in the context of growing reliance of U.S. adversaries on asymmetric tactics.

Adopting a Reasoned View of Chemical and Biological Weapons Exposure Environments

In designing a protective posture against chemical or biological warfare agents, it is necessary to have some understanding of the exposure levels that forces might encounter. The Joint CBD Program—in establishing requirements under the contamination avoidance philosophy and driven largely by the environments expected by the Army—has focused on conditions at or near the point of release of warfare agents. Adopting a risk-based approach leads to a different concept for setting requirements—one based on challenge instead of threat. "Challenge" is defined as the physical conditions of the threat environment that those requirements must address. In the case of chemical and biological agents, challenge is defined in terms of concentration (vapor) or deposition (liquid or solid) and duration (time of exposure).

At the height of the Cold War, challenge concentrations were defined against the Soviet threat, which was then massive. Protective garments (suits and masks) were required to withstand a liquid chemical challenge of 10 g/m^2 and a chemical vapor challenge of 5,000 to 10,000 $mg\text{-}min/m^3$—conditions typical of the center of a chemical munitions detonation, especially if delivered by artillery in a standard firing pattern.[23] Biological weapons challenge parameters were not defined; rather, it was assumed that protective measures effective against chemical weapons would be effective against biological weapons. Current design requirements for garments are still based on this challenge, and properly used gear is intended to provide 100 percent protection against the defined challenge.

The Navy should consider whether these challenge levels are appropriate for the post-Cold War threat environment. The current requirements have been set from a combination of factors: the legacy concerns of the Army in battlefield environments, the constraints of the Joint CBD Program (described more fully in Chapter 2, Box 2.1) that tend to drive requirements to meet those concerns, and the lack of realistic analyses by the Navy to allow an understanding of how its operational needs might differ from those established in the Joint CBD Program. While the chemical challenge defined above might exist at the center of an open-air detonation, the challenge is much diminished a short distance away. Moreover, in the types of asymmetric attacks on naval forces described in the risk matrixes in Tables 1.1 and 1.2, which could include attacks aimed at facilities or ship interiors, sustained precision attack with chemical munitions is highly unlikely. The more likely scenarios involve at most infrequent attack with uncertain but not Soviet-style consequences. Moreover, explicit considerations of the differences that a

[23]Barrett, Gloria, Program Manager, Enhanced Soldier Systems. 1999. Presentation to Advisory Panel on Strategies to Protect the Health of Deployed U.S. Forces, Task 2.3: Physical Protection and Decontamination, Soldier Systems Center, Soldier and Biological Chemical Command, Natick, Mass., November 16.

biological attack would introduce also need to be considered. An outcome of such naval force–specific analyses might be an easing of the technical or operational requirements for naval passive–defense gear. Relaxing the current policy from full protection in all situations to lower levels of protection in defined situations could prove invaluable in avoiding the degradation of individual and unit performance.

Capabilities-based Planning

The three points discussed above for framing the solution, coupled with the inherent limitations on intelligence related to CW and BW threats, are consistent with a central theme of the 2001 QDR—a shift of emphasis to capabilities-based planning. This shift

> . . . reflects the fact that the United States cannot predict with confidence what nation, combination of nations, or non-state actor will pose future threats to vital U.S. interests. A capabilities-based model broadens the strategic perspective. It requires identifying capabilities that U.S. military forces will need to deter and defeat adversaries who will rely on surprise, deception, and asymmetric warfare to achieve their objectives. It focuses more on how an adversary might fight than on who the adversary might be and where a war might occur. The shift is intended to refocus planners on the growing range of capabilities that adversaries might possess or could develop.[24]

Although addressing military capabilities in general, these statements regarding capabilities-based planning are particularly relevant to the approach and solutions for chemical and biological weapons defense—and should provide the basis for the path forward for the Navy.

[24]Rumsfeld, Donald H., Secretary of Defense. 2001. *Quadrennial Defense Review Report,* Washington, D.C., September 30. Available online at <www.defenselink.mil/pubs/qdr2001.pdf>.

2

General Findings and Recommendations

INTRODUCTION

In developing the findings and recommendations on chemical and biological defense in the areas of operations, non-medical science and technology, and medical countermeasures presented in Chapters 3, 4, and 5, respectively, the committee observed that two general themes emerged. Both are fundamental and must be addressed in order for the more specific recommendations of those chapters to have lasting impact and to achieve the needed improvements in naval forces' defensive posture. This chapter articulates those two general areas: (1) the leadership considerations for lasting improvement in posture and (2) the approach for getting started. The general findings and recommendations elaborated in the rest of this chapter are as follows:

1. *Naval leadership for chemical and biological warfare defense*. In spite of both the general military and the naval-specific concerns and guidance regarding preparedness for chemical and biological warfare defense articulated for more than a decade, little improvement in the Navy's posture could be found. The Navy's senior leadership should commit to strengthening and integrating chemical and biological defense throughout all Navy functions in order to achieve both near-term and sustained improvements. Leadership within the Marine Corps has been more visible and sustained, but gaps remain in preparedness. For both Services, especially the Navy, this includes having a much higher profile in the Joint Chemical and Biological Defense (CBD) Program to ensure that naval-specific requirements are being adequately addressed.

2. *Getting started with operational net assessments.* Chemical or biological warfare defense alone will never be perfect, nor are there single robust elements within any defensive approach. Consequently, a defense-in-depth strategy—that is, a layered defense that exploits the synergies among individual components in order to have the strongest possible performance of the overall system—should form the basis for the future. Models for developing defensive capabilities can be found in the Fifth Fleet, with selected Marine base commands, with most commercial fleet operators, with the British Royal Navy, and with the U.S. Air Force. The Navy and Marine Corps should get started with an operational net assessment, particularized to each combat or supporting commander's operating environment.

NAVAL LEADERSHIP FOR A FORCE BETTER PREPARED

General Finding: A History of Concerns—and Some Response

Advice to naval leadership on the chemical warfare (CW) and biological warfare (BW) threat can be traced to the Cold War period. As the Navy undertook a major force buildup in the early 1980s, a memorandum from committee member Joshua Lederberg to the CNO, Admiral James Watkins, USN, was instrumental in precipitating the decision to equip some new vessels with collective protection capabilities and improved chemical weapons detectors.[1]

Following the experiences of the Persian Gulf War in 1991, including the preparations for chemical and biological warfare and controversies about possible exposure to chemical warfare agents during the war, considerable concern existed at senior levels in the Joint Staff, Office of the Secretary of Defense, and U.S. Navy about the ability of U.S. forces to fight and survive in a contaminated environment. As indicated in the following sequence of events, attempts to address these concerns have been made, but sustaining efforts have largely fallen flat.

- *1992.* In the wake of the Persian Gulf War, Chairman of the Joint Chiefs of Staff Colin Powell reports that the vulnerability of U.S. forces to biological attack had been one of his greatest concerns.
- *1993.* Secretary of Defense Les Aspin launches the Defense Counterproliferation Initiative, aimed at gaining short- and longer-term improvements in the ability of U.S. forces to project power and prevail against regional adversaries armed with weapons of mass destruction (WMD).
- *1994.* The new Defense Planning Guidance specifies that chemical and biological weapons should be considered a likely condition of war.[2]

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[1]Lederberg, Joshua. 1982. Memorandum for ADM James D. Watkins, USN, re: *Report of the Chemical Warfare Task Force of the CNO Executive Panel (U),* Chemical Warfare Task Force, CNO Executive Panel, Office of the Chief of Naval Operations, Washington, D.C. (classified).

[2]Department of Defense. 1994. *Defense Planning Guidance,* Washington, D.C. (classified).

- *1994.* Deputy Secretary of Defense John White creates the Counterproliferation Council as a way to generate high-level and sustained Service engagement.
- *Mid-1990s.* Navy Under Secretary Richard Danzig makes a serious effort to persuade Service leadership of the high risks to the Navy from failing to address the biological threat.[3]
- *1996.* The General Accounting Office (GAO) concludes that military Services "face many of the same problems [of chemical and biological defense] that they confronted during the Persian Gulf conflict in 1990 and 1991."[4]
- *1997.* The first Quadrennial Defense Review (QDR) highlights the risk to U.S. forces posed by the proliferation of WMD in major theater war scenarios.[5]
- *1998.* Deputy Secretary of Defense John Hamre creates the Defense Threat Reduction Agency (DTRA) to encourage improved focus and effectiveness in coming to terms with the threat of WMD.
- *1998.* The CNO issues OPNAV (Office of the Chief of Naval Operations) Instruction 3400.10F, "Chemical, Biological, and Radiological (CBR) Defense Requirements Supporting Operational Fleet Readiness," outlining revised and comprehensive responsibilities throughout the Navy.
- *2001.* The second QDR, under Secretary of Defense Donald Rumsfeld, highlights rising concern about asymmetric challenges to U.S. power and the specific utility of chemical and biological weapons in the hands of adversaries seeking to inhibit U.S. access to their regions.[6]
- *2001.* The GAO again concludes that major capability shortfalls remain among the Services.[7]
- *2002.* The Secretary of the Navy (SECNAV) issues SECNAV Instruction 3300.3A, "Combating Terrorism Program Standards," which includes a policy statement directing the assessment of "vulnerabilities and planned countermeasures" to WMD.[8]

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[3]See Danzig, Richard. 1996. "Biological Warfare: A Nation at Risk—A Time to Act," Strategic Forum Number 58, Institute for National Strategic Studies, National Defense University, Washington, D.C.; and Danzig, Richard. 1996. "Why Defense Against Biological Warfare Should Be a Priority," *Surface Warfare Magazine,* November/December, pp. 10-13.

[4]U.S. General Accounting Office. 1996. *Chemical and Biological Defense: Emphasis Remains Insufficient to Resolve Continuing Problems,* GAO/NSIAD-96-103, Washington, D.C., March.

[5]Cohen, William S., Secretary of Defense. 1997. *Quadrennial Defense Review Report,* Washington, D.C.

[6]Rumsfeld, Donald H., Secretary of Defense. 2001. *Quadrennial Defense Review Report,* Washington, D.C., September 30. Available online at <www.defenselink.mil/pubs/qdr2001.pdf>.

[7]U.S. General Accounting Office. 2001. *Chemical and Biological Defense, Improved Risk Assessment and Inventory Management Are Needed,* GAO-01-667, Washington, D.C., September; U.S. General Accounting Office. 2001. *Chemical and Biological Defense, DOD Needs to Clarify Expectation for Medical Readiness,* GAO-02-38, Washington, D.C., October.

[8]SECNAV Instruction 3300.3A, "Combating Terrorism Program Standards," May 16, 2002, Office of the Secretary of the Navy, Washington, D.C., includes links to the civilian sector. Available online at <http://neds.nebt.daps.mil/directives/3300_3a.pdf>.

This record of high-level concern, guidance, and DOD actions was paralleled by more intense oversight from Congress in defense planning challenges associated with WMD. New committees were formed in both houses to focus legislative attention on these matters. Congressional support agencies, including both the Congressional Research Service and the Congressional Budget Office, were tasked over the decade after the Persian Gulf War with providing numerous studies and analyses to inform the oversight process. Concerned about the seemingly ineffectual and redundant technology investment efforts of the individual Services, in 1994 Congress legislated a joint approach for research, development, and acquisition. (Box 2.1 summarizes the organization of the Joint CBD Program.)

BOX 2.1
DOD's Joint Chemical and Biological Defense Program

The National Defense Authorization Act of Fiscal Year 1994 (Public Law 103-160, Section 1703) stipulated that "the Secretary of Defense shall . . . assign 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 [OSD]." Concerned about the "backwater" status of chemical and biological defense in the Services, with many redundant and subcritical efforts, Congress sought both to raise the visibility of the new program—the Joint Chemical and Biological Defense (CBD) Program—and to create critical levels of effort around common Service needs. The program integrates and controls funding for all research, development, and acquisition (RDA) but not operations and maintenance or training, which remain the responsibilities of each Service.

The program is managed through a complicated joint Service/OSD committee structure that separately addresses medical and non-medical defensive measures. In the non-medical area, the program is further broken down into requirements and materiel groups, each organized around five "commodity" areas: contamination avoidance, individual protection, collective protection, decontamination, and modeling and simulation. Each committee is governed by the "one Service, one vote" principle. Total funding for the program in Fiscal Year (FY) 2001 was approximately $870 million, with about 45 percent in research, development, testing, and evaluation (RDT&E) and the rest in procurement. Funding for FY 2002 remained at about the same level, but reversed the split between RDT&E and procurement. The Army serves as the executive agent, but a Service lead executes each program.

As of the writing of this report, the management structure of the Joint CBD Program is undergoing change at the direction of the under secretary of defense for acquisition, technology, and logistics. The requirements committee (the Joint Service Integration Group) has been replaced by a single office in the J8 (plans and programs) section of the Joint Staff that will develop the joint requirements documents in keeping with the norm for joint programs. The materiel process for RDA is still undergoing reorganization, but one step taken is that of reassigning the lead role for RDA to the Defense Threat Reduction Agency.

In addition to the concerns of DOD and congressional leadership noted above, the Defense Science Board (DSB) has generated a series of reports flagging the urgency of addressing asymmetric threats in general and BW threats in particular, and elaborated strategies for dealing with them. The 1997 DSB study on the transnational threat highlighted the emerging asymmetric challenge posed by new forms of terrorist organizations and, specifically in the chemical and biological weapons domain, recommended strategies for reducing vulnerabilities while "getting smarter" about the problem.[9] The 2001 DSB study on biological defense, cosponsored by the Threat Reduction Advisory Committee (TRAC), characterized the threat to U.S. military strategy posed by biological weapons and elaborated a systems approach to dealing with that threat.[10] The DSB Task Force on Intelligence Needs for Homeland Defense[11] and its Task Force on Defense Against Biological Weapons[12] reinforced similar themes and provided direction for analytical and technical investments. The alarm bell rung in these studies has been echoed in a string of consistent statements from senior intelligence community officials before congressional committees describing a growing body of evidence about and increasing sophistication in the capabilities of chemical and biological weapons proliferators.

General Finding: A Navy Not Well Prepared

Despite the high level of concern and guidance described above, there was a substantial body of informed criticism on the progress of the Services, including the Navy, in developing strategies and sustaining readiness to address the growing specter of the threat:

- *1995 and 1996.* The Center for Counterproliferation Research at the National Defense University undertook a series of assessments of Service readiness. A February 1996 report on the Navy concluded that fleet readiness had substantially eroded in the period since the Persian Gulf War.[13]

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[9]Office of the Under Secretary of Defense for Acquisition and Technology. 1997. *Report of the Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Vol. I,* Washington, D.C., October. Available online at <http://www.acq.osd.mil/dsb/trans.pdf>.

[10]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June, p. vi..

[11]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2002. *Report of the Defense Science Board Task Force on Intelligence Needs for Homeland Defense,* Washington, D.C., January.

[12]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board Task Force on Leveraging Advances in Biotechnology and Medical Informatics to Improve Homeland Biodefense Capabilities, Vol. IV,* Washington, D.C., October.

[13]Center for Counterproliferation Research. 1996. *The Impact of Nuclear, Biological, and Chemical Weapons on Naval Operations and Capabilities,* National Defense University, Washington, D.C., February.

• *1997.* The Institute for Defense Analyses undertook a review of the counterproliferation effort for the Defense Special Weapons Agency (which was later subsumed by the Defense Threat Reduction Agency). This review included a survey of thinking within the defense community about how much progress had been made by the Services, the combatant commanders, the acquisition program, and so on, in coming to terms with the implications of chemical and biological weapons proliferation as a defense planning problem. That survey described a widespread perception that the Navy was the farthest behind of the Services and that it showed little evidence of seeking to catch up.[14]

• *1997 to 2001.* The Center for Naval Analyses Corporation (CNAC) undertook a variety of studies, some with Navy sponsorship and others with sponsorship by DTRA, to assess and recommend improvements in the defense against chemical and biological weapons. A number of consistent themes run through these studies:

— "The Navy does not fully understand if its forces can operate effectively in a CBW [chemical and biological warfare] environment."[15]

— "The Navy currently has little, if any, data that quantify operations in a CBW [chemical and biological warfare] environment."[16]

— "Despite the apparent consensus at the policy level on the seriousness of the CBW [chemical and biological warfare] threat and the need to take action, there seems to be some degree of ambivalence in the Navy outside the CBW community."[17]

Many of these studies provide baseline assessments of naval response capabilities to chemical and biological threats. The assessments are strikingly negative. They note technical kinds of deficiencies, including the ability of naval forces to detect chemical and biological warfare agents in a timely and adequate manner; to protect sailors, ships, facilities, and operations; and to decontaminate without compromising mission performance. They also note deficiencies of an operational kind, including both training and readiness shortfalls. The cumulative picture of naval capabilities that emerges from these studies is that naval forces need to substantially improve their preparedness—across the full spectrum of technical and operational requirements—in terms of capabilities, understanding,

[14]Roberts, Bradley, and Victor Utgoff. 1998. *Counterproliferation: A Mid-term Review,* Institute for Defense Analyses, Alexandria, Va., annotated brief.

[15]East, James R., Stephen J. Guerra, J.G. Ebert, Susan C. McArver, M.W. Ewell, and A.S. Hashim. 1999. *Navy Implications of Nuclear, Biological and Chemical (NBC) Proliferation,* Center for Naval Analyses, Alexandria, Va.

[16]East, James R., Stephen J. Guerra, J.G. Ebert, Susan C. McArver, M.W. Ewell, and A.S. Hashim. 1999. *Navy Implications of Nuclear, Biological and Chemical (NBC) Proliferation,* Center for Naval Analyses, Alexandria, Va.

[17]Perrin, David A. 2000. *Chemical and Biological Defense Requirements Study*, CRM D0002877.A1, Center for Naval Analyses, Alexandria, Va., p. 1.

and planned improvements, both today and tomorrow, in order to better address chemical and biological threats.[18]

These studies also emphasize that the Navy lacks a common operational picture of the chemical and biological threat environment and thus is moving chemical and biological defense technology into the force without the concepts necessary to exploit new capabilities for winning at the campaign level against an intelligent and determined adversary. (Without a common operational picture, the Navy might also be moving poorly suited, or even the wrong, technologies into the force.) Navy Component, Central Command (NAVCENT) and other Navy groups facing the possibility of operations in high-threat environments are only beginning to assess and understand the conceptual, operational, and command and control challenges associated with effective protection, defense, recovery, and sustained operations in chemical and biological environments.[19]

These concerns about naval capabilities, readiness, and even interest have also been echoed in a series of studies commissioned by Congress and conducted under the auspices of the Congressional Budget Office.[20] Readiness concerns have been echoed by DOD's own Inspector General.[21]

The committee found that, with some notable exceptions as discussed later in this chapter, these assessments appear to be accurate. In fact, the information gathered in the course of this study suggests that the Navy is not as prepared as it should and could be in terms of its readiness posture for defense against chemical or biological attack. The Marine Corps is significantly better prepared than the Navy in terms of operational readiness, but its emphasis has been on dealing with

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[18]Brooks, L.F. 1999. *Report on CNA Tasks for the Project on Integrated NBC Defense for the Defense Threat Reduction Agency,* Defense Threat Reduction Agency Annual Conference, CME 0599061900, Center for Naval Analyses, Alexandria, Va., June.

[19]Edsel D. McGrady (Center for Naval Analyses) has led a series of studies for the Navy, including "Shipboard Biological Hoax," "Biological Attack on a Pier," "Shipboard Biological Contamination Scenarios," "The NBC Warfight: Concepts from the COMUSNAVCENT Experience," "Biological Warfare Limited Objective Experiment," "Preparing a Forward Fixed Site for Chemical, Biological, and Radiological Defense: The COMUSNAVCENT Experience," "Operation Desert Thunder Quicklook: Chemical and Biological Defense," "Operation Desert Fox: CBR Defense," and "Navy Role in Homeland Defense Against Asymmetric Threats."

[20]See, for example, General Accounting Office. 2000. *Weapons of Mass Destruction: DOD's Actions to Combat Weapons Use Should Be More Integrated and Focused,* GAO/NSIAD-00-97, Washington, D.C., May 26; General Accounting Office. 2001. *Chemical and Biological Defense: Units Better Equipped But Training and Readiness Reporting Problems Remain,* GAO-01-27, Washington, D.C., November 14; General Accounting Office. 2001. *Chemical and Biological Defense: Improved Risk Assessment and Inventory Management Are Needed,* GAO-01-667, Washington, D.C., September 28; General Accounting Office. 2001. *Chemical and Biological Defense: DOD Needs to Clarify Expectations for Medical Readiness,* GAO-02-38, Washington, D.C., October 19.

[21]Office of the Inspector General. 1998. *Unit Chemical and Biological Defense Readiness Training,* Report No. 98-174, Department of Defense, Arlington, Va., July 17.

chemical agent threats. (Chapter 3 provides more specific findings and recommendations with respect to the Marine Corps and what the Navy can build on.)

General Finding: Lessons to Be Learned from the Air Force

In the period since the Persian Gulf War, the Navy has been slow in dealing with chemical and biological defense planning requirements, while the Air Force, by contrast, is widely seen as having been more responsive to the new situation and having taken substantial initiatives to innovate and find practical operational solutions. The following short description of the Air Force's learning curve may be instructive to the Navy as it considers how to reap similar operational benefits.[22]

- *Awareness.* Like the Navy, the Air Force was left with concerns following the near brush with chemical and biological weapons in the Persian Gulf War. Although the Air Force had established passive defense capabilities and a program to bring new technologies into the field, it took a series of discussions in Deputy Secretary of Defense John White's Counterproliferation Council, backed by associated critical analyses, for Air Force leadership to admit that having some capabilities in hand and some better ones in the technology pipeline does not necessarily equate with an operational ability to fight and survive in a CW or BW environment.
- *Commitment and guiding principles.* Following a reorganization to increase command emphasis and focus on chemical and biological defense, the Air Force undertook a series of internal reviews, studies, and analyses in a search for lessons that could guide more effective planning. One of these lessons was that the Air Force could not rely on another Service (in particular, the Army as executive agent for the Joint CBD Program) to understand its unique operational environment. A second lesson was that the specific operational requirements of sustaining Air Force combat operations in a contaminated environment were not necessarily in line with generalizations across all the Services regarding combat degradation factors, as developed in the Joint CBD Program. A third lesson was that there are substantial operational, organizational, and planning differences between CW and BW.
- *Near-term implementation steps.* The Air Force then defined a view more tailored to its own needs of what comprehensive chemical and biological defense readiness should look like. That view encompassed clear and executable guidance, educated and aware personnel, the right people responding with the right equipment, training, and exercises focused on these threats—all backed by a comprehensive and functioning assessment and inspection program.

[22]This summary is drawn from a presentation made on December 18, 2001, to this committee by Col Thomas (Dutch) Miller (USAF ret.) and Col Donald Minner, USAF: "Counterproliferation: Air Force Perspectives on Chem/Bio Defense."

• *Longer-term strategy.* The Air Force next elaborated its Counterproliferation Master Plan. That plan consolidated existing counterproliferation guidance to provide overarching guidance for coordinating Air Force assets and efforts for counterproliferation, instituted an investment strategy process, and directed the major commands to develop implementation plans to organize, train, and equip forces. It is important to note that the Air Force has addressed chemical and biological passive defense in the context of the broader mission space of counterproliferation to understand the trade-offs and synergies with active defense, counterforce, and consequence management.

• *Refining requirements.* Keeping in mind its specific technology needs, the Air Force then took a more critical look at the ability of the Joint CBD Program to meet its long-term needs. This process led to more effective exploitation of the Joint CBD Program to meet Air Force-specific requirements, as well as to a more independent parallel program for defining and meeting Air Force-unique operational needs, most notably for determining agent fate on contact with runway surfaces.[23] Of note also are the operational procedures that the Air Force has developed in concert with the National Oceanic and Atmospheric Administration (NOAA) to assign risk levels to geographic regions on the basis of local meteorological conditions and to take sensible precautions if warranted (e.g., simple protective masks for sleeping when threat concerns combine with meteorological conditions for "ideal" biological weapons attack conditions at night).

General Recommendation: Strengthen and Integrate Across the Board

Naval leadership should commit to strengthening and integrating chemical and biological weapons defense considerations into all naval functions.

In order for the Department of the Navy to achieve the needed improvements in chemical and biological weapons defensive posture, naval senior leadership, especially in the Navy, should step up to every aspect of the problem. An approach that is too narrow will leave potentially crippling vulnerabilities in naval power projection capabilities. Chemical and biological defense crosscuts warfighting, support, and infrastructure operations. As such, chemical and biological defense should become integral to each area—currently it is not—and it should be supported with expertise in the technical and operational organizations throughout the Department of the Navy—currently it is not. The route to that integration is through the normal institutional mechanisms: experimentation and concept development; policy, doctrine, and tactics, techniques, and procedures

[23]The committee recognizes that the larger chemical and biological defense community has concerns about the technical results of the agent fate studies from which the Air Force has revised its CONOPS, but the committee finds that the general approach the Air Force has taken, as described in this section, offers an excellent model to follow.

(TTPs) development and promulgation; RDA prioritization; test and evaluation; education and training; readiness assessments; and so on. The needed integration should also be reinforced through career paths for chemical and biological defense professionals. Such a comprehensive approach can only be motivated and sustained by the CNO and his senior leaders. Commitment also includes a much higher profile in the Joint Chemical and Biological Defense Program to ensure that naval-specific requirements are being adequately addressed. (See also Chapter 4, "Non-Medical Science and Technology," for a more complete discussion on this point.)

GETTING STARTED

General Finding: The Need for Defense in Depth

As the Air Force experience suggests, an effective defense posture against the CW or BW threat requires far more than passive defense. Effective passive defenses against CW or BW, which are the focus of this report, are an essential capability, but they are only one part of a larger whole—and both the Navy and the Marine Corps should understand the trade-offs and synergies that exist among the other contributors to a robust defensive posture. Against a state adversary willing and able to use chemical and biological weapons in battlefield and theater-wide attacks, effective defense requires not only passive defense, but the development of a more comprehensive architecture that would include the following: counterforce attack capabilities to diminish the adversary's attack capability, active defenses to reduce any attacks launched by air, passive defenses to diminish the impact of those attacks on forces in theater, decontamination capabilities to restore contaminated facilities and personnel to service, consequence management capabilities to cope with broader base and public demands, medical therapeutics both pre- and post-attack, and so on.[24] The existence of robust active and passive chemical and biological defense capabilities would positively influence overall counterproliferation capabilities. Against a state or nonstate adversary employing chemical or biological weapons in covert and limited attacks on U.S. forces, a high level of force protection is also essential. The recent DSB/TRAC study on BW summarized the spectrum of capabilities necessary to meet the BW challenge in this context:

- Effective intelligence and awareness;
- Capability for warning and characterization of attacks;
- Capability for vaccination against biological agents;

[24]Cohen, William S., Secretary of Defense. 1997. *Proliferation: Threat and Response 1997,* Washington, D.C. Available online at <http://www.defenselink.mil/pubs/prolif97/>.

- Widely available passive protection—masks, citadels;
- Rapid, effective incident and crisis response;
- Access to therapeutics to minimize casualties;
- Capability to decontaminate and restore function;
- Forensic capability to guide attribution, retribution, and deterrence; and
- International laws and treaties and methods of enforcing them that prevent the development and use of biological weapons.[25]

Because none of the tools in this toolkit can be relied upon to provide the complete solution to the problem, it is necessary to develop a defense-in-depth approach—essentially, a layered defense that exploits the synergies among individual components in order to provide the strongest possible performance of the overall system. The DSB/TRAC BW study describes the utility of such a systems approach as follows:

> This strategy is a composite of defensive components. Individually, none provides a strong defense; collectively, they will make biological attacks uncertain, often unsuccessful, and risky for the attacker, and thus reduce the attractiveness of biological weapons. It will deter the use of biological weapons and blunt their impacts in the event they are used. It will also provide the United States with options to hold accountable those determined to be responsible.[26]

Given that there is no perfect solution to the problem in the sense that risks cannot be fully eliminated, the challenge for naval forces is to manage those risks in ways that enable it to accomplish its missions at reasonable costs.

General Finding: Basis for Optimism

The kinds of operational capabilities that the Navy needs in order to be able to carry out its missions in a chemical or biological threat environment appear within its reach. To attain the necessary capability and readiness, it should support and sustain improvements in passive defenses, training, and leadership awareness—but it should also do some major things quite differently. It should see the threat in an entirely new way. It should not rely solely on the notion that the mobility of ships at sea is adequate defense against this threat in the era of asymmetric conflict. The Navy should look well beyond passive defenses to understand the full contours of a CW or BW defense posture. It must plan on the basis of a risk-management approach and train and test to refine its TTPs.[27]

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[25]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June., p. vi.

[26]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June, p. 4.

Given the apparent lack of progress over the last decade, some will be skeptical that the Navy will actually succeed at engineering the necessary risk management posture, but there are good reasons to be optimistic:

- Within the Navy there are pockets of excellence on these issues—for example, at NAVCENT, which has been aggressive at finding innovative solutions to the challenges facing naval operations on base and at sea in the Persian Gulf.
- The Navy's own experience in struggling to come to terms with mine warfare vulnerabilities, an area with analogous problems, has shown that diligence, leadership, and innovation can pay substantial dividends.[28]
- The U.S. Air Force has used risk-based analyses to develop innovative approaches to sustaining air operations in a chemical or biological threat environment, offering another useful model, as presented above. Of special note is the Air Force's ability to quantify the relationship between sortie generation rates and improved technical chemical and biological defense capabilities and CONOPS for contaminated battle environments.
- The British Royal Navy has characterized and solved some of the problems now coming into focus for the U.S. Navy and can serve as a useful model and partner.[29]
- Fleet operators in the commercial world and emergency response personnel in the civil sector, who face hazardous risks not unlike the chemical and biological threat to naval forces, have developed and implemented an effective risk management capability, which can also serve as a useful qualitative, if not quantitative, model.[30]

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[27]Standards for risk factors in contamination are discussed in the subsection entitled "Decontamination" in Chapter 4 and in the subsection entitled "Standards" in Appendix C.

[28]While there are many differences between chemical and biological warfare (mainly antipersonnel) and mine warfare (mainly antiplatform), there is a broad analogy between them in net effect on operations. In a warfighting context, both are used to slow operations, to deny areas to maneuver, and thereby to affect entire campaigns. Additionally, both involve mixtures of old and new technologies, are attractive for use in "asymmetric" attacks, and are difficult, persistent, and unpopular problems. The Navy had embarrassing mine warfare experience in Desert Storm and has taken corrective steps to improve its defensive mine warfare capability. The Navy has improved the capabilities of its specialty mine countermeasures (MCM) force, not with new systems but through training and organizational changes. The Navy is also moving to gain an organic MCM capability in battle groups so that they will not be slowed waiting for the arrival of its dedicated ships. For chemical and biological warfare, similar steps can be taken (as elaborated in subsequent chapters): train and organize specialty groups and develop an "organic" capability in the fleet to maintain speed of operations.

[29]Examples include assessments on likely threat environments (e.g., toxic industrial chemicals in littorals); operational approaches (e.g., splash wetting by rocking ships' surfaces in high-threat environments); and technical developments that closely tie the R&D community with operators throughout the development cycle.

General Recommendation: Operational Net Assessment

Get started with an operational net assessment.

The landscape of chemical and biological threats and targets is enormous, but all environments and situations do not carry the same level of risk, as discussed in Chapter 1. The basis for focusing energies and investments should be an operational net assessment by each operational fleet commander. Such an assessment would elucidate the consequences of adversaries' use of chemical or biological weapons, examining not just impacts on individual ships but on missions more broadly, including the combatant commander's operational theater and strategic goals. The assessment should identify not just primary but also secondary and tertiary effects of attack. It should, for example, look beyond ship and facility vulnerabilities and the challenges of recovering and sustaining operations post-attack. It should understand the impact of an attack on nearby civilian populations, whether CONUS or OCONUS, and the consequences for logistics support and future access to a port if it were attacked. The assessment should also explore the consequences of an adversary's capability to subject U.S. forces to periodic re-attack. Such an assessment should provide a vision of both mission failure—at the tactical, operational, and strategic levels—and the essential ingredients of mission sustainment and success.

This assignment should be undertaken by groups with the depth of analytical experience needed to conduct such assessments, including those of both threats and responses in context. As an example of what is needed, the Fifth Fleet has enlisted expert help from the analytical community to perform assessments specifically relevant to its area of responsibility (AOR). In addition, the U.S. Joint Forces Command (USJFCOM) is developing an operational net assessment capability for dealing with terrorist threats in the joint context. N-70, responsible for requirements in the Office of the Chief of Naval Operations, aided by appropriate organizations with the know-how for performing such assessments, should then work with the regional commands to develop assessments tailored to the specific attributes of the respective regions—specific adversaries' threats, U.S. and allied

[30]In spite of the impression the press may have created, management of Norwalk virus infection aboard cruise ships is a good example of risk management. The virus is a worldwide problem in both land- and sea-based environments. It is spread by close personal contact, with transmission accelerated in confined spaces. The illness is being brought aboard ships primarily by passengers from Europe and Africa. The detailed record keeping and reporting of the cruise industry compared with that of land-based institutions makes occurrence of the illness in that environment more visible. The cruise industry has established a risk management committee that has developed extensive technical information on the illness and on methods for bringing it under control. Compared with land-based situations in which data are available, these methods have been effective at managing both the incidence and severity of the illness. The techniques employed include surveillance, reporting, and response actions graded to the degree of risk.

capabilities, geographic factors, and operational objectives—as the foundation for risk-based planning. This task should draw on the collective experience and knowledge of operators within the fleet and naval command as well as on expertise in the intelligence community and regional commands.

SUMMARY

Box 2.2 provides a summary of the findings and recommendations in this chapter.

BOX 2.2
Summary of General Findings and Recommendations

Leadership

Findings

- For more than a decade, concerns have been expressed in Congress and the Office of the Secretary of Defense and by selected senior naval civilian and military leaders regarding Service-general and Navy-specific abilities to deal with chemical or biological warfare.
- Internal and external studies and assessments have highlighted the erosion of Navy readiness and capabilities for chemical and biological defense since the Persian Gulf War. The Marine Corps, on the other hand, has been more aggressive and consistent in improving both capabilities and preparedness.
- Finding the Air Force in a similar situation in the mid-1990s, Air Force leadership undertook internal initiatives to innovate and find practical operational solutions.

Recommendation for the Navy

- Naval leadership, building on the policies recently established by the Chief of Naval Operations and the Secretary of the Navy, should commit to the integration of chemical and biological defense considerations into all naval functions. As with any warfighting and sustainment function, this integration can be accomplished through the normal institutional mechanisms: experimentation and concept development; policy, doctrine, and tactics, techniques, and procedures (TTPs) development and promulgation; research, development, and acquisition prioritization; test and evaluation; education and training; readiness assessments; and so on. (More specific ownership for these actions is discussed in Chapters 3 through 5 of this report.)

Getting Started

Findings

- Since no single element can achieve the goals for effective chemical and biological warfare defense, a defense-in-depth approach, which creates a layered defense that exploits the synergies among individual components in order to pro-

continues

vide the strongest possible performance of the overall system, should serve as the basis for future naval actions to improve posture.

- Examples of such approaches that assess and weave together options in the context of acceptable levels of risk can be found with the Navy Component, Central Command (NAVCENT); the British Royal Navy; the U.S. Air Force; and commercial fleet operators and emergency responders.

Recommendation for the Navy

- Following the example set by the Fifth Fleet, each operational fleet commander should get started with an operational net assessment that provides a vision of both mission failure—at the tactical, operational, and strategic levels—and the essential ingredients of mission sustainment and success.

3

Operations: Specific Findings and Recommendations

INTRODUCTION

How can the principles elaborated in Chapter 1 be translated into real improvements in the chemical and biological weapons defense posture of U.S. naval forces? This chapter explores the operational dimension and priorities for achieving tangible operational improvements, both near term and far term, regardless of the state of the art of supporting technical capabilities. The discussion, expanded in the remainder of the chapter, focuses on three basic findings and recommendations:

1. *Operational requirements.* The committee found that the Navy—and in some respects the Marines—have not defined the chemical or biological warfare defense operational requirements for mission success. The committee recommends that this situation be remedied throughout the entire force by defining a comprehensive concept of operations (CONOPS) with supporting policies and practices. This CONOPS should address all dimensions of naval operations that go into sustaining a mission: how to prevent an attack, how to recover from and minimize the impact of an attack, how to restore naval operations after an attack, and, above all, how to achieve mission goals. How U.S. naval forces plan to operate and fight in a chemical or biological warfare environment should then drive naval priorities in doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF), as well as in research and development (R&D) and acquisition.

2. *Focal point for CONOPS.* The Navy appears to lack a focal point for the development of policy, concepts of operations, and doctrine for chemical or biological warfare defense; the Marine Corps appears to place greater emphasis on the problem. The committee recommends that the Navy Warfare Development Command (NWDC) and the Marine Corps Combat Development Command (MCCDC) be clearly designated as the primary authorities and given the requisite resources for the development of policy, concepts of operations, and doctrine for chemical and biological warfare defense issues.

3. *Readiness.* Navy readiness for chemical and biological warfare defense needs improvement. Sustained improvements toward remedying these deficiencies require establishing standards for readiness, training and exercising to those standards, and developing a reporting system attuned to this area. Special urgency should be given to bases and shore installations and to the logistics chain. *In fact, if the Navy chooses to implement only one recommendation from this report, it should be that of committing to dramatically improve readiness.*

OPERATIONAL REQUIREMENTS

Operational Finding: A Need to Expand and Clarify

Although this committee reviewed a great deal of material about the chemical warfare (CW) and biological warfare (BW) threat and the requirements of CW and BW defense, it found little evidence that the Navy has effectively defined the operational requirements for mission success in the presence of such threats across its full mission space. To be sure, the Navy has thought about the requirements of operating ships at sea in contaminated environments, but in asymmetric strategies, attacks on ships at sea are less likely than are attacks on ships in port and on shore installations and logistics infrastructures. Attacks on ships in the littorals also seem a higher probability than do attacks on ships in deep-ocean waters. The need for concern regarding shore installations and logistics as potential points of CW or BW vulnerability is especially evident in the context of findings of the USS *Cole* Commission regarding the October 2000 attack on that ship in Yemen.[1] In surveying this broader base of naval targets, the Navy's goal must be an understanding of how to sustain the mission—how to minimize the effects of such attacks if it is unable to prevent them in the first place, how to recover from attacks once they are conducted, how to restore normal operations, and how to achieve mission goals in a post-attack environment.

[1]Crouch, GEN William W., USA (Ret.), and ADM Harold W. Gehman, USN (Ret.). 2001. *DOD USS Cole Commission Report*, Washington, D.C., January 9. Available online at <www.defenselink.mil/pubs/cole20010109.html>.

Operational Recommendation: Comprehensive CONOPS

Define the chemical and biological warfare defense operational requirements for mission success across the entire naval force through a comprehensive concept of operations, with supporting policies and practices. The scope must address all dimensions of naval operations.

- *Ships at sea.* These ships make very difficult and thus unlikely targets for attack with biological or chemical weapons, although it is important for the Navy to address potential contingencies as a result of other indirect means. The Navy has some tactics, techniques, and procedures (TTPs) for such contingencies, but those reviewed by the committee appear to be outdated, inconsistent, and/or incomplete with respect to the types of consequences that might be expected from an attack of this kind.
- *Ships in the littorals.* These ships make far more lucrative targets to asymmetric adversaries seeking to impede force projection operations than do ships at sea. In such situations, chemical weapons in particular may be a threat. Here again, U.S. Navy TTPs and protective equipment allocations reviewed by the committee appear to be holdovers from the Cold War era and do not effectively address current threats. The focus of these TTPs seems to be on the challenges of protecting personnel from the adverse effects of chemical or biological attack without sufficient attention to sustaining and/or restoring combat operations or other missions.
- *Shore installations and bases.* The committee believes that shore installations are at risk to a broad spectrum of asymmetric threats. They are both operational and symbolic targets, offering an adversary the opportunity to disrupt power projection operations while also punishing nations which host that presence and tarnishing the image of American power.

In general, the committee found in its review no TTPs for shore installations that effectively address these vulnerabilities outside the recent Joint Staff guidance.[2] Navy shore installations appear better equipped to deal with chemical attacks than with biological attacks, but their emphasis has been on consequence management from a hazardous material (HAZMAT) perspective more than on field decontamination and collective protection capabilities as needed to sustain and/or restore operations. At present, relevant expertise resides largely in base fire departments and HAZMAT teams. In addition, given the potential that such an attack may cause broad area contamination as well as many casualties (and if biological, may go undetected for days or longer), the committee believes that base commanders should forge strong relationships with local civil authorities in

[2]"Chemical Warfare (CW) Agent Exposure Planning Guidance" Joint Staff memorandum MCM-0026-02, April 29, 2002, Office of the Chairman, Joint Chiefs of Staff, referred to in Chapter 1, provides CW defense planning guidance that covers the spectrum of operating environments.

charge of emergency response and public health care.[3] On the basis of its limited observations, the committee believes that the requisite leadership-level relationships, which must be both formal and informal to be effective, have been established in only a few cases; most working relationships between base and off-base HAZMAT and other first-responders, where they do exist, have not been reinforced by adequate joint exercises.

In contrast, the Marine Corps appears markedly better prepared with respect to chemical and biological warfare threats to shore installations and bases, if the committee's limited exposure accurately reflects the larger picture. In particular, the committee applauds the leadership of the Marine Corps Base at Camp Lejeune, North Carolina, and its partnership program with Onslow County, North Carolina, designed to improve safety, security, and emergency response. Objectives of the Camp Lejeune–Onslow County partnership include cooperative efforts in the areas of fire and rescue, law enforcement, and hospital and medical services, as well as in other important areas such as common/interoperable communications capabilities and school safety concerns. The committee observed that the Camp Lejeune–Onslow County partnership provides a model that would yield significant benefits if adopted by base commanders throughout the Navy and Marine Corps.

- *Commercial ports.* Today's naval forces are dependent on continuing access to and use of a wide range of commercial capabilities and facilities. Despite this dependence and the attendant vulnerability—and despite the hard lessons learned from the USS *Cole* attack—the committee found in its review little more than sporadic evidence that the Navy's TTPs effectively address defense against chemical or biological attack while ships are in port. On a positive note, the fact that the Office of the Secretary of Defense is sponsoring a new advanced concept technology demonstration (ACTD) focused on the problem of contamination avoidance at seaports of debarkation suggests some level of recognition that the problem needs to be addressed.
- *Logistics.* The committee observes that the supply chain provides a delivery mechanism for surreptitious chemical or biological attack. Our nation's recent experience with anthrax delivered through the U.S. mail system provides a relevant illustration of the disruption and psychological response that such an attack can cause. Food and water supplies offer similar delivery opportunities. Attacks by such means should be considered within the context of an overall risk assessment, since they could significantly degrade operational readiness.

In each of the operational dimensions discussed above, it is necessary to have a clear idea of how an adversary might use chemical and/or biological

[3]SECNAV Instruction 3300.3A, "Combatting Terrorism Program Standards," May 16, 2002, Office of the Secretary of the Navy, Washington, D.C., includes links to the civilian sector. Available online at <http://neds.nebt.daps.mil/directives/3300_3a.pdf>.

attacks to achieve its objectives, whether operational or political. And it is necessary to have a clear idea of how to restore mission-essential capabilities in the wake of such attacks, while also coping with their consequences and trying to prevent follow-on attacks. As this review of TTPs suggests, the Navy's current efforts at dealing with these issues address only a small part of the problem.

The committee believes that, as a more focused aspect of the operational net assessment recommended in Chapter 2, defining the operational requirements for mission success is essential before the Navy and Marine Corps can take further steps for achieving significant improvements in chemical and biological warfare defense. How U.S. naval forces plan to operate and fight in a chemical or biological warfare environment should then drive naval priorities in doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF), as well as in R&D and acquisition. Joint Publication 3-11[4] prescribes that U.S. armed forces be prepared to conduct operations in a chemical or biological warfare environment with minimal degradation of warfighting abilities. Units of the Navy, and to some extent the Marine Corps, do not fully comply with this requirement today because they lack an effective warfighting strategy for these environments. Absent a comprehensive strategic concept, it may actually be counterproductive to acquire the various pieces of hardware currently in development by the Joint CBD Program. A comprehensive strategic concept should recognize that the effects on personnel, methods of delivery, and resulting force vulnerabilities would be different for a chemical attack and a biological attack. Modeling, simulation, and force- and unit-level experimentation can help sort out what that operational concept might be, but these are operational rather than technical issues. At the root of Navy and Marine Corps discussions in each of these areas is an operational decision regarding how they plan to fight and win in an environment that has been or may be contaminated by biological or chemical agents.

The operational perspective adopted by naval forces will, in large measure, determine how the Navy and Marine Corps address challenges posed by chemical and biological threats. For example, one could assume that biological and chemical weapons pose an overwhelming threat to the effectiveness of naval operations whenever the forces are not on the high seas. Alternatively, one could take the position that chemical and biological weapons create a special environment in which the Navy and Marine Corps will continue to conduct operations in support of national objectives. The former might lead to a focus on detection, avoidance, and retribution. The latter might lead to placing higher priority on consequence management and the ability to sustain operations (as is being recommended

[4]Kross, Lt Gen Walter, USAF, Director, Joint Staff. 1995. *Joint Doctrine for Nuclear, Biological, and Chemical (NBC) Defense*, Joint Publication 3-11, Joint Chiefs of Staff, Washington, D.C. Available online at <http://www.oep-ndms.dhhs.gov/CT_Program/Response_Planning/NBC_Defense.pdf>.

throughout this report). This latter approach might include inquiry into agent fate and effects in a marine environment, decontamination, systems analysis of the effectiveness of various approaches to personnel protection versus acceptance of minimal exposure, and so on.

DOCTRINE

Operational Finding: No Focal Point

To conduct an operational net assessment of the type discussed in Chapter 2—that is, wide-ranging, integrated, tactical, and strategic—requires that the Navy have designated primary authorities and the requisite resources, that is, a focal point. This committee did not find one in the information provided to it. The NNWDC believes that aspects of support could fit within its scope of responsibility, but is not sure that others would agree. The Office of the Chief of Naval Operation's (OPNAV's) recently created Office of Counterproliferation (N70CP) appears to be focused primarily on the Joint CBD Program for technology development and acquisition rather than on operational issues, and the staff from the new office who interacted with the committee had little subject matter expertise in this area. No emphasis on systems analysis was evident from these interactions, possibly due to the lack of staff expertise but more likely due to the absence of tasking. Yet such analysis, underpinned by modeling and simulation, is essential to inform the development of operational procedures, given the diverse spectrum of potential threats and the equally diverse possible consequences.

Operational Recommendation: Roles for NWDC and MCCDC

The Navy should recognize and strengthen the Navy Warfare Development Command in its role of developing and promulgating a concept of operations and the supporting policies describing how naval forces will execute their warfighting and base support missions in an environment that has been or may be contaminated with chemical or biological agents. The Marine Corps should build on the work already under way at the Marine Corps Combat Development Command and with its Chemical and Biological Incident Response Force—and the Navy should leverage that work.

Why NWDC and MCCDC?

The committee discussed, but ultimately decided not to recommend, establishing a separate command to lead Navy warfighting efforts in chemical and biological threat environments. Unlike Navy mission areas (such as antisubmarine warfare), chemical or biological attack or the threat of such attack defines an environment in which all naval forces must be prepared to carry out their as-

signed missions in support of national strategy; thus, a separate operational commander for CW and BW does not appear to be appropriate.

As an alternative approach, some experts who met with the committee suggested that OPNAV could motivate the necessary operational changes. In the Office of Counterproliferation, a core of chemical and biological defense acquisition expertise appears to be coming together, but the organization seems not well suited to the operational challenge identified above. A staff support office with greater depth and seniority than is currently invested in the Office of Counterproliferation is necessary if the requisite expertise, visibility, advocacy, and coordination of planning and programming issues related to BW and CW are to be accomplished. To illustrate this point, let us pose a simple hypothetical question: How would the OPNAV staff be organized two months after a successful chemical or biological attack on a deployed naval unit or on a major naval base in the continental United States? At the very least, it would be invested with more seniority and expertise than are currently found in the responsible OPNAV offices.

The operational answers that the Navy needs can only be found in that part of the Navy devoted to doctrinal questions—the Navy Warfare Development Command. This command appears to be proactive and innovative in analyzing what the Navy should be doing in the near term as well as the long term with respect to both fleet operational procedures and priorities for headquarters actions and acquisition. Reportedly, NWDC seeks to stimulate parallel development of warfare concepts, supporting technology, and the requisite doctrine to effectively employ any new operational capability inherent in the concept.

On the basis of the information presented to the committee, it appears that NWDC has devoted only minimal attention thus far to concept development for explicitly addressing chemical and biological threats. However, joint TTPs for chemical and biological weapons environments have just begun to appear, and the CNO should strengthen this command to develop such concepts. He should also recognize that success will necessarily require an augmentation in terms of subject-matter expertise.

The Marine Corps focuses its concept development and center of warfighting expertise in the Marine Corps Combat Development Command. Fortuitously, it has already expanded MCCDC's scope to include concept development for chemical and biological threats. Concepts for response are also being put into practice and refined through a dedicated operational unit, the Chemical and Biological Incident Response Force (CBIRF), described in the next subsection. The committee commends the progress of both organizations and recommends a sustained effort, especially to address biological threats more comprehensively.

An important point to be made in CONOPs and policy development for this area is that tabletop and computer-simulated experiments are unlikely to be sufficient for defining practical approaches. The Air Force is discovering this with its

field tests on agent fate at contaminated airfields. The committee understands that in these experiments, previously accepted re-aerosolization and/or decomposition and absorption assumptions derived from laboratory results are inconsistent with data being obtained. The data, in fact, would suggest that there is far more latitude for resuming sortie generation than had been previously thought.[5] NWDC and MCCDC should assess the technical basis for assumptions defining their own doctrines and undertake the necessary field experiments in relevant maritime operating environments where those assumptions may not be well founded.

Synergistic Efforts

The role of a focal point is in part to integrate the expertise and capabilities of organizations beyond the focus organization. There are a number of valuable assets for NWDC to enlist as it moves to define the operational requirements of mission success. These include the following:

- *Commander, Fifth Fleet,* has been working these issues in his area of responsibility because the threat of chemical or biological attack is acknowledged as real and urgent. NWDC's ideas will need to be subjected to rigorous operational analysis and validated in fleet experiments. NWDC has worked with the Fifth Fleet to develop standard operating procedures for chemical and biological weapons in Fleet Battle Experiment Foxtrot (FBE F), and continued partnership with Commander, Fifth Fleet, toward this end is recommended.
- *Commander, Fleet Forces Command (CFFC)*, as the parent command of NWDC, can contribute lessons learned in fleet exercises by setting up a center of naval warfighting expertise in CW and BW environments. Operating forces and naval commanders need the advice that could be available from such a center. Establishing this center of warfighting expertise under the CFFC is a logical choice—and may overlap the expertise gathered at NWDC for CONOPS and doctrine development.
- *The naval analytical community* also has something to contribute to the effort of defining the operational requirements of mission success—a defense analysis capability that is currently underutilized. (For example, the Center for Naval Analyses Corporation (CNAC) has developed operational net assessment capabilities specific to the needs of the Commander, Fifth Fleet, but has not been recruited to apply that skill base to other functions in the Navy.)
- *The Homeland Security Office*, recently reassigned from USJFCOM to the U.S. Northern Command (Homeland Security) (NORTHCOM), has a matur-

[5]The committee further understands that there is some controversy associated with the data and that the Joint CBD Program is undertaking a more comprehensive test program.

ing and well-thought-out approach to this problem, focusing on installation preparedness and working with responders in the civilian sector.

- *The Marine Corps's Chemical and Biological Incident Response Force* is a unique institutional resource that should prove extremely helpful in developing operational mastery of the chemical and biological threat. Naval leadership should understand the full importance and promise of CBIRF.

Created in 1996, CBIRF is organized, trained, and equipped to support a lead federal agency in managing the consequences of a terrorist attack. The CBIRF mission states:

> When directed, forward-deploy and/or respond to a credible threat of a chemical, biological, radiological, nuclear, or high yield explosive (CBRNE) incident in order to assist local, state, or federal agencies in the conduct of consequence management operations by providing search, rescue, and personnel decontamination; and emergency medical care and stabilization of contaminated personnel.[6]

CBIRF is a sizable force of about 300 military and civilian contractor personnel—all have other assignments and duties. About half of the force is on alert at any time, while the other half is off alert but working and available in a crisis or emergency.

CBIRF's mission statement indicates that it has capabilities for nuclear, biological, and chemical (NBC) detection, identification, and reconnaissance; casualty extraction; casualty decontamination; technical rescue; provision of medical trauma supplies; and explosive ordnance disposal. It works best if it can be pre-positioned. Its strengths include these:

- It is self-contained.
- It possesses a command and control system that can lead or subordinate itself to local authorities.
- It has the equipment and training to work in a contaminated environment.
- It offers search and rescue capabilities.
- It can provide personnel decontamination services.
- It can provide for emergency medical care and stabilization of contaminated personnel.
- It can offer flexibility in types of personnel deployed for a given situation.

[6]Hammes, Col Thomas X. USMC, Commanding Officer, Fourth Marine Expeditionary Brigade, "United States Marine Corps Chemical Biological Incident Response Force," presentation to the committee on December 18, 2001.

The ability of CBIRF to conduct both domestic and foreign operations has expanded its impact, and the unit has become a catalyst for enhanced chemical and biological warfare defense training throughout the Marine Corps. Although the CBIRF title includes both chemical and biological incidents, the unit's early emphasis has been on responding to chemical attacks.

The committee notes that the CBIRF charter specifically calls for a capability to provide incident response and consequence management training to the other Services. The only instance of which the committee is aware in which the Navy availed itself of this training was by the Commander, Fifth Fleet. It is recommended that the Commander, Fleet Forces Command, direct the utilization of this valuable resource, particularly for or by shore establishments.

- *The Fourth Marine Expeditionary Brigade (Anti-terrorism),* or 4th MEB(AT), which was activated on October 31, 2001, encompasses CBIRF. It is chartered to provide unified combatant commanders with a specialized antiterrorism force to conduct initial incident response as well as to combat the threat of worldwide terrorism.
- *The Marine Corps Marine Expeditionary Units (Special Operations Capable) (MEU(SOC)s)* have an enhanced internal capability, in terms of NBC threats, to support operations from ships in the littorals. The enhanced capability consists of 19 personnel who are trained in the requisite occupational fields and receive an additional level of expertise that is supervised by CBIRF during workups at the home base. This capability should be exploited for cross-training with the Navy during deployment aboard amphibious ships at sea.

Leveraging the Progress by the Marine Corps

The contrast between Navy and Marine Corps progress in defining the operational requirements for mission success, especially in a chemical warfare environment, is striking. The Marines have made significant strides in the development of doctrine to support these activities, whereas the Navy's doctrine development process does not appear to have effectively considered these threats. While acknowledging the growing gravity of the chemical and biological threat, NWDC currently has little of the needed expertise. The committee observes that the Navy could leverage the doctrine developed by the Marine Corps to strengthen its own efforts. The committee also notes that there are opportunities for the Navy to provide officers to the Fourth Marine Expeditionary Brigade command element; staffing the positions could enable the Navy to synchronize its efforts more closely with those of the Marine Corps.

Policy Issues

Working with all of the many assets described above, the Navy should be in a position to define operational requirements by mission area. The more deeply it

delves into these operational questions, however, the more likely it will encounter some analytical problems with significant policy dimensions. This study did not include a comprehensive policy review but did identify a number of problems in which operations and policy overlap. Some of them are described below.

- *Decontamination.* A classic example of operations and policy overlap is in the area of decontamination, as seen in these questions: When is it not possible to fully remove all contaminant, or at least not to do so quickly in time of crisis or war? When has some level of "clean enough" been reached to allow resumption of military or other activity? What should that standard (level) be? Ideally the standard would be established as common across all Services.
- *Levels of protection for warfighting.* Current doctrine appears to imply that incurring zero casualties is the only acceptable outcome for forces under chemical or biological attack. Yet acceptance of some level of casualties is inherent in every other form of warfare. The issue here is when and how to don protective gear and how long to wear it. The committee believes that in many operational situations it may be acceptable for operational forces to wear normal battle clothing, augmented by an adequate mask and gloves, rather than the entire individual protective equipment (IPE) ensemble. Some increase in personnel injury or death from chemical and/or biological attack may be experienced, but the resulting warfighting capability could be significantly greater than that of a similar force that is fully protected in IPE. More importantly, the net threat to the force may, in fact, be reduced more in partial IPE gear than if the naval forces were fully outfitted. An example of an operational scenario in which a trade-off might be appropriate between increased personal protection against the effects of chemical weapons on the one hand and increased mobility and dexterity on the other would be that of a force under conventional high-explosive attack shortly after a chemical agent attack.

Mission-oriented protective posture (MOPP)-level TTPs are, in the committee's view, insufficiently flexible to permit continued operations in a "dirty" environment. Commanders should be provided with a wider array of protective equipment materiel and operational options. It is recommended that NWDC undertake a review of MOPP-level standards and definitions specifically to establish a mask-only condition (currently the mask is donned only at MOPP levels three and four (after the outer garment and boots)). It is equally important to provide local commanders with guidance on when to select one protection option rather than the others. It is noted that both Army and CBIRF doctrine allow employment of a mask-only posture in certain circumstances.

- *Scope of protection at shore establishments and bases.* Defining acceptable levels of risk is important not just at sea but also in shore-based facilities. Since such installations house civilians and dependents in addition to military personnel, questions arise as to who should be issued personal protective equip-

ment and at what level.[7] Personnel at shore establishments (e.g., active duty, civilian employees, dependents) are, in the vast majority of cases, not furnished with personal protective equipment. The level of protection required by these personnel does not rise to the level required by warfighters and should be sufficient only to permit escape from contaminated areas. It is recommended that the CNO's Deputy Chief of Naval Operations (Logistics) (N4), in cooperation with the Naval Facilities Engineering Command (NAVFAC), consider the definition of a requirement for disaster evacuation escape kits (basic overgarment, hood with filter) in selected high-threat/high-value shore facilities. These kits are available commercially for under $500 each.

• *Design standards for protective gear.* An important policy concern relates to the design standards appropriate for personal protection gear for naval personnel. Recall the Air Force experience: it came to understand that the operational requirements of sustained air operations in a CW or BW environment were different from operational requirements from a ground combat perspective (as seen by the Army as the lead agency). The Air Force then began to define performance standards for protective gear unique to its own requirements and to use the Joint CBD Program more directly to support its needs, or to turn to developmental activities outside the Joint CBD Program when its Service-specific requirements were not being met.

The Navy faces a similar issue. For example, as described in Chapter 1, it is acquiring protective clothing and respiratory protection designed to meet very specific challenge conditions that have roots in the Cold War. The Navy must consider whether these challenge levels are appropriate for the post–Cold War threat environment. All such examples lead policy makers to seek greater understanding of the risk being accepted—and these are questions requiring long-term investment—but clear policy guidance, based on what is already known about the threat and practices of other Services, is nonetheless needed now to ensure consistency in near-term actions.

• *Medical countermeasures.* Questions involving operations and policy overlap in this area include these: Who—among the military, dependents, contractors, host nationals, and so on—should be vaccinated and under what indemnification agreements? When is post-exposure treatment more appropriate?

[7]The Joint Staff recently issued new guidance for chemical agent exposure (Joint Staff Memorandum MCM-0026-02, April 29, 2002) that recommends individual protective gear for "other personnel" in addition to military and essential civilians who support military operations. It also comments on what to do with contaminated commercial sea lift ships.

READINESS

Operational Finding: Low Readiness Levels

Although the committee did not visit or evaluate a sufficient number of ships or stations to provide a fully generalized conclusion on overall Navy BW and CW defense readiness levels, the data gathered throughout the study combined with the collective experience of the committee point to a clear conclusion: *Navy chemical and biological warfare defense readiness needs improvement*. In particular, careful attention must be paid to threats in ports and at shore installations.

All elements of readiness were found to be deficient to one degree or another: establishment and enforcement of standards, performance and material condition of installed protective systems, availability and condition of protective equipment, shelf life of medical countermeasures, field exercise programs, basic and unit training, and readiness reporting. To make lasting operational improvements will require addressing each of these areas. This is a topic about which the Navy has previously received strongly worded advice. For example, a recent GAO report[8] pointed out that in 11 years since the completion of Operation Desert Storm, the maintenance and reliability of installed CW and BW defense systems appear to have declined markedly.

One notable exception to the Navy's generally inadequate chemical and biological defense readiness was found in the U.S. Fifth Fleet. In the Fifth Fleet AOR, an acceptable degree of near-term readiness has been achieved—and is being maintained—through rigorous maintenance of legacy systems, aggressive training and exercise programs, training visits by CBIRF, use of CNAC to support ongoing operational net assessments, and most importantly, a command climate which accepts the threat as real and appreciates that the potential consequences are grave. This commendable degree of readiness to confront CW and BW threats was reportedly achieved at reasonable cost.

With the exception of the Fifth Fleet AOR, little evidence of leadership involvement in CW and BW readiness above the unit/base level could be found. Wargaming for these threats has been minimal, although the Desert Breeze series conducted by the Commander, Fifth Fleet, is a notable exception. A robust training program that addresses chemical and biological threats is a vital component of operational readiness, but such training appears woefully inadequate. There is also no uniform unit-level tracking or evaluation of readiness to operate in a chemical or biological threat environment.

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[8]General Accounting Office. 2000. *Chemical and Biological Defense: Units Better Equipped, But Training and Readiness Reporting Problems Remain*, GAO-01-27, Washington, D.C., November, p. 17. Available online at <http://www.gao.gov/new.items/d)127.pdf>.

Recommendation: Establishing Standards and Raising Readiness

The Navy should institute a system of exercises, training, assessment, and reporting aimed at meeting high standards of chemical and biological warfare defense readiness. Central to its effort to come to terms with the readiness challenge is the requirement to define appropriate standards of readiness in each of its mission areas; these standards should be derived from the operational requirements generated by the recommended operational net assessments.

Once again, the Marine Corps provides an important model of how to get started on the problem of establishing standards and raising readiness. The Fourth MEB(AT) has devoted significant attention to chemical and biological defense training. CBIRF also offers a training program from which the Navy could benefit. In addition, the Army has a training program that could be more fully exploited—the Navy currently limits its participation in this program largely to medical personnel, and even that level of participation is low (see Chapter 5).

The MEU(SOC) units receive both individual and unit training prior to deployment, they participate in field exercises, and they are then certified as ready. In addition to this unit, all sailors and Marines in the MEU(SOC) are qualified in NBC individual protective measures before they deploy. While this training meets current requirements, there is an ongoing effort within the Marine Corps to enhance the training content, particularly with regard to biological warfare defense. This capability is resident in the MEU(SOC) units deployed in support of Operation Enduring Freedom.

Standards

The committee observed that a subset of the Marine Corps, specifically the MEU(SOC) units, has established readiness standards in place and is extending them throughout the Marine Corps. In the Navy, CW and BW defense readiness standards are to a large degree defined by individual commanders and commanding officers. It is recommended that the Commander, Fleet Forces Command, coordinate the establishment, validation, and promulgation of readiness standards for CW and BW defense. These standards should be comprehensive and should include exercise frequency, chemical/biological equipment stock levels, C-rating criteria with perishability standards, and reporting requirements.

At the very least, given the drop in readiness over the past decade, it is recommended that the Chief of Naval Operations direct increased attention to the upkeep and maintenance of installed Collective Protection Systems (CPS) and countermeasure washdown systems. The assistance of the president of the Navy's Board of Inspection and Survey should be solicited in this effort.

Of most concern to the committee is that there appear to be no chemical or biological warfare defense readiness standards in place for the shore establish-

ment. Given that this is an area of significant vulnerability, the Chief of Naval Operations, through N4, should establish CW and BW defense readiness standards for all Navy shore installations and ensure their adoption and implementation. In particular, CW and BW defense of shore installations will depend heavily on effective cooperation with local civilian first-responders. The standards should include a requirement for shore installation commanders to establish and exercise civil–military disaster response protocols periodically. The committee believes so strongly in this last point that it is further expanded as a separate recommendation (see the subsection below, "Operational Recommendation: Shore Establishment").

Exercises and Training

The development of innovative and provocative CW- and BW-related wargames and exercises is sorely needed throughout the Navy. The committee observes that useful tabletop exercises, the Desert Breeze series (Commander, Fifth Fleet) and the Coral Breeze series (Commander, Pacific), have been developed and that learnings from the exercises led to both operational and materiel changes in force posture. The CNO should task the CFFC to enlist the appropriate expertise to enable more such exercises. These exercises should be conducted by the numbered fleet commanders and by OPNAV staff at the three-star level to facilitate education in dealing with chemical and biological threats.

The long-term solution to the readiness requirements on both ship and shore is a sustained education and training program for both officers and enlisted sailors. As an interim measure, it is recommended that a special weapons and tactics (SWAT) team for chemical and biological weapons be established within CFFC to (1) validate readiness standards, exercise objectives, training levels, and training and exercise scenarios; (2) develop threat, consequence, and recovery scenarios; and (3) evaluate TTPs for the operating forces as well as for the shore establishment. On a more permanent basis and in keeping with the CNO's training initiative, chemical and biological defense–specific training should be a priority element of Task Force ExCEL (*Ex*cellence through *C*ommitment to *E*ducation and *L*earning). Consideration should be also given to increasing the number of officers with graduate education in chemistry and biology.

Reporting

The standard operational readiness reporting system is largely silent on chemical and biological warfare defense readiness reporting. It is recommended that the Chief of Naval Operations include CW and BW defense readiness reporting in the Status of Resources and Training System (SORTS) for the operating forces and in an appropriate parallel system for the shore establishment. The

committee observed that the Marine Expeditionary Units (Special Operations Capable) are already using the SORTS system for this purpose.

Operational Recommendation: Shore Establishment

Special urgency should be attached to the readiness of shore installations and bases. The Chief of Naval Operations should direct his regional commanders to develop and exercise cooperative safety, security, and emergency response capabilities with their local communities. The Deputy Chief of Naval Operations (Plans, Policy and Operations) (N3) and Director of Naval Reserve (N095) should support regional commanders to access and leverage, where possible, active and/or reserve consequence management units with specialized chemical and biological capabilities that could assist in this area, or to add new units if necessary.

Partnerships with Local Responders

The Navy should focus attention for shore-based units and installations on (1) protecting perimeters and contents of shore installations and ships in port from attack, (2) being prepared to respond in the event of an attack, and (3) planning to mitigate the consequences of any such attacks. The Marine Corps already has an active program focusing on these goals and is making steady progress. The reality of executing these tasks is complicated, however, because the impacts of chemical or biological attacks will rarely be constrained to the boundaries of either military or civilian communities. It is therefore essential that military and civilian leadership and response forces work together in the localities that they share. In fact, the military will not typically be the dominant factor in many localities where significant numbers of military personnel reside, and many installations will have to deal with many rather than one local government entity to achieve cooperative arrangements. In addition, if a chemical or biological attack occurred in communities containing military installations, there would be a nonmilitary local incident commander unless the incident was confined to the military base. The local military commander would then be supporting the local (or state) incident commander or the lead federal agency in the area.

As noted above, in its briefings from and visits to CONUS Navy installations, the committee found scant evidence of chemical and/or biological defense TTPs for shore installations in the event of a military or terrorist attack. Selected elements of the Navy have instituted protocols and Memorandums of Agreement with specific civil agencies to provide for cooperative action in the event of an attack or incident requiring emergency services. However, the committee did not see evidence of any concerted effort to ensure that all Navy installations develop cooperative arrangements both to reduce the likelihood of asymmetric attacks and to mitigate the results of accidental or intended incidents.

The keys to successful military–civilian working arrangements include frequent dialogue among military and civilian counterparts with similar functional responsibilities, annual or more frequent exercises, and mutual assistance, when needed, on a day-to-day basis. A true partnership program goes far beyond the existence of a Memorandum of Understanding or other formal agreement to cooperate. As civilian communities and base commands of other Services are already learning, it is better to sort out how to cooperate and integrate military and civilian activities before a crisis rather than during one. The Navy and Marine Corps force protection and emergency response personnel in U.S. locations should develop excellent working relationships with their civilian counterparts in their areas in light of the asymmetric threats facing the nation.

As noted above, an excellent model of how to accomplish this exists in the award-winning community partnership program that brings together Camp Lejeune on-base capabilities with those of neighboring Onslow County, North Carolina, to improve safety, security, and emergency response. The lessons learned from the activities of this program include the value of—

- Focusing on a laudable goal for all (i.e., improving public safety),
- Achieving improvements through cooperation and synergistic efforts among previously independent entities rather than by requests for added funds, and
- Letting others receive the credit for success (e.g., local politicians and superiors).

All the benefits of this partnership were gained at little marginal cost through the synergies of collective effort. The benefits of such military–civilian cooperation should be sought by all Navy and Marine Corps installations in the United States.

Another laudable Marine Corps effort is an aggressive training process for developing TTPs for all Marine Corps bases for force protection and consequence management. Each exercise, which is based on a contractor-developed scenario, is designed to standardize procedures for incident response and coordination with local agencies and authorities. The Marine Corps is urged to place greater emphasis on chemical and biological attack issues in these exercises at each base. The committee also believes that such exercises would be of benefit to the Navy as it develops its own procedures.

Specialized Response Capabilities

Besides the Chemical and Biological Incident Response Force, there are two other specialized response capabilities of note—the National Guard's civil support teams (CSTs) and the Joint Task Force/Civil Support (JTF/CS).

A CST is a federally funded National Guard unit established under Presidential Decision Directive 39.[9] Under current plans, each state will have at least one CST; more than half of these teams have been certified to date. The mission of a CST is to augment local and regional responders to terrorism attacks in events known or suspected to involve weapons of mass destruction when the local and regional responders need the added and/or specialized skills of the CST. Each CST has about 23 members, all of whom are individually selected and highly cross-trained in multiple specialties. CST capabilities include these:

- Rapid confirmatory analysis of chemical or radiological hazards and presumptive identification of biological agents;
- Expertise to advise on event mitigation, medical treatment, follow-on resources, and other response concerns;
- Verification of the perimeter of the exclusion zone and reconnaissance, surveillance, detection, and sampling capabilities within the contaminated area or "hot zone";
- Downwind contamination projection and assessment of the extent of area to be evacuated;
- On-site analysis of nuclear, biological, chemical, and radiological agents in a mobile laboratory, and sample preparation for subsequent analysis by state and federal laboratories or law enforcement agencies; and
- A communications suite to integrate CST radios with local responders and facilitate wide-bandwidth data reach-back.

The committee also received briefings on the JTF/CS at the Joint Forces Command (recently reassigned to the U.S. Northern Command (Homeland Security)). The JTF/CS can provide a company-sized force ("quick-response force") to support civil authorities in a civil emergency within a 4-hour reaction time, or a battalion-sized force ("rapid-response force") within 18 to 24 hours. The task force is designed to provide life saving, protection, populace care, logistics, engineering, and medical support to civil authorities during emergencies in which state and local authorities need more help.

The committee observes that the JTF/CS, CSTs, and CBIRF contain complementary capabilities and that they are chartered to support different missions. From all three, the Navy can learn much to improve its own preparedness. In CONUS, Navy installations should assess whether naval units will be needed in addition to the expanded set of National Guard CSTs for adequate responsiveness to naval needs and/or to provide backup in case of multiple attacks. For Navy and Marine Corps units and installations overseas,

[9]The White House. 1995. *Presidential Decision Directive 39* (U.S. Policy on Counterterrorism), Washington, D.C., June 21.

the questions are whether the benefits warrant the costs for new, specialized, active duty units and/or what viable alternatives exist that would meet needs in different localities. The committee recommends that the Navy and Marine Corps determine such needs by performing chemical and biological risk assessments for each base. The committee further recommends that the Navy establish a program, much like that of the Marines, whereby each base commander is directed to take action to ensure responsive access to the spectrum of capabilities recommended by such assessments. Options include agreements to draw on assets resident within the local community, established contractor support, and trained military personnel. Such agreements might also include Navy assistance to local communities, including emergency evacuations by ship.

Operational Recommendation: Logistics

Readiness of the logistics system to meet mission requirements under a chemical or biological attack should also be made a priority. The CNO's Deputy Chief of Naval Operations (Logistics) (N4), and the Naval Facilities Engineering Command (NAVFAC) should continue to assess biological and chemical threats to their logistics chain and take action to defend essential support as well as to mitigate the consequences in case of an attack.

Logistical support for Navy and Marine forces, whether they are in or near CONUS or thousands of miles from their home ports and bases, is highly dependent on continuing access to and use of a wide range of commercial capabilities and facilities such as these:

- Container ships (including Marine Corps pre-positioning ships),
- Air freight,
- Ports and airfields,
- Stevedore and air cargo services,
- Fuel vendors and delivery systems,
- Food and potable water sources, and
- Ship maintenance and salvage capabilities.

Absent these and related commercial elements of logistical support, Navy and Marine Corps forces would be incapable of operating forward in any tactically significant way. In other words, U.S. naval forces are unable to sustain themselves without commercial support.

Despite this dependence, the committee did not find that the threat of surreptitious chemical or biological attack delivered by means of the logistics chain has been assessed, much less adequately addressed. During the course of the

committee's several visits to ships and stations and numerous briefings, the issue of operating and support force vulnerability through logistics was never raised. The omission in itself is a concern. The Navy must appreciate that the near-complete reliance on commercial logistical support, both U.S. and foreign, is the Achilles' heel of the forward-deployed force. In the committee's relative assessment of chemical or biological weapons attack options available to adversaries (illustrated in Tables 1.1 and 1.2 in Chapter 1), the most serious vulnerability/consequence scenarios appear to be chemical or biological weapons attacks on commercial ports and airfields and/or on other elements of the logistics chain. Chemical or biological weapons attacks on logistics support nodes and capabilities overseas are much easier to execute than are similar attacks on U.S. bases and ports. Moreover, at the overseas facilities (such as Fujaira, United Arab Emirates), commercial dependence and its attendant vulnerability is greatest. Playing this story out, the committee believes that moderately successful overt attacks on overseas elements of logistics support may be sufficient to induce host countries to deny U.S. forces their use. In some cases the threat of such an attack, or even the perception of such a threat, will be sufficient.

While the risk cannot be eliminated, it can be significantly mitigated. The committee recommends that a threat and consequence analysis focused on the logistics chain, particularly overseas, be undertaken. Findings will assist the regional commanders in adjusting force protection measures. Findings should also be provided to Navy logistics staffs (e.g., Commander, Task Force (CTF) 73) and Military Sealift Command regional offices. Such an analysis can be incorporated into the exercises and gaming activities recommended in the section on "Readiness" above.

SUMMARY

Box 3.1 provides a summary of the findings and recommendations in this chapter.

BOX 3.1
Summary of Findings and Recommendations: Operations

Operational Requirements

Finding

- The Navy has not effectively defined the chemical warfare (CW) or biological warfare (BW) defense operational requirements for mission success across its full mission space, most especially with the shift from Cold War to asymmetric threat environments.

Recommendation for the Navy

- Define the chemical and biological warfare defense operational requirements for mission success across the entire naval force through a comprehensive concept of operations, with supporting policies and practices. Explicit consideration should be given not just to ships at sea, but also to ships in the littorals, ships in port, shore installations and bases, and logistics. Implementation of this recommendation will require commitment throughout the operational Navy, starting with leadership by the Chief of Naval Operations (CNO) and Commander, Fleet Forces Command (CFFC). (See the recommendations below for more specific actions and assignments.)

Doctrine

Finding

- The Navy appears to lack a focal point for chemical and biological warfare defense policy, concepts of operations, and doctrine development related to chemical and biological warfare defense. The Marine Corps appears to utilize the Marine Corps Combat Development Command (MCCDC) for this role.

Recommendations for the Navy

- The Navy Warfare Development Command (NWDC) should be recognized and strengthened in its role of developing and promulgating a concept of operations and the supporting policies describing how naval forces will execute their warfighting and base support missions in an environment that has been or may be contaminated with chemical or biological agents. The Marine Corps should build on work already under way at the Marine Corps Combat Development Command and with its Chemical and Biological Incident Response Force—and the Navy should leverage that work.
- Both the Navy and the Marine Corps should enlist the expertise and support of key assets: the Fifth Fleet; the Commander, Fleet Forces Command; the naval analytical community; the U.S. Northern Command (Homeland Security); the Marine Corps's Chemical and Biological Incident Response Force; the Fourth Marine Expeditionary Brigade (Anti-terrorism); and Marine Expeditionary Units (Special Operations Capable).

continues

Readiness

Finding

- Navy readiness for chemical and biological warfare defense needs improvement in the following areas: establishment, validation, and enforcement of standards, performance and material condition of installed protective systems, availability and condition of protective equipment, shelf life of medical countermeasures, field exercise programs, basic and unit training, and readiness reporting.

Recommendations for the Navy

- The Navy should institute a system of exercises, training, assessment, and reporting aimed at meeting high standards of chemical and biological warfare defense readiness. Central to its effort is the requirement to define appropriate standards of readiness in each of its mission areas; these standards should be derived from the operational requirements generated by the recommended operational net assessments. Specific actions should include the following:

—The Commander, Fleet Forces Command, should coordinate the establishment, validation, and promulgation of readiness standards for CW and BW defense. These standards should be comprehensive and should include exercise frequency, chemical/biological equipment stock levels, C-rating criteria with perishability standards, and reporting requirements.

—The CNO should include chemical and biological warfare defense readiness reporting in the Status of Resources and Training System (SORTS) for the operating forces and in an appropriate parallel system for the shore establishment.

—The CNO should direct increased attention to the upkeep and maintenance of Collective Protection Systems and countermeasure washdown systems, with the assistance of the president of the Navy's Board of Inspection and Survey.

—The Navy Warfare Development Command should develop and conduct innovative and provocative CW- and BW-relevant wargames and exercises, such as the "Breeze" series set up for the Commander, Fifth Fleet, and the Commander, Pacific. As an interim measure, it is recommended that CW and BW special weapons and tactics (SWAT) teams be set up by CFFC to validate readiness standards; training; exercises; and tactics, techniques, and procedures (TTPs) for the fleet and shore establishment.

—Both the Navy and Marines should attach special urgency to the readiness of shore installations and bases. The CNO's Deputy Chief of Naval Operations (Plans, Policy and Operations) (N3) and Director of Naval Reserve (N095) should support regional commanders to access and leverage, where possible, active and/or reserve consequence management units with specialized chemical and biological capabilities that could assist in this area, or to add new units if necessary.

—The CNO's Deputy Chief of Naval Operations (Logistics) (N4) and the Naval Facilities Engineering Command should continue to assess biological and chemical threats to their logistics chain and take action to defend essential support as well as to mitigate the consequences in case of an attack.

4

Non-Medical Science and Technology: Specific Findings and Recommendations

INTRODUCTION

As noted in Chapter 2, Box 2.1, all research, development, and acquisition for chemical and biological defense is carried out through a legislatively mandated Joint Chemical and Biological Defense (CBD) Program and is organized around two principal areas—(1) Non-Medical Science and Technology and (2) Medical Defense. Although the committee was tasked to make R&D projections in specific time frames—to 2005 (near term), to 2010 (mid-term), and to 2015 (far term)—it found this practically impossible for two reasons:

1. The establishment of the Department of Homeland Security and the significantly increased investment by the National Institutes of Health (NIH) in medical countermeasures and vaccines are leading to increased activities in these areas, which should in turn impact the Joint CBD Program. The committee believes, however, that its recommendations remain applicable. The Department of the Navy should follow closely and leverage any such future activities to accelerate developments appropriately in the Joint CBD Program.
2. The Joint CBD Program has been undergoing substantial reorganization and reassignment of responsibilities that should affect current near-, mid-, and far-term plans. The Navy is urged to engage more actively with the program to influence those changes.

However, the committee does offer observations on activities in the context of the near, mid-, and far term based on the technical or development difficulties associated with a particular area.

The Non-Medical Science and Technology part of the Joint CBD Program is organized in five "commodity" areas: contamination avoidance, individual protection, collective protection, decontamination, and modeling and simulation.[1] The wide range of activities in each of these commodity areas is indicated in Figure 4.1; the commodity areas are further described later in this chapter and in Appendix C.

The committee attempted to gain as complete a view as possible in order to understand how well the activities of the Non-Medical Science and Technology Program are meeting the needs of the Navy—and how well the Navy is engaging the Joint CBD Program to ensure that its interests are being addressed. In the committee's opinion, most of the issues identified in addressing these broad questions arise from a shift in the threat landscape—from an at-sea military adversary of Cold War scenarios to an adversary willing to use asymmetric techniques aimed at both military and civilian targets. It is also the committee's belief that the Joint CBD Program and most of the Navy have not adjusted to that shift. The most important observations and recommendations relevant to non-medical science and technology (S&T) and the implications for acquiring improved capabilities are summarized below and elaborated in the following sections.

• *Non-Medical Science and Technology Program.* Two aspects of the Joint CBD Program appear not to serve naval needs well and can be ameliorated with appropriate attention by the Navy:

1. The Non-Medical Science and Technology Program has been and remains dominated by a philosophy of "contamination avoidance," a laudable goal indeed, but one that the committee believes is unrealistic as the driving force, considering the broad range of possible asymmetric attacks (as discussed in Chapters 1 and 3). Such a philosophy requires detection to facilitate avoidance and the identification of a threat agent as early as possible, which in turn drives investments heavily toward sensor systems for both standoff and point detection to provide rapid early warning. *The committee recommends that the Navy champion a fundamental change in philosophy in the Joint CBD Program—one that moves toward a risk management approach which assumes that contamination will happen and focuses on managing the response.* Such a shift should result in a

[1]Joint Science and Technology Panel for Chemical and Biological Defense. 2002. *DOD Chemical and Biological Defense Program, Non-Medical Science and Technology Program*, draft version 2002.01.05, Office of the Deputy Assistant Secretary of Defense for Biological and Chemical Defense Programs, Washington, D.C.

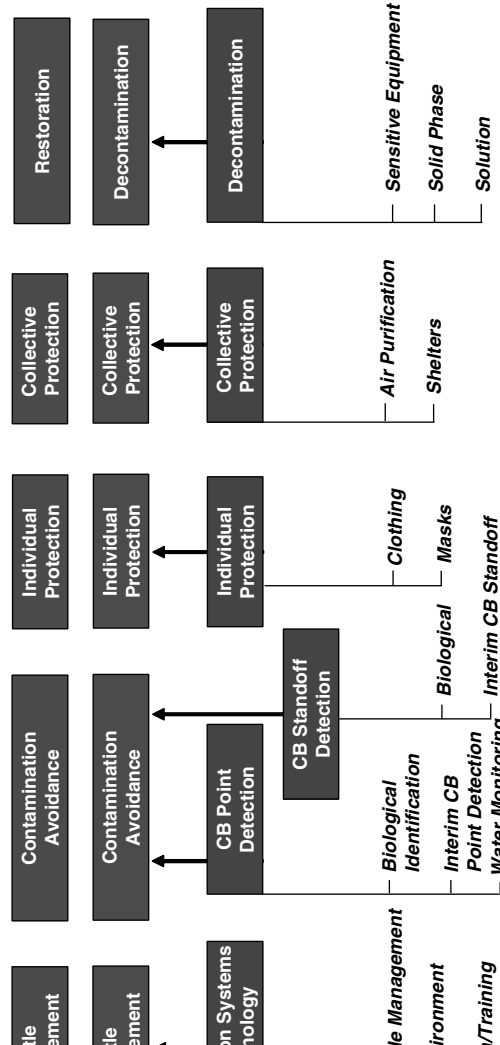

FIGURE 4.1 Taxonomy of the Joint CBD Program's Non-Medical Science and Technology Program.

more balanced investment portfolio, to also include detection capabilities to support decontamination and diagnostics characterization of agent fate on exposed surfaces; protective equipment in consonance with tactics, techniques, and procedures (TTPs) that better facilitate operating through an exposure; and rapid and "friendly" decontamination techniques and procedures.

2. A second observation is that the requirements and acquisition processes of the entire Joint CBD Program, as described in Box 2.1 in Chapter 2, have pushed acquisition schedules out far too long into the future for providing capabilities that could significantly improve the current operational posture. Those processes are undergoing revision, with reassignment of responsibilities within the Joint CBD Program and the Office of the Secretary of Defense (OSD). The committee recommends that the Navy seize the opportunity to ensure that processes are truly revamped to accelerate the introduction of improvements into the fleet.

• *Navy participation.* Achieving the changes in the Joint CBD Program recommended in point 1 above would be challenging enough if the Navy were fully engaged in the joint process. But in fact the Navy has been the least aggressive of the Services in its participation. Personnel from the Naval Sea Systems Command (NAVSEA), the Office of Naval Research (ONR), and the Commander, Fleet Forces Command (CFFC), assigned to represent naval interests are well informed and committed to their assignments; however, they do not have sufficient support from senior Navy leadership and commands to analyze joint requirements in the naval context and, if need be, to influence the program for it to address Navy-unique needs. It was not clear to the committee how serious an issue this might be. Lacking a robust, independent assessment of its own, the Navy is captive to equipment and accompanying operational procedures derived largely from the most stressing requirements of environments expected for ground forces in combat, based on conditions at or near the point of agent release.

The recommendation in Chapter 3 (in the subsection "Operational Recommendation: Roles for NWDC and MCCDC") to assign the Navy Warfare Development Command responsibility for developing and promulgating a carefully analyzed and gamed concept of operations would go a long way toward addressing this issue. Here the knowledgeable personnel at NWDC could also provide to naval personnel involved in the Joint CBD Program sorely needed support and expertise for ensuring that naval needs are met. In carrying out this recommendation, the Navy should make good use of Naval Research Laboratory (NRL) personnel who have well-established reputations in the chemical and biological S&T community.

• *Testing and evaluation.* The maritime environment introduces unique factors that should be explicitly considered before accepting equipment from the Joint CBD Program and developing procedures for its use. The Navy's research, development, testing, and evaluation (RDT&E) community is limited in its capa-

bilities to make such assessments. The committee recommends that a more serious and comprehensive program in testing and evaluation be undertaken by the Navy, to include both modeling and simulation and realistic test environments for chemical and biological warfare defense. The committee, in fact, recommends that the Navy consider dedicating a ship to chemical and biological simulant testing in a fashion analogous to the use of the ex-LSD *Shadwell* for fire research.

In addition to discussing each of the points above in more detail, in this chapter the committee provides an assessment of each of the commodity areas on the basis of presentations (see the section entitled "Committee Meetings" in the preface of the report), discussions, and material received. The chapter emphasizes naval-specific issues and defers to Appendix C descriptions of specific technologies and key demonstration programs. More comprehensive overviews and details of specific systems and detection requirements are available from other sources.[2]

THE NON-MEDICAL SCIENCE AND TECHNOLOGY PROGRAM

Non-Medical S&T Finding: Contamination Avoidance—A Limiting Philosophy Against Asymmetric Threats

In order to evaluate the utility to naval forces of non-medical science and technology that is current, in development, and proposed, the committee assessed naval issues from the five operational perspectives described in Chapter 3: (1) ships at sea, (2) ships in the littorals, (3) shore installations and bases, (4) commercial ports, and (5) logistics. Naval operations in these five environments can require different types of support and therefore lead to different priorities for science and technology, but a few general points can be extracted. As shown in Figure 4.2, the earlier a chemical or biological threat can be detected, the less complex the response required—if not to avoid contamination altogether, then to minimize the consequences and therefore the responses to an attack.

This importance of early detection has promoted the focus of non-medical S&T on threat discovery and environmental detection—that is, on avoiding contamination altogether so as not to be faced with subsequent situations and with actions needed farther along the time line. Avoiding contamination eliminates or reduces the need for (1) decontamination, (2) utilization of protective equipment (and the associated loss of performance), and (3) medical response, both short

[2]For example: Institute of Medicine and Board on Environmental Studies and Toxicology, National Research Council. 1999. *Chemical and Biological Terrorism: Research and Development to Improve Civilian Medical Response,* National Academy Press, Washington, D.C., pp. 239-240.

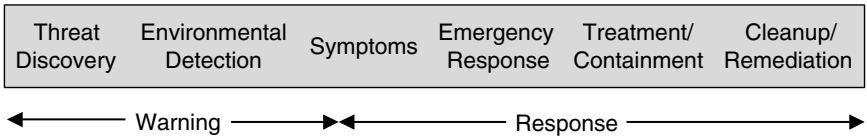

FIGURE 4.2 A generic time line helpful in evaluating the utility of non-medical science and technology in response to chemical and biological threats. SOURCE: Adapted from "CB Defense Program Taxonomy (slide 16)," of the "DOD Chemical and Biological Defense Program Overview" presentation to the committee on September 18, 2001, by Anna Johnson-Winegar, Deputy Assistant to the Secretary of Defense for Chemical/Biological Defense.

and long term.[3] The cornerstone of contamination avoidance is the detection and identification of a threat agent as early as possible. If complete avoidance is not possible, detection and identification can be used to minimize the impact of contamination.

This emphasis on contamination avoidance has led to non-medical S&T's principal investment (for decades even before it was joint program) in sensors and sensor systems, at levels as high as about 70 percent of the total. The committee believes that this approach is highly limiting, however, because any sensor shield for warning will have gaps, and trade-offs should be made between better warning and better response. Echoing a theme that runs throughout this report, the committee finds that a much more prudent approach would be based on risk management and early consideration in the operational assessments and in the S&T program of how to integrate both warning and response into the conduct of operations. These considerations will be critical to continuous or rapid return to military operations by forces under chemical or biological weapons attack.

The committee's assessment derives from the fact that the risk from asymmetric, or at least unconventional, attacks has increased. A determined adversary with even a small quantity of chemical or biological agent and a well-executed attack plan could produce significant consequences if supply chains, civilian support operations, and/or deployment schedules were disrupted. For example, the contamination of a ship in a foreign port raises the question as to how a captain should best utilize the non-medical science and technology at his disposal in response to an attack in which no sensor system allowed the avoidance of exposure. The extension of that question for the Non-Medical Science and Tech-

[3]If an adversary's intent can be determined early enough, contamination avoidance also includes the destruction of capability before an agent is actually used. This is the agent-defeat program in DOD's "active defense" element for countering weapons of mass destruction. It is not discussed here because the committee's focus, as directed by the terms of reference, was on the "passive defense" element.

nology Program is this: W*hat are the next-generation systems that would add the most value in the current and emerging asymmetric threat environment?*

Civilian approaches to managing similar situations may offer insight. Managing the problems created by industrial accidents, train derailments, toxic gas leaks, infectious and communicable disease outbreaks, and intentional contamination of victims has become nearly routine for civilian local responders and health agencies. These events are managed using the same systematic planning, training, communications, logistics support, command and control, task analysis, and expertise that the military uses in warfare planning and exercises.

Perhaps the most important aspect of the civilian approach is that of grading the response to meet the objectives of reducing the spread of contamination, impact, casualties, and property damage. Understanding the physical, chemical, and biological properties of the suspected agents is a critical science and technology issue. Moreover, a great deal of uncertainty exists in the early stages of a civilian event. Deployment of monitors may or may not be possible, and, if deployed, they may not have the capability to characterize the causative agents or assess agent dispersion. In all cases there is need for scientific knowledge about the possible agents, health risks from exposure, and interaction with materials and the environment. This scientific understanding significantly affects the actions to be taken, including the definition of a perimeter, the levels of protection provided for response personnel, the decontamination measures used, and the treatment of casualties. This close coupling of operational considerations with S&T capabilities should guide the priorities for investment in S&T and training.

Non-Medical S&T Finding: An Opportunity for Change

The Joint CBD Program's committee processes—both for setting requirements and for prioritizing research, development, and acquisition (RDA) efforts—have come under scrutiny and criticism by a number of advisory panels in the past few years.[4] Two factors contribute to the problem: (1) The "one Service, one vote" approach of the proceedings tends to result in a roll-up of requirements that attempts to meet "the envelope," or combined worst-case scenario, for all Services' needs. This objective of meeting the worst-case scenario can produce a difficult challenge and commensurate long lead times for the development of techniques and can lead to systems entering acquisition well behind the state of the art. (2) In addition, the dominance of contamination avoidance as the guiding principle for the program has resulted in requirements that are rarely informed by systems analysis and trade-offs between response time and sensitivity of instruments. Comprehensive end-to-end solutions that address all of the response ele-

[4]For example: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. 2001. *Report of the Defense Science Board/Threat Reduction Advisory Committee Task Force on Biological Defense,* Washington, D.C., June.

ments shown in Figure 4.2 in a balanced way have not been a part of the program. The lack of such solutions introduces considerable risk in any number of scenarios typical of asymmetric threats, in which contamination avoidance would never even be possible.

The under secretary of defense for acquisition, technology, and logistics (USD(AT&L)) recently responded to the criticisms referred to above by requesting a revamping of the program's requirements and RDA processes. To date, that request has resulted in the elimination of the Joint Service Integration Group for requirements setting—it has been replaced with a single accountable individual at the one-star level in the Office of the Joint Staff/Director for Force Structure, Resources, and Assessment for setting joint requirements—an arrangement more in keeping with other joint requirements processes. In addition, the executive agent lead held by the Army for RDA has been largely dismantled. More recently, while the Office of the Secretary of Defense will continue to provide managerial oversight, the Joint CBD Program has been reorganized in three major parts: specifically, (1) a newly named joint program executive officer will be responsible for the acquisition of systems, including product development; (2) the Defense Threat Reduction Agency (DTRA) will be responsible for the S&T base; and (3) the Joint Staff's Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense will be responsible defining requirements to meet operational needs.[5]

Non-Medical S&T Recommendation: Promulgating a Risk Management Approach

The Navy, and with it the Joint Chemical and Biological Defense Program, should shift from a philosophy dominated by contamination avoidance toward an approach based on risk management which assumes that contamination will happen and focuses on managing the response. The foundation for a risk management approach should come from the doctrine development efforts at the Navy Warfare Development Command (as recommended in Chapter 3 of this report) and from the results of the operational net assessments in each area of responsibility (as recommended in Chapter 3).

Minimizing or avoiding contamination should certainly be part of the strategy, but it may not be pragmatic, or even feasible, to do so in an era of wide-ranging possible asymmetric threats. Broadening the focus to include decontamination and resumption of operations will drive much of the science and technology in the same direction toward which it is already headed, but with the benefit of

[5]*Defense News*. "Defense Program Implementation Plan Approved." April 24, 2003. Available onlne at <http://www.defenselink.mil/news/Apr2003/b04242003_bt270-03.html>.

providing a different perspective for trading off parameters such as response time and sensitivity of instruments. Most importantly, and as demonstrated in civilian applications, many of the needed technologies for protection and decontamination exist to support this strategy.

The Navy has an opportunity to lead such a shift in the Joint CBD Program with the recent organizational changes for requirements and RDA. Such a shift will require, however, the commitment of knowledgeable personnel to the new Office of the Joint Staff/J8, program executive office, and DTRA, as well as the support of Navy in-house expertise.

NAVY INVOLVEMENT

Non-Medical S&T Finding: Limited Navy Participation in the Joint CBD Program

It appears to the committee that in the years before the Joint CBD Program was established, naval investments in chemical and biological defense S&T at the NRL had led to substantial progress, and that the work had coupled into a commitment in the operational Navy for improving its posture at sea. One of the best examples of that commitment was the move to collective protection systems as a requirement on new destroyers, as a result of recommendations made by one of this study's committee members in the early 1980s.[6] Since the advent of the Joint CBD Program, however, it has been difficult for NRL to sustain continuity and cohesion of effort, given the "decision by committee" process of the program and the tendency toward proposal-by-proposal awards instead of the creation and sustainment of centers of excellence.

As part of the Joint CBD Program, the Navy is to be commended for taking the lead in modeling and simulation and for the Artemis standoff detection system. The Marine Corps is to be acknowledged for leadership of the Joint Warning and Reporting Network (JWARN). But these efforts represent a sharing of the load for program management among the Services and have not led to maintaining a critical mass of S&T and operational personnel to guide priorities for naval forces in the Joint CBD Program. In short, the committee developed the impression that with the creation of the Joint CBD Program, the Navy "threw it over the fence" to that program or, in effect, took the position of letting the Joint CBD Program take care of its chemical and biological defense needs. Based on the information presented to the committee, the initial percentage of funds transferred from the Navy to the Joint CBD Program has never matched the return to the Navy for program elements that it leads or directs or for the equipping of

[6]Lederberg, Joshua. 1982. Memorandum for ADM James D. Watkins, USN, re: *Report of the Chemical Warfare Task Force of the CNO Executive Panel (U)*, Chemical Warfare Task Force, CNO Executive Panel, Office of the Chief of Naval Operations, Washington, D.C. (classified).

naval forces. In addition, non-Service aligned participants in the Joint CBD Program view the Navy as the least aggressive participant. The committee also interviewed highly committed and knowledgeable personnel at NAVSEA, ONR, and CFFC who participate in the joint process; to a person they admitted that chemical and biological defense appears close to the bottom of the list of concerns for senior Navy leadership, and the committee heard as much from CFFC and warfare integration (N70) leadership directly. While this may not be the intent of senior leadership, it is the message being conveyed.

Without a more in-depth assessment and analysis of the adequacy of the Joint CBD Program's products for meeting Navy needs, the committee cannot judge how serious an issue the relative lack of Navy participation in the program is. What is clear is that the Navy has no basis for judging how well the requirements and priorities of the Joint CBD Program address its needs—indeed, how well the Navy understands those naval-unique needs at all.

Non-Medical S&T Recommendation: Reaffirming the Role for NWDC

The Navy should recognize and strengthen the Navy Warfare Development Command (NWDC) in its role of developing—through analysis, experimentation, and testing—and promulgating a concept of operations and the supporting policies for describing how naval forces will execute their warfighting and force protection missions in an environment that has been or may be contaminated with chemical or biological agents. In this role, NWDC should also provide consultation to Navy participants in the Joint Chemical and Biological Defense Program.

The corresponding recommendation from Chapter 3 (see the subsection "Operational Recommendation: Roles for NWDC and MCCDC") regarding NWDC responsibility for developing and promulgating a concept of operations (CONOPS) would go a long way toward addressing the issue of the Navy's participation in the Joint CBD Program. In undertaking the important elements of analysis, experimentation, and testing that would lead to well-formulated CONOPS, NWDC would develop the cadre of expertise needed to support Navy participation in the Joint CBD Program as a "smart buyer." In carrying out this recommendation, NWDC should make use of NRL personnel who have well-established reputations in the chemical and biological S&T community, and of members of the analytical community who have provided direct support to fleet commanders.

The committee notes that the Marine Corps has been much more aggressive in its engagement of the Joint CBD Program and has put appropriate pressure, when needed, on the program to have critical operational needs addressed. However, the Marine Corps also lacks a strong analytical base through which requirements can be assessed.

NON-MEDICAL TESTING AND EVALUATION

Non-Medical S&T Finding: Lack of Realistic Testing and Evaluation for Accepting Chemical and Biological Defense Equipment

The committee believes that deploying to the fleet or fleet Marine force (FMF) equipment that is either operationally ineffective or unsuitable for the operational purpose for which it is intended can have a detrimental effect on unit readiness.

The committee believes that only realistic testing will ensure that the fleet and fleet Marine force receive equipment which is consistent with operational needs and environments, and that some systems now in development or being readied for procurement may confront operational effectiveness challenges similar to those cited above. For example, the technological approaches underlying the next generation of biological detection systems address only a narrow range of the potential threat spectrum, because the underlying biochemistry will identify a particular bacterial genus but not a specific threat species. In addition, agent dispersion and aggregation phenomena particular to a marine environment are not understood. The only way to ensure that the fleet receives the equipment it needs, together with the requisite operational training and maintenance support, is for the system in question to undergo thorough operational testing by fleet sailors in the operational environment in which the system is intended to be employed.

The preceding, of course, merely restates long-standing DOD policy on the testing and evaluation (T&E) of new acquisitions. The problem in this case is twofold: (1) the T&E policy is not consistently applied, and (2) operational testing of potential fleet systems in environments contaminated by chemical or biological agents is very difficult to achieve.

A common example of a system development path that bypasses the normal T&E requirements is the advanced concept technology demonstrations (ACTDs). The advent of ACTDs has served to speed potential solutions and new capabilities to the operating forces; but in the process, the operational forces frequently are paying the price of receiving equipment that may not have been adequately tested through normal developmental and operational testing practices. Equipment and capabilities demonstrated in an ACTD may have inadequate supply support, operators may have received little or no documentation or training on the equipment, and these warfighters may have limited knowledge of what a system actually will (and will not) do, even if it is working to the stated specifications. ACTDs are essentially prototypes, not operational hardware, and they should undergo thorough operational T&E before follow-on production versions are procured and installed on fleet units.

Replicating realistic, representative operational scenarios for T&E in contaminated environments presents a different, but no less important, challenge.

Current practices do not allow for open-air release of actual chemical or biological threat agents in the vicinity of operational Navy or Marine Corps units. In fact, the national facility at Dugway, Utah, provides the only currently available open-air test capability in the United States at which limited dispersal of real chemical or biological threat agents is permitted. However, the high-desert environment of Utah bears little resemblance to the marine environment in which naval forces predominantly operate. Therefore, in order to inform the acquisition decision maker about the operational effectiveness and operational suitability of a proposed new system before it is procured and deployed, test plans must depend on a number of other sources of data or information. These include sophisticated numerical modeling and simulation, augmented by agent tests in environmentally controlled chambers, testing in near-operational conditions using surrogate agents where available, the results of what open-air testing may be possible, and the experience of our international friends and allies. For almost every one of these sources, the committee found that the Navy is committing, at best, a limited level of effort and resources.

In considering options for dealing with this shortcoming, the committee found an analogous situation in the acceptance of shipboard firefighting equipment and procedures. After serious shipboard firefighting shortfalls in operational environments, the Chief of Naval Research and the Commander, Naval Sea Systems Command, agreed that it was advantageous to collaborate in establishing a fire research test ship, the ex-LSD *Shadwell*, now run aground in Mobile Bay, Alabama, to test new firefighting capabilities in controlled burns aboard a realistic representation of a Navy combatant.

Non-Medical S&T Recommendation: Naval-specific Testing and Evaluation

A much more serious and comprehensive program in testing and evaluation for chemical and biological warfare defense should be undertaken by the Navy. It should include both modeling and simulation and realistic test environments. Modeling and simulation efforts should be assigned to the Naval Surface Warfare Center, Dahlgren Division, as an adjunct to the role it is already serving for the Joint Chemical and Biological Defense Program. The provision of realistic test environments is the responsibility of the Director of Navy Test and Evaluation and Technology Requirements (N91).

Difficult or not, operational testing should be considered a headquarters responsibility to its warfighting customers before new systems are introduced to the fleet. Such testing may employ compromises necessitated by the potential hazards involved, but it should use every information source available to answer the same set of questions that would be asked about any other new operational system being introduced to the fleet.

Because of the impossibility of replicating the full range of chemical or biological threat environments, there will be a necessary reliance on modeling and simulation to help shape the decision maker's conclusions with regard to the operational effectiveness and suitability of new systems. The Chief of Naval Research, in his dual role as the director of Navy Research, Development, Test and Evaluation, should insist that the scientific, technological, and analytic foundations of the models under development through the Joint CBD Program are computationally sound and consistent with known physical principles. With the lead that the Navy holds in the modeling and simulation commodity area, the Chief of Naval Research should have a direct route into the process.

Given the Navy's natural reluctance to use an operational unit in the T&E of equipment and procedures applicable to a chemically or biologically contaminated environment, the Navy should consider establishing a chemical and biological simulant test ship analogous to the ex-LSD *Shadwell* for assessing the dispersion of agents on the surfaces and interior spaces of a ship and for testing chemical and biological agent detectors, decontamination procedures, and similar processes that are incompatible with use of an active-force ship.

ASSESSMENTS OF THE FIVE COMMODITY AREAS

Summary observations and issues of importance to naval forces within each of the five commodity areas are offered in this section to help underpin the recommendations that have been discussed so far in this chapter. (Appendix C offers a more complete discussion of these areas.)

Contamination Avoidance

Consistent with the Joint CBD Program's organization of the science and technology associated with contamination avoidance, the following is divided into a discussion of point detection and standoff detection. Within those divisions, sensors for chemical and biological agents are discussed separately, because each almost always requires different science and technology. Working from the contamination avoidance principle, both standoff and point detection programs have an eventual goal of "detect to warn" versus the more closely realized current capability of "detect to treat," although chemical sensors are getting close to the goal technically if they can be successfully coupled into a command and control system.

Chemical Point Detection

Modern chemical warfare (CW) agents are produced as solids, vapors, or liquids, depending on the application. Liquids can be volatile, such as sarin (GB), which converts to vapor form quickly, or nonvolatile, such as the nerve agent VX

(O-ethyl S-diisopropylaminoethyl methylphosphonothiolate), which emits little vapor at standard temperatures. Liquids can also be sprayed into the air as aerosols or fixed on a solid matrix such as silica particles (dusty agents), or perhaps be fixed on soil particles. In these cases, volatile agent droplets or volatile agents loaded on inert particles will still emit a vapor signature. Liquid agents can also leave ground contamination. Agents such as mustard and VX are designed for use in terrain denial. They persist in the environment because of their low volatility. Solid agents, such as BZ (3-quinuclidinyl benzilate), will often be aerosolized as an inhalable powder. Many of the techniques for delivering solids are designed to defeat the standard vapor detection devices used by most military forces. Precursors and by-products can be found in any of these physical forms.

Unfortunately, because the response to direct exposure to CW agents is typically very fast and violent, humans may provide the initial warning for the presence of such substances in the immediate environment. It is obviously preferable to be able to detect the presence of CW agents through some other form of interaction. There are numerous other physical mechanisms, which can be exploited to produce robust detection, classification, and identification signatures. Although CW agents can appear in many different physical forms—solids or liquids, with or without inert components—such chemical substances typically have distinctive and measurable mass and chemical and electromagnetic properties.

The Navy has done significant work on chemical weapons point sensors in the past—for example, NRL pioneered the surface acoustic wave (SAW) approach, which has been selected for the next-generation chemical point detector (the joint chemical agent detector (JCAD)). Since the advent of the Joint CBD Program, however, sustaining support for the work at NRL has evaporated. The Joint CBD Program has not supported centers of excellence as had existed at NRL, because of the processes described earlier. In fact, the Joint CBD Program has left the NRL group somewhat on the outside—for example, the group currently exists largely on funding secured from other agencies on a project-by-project basis and does not play strongly in the Joint CBD Program, in strong contrast to the Army's Edgewood Chemical and Biological Command (ECBC) research group, which is very much in evidence in key joint positions. Encouragingly, NRL has been a major consultant in the JCAD development, although the Air Force leads the effort.

The chemical and biological defense community has long viewed chemical and biological agents, not unreasonably, as best avoided and has tacitly assumed that this is the primary function of sensors, that is, to warn so that the threat can be avoided. The fact that the Joint CBD Program, under the title of "Contamination Avoidance," groups all chemical and biological sensors together strongly emphasizes this point. The avoidance assumption has a large effect on the requirements and technology selection of chemical weapons point detectors—speed is very important, which stresses competing requirements for specificity and

sensitivity. It also appears that there has been a focus on the technologies requiring sample capture (i.e., true "point") versus optical possibilities for point detectors—only ion mobility spectrometry (IMS) and SAW seem to be serious contenders. Given the above, the existing chemical weapons point sensor technologies of IMS and SAW are relatively mature technologies.

Existing chemical weapons point detectors do not satisfy the fundamental needs of decontamination—that is, "When is it clean enough?" This requires a new look at chemical weapons point sensor requirements, probably leading to different parameter trade-offs (e.g., "Bigger might be OK! Slower might be OK!") and different technologies (e.g., mass spectrometry (MS) rather than IMS, spectral signatures versus mass, and so on). Research at Edgewood seems to be revectored, at some level, in this direction; investigators reported to the committee members that the demonstration of real-time detection and surface mapping to 0.5 g/m^2 by an experimental carbon dioxide (CO_2) light detection and ranging (LIDAR) "proves the concept for decontamination applications."[7]

Actions for the Navy to consider in the area of chemical point detection include these:

- *Working with the Joint CBD Program to reconsider the requirements and technologies for decontamination applications.* The greater sensitivities required for such applications can be achieved at the expense of longer response time, allowing for consideration of different technologies, such as MS. Optical spectral approaches may also be practical, and can eliminate the need for sample capture and injection into the sensor.
- *Development of system concepts for contamination avoidance (CA).* For CA applications (i.e., the existing sensors already in the field or in development), the implications of networking remote arrays—for example, automatic target recognition, fusion, data and communications formatting, and so on—are largely nonexistent.
- *"Tech watch" by the Office of Naval Research* of novel developments in microfabricated concepts suitable for very small dosage monitoring and multiple, distributed sensor arrays for area or perimeter monitoring.

Biological Point Detection

At least six approaches are being used for the detection and identification of biological agents:

[7]Meeting of the Non-Medical S&T Panel of the Committee for an Assessment of Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats, Naval Studies Board, at the Edgewood Chemical and Biological Command, Aberdeen Proving Ground, Md., on January 17-18, 2001.

1. Nucleic acid sequence detection and identification,
2. Binding affinity and specificity using natural antibodies to target antigens,
3. Ligands and artificial antibodies for binding affinity and specificity,
4. Response of living cells or tissue to pathogen or toxin exposure,
5. Chemical analysis, and
6. Culture-based approaches including microscopy.

Numerous measurement approaches use these basic six techniques. For instance, a binding event between the target agent and the test probe can be measured using the differences in mass between the individual molecules and the bound complex. Alternatively, an optical label can be attached to the probe and detection achieved after physical filtering of the molecular complex to provide separation from the labeled probe. Each of the six basic techniques has resulted in numerous instrument prototypes and concepts for detection and identification.

The program goal of detecting all biological threat agents at sensitivities of 1 agent-containing particle per liter of air (1 ACPLA) had not been achieved in any instrument discussed with the committee, however. Moreover, for the foreseeable future, there is no biological sensor or sensor network that can completely realize the goals of contamination avoidance. The most advanced sensors reviewed by the committee were based on either antibody or nucleic acid detection. Antibody-based instruments, while widely fielded, suffer from false positives that can result in failure to use them when needed. Nucleic acid–based systems are both sensitive and specific, but may require significant sample preparation and are currently expensive. Both types of sensors need more assays so that a broader range of threats can be detected and identified. Both types of sensors would benefit from being able to perform tests for multiple agents simultaneously. Because some of the most aggressive prototyping has been done as part of demonstrations, the logistics and maintenance aspects of deploying many of these systems are not complete. Both types of sensors are becoming simpler, but need to get closer to the use and maintenance of an instrument such as a Geiger counter. In addition, it was not clear to the committee how the results of a measurement are expected to be integrated into the command and control infrastructure.

Sample collection and preparation have advanced but are also important areas for improvement. The challenge is to adequately sample large volumes of air, water, solids, or surfaces for contamination in a time frame and with equipment that is operationally effective. Concentrating the target molecules into a much smaller volume without adversely affecting detection and identification is also difficult.

In the near term, a single instrument will not be able to adequately detect and identify both chemical and biological agents. Mass spectrometry has some promise in this area but will require long-term investment. It is likely that different sample preparations will be required for chemical and biological samples.

Since there is no biological point sensor or sensor system available in the foreseeable future that can come close to meeting the goal of complete contami-

nation avoidance, science and technology priorities in this area should be assessed in the context of managing the end-to-end risk for naval operations, with an overall goal of executing the military mission. The trade-offs among sensors for environmental aerosol point samples (traditional contamination avoidance approach), testing of food and water supplies, medical surveillance, and supporting decontamination and restoration of operations need to be made for naval applications at sea, in the littorals, at port, and on air bases. The committee's opinion is that a combined analytic and experimental evaluation is needed to prioritize additional investments in biological point detection science and technology. The best path for achieving this evaluation is for ONR to undertake an analysis relevant to naval operational environments and then work with the Joint CBD Program to define an appropriate experimental program to address the key shortcomings in sensitivity, selectivity, and timeliness in order to meet naval operational needs. Providing science and technology that helps the commanding officer make risk-based decisions is the priority. Sensors have advanced sufficiently so that an evaluation could begin immediately. Several biological point detection and identification systems have been deployed for DOD and civilian applications. An assessment of what has been learned through these deployments is an appropriate starting point for the larger analysis and experiments needed for a full-scale evaluation.

In the short term, there are opportunities to enhance sensor performance. A first step is expanding the number of biological agents that can be detected. This requires producing the signature—for example, the nucleic acid signature or antibody—and implementing the assay consistent with current sensors. A second step is improving sample preparation for representative naval environments. For example, the Navy should undertake extensive testing of nucleic acid detection in a marine environment and develop techniques to use contamination avoidance sensors for decontamination and restoration operations as well as for food and water supply testing.

In the long term, the sensors will get smaller, cheaper, faster, and easier to use and to network into large systems. These changes will provide an opportunity to deploy networks of point detectors forward to accomplish the same goals as those of a standoff system. These sensor networks will require attention to logistics and risk management issues. In the committee's opinion, addressing the risk management issues in the near term will help focus the development of these more complex networks available in the future.

Chemical Standoff Detection

With respect to contamination avoidance, there are obvious advantages to being able to detect and classify agents at ranges sufficient for avoidance reaction times. Electromagnetic (EM) interactions, which probe the energy-level structure of chemical molecules, are particularly useful in this context, leading to various

forms of classical spectrometry that are known to be capable of both excellent sensitivity and specificity. Because of the propagation properties of EM waves, spectroscopic approaches can be successfully applied remotely for standoff detection and classification of CW agents. The optical technologies (e.g., telescopes, lasers, beam splitters, detector arrays) needed to support these applications are quite mature, having been developed over many decades in other contexts. Both active and passive optical techniques are possible. Active approaches utilize a laser source that can illuminate the suspect cloud or surface with several different wavelengths of laser light. Passive optical techniques exploit the natural illumination in the environment (e.g., thermal radiation from the elements in the scene, the Sun, the agent cloud itself, and so on) in place of the active laser beam. While simpler in principle, passive systems may not be as sensitive or robust as active systems in many operating environments.

A general problem for standoff optical sensors is that they are complex and grow rapidly in size and cost of the optics (and laser, if active) as the range requirements are increased. Thus, standoff sensors are best applied in relatively fixed locations, such as perimeter warning systems to protect large installations, or on ships, looking upwind at sea. Vehicle mounting is not excluded, but handheld versions will necessarily be limited to short-range applications.

Although it would not be surprising to learn that NRL has in the past investigated both active and passive remote sensing optical systems, the only activity in the Navy prior to the establishment of the Joint CBD Program of which the committee was aware was the fielding in the 1990s of the AN/KAS-1, chemical weapon directional detector (CWDD), a multispectral passive imaging system that uses a thermal imager and a wheel that contains filters which absorb in three spectral regions that are agent-specific. This sensor is not considered user-friendly and requires an alert, skilled operator to manually address suspicious cloud formations. With only three spectral bands, this sensor is not particularly discriminating. In discussions with fleet personnel, it was found that the CWDD is prone to false-positive cloud detections, especially in port, where there are a significant number of pollutant vapors that can confound the system and its operator. As a result, the CWDD has often been ignored in practice, leaving the Navy at present without any effective long-range CW agent detection capabilities in the field.

A new concept, based on Fourier transform infrared (FTIR) spectrometry, forms the basis for the Joint CBD Program passive sensor in development known as the joint service lightweight standoff chemical agent detector (JSLSCAD). Described as a second-generation chemical agent detector, it is said to represent an improvement over the Army's currently available M21 remote sensing chemical agent alarm (RSCAAL). As a hyperspectral rather than a multispectral approach, better performance can be anticipated. Under the Army's lead, the JSLSCAD is currently scheduled to move into production in the next few years. While the performance potential of the FTIR technology seems large, a great deal of development remains, and slippage in the program schedule should not come

as a surprise. The program does not anticipate that the naval environment will introduce any anomalous behavior, and it is hoped that the final system will be characterized by a very low rate of false positives. The committee nonetheless recommends that the Navy assess the JSLSCAD in marine environments before accepting it for fleet operation.

In the area of active standoff systems, the Navy currently has the lead in the development of a standoff chemical weapons agent detection system known as Artemis, a project in the Joint CBD Program started in FY 2001. The Joint CBD Program and the Department of Energy (DOE) have already demonstrated airborne liquid and vapor detectors and cloud mapping techniques with prototype LIDAR systems, although detection of liquid ground contamination has yet to be demonstrated. Artemis is scheduled to complete development and enter production in FY 2007. The Joint Service Chemical and Biological Defense Research, Development, and Acquisition Plan describes Artemis as a LIDAR-based "real-time, standoff detection system for chemical agent contamination monitoring and avoidance as well as for dewarning (i.e., indication that agent is no longer present) and indicating areas for decontamination."[8] A successful LIDAR technology could have important applications across the range of naval operations.

The Navy should fully support the JSLSCAD and Artemis standoff CW agent detector developments, as such sensors would be very useful for naval operations. The lessons learned from the CWDD should not be lost—too many false positives can nullify any other performance benefits that the sensor may possess.

Biological Standoff Sensors

The remote detection of biological warfare (BW) agents by interaction with electromagnetic radiation differs from the case of CW agents primarily in the nature of the spectral properties of complex organic materials. Except under very high spectral resolution, the spectra of biological agents appear broad and relatively featureless, offering few unique characteristics to distinguish lethal agents from benign organisms. Complicating the situation is the fact that BW agents can be distributed at far lower concentrations (i.e., three or more orders of magnitude) than CW agents and still be effective. A further exacerbation is the presence of naturally occurring background biological species in typically far greater concentrations and with similar spectral features. Given these factors of weaker returns, featureless spectral properties, and interfering background species, the active LIDAR differential absorption/scatter and passive multi- and hyperspectral techniques that work so well for standoff detection of CW agents are generally

[8]Joint Service Materiel Group. 2001. *Joint Service Chemical and Biological Defense Research, Development and Acquisition Plan; Supporting Planning Period FY03-17*, Aberdeen Proving Ground, Md., July.

ineffective against biological agents. This is not to say that these techniques do not work at all with biological agents but rather that the discrimination capabilities are poor (high false-positive rate). LIDAR systems, which detect only the presence of aerosols, independent of their nature, have been used a number of times. However, no BW agent standoff detection systems with useful classification/identification capabilities have been developed so far using these techniques.

On the other hand, biological materials do respond to electromagnetic radiation in a very characteristic and measurable way that is used commonly in biological laboratories—under ultraviolet (UV) excitation they fluoresce at longer wavelengths in the visible to infrared (IR). Active irradiation with a UV laser pulse followed by multi- or hyperspectral detection in the visible/IR offers the potential for effective standoff detection of airborne BW agents at reasonable concentrations and ranges, and several such systems have been under development in recent years. As a practical matter, however, fluorescence of biological materials tends to decrease as the exciting wavelength approaches the visible region of the spectrum, so the design of such a UV LIDAR fluorescence system involves difficult trade-offs between laser wavelength availability, range of propagation, and strength of the resulting fluorescence signals.

The committee uncovered no evidence that the Navy had conducted any R&D appropriate to airborne biological weapons standoff detection prior to the establishment of the Joint CBD Program. There has been relevant and interesting work on UV laser systems under development in the Army for a number of years. A prototype system known as the short-range biological detector system (SRBSDS) has been field-tested successfully. Using a frequency-multiplied yttrium aluminum garnet (YAG) laser, this system irradiates in the UV and detects the amino acid fluorescence in the near-UV spectral region. Because the interrogating radiation is strongly absorbed in the atmosphere, this is a short-range system, but it clearly demonstrates that the overall approach is feasible for discriminating biological weapons from background. The use of longer UV wavelengths would improve the range capabilities, and the application of sophisticated multi- or hyperspectral techniques should improve the discrimination capabilities. DOE also has been sponsoring work along these lines, and a prototype biological weapons standoff detection system based on similar principles is currently undergoing field tests. This particular system has also been under assessment by the Third Fleet for shipboard applications. Because of the nature of the BW threat, the many ways in which it could be delivered, and the latency of effects, it seems difficult to argue that real-time, long-range standoff detection of airborne biological weapons should be of the highest priority. On the other hand, a real-time, short-range standoff system, particularly if it had good classification/identification capabilities, would be very useful for decontamination. The UV fluorescent phenomenon and the progress in system development to date suggest that the Navy should evaluate requirements for—and push priority for—the Joint CBD Program to develop such a capability, which would be of value to the other Services, as well.

Individual Protection and Collective Protection

Physical protection traditionally involves methods of avoiding injury from chemical or biological weapons that enter the body through mucous membranes and/or contact the skin. The subject has been reviewed in depth recently.[9] The Joint CBD Program currently funds the development of a suite of physical protective technologies. These can be divided into individual protective equipment and collective protection systems. Both individual and collective protective techniques depend on creating a barrier between the contaminated environment and personnel and/or equipment. Currently technologies are designed to protect against CW and BW agents, while future improvements will add protection against toxic industrial chemicals. Individual protective equipment generally consists of suits and masks, while collective systems involve sealed shelters and compartments to create an agent-free environment. For individual protection, five levels of mission-oriented protective posture (MOPP) were originally established. These range from MOPP-0 (no individual protective gear) to MOPP-4 (all protective gear worn—gloves, boots, overgarments, masks).

The Joint CBD Program currently funds research, development, and testing for both individual and collective protection. Collective Protection System (CPS) retrofits and the shipboard collective protection equipment (SCPE) project are focused on extending the lifetime of shipboard high-efficiency particulate air (HEPA) filters for protection systems based on overpressurization with clean air. It should be noted that the Navy made a significant commitment to integrating CPSs into the design and construction of new destroyers in the 1980s, so a number of such platforms have found their way into the fleet. The commitment has recently been extended to amphibious ships and to retrofitting some existing vessels. This was a cost-effective decision under the assumptions of the Soviet-era threat against the battle group, but it should be reexamined as a potential upgrade for all ships in the current environment of asymmetric threats in which attacks could be targeted to individual vessels in port or in the littorals.

Based on the committee's investigation, the following observations—which strongly validate the recommendations of this chapter—are made:

- Sustained military operations at MOPP-4 are unlikely owing to heat and respiratory loads and the inability to perform fine-motor functions at this level. This will remain the case for some time. Efforts to develop improved, semipermeable "breathable" fabrics are unlikely to yield new, widely fielded garments for a number of years.

[9]National Research Council. 2000. *Strategies to Protect the Health of Deployed U.S. Forces: Force Protection and Decontamination*, Board on Army Science and Technology, National Academy Press, Washington, D.C.

- Current Navy practice apparently dictates either MOPP-0 (no individual protective gear) or full MOPP-4–level protection. In response to some asymmetric attacks, intermediate levels of protection may be acceptable and could minimize the impact on operations. For example, a "mask only" posture would protect against most biological weapons and vapor chemical weapons.
- The availability of individual protective equipment within the Navy is limited if one considers the expanding needs associated with protecting not only deployed forces, but also personnel at bases and shore installations, OCONUS ports, and civilian and logistics support.
- Adequate protection against the broad spectrum of toxic industrial chemicals and materials that might be employed in asymmetric warfare is currently lacking.

A number of short-term actions by the Navy would significantly improve combat readiness and post-exposure recovery:

- As noted in Chapter 3, the Navy should prioritize the acquisition and distribution of additional protective garments and masks to the fleet, bases, installations, and port facilities to enhance operational readiness against the mounting specter of asymmetric chemical or biological attacks.
- The Navy should acknowledge the operational need for several levels of individual protection, consistent with varying levels of risk. Not all scenarios will dictate full MOPP gear. Guidelines should be developed that enable a commander to assess the risk and impact to operations when making decisions on the appropriate level of protection. The commander should be able to develop a rationale based on clearly developed and understood guidance for balancing protection and operational performance. Additional investigations into the health effects of operating in MOPP gear (e.g., heat and respiratory stress) and both short- and long-term toxicology associated with CW agents are needed as part of establishing the required data base. Furthermore, a transition to higher-level MOPP protection should not temporarily subject the warfighter to unnecessary risks (e.g., temporary removal of the protective mask). The use of toxic industrial materials during an asymmetric attack is possible; thus, development and/or acquisition of filters capable of removing a wider variety of chemical compounds should be aggressively pursued. Civil and industrial response units have well-developed procedures and practices for many toxic industrial chemicals, which the Navy should assess and appropriately adapt. Naval commanders should also determine if commercial off-the-shelf (COTS) technology can be used effectively today for incidents at bases and ports or to remedy current shortfalls in the quantity of available protective equipment.
- Overall, near- and long-range R&D plans are reasonably well thought out and should address most of the important concerns. For example, regenerative

filters would minimize the number of required filter change-outs and thus reduce the risk of contaminating the protective citadel. The Navy should champion the development, testing, and fielding of regenerative filters for collective protection systems. Similarly, emerging portable CPSs can provide a contamination-free area for intermittent respites from full MOPP gear and also for treating contaminated casualties. Adaptation of the portable protective systems should be aggressively pursued, since this capability is needed on many vessels and at fixed naval sites. Work should also continue to improve the seals around individual protective masks, including the use of barrier creams.

Decontamination

From the briefings received by the committee, there seems to be a prevailing attitude that decontamination results when "the battle is lost." It is seen as the undesirable consequence of failure to do an adequate job of protecting against attack. It is about dealing with the mess that is left over. It is relegated to the status of damage control and largely hoped to be an operation never exercised. In the committee's opinion—and as stated many times throughout this report—this thinking is inappropriate for the asymmetric threat environment. Attacks with chemical or biological agents or toxic industrial chemicals will occur—and some of them will be successful.

The tools and methods of decontamination should, more appropriately, be viewed as an integral part of the suite of passive defense capabilities that are necessary to survive attack and quickly bring operations back up to tempo. Therefore, a key element to managing the consequences of such an attack is to achieve rapid recovery to operational status, which in turn requires a well-planned decontamination capability. With improved materials, tools, protocols, and training, decontamination can be made much more efficient and effective.

Decontamination Standards

Effective decontamination requires reducing the presence of the toxic compound or biological agent to a level that is considered safe for personnel. The acceptable risk level in some cases may well be higher than those that might be allowed for civilian operations, depending on the scenario and operational procedures in place. Determining the appropriate level of decontamination for a situation is the result of assessment and decision making based on all of the risks. Setting the appropriate risk levels and decontamination specifications is an area in need of Navy doctrinal development that should then lead to the development of testing and performance standards to be used for field as well as base and long-term equipment decontamination procedures.

Decontamination Test Equipment

The ability to decontaminate equipment and buildings to specified levels of cleanliness requires the ability to measure levels lower than the capability of current field sensors being developed for contamination avoidance. While the technologies will generally be the same for both contamination avoidance and decontamination applications, the sensitivities for decontamination assessment are typically more stringent because of the uncertainties in the risks of long-term, low-level exposures. At the same time, timescales for getting a measurement are more relaxed, compared with contamination avoidance requirements. It is crucial that the R&D community develop instruments and procedures capable of making these measurements for both chemical and biological agents in order to facilitate a rapid return to normal operations.

Decontamination Methods and Materials

Decontamination of chemical agents can be accomplished by (1) chemically destroying the active molecule through reactive conversion to less toxic compounds, (2) removing the agent with high-absorption materials, (3) creating a barrier between the chemical agent and the environment, or (4) diluting the agent to such a low level of concentration that it is rendered harmless.

Traditional decontaminating reagents, such as DS_2 (the currently fielded standard decontaminating solution containing diethylenetriamine, 2-methoxyethanol, and sodium hydroxide), chemically convert the CW agent into a much less harmful compound. These reagents are based on solutions of strong solvents, powerful oxidizing agents, and alkaline substitution reactions. They are capable of decontaminating a wide variety of conventional CW agents (H, G, V agents), but they are also caustic and corrosive to many common materials, especially plastics and elastomers. Because of the toxicity of such reagents and the products that they form, the process of decontamination creates environmentally hazardous residues requiring special treatment. Similarly, the decontamination of biologically contaminated areas also uses solutions and gaseous mixtures containing strong oxidants such as hypochlorite, hydrogen peroxide, or chlorine dioxide. These materials also have the disadvantage of being toxic and corrosive.

Because of their corrosive properties, none of these materials is fully suitable for decontaminating sensitive electronic equipment. Alternative methods such as the use of liquid or supercritical carbon dioxide or aromatic solvents do not involve the use of corrosive solution decontaminants and could be used on electronics and other sensitive equipment.

Decontamination of personnel and wounds requires materials that can effectively remove the toxic agent without further damaging the skin or tissues. Historically this has been done with dilute solutions of hypochlorite and soap and water for both biological and chemical agents. Absorbent packets that contain

activated carbon and a variety of other ingredients are also used for chemical decontamination.

The Navy has some equipment and situations that present special challenges for decontamination owing to the sensitivity of certain surfaces to degradation by some of the conventional decontaminants (aircraft, optical instruments, canopies, and the like). On the other hand, there are other surfaces that are more resistant to decontamination because of the tenacity of certain surfaces for retaining agents (e.g., antiskid surfaces), and these require more aggressive treatments.

Because of the wide range of often-conflicting requirements placed on the design of decontaminating materials, it is practically impossible to design a formulation and application method that can accommodate all needs. This problem becomes even more difficult when one considers the possible use of toxic industrial chemicals as chemical warfare agents.

Finally, when one considers the environmental requirements and long-term safe exposure levels necessary to restore activity at a base or a harbor, it becomes clear that many of the materials that were designed for battlefield decontamination (such as DS_2) do not provide good solutions for allowing a rapid return to sustained operations. For all of these reasons, it is important to have a variety of high-performance decontamination materials and methods that can address the spectrum of decontamination needs.

Some currently fielded and in-development decontamination materials and equipment are described in Appendix C. Decontamination materials becoming available are substantially less corrosive, less toxic, and much more environmentally acceptable, and still maintain a broad spectrum of effectiveness against a wide range of nerve, mustard, and biological agents. In addition, new, special-purpose decontaminating agents are being developed to deal more effectively with a number of special needs. Finally, the logistical burden created by the decontamination system is also important, and future systems are aimed at making significant reductions relative to currently fielded systems.

The technical approaches to achieving efficient decontamination with milder, less toxic, and more environmentally acceptable materials use catalysts and enzymes, along with new types of surfactants. Combinations of catalysts and surfactants permit the use of nontoxic oxidizing agents that are effective without being corrosive or having undesirable environmental impact. New formulations use hydrogen peroxide, peroxy compounds, or dioxiranes, which are commonly employed in the commercial detergent industry as an alternative to chlorine bleach. These approaches have been successful in destroying both chemical agents and biological organisms in laboratory tests. Other catalysts can destroy chemical agents by causing water to rapidly react with the chemical agents, transforming them into relatively nontoxic products.

New types of enzymes that are being studied have demonstrated the ability to destroy nerve agents, as well as sporulated BW agents. These reactions have

been shown to take place rapidly and thoroughly at relatively mild conditions. In addition, enzymatic decontamination could lead to a large reduction in the quantities of decontamination materials needed and the associated logistical requirements.

Efforts to decontaminate electronics and sensitive equipment are exploring the use of nonaqueous solvent systems such as supercritical carbon dioxide. Nanoparticles of certain metal oxides are being studied as candidates for future dry decontamination systems. Other work is under way to identify decontamination materials that would be safe and approved for use on aircraft surfaces.

The Navy has seawater washdown capability on its ships (not a part of the Joint CBD Program), and there are tactics, techniques, and procedures (TTPs) relating to washdown before anticipated exposure to chemical and biological warfare attacks, to reduce contamination absorption on surfaces, and to wash down again for decontamination after exposure. An understanding of the effectiveness of this procedure coupled with effective use of the capability should be regarded as an important element of readiness to manage risks for chemical and biological warfare defense.

Agent Fate Studies

Critical to setting standards, and from those the requirements for decontamination test equipment, methods, and materiel, is a sound understanding of the fate of agents on contact with the surfaces exposed. The recent Air Force–led experiments on runway surfaces demonstrated that physical and chemical attributes of a contaminated substrate are important considerations in assessing agent fate. The absorption of a CW agent into a porous substrate, such as asphalt or decking, will lead to specific substrate–agent interactions, dictating the effective vapor pressure and influencing the agent leach rate over time. Similarly, the chemical reaction of agent with substrates such as concrete and paints may favorably reduce the amount of agent. In some cases, it is conceivable that military operations may proceed with minimal, or even no, protection or active decontamination following a specified time after an attack by an identified agent in certain environmental conditions.

An understanding of agent–substrate interactions also provides the physical basis for more accurate source and sink terms that are essential input into dispersion and transport models. Thus, there should be examination in considerable depth of chemical agent permeation into porous substrates by diffusion and/or of surface-tension-driven flow and agent integrity as a function of environmental conditions such as temperature and moisture levels, in order to elucidate the governing variables and to develop guidelines to assist commanders in planning a restoration of operations. Work along these lines was recently initiated at ECBC in apparent response to the Air Force experiments on agent fate. As outlined to the committee, however, the ECBC agent–substrate program does not appear to

be complete in scope, given the emergence of the asymmetric threat and the many variants that it introduces. This assessment of the ECBC agent–substrate program is similar to the finding by the DOD's 2002 Technology Area Review and Assessment (TARA) panel,[10] and the related part of the ECBC program is being overhauled in response but is unlikely to address all the naval environments of interest. In particular, the agent fate program focus appears to be on interactions between agent and selected militarily important surfaces. However, given the vulnerability of a CONUS base to asymmetric attack, the suite of materials should be expanded beyond traditional military hardware and paints. The classes of materials found in command, support, and logistical facilities should be included in the testing and evaluation plan, since their characteristics and decontamination (if required) would also play an important role in restoring full operational capability.

Furthermore, the role that a substrate plays in determining subsequent decontamination efficacy (e.g., required number of applications of reagent) cannot be ignored. For example, wicking of CW agents into pores will undoubtedly prove to be important regardless of the type of decontamination reagent employed (e.g., aqueous, foam, gaseous, and/or gelled), while the surface tension of aqueous reagents may limit permeation into small pores containing agent. Thus, the program should include decontamination testing with both fielded and developmental decontamination reagents. In addition, with the emergence of surfactant-laden decontamination reagents, evaluation should also include activity tests to ensure that the observed reduction in agent concentration is not due to the formation of new chemical or physical structures involving the surfactant (e.g., lipid-like interfacial layers) that might be missed with conventional sampling protocols.

The Navy is urged to consider spearheading similar agent fate studies focused on Navy-centric restoration issues, employing materials of utmost importance to Navy operations (e.g., carrier deck surfaces). In some cases, testing and evaluation costs can be controlled by the use of surrogates rather than live agents, although surrogate results must be reconciled with live agent data.

Performance Requirements for Decontamination

The Navy should review and redefine as necessary its specific performance requirements for the restoration of base or supply chain operations. For example, ECBC indicated that there was a push toward reducing the decontamination times in new systems from 30 minutes to 15. This appears to be driven by the traditional requirements for land-based, battlefield decontamination stations at which every

[10]Foster, Robert, and Anna Johnson-Winegar. 2002. *Defense Science and Technology Advisory Group (DSTAG) Technology Area Review and Assessment*. Office of the Director of Defense for Research and Development, Washington, D.C., March 25-29.

minute counts. However, in a CONUS attack, the restoration of operations would likely be measured in hours (or days), owing to other factors such as estimating the route taken by a plume and restoring order in surrounding civil communities. The 15-minute reduction in decontamination time is unimportant in such cases. In the short term (5 years), studies should be able to determine the operational importance of agent fate and should establish the basis for answering operational questions such as, "When and where is decontamination likely to fail?" "When can protective gear be shed with acceptable risks?" and "Should point sensors be placed near specific (problematic) substrate materials?" This committee recommends that the Navy increase its physical presence at and interaction with Edgewood Chemical and Biological Command to ensure that Navy- and maritime-related issues are more visible to those formulating and executing the research and development programs.

Leveraging Civilian Best Practices

The tactics, techniques, and procedures developed in the chemical process industries for responding to the release of toxic industrial chemicals are well developed and should be fully exploited in the process of redefining Navy readiness planning. The Navy should identify and employ the best of these industrial practices (which generally satisfy the civil regulatory requirements) and expertise in its plan for responding to asymmetric attacks on CONUS bases, ports, and the logistical supply chain. It is not necessary, and it would be a mistake, for the Navy to try to reinvent this capability independently. Instead, the Navy should acquire this knowledge and adapt it to specific Navy needs. Careful consideration should be given to the balance between centralized doctrine and local planning. Navy-wide standardization favors centralization, while recognition of site-specific threats (e.g., a nearby chemical plant producing chlorine) favors more local planning. A balance should be struck.

Developing Operational Guidelines for Decontamination

The Navy should develop operational guidelines for the effective decontamination of its ships, bases, ports, airfields, and logistical chains—that is, make specific the joint doctrine expected as a product of the new Joint CBD Program requirements office in Office of the Chairman, Joint Chiefs of Staff/Director for Force Structure, Resources, and Assessment (OJCS/J8). Future Navy doctrine should discuss acceptable risks and evolve operational guidelines as to levels of decontamination and the levels of personnel protection that should be employed in order to minimize restoration time after contamination and maximize operational viability.

In the commercial world, in responding to chemical or biological events the objectives are to reduce the spread of the agent, the impact and casualties, and

property damage. Pre-deployment of response equipment, training of responders, establishing expert advisers and resources, establishing command, control, and communications functions, and, most importantly, grading the response to fit the need are all essential to meet these objectives. Understanding the physical, chemical, and biological properties of the suspected agent is critical. A great deal of uncertainty often exists during the early stages of an event. The causative agents (e.g., the concentrations, dispersion, and so on) are open to debate and speculation. In many cases, there is a need for scientific understanding of the array of possible agents and their properties. This understanding will significantly affect the actions taken, such as defining of the perimeter of response; levels of protection taken for responding personnel; decontamination and treatment of casualties, equipment, facilities, and terrain; and, in general, how to define the event (as major or minor). As the response advances and the situation is managed, the on-scene manager needs continuous expert advice on how to adjust the protection levels for personnel in various working modes and on how and when normal operations can be restored.

In a similar vein, as described in Chapter 3 on CONOPS development, the Navy is urged to make use of the Army and Marine Corps experience in establishing *pre-event* working relationships with the civil authorities who would be key resources in the event of both CONUS incidents and attacks on overseas bases and ports. Guidelines should be established a priori so that base commanders can make informed decisions regarding where best to obtain assistance (e.g., from the Navy surgeon, Army chemical corps, civil responders, Chemical and Biological Incident Response Force, the chemical industry, and so on). Necessarily, the operational concepts will vary depending on the attack scenario (e.g., involving ships at sea, littoral operations, CONUS base, supply chain, and so on) and situation.

In all cases, however, doctrine must clearly define the operational concepts and specify performance standards, providing logical and clear guidance that can be applied in each situation. The doctrine must be risk management–based. This approach implicitly acknowledges that characterization of the contaminated areas and their subsequent decontamination will not be perfect, and that residual chemical or biological risks will probably linger as operations are restored. Doctrine must provide the performance requirements (e.g., "How clean is acceptable?"), the definition of testing and evaluation techniques, and ultimately, what research and development needs remain. With the doctrine in hand, the investments in effective decontamination technology and procedures then can be clearly linked to Navy-specific needs.

Summary of Findings Related to Decontamination

The decontamination story is multifaceted, as evident in the preceding discussion, but capabilities sorely lag those in the areas of contamination avoidance and individual and collective protection. Recapping the findings noted in the discussion above:

- Effective decontamination materials and procedures should be viewed by the Navy as critical parts of a risk management–based, layered defense against chemical and biological agents.
- The Navy should develop a doctrine about decontamination that sets guidelines, procedures and methods, standards of cleanliness, and sources of technical guidance that apply to ships and shore-based facilities.
- No guidelines exist for what are acceptable or "safe" long-term exposure levels of chemical or biological agent that remains after decontamination. Studies should be undertaken to set the appropriate levels for short- and long-term exposures and address whether standards should differ between civilian and military environments.
- No field instruments are capable of measuring to the concentration of a chemical or biological agent on decontaminated surfaces consistent with acceptable long-term exposure levels. Work should be started to develop equipment and test procedures that become a part of the decontamination toolkit. Most desirable would be a standoff surface scanning capability.
- Little data exist on chemical or biological agent fates. Studies are needed to understand the consequences of the interactions of agents with substrates common to Navy ships and shore facilities. This information is critical for guiding an intelligent approach to decontaminating a site as well as for providing information about the long-term safety of decontaminated surfaces.
- There also appear to be little data available on the health effects of long-term exposures to low-level concentrations of either chemical warfare agents or biological warfare agents or toxins. This information would be very helpful in establishing realistic standards for decontamination.
- Progress is being made in research and development for significantly improved decontaminating reagents (low toxicity, low corrosiveness, environmentally benign) for both chemical and biological agents; these reagents should be able to address key Navy needs. In particular, the Joint Services Fixed Site Decontamination (JSFSD) Program is addressing the critical Navy need for a low-toxicity decontamination system for airbases, ports, and fixed base logistics nodes. The program is scheduled to deliver nontoxic and noncorrosive decontamination materials and application equipment.
- Toxins, new-generation nerve agents, and toxic industrial chemicals have chemical properties different from those of traditional chemical agents. Fielded decontamination materials may not be effective against some of these threats. It is therefore important that the DOD program continue active surveillance, assessment, and countermeasure development against new chemical and biological threats and that the Navy understands in particular which toxic industrial chemicals might pose a threat to its installations.
- Development work in the commercial sector and in other federal agency laboratories has resulted and/or will result in promising new products that may be

good fits to Navy decontamination needs. The committee recommends that the Navy explore these options in addition to participation in the Joint CBD Program.

In summary, the committee believes that the perception that chemical and biological incidents can be largely avoided by better vigilance and greatly improved sensors is flawed. The risk to the Navy of an asymmetric attack with chemical or biological agents or toxic industrial chemicals is serious. The tools and methods of decontamination should be viewed as an integral part of the suite of weapons and capabilities that are necessary to survive attack and quickly bring operations back up to tempo. With improved materials, tools, protocols, and training, decontamination can be made much more efficient and effective. To achieve an adequate state of readiness to counter an attack with chemical or biological agents, the Navy should significantly improve its decontamination agents, methods, technical understanding, training, and doctrine, as outlined above.

Modeling and Simulation

Over the past 10 years, much of the emphasis in the chemical and biological modeling community has been on plume modeling—which includes estimating the dispersion and fate of plumes generated from explosive air or ground bursts, agent transport within enclosed spaces (e.g., high-value facilities), semienclosed spaces (e.g., subway systems), and plume migration and deposition within the urban landscape. In addition, high-fidelity modeling around the superstructure of specific ships has been conducted. The use of models in fixed-site locations to guide the placement of sensors is also being explored. Work in modeling and simulation for chemical and biological agent dispersion has been performed under the auspices of the DOD (NRL and the Naval Surface Warfare Center (NSWC) within the Navy), DOE, and academia. The models in use may be cast in terms of a variety of mathematical formulations and may employ different computational schemes; thus, one finds models based on Gaussian puffs, computational fluid dynamics, and random walk Lagrangian particle codes. In addition to the use of finer computational grids (directly related to available computational power), the models are continually being refined to include more realistic descriptions of local wind fields, solar heating/nighttime cooling, source and sink terms, droplet aerodynamics, and evaporation.

With the goal of verifying, validating, and accrediting DOD modeling tools, the deputy assistant to the Secretary of Defense for chemical and biological defense has established a council to provide advice on modeling and simulation and associated data needs. The Joint Service Integration Group convened a "requirements" panel to define programmatic requirements. (It remains to be seen if this panel will continue under the new Office of the Joint Staff/J8.) Similarly, the

Joint Service Materiel Group has also defined a business commodity area for modeling and simulation, with the Navy serving as the lead Service.

Based on the information made available to the committee, the following summary observations describe the committee's impressions:[11]

- The immediate capability need is for modeling and simulation tools that will enable a commander to estimate exposure levels as a function of location and identify the areas that will likely suffer further contamination.
- Accurate estimates of plume dispersion and deposition of agent are unlikely using real-time computations.
- The accuracy of models will ultimately be limited by practical considerations. These include uncertainties both in the input data (time and precise location of release, initial plume characteristics, or interior dispersion characteristics) and in the local meteorological conditions.
- High-fidelity models are a useful tool for predicting flow over and around the superstructure of naval vessels under a variety of meteorological conditions; as such, they provide useful guidance for the optimal placement of onboard sensors. Less work has been done on predicting flow at ports and bases.
- Threats from industrial manufacturing sites or those using industrial chemicals are viable and potentially crippling to operations. Relatively small-scale releases involving toxic industrial chemicals could have a major impact on operational capability if executed with precision.
- For biological attacks, the time lag between exposure and symptoms and the current lack of reliable, deployable sensors suggest that a model-based system formulated from the perspective of tracking agent dispersion and distribution and the location of the exposed individuals may be the most useful approach for some time.
- The possibility of genetically altered agents, which introduces the potential for many more scenarios, suggests that model-based approaches to identify and track biological attacks for estimating who might be exposed will be prudent for some years.
- Emerging efforts to link chemical fate prediction and/or measurement with operational decision-making tools (battlefield management information systems) is a promising direction for new modeling and simulation efforts.

The observations above lead the committee to the following assessment:

- Rather than trying to improve the accuracy of poorly characterized input parameters, the details of which will likely remain uncertain, it might be more

[11] Appendix C elaborates on descriptions of current chemical and biological modeling approaches.

productive to use simplified plume dispersion and deposition models in conjunction with sensor arrays to give an operationally predictive capability. For this purpose, a simple dispersion model could be used to give an indication of the shape of the dispersion plume as a function of time and location, and then the magnitude of release could be estimated by normalizing to distributed sensor readings. Efforts to integrate computationally simplified models and sensor arrays can provide a means of sidestepping the need for highly accurate initial release data and precise knowledge of local meteorological conditions and thus could provide a valuable capability for consequence management.

- Additional high-fidelity modeling of releases in and near ports and bases is warranted. As with individual ships, predictive simulations will guide sensor placement. Furthermore, detailed modeling of plume transport and deposition about each major port or base under a wide variety of conditions could be condensed into a simplified form (nomographs or computerized expert systems) and made available to the commanders for use in real time. Some work along these lines has been conducted at NRL. This is a significant undertaking, since simply establishing detailed computational grids for a large port requires much work. Validation of the models will also require considerable effort. Nevertheless, the investment should provide useful operational tools for incident response and consequence management.
- Additional investment in discrete event simulations focused on elucidating the operational bottlenecks during a recovery operation may also prove fruitful. These tools can assist decision making with respect to a myriad of possible scenarios that involve considerable uncertainty. Recognizing that aspects of the problem are stochastic in nature (e.g., sensor failures and fluctuations in the meteorological conditions), such computer simulations may offer the best approach for doing systematic trade-off studies for incident response and consequence management, at least in a *statistical* sense. An example of a structure for such a simulation is outlined in Appendix C. This example is offered not for completeness, but to illustrate the methodology and basic concepts. At another level, operationally focused simulations could also be used as a guide in determining how to allocate resources to the various aspects of the Joint CBD Program itself (e.g., sensors, models, protective equipment, decontamination techniques, vaccines, medical treatment, and so on).

COMMAND, CONTROL, AND COMMUNICATIONS: FINDINGS, ASSESSMENTS, AND ANALYSIS

The committee believes it important to include comments on the critical system-level issues related to command, control, and communications (C3) for chemical or biological defense. The discussion is limited to the physical C3 structure needed to support operations in a chemical or biological environment, that is, the interconnection of sensors, databases, and decision makers.

The committee was pleased to learn that the Joint CBD Program is aware of the importance of adequate command, control, and communications, and in the form of the JWARN has begun to address the problem. The Marine Corps is the lead Service for the network. JWARN today appears to be in an early stage of development (having been restructured after a false start a few years ago)—defining concepts and standards and developing and demonstrating prototype hardware and software. Several contractual efforts have been funded over the past several years for hardware and software suitable to provide sensor connectivity between various host computers and interfaces with a number of legacy and proposed sensors—chemical, biological, and otherwise (e.g., automatic chemical agent detector alarm (ACADA); Global Positioning System (GPS); joint biological point detection system (JBPDS); improved point detection system (IPDS); JSLSCAD; JCAD; radiation, detection, indication, and computation (RADIAC) nuclear detector; and so on).

It appeared to the committee, however, that JWARN is being viewed as a self-contained system that will provide the warfighter with sensor connectivity, analysis, and warning and reporting capabilities specific to a biological or chemical threat environment. This appears to be dangerously like another stovepipe approach to C3. JWARN should be fully integrated into the overall battle management system in use. Unfortunately, battle management systems are continuously evolving under the combined stimulus of the exponential growth of computers and modern communications technology, and there is no single battle management system currently in use by all the Services. Thus, JWARN faces enormous obstacles to achieving broad interoperability.

The Navy should pay close attention to JWARN, since such a capability is sorely needed. As a participant in the joint process, it should ensure that JWARN is compatible with whatever Navy battle management systems are currently in use and that it is as free of "stovepipe" limitations as possible. As network-centric concepts evolve into future battle management systems with ForceNet, the Navy must ensure that chemical and biological sensors of all types are fully included in the sensor grid concepts from the start and not added as an afterthought.

SUMMARY OF NON-MEDICAL S&T FINDINGS AND RECOMMENDATIONS IN THE FIVE COMMODITY AREAS

Box 4.1 provides a summary of the findings and recommendations in this chapter. Recommendations are directed to the Navy's technical community, principally at the Office of Naval Research and the Naval Sea Systems Command, involved in the Joint CBD Program.

BOX 4.1
Summary of Findings and Recommendations in the Five Commodity Areas

Commodity Area: Contamination Avoidance

Chemical Point Detection

Findings

- Existing contamination avoidance (CA) point sensor technology is relatively mature for vapor phase threats.
- Decontamination requires sensors with characteristics different from those being developed for CA—and little work is addressing that need.

Recommendations for the Navy

- Develop system concepts for CA balanced through risk assessment with post-exposure consequence management.
- Work with the Joint Chemical and Biological Defense (CBD) Program to reconsider the requirements and technologies for decontamination applications.
- Institute a "tech watch" by the Office of Naval Research of novel developments in microfabricated concepts suitable for very small dosage monitoring and multiple, distributed sensor arrays for area or perimeter monitoring.

Biological Point Detection

Findings

- No biological weapons sensor (or sensor network) can realize the goal of CA in the foreseeable future.
- Most biological weapons sensors are either antibody- or nucleic acid-based.
  - —Both types need more capability to detect and identify a broader range of biological warfare agents.
  - —Antibody-based instruments have had significant field use, but false-positive issues remain.
  - —Nucleic acid approaches are promising, but sample preparation and overall cost challenges need to be addressed.
  - —Other techniques, such as mass spectrometry, have promise, but are a long way from being moved into the field.
- The Joint CBD Program focus on CA fails to address risks and responses end to end, and as a result, science and technology investments in biodetection do not provide a balance among CA, exposure diagnosis, and contamination assessment/decontamination.

Recommendations for the Navy

- Undertake a combined analytic and experimental evaluation to prioritize additional investments in biological point detection science and technology.
- To enhance sensor performance, expand the number of biological agents that can be detected and improve sample preparation for representative naval environments.

continues

Chemical Standoff Detection

Findings

- Both active and passive concepts have been developed, but grow rapidly in size, complexity, and cost as the range requirements are increased.
- The Navy's current chemical weapons standoff detection system, the AN/KAS-1, is neither user-friendly nor robust to the full range of agents and probable background.

Recommendation for the Navy

- Fully support the current development programs in the Joint CBD Program, paying particular attention to naval operating environment and false-positive issues.

Biological Standoff Detection

Findings

- Biological weapons standoff detection is difficult because of the characteristically broad and generally featureless spectral signals of biological molecules, coupled to the low concentration of agent needed for an effective attack and its presence among higher concentrations of naturally occurring background.
- Ultraviolet lidar fluorescence, although inherently short range, may have some potential for shipboard warning, but more likely, for decontamination assessment.

Recommendation for the Navy

- Evaluate requirements—and campaign within the Joint CBD Program—for a real-time, short-range system with good classification/identification capabilities to detect the presence of biological warfare agents.

Commodity Areas: Individual Protection and Collective Protection

Findings

- Sustained military operations in full protective individual gear are unlikely, owing to heat and respiratory loads. This will remain the case for some time.
- Current Navy practice apparently dictates either no individual protective gear or full protection. In response to some asymmetric attacks, intermediate levels of protection may be acceptable and could minimize the impact on operations.
- The availability of individual protective equipment within the Navy is severely limited if one considers the expanding needs associated with protecting not only deployed forces but also personnel at bases and shore installations, ports outside the continental United States, and civilian and logistics support.
- Adequate protection against the broad spectrum of toxic industrial chemicals and materials that might be employed in asymmetric warfare is currently lacking.

Recommendations for the Navy

- Prioritize the acquisition and distribution of additional protective garments and masks to the fleet, bases, installations, and port facilities.
- Acknowledge the operational need for several levels of individual protection, consistent with varying levels of risk, and develop the appropriate guidelines for commanders.
- Champion the development, testing, and fielding of regenerative filters for collective protection systems. Adapt portable protective systems for vessels without collective protection systems and at fixed naval sites.

Commodity Area: Decontamination

Findings

- Effective decontamination materials and procedures should be viewed by the Navy as critical parts of a risk management–based, layered defense against chemical and biological agents.
- No guidelines exist for what are acceptable or "safe" levels of chemical or biological agent remaining after decontamination.
- No field instruments are capable of measuring to acceptable long-term exposure levels the concentration of a chemical or biological agent on decontaminated surfaces.
- Little data exist on chemical or biological agent fates, but such information is critical for guiding an intelligent approach to decontaminating a site and providing information about the long-term safety of decontaminated surfaces.
- Little data are available on the health effects of long-term exposures to low-level concentrations of either chemical or biological warfare agents.
- Progress is being made in research and development for significantly improved decontaminating reagents (low toxicity, low corrosiveness, environmentally benign) for both chemical and biological agents. In particular, the Joint Services Fixed Site Decontamination Program is addressing the critical Navy need for a low-toxicity decontamination system for airbases, ports, and fixed base logistics nodes. The program is scheduled to deliver nontoxic and noncorrosive decontamination materials and application equipment.
- Toxins, new-generation nerve agents, and toxic industrial chemicals have chemical properties different from those of traditional chemical agents. Fielded decontamination materials may not be effective against some of these threats.
- Development work in the commercial sector and in other federal agency laboratories has resulted in or will result in promising new products that may be good fits to Navy decontamination needs.

Recommendations for the Navy

- Develop doctrine for decontamination that sets risk-based guidelines, procedures, and methods, standards of cleanliness, and sources of technical guidance that apply to ships and shore-based facilities.
- To support doctrine development:
  —Undertake studies to set the appropriate levels for short- and long-term exposures.

continues

—Building on work by special units in the Marine Corps, develop equipment and test procedures that become a part of the decontamination toolkit.

—Investigate the use of seawater washdown for the decontamination of Navy facilities enjoying ready access to seawater.

—Undertake agent fate studies to understand the consequences of the interactions of agents with surfaces, coatings, and subsurfaces common to Navy ships and shore facilities before and after washdown.

- Explore the options for decontaminants emerging from other agencies and the commercial sector in addition to participation in the Joint CBD Program.

Commodity Area: Modeling and Simulation

Findings

- Modeling and simulation tools are needed that will enable a commander to estimate exposure levels as a function of location and identify the areas that will likely suffer further contamination.
- Accurate estimates of plume dispersion and deposition of agent are unlikely using real-time computations.
- The accuracy of models will ultimately be limited by practical considerations, such as uncertainties both in the input data (time and precise location of release, initial plume characteristics) and in the local meteorological conditions.
- High-fidelity models are a useful tool for predicting flow over and around the superstructure of naval vessels under a variety of meteorological conditions; as such, they provide useful guidance for optimal placement of onboard sensors. Less work has been done on predicting flow at ports and bases.
- Threats from industrial manufacturing sites or those using industrial chemicals are viable and potentially crippling to operations. Relatively small-scale releases involving toxic industrial chemicals could have a major impact on operational capability if executed with precision.
- For biological attacks, the time lag between exposure and symptoms and the current lack of reliable, deployable sensors suggest that a model-based system formulated from the perspective of tracking agent dispersion and distribution and the location of the exposed individuals may be the most useful approach for some time.
- The possibility of genetically altered agents suggests that model-based approaches to identify and track biological attacks will be needed in the long term as well, since the sensors may not be robust to these new agents.
- Emerging efforts to link chemical fate prediction and/or measurement with operational decision-making tools (battlefield management information systems) is a promising direction for new modeling and simulation efforts.

Recommendations for the Navy

- Use plume dispersion and deposition models in conjunction with sensor arrays to give an operationally predictive capability rather than trying to improve the accuracy of input plume and meteorological parameters, the details of which are likely to remain uncertain.
- Invest in high-fidelity modeling of releases in and near ports and bases to guide sensor placement and to form the basis for simplified operational tools.
- Develop discrete event simulations focused on elucidating the operational bottlenecks during a recovery operation to assist decision making in the face of uncertainty.

5

Medical Chemical and Biological Countermeasures: Specific Findings and Recommendations

INTRODUCTION

Medical defense against chemical and biological warfare agents is critically important in preserving combat effectiveness of naval forces. Medical defense has great commonality across all of the Services—the affected asset in all cases is the individual Service member, not a weapon system or a logistics facility. While the level of threat may differ, individuals' medical defense needs are the same whether personnel are stationed on a forward-deployed aircraft carrier, at an airbase, or at a home port. This chapter reemphasizes the need to differentiate clearly between the response to chemical agents and the response required to wage an effective medical defense against biological agents. Exposure to chemical agents is quickly detectable because the toxic effects are rapid; there are also specific medical responses available for some of the agents. In contrast, biological attacks will most certainly be silent and will not present an immediate, concentrated mass casualty situation. Biological warfare defense is clearly the most challenging from a medical perspective, and, not surprisingly, the committee found the greatest gaps between that threat and our capacity to manage the consequences of an attack.

Medical defense for naval forces must be viewed holistically and should recognize the importance of individual service members, corpsmen, and health care providers as the main elements of the medical defense equation. The Navy medical command is responsible for both Navy and Marine Corps medical defense. As will be discussed, there is a limited number of drugs, vaccines, and

antidotes to support medical chemical warfare (CW) or biological warfare (BW) defense. Training is currently the most obvious weakness for the Navy in the area of medical defense, and improvements in training will offer the greatest return on investment. Vaccines could provide the most comprehensive defense against BW agents, but the Navy should be under no illusions that a stream of effective approved vaccines will become available in the near term to mid-term. In the absence of adequate supplies of effective vaccines, casualties must be anticipated, but observant sailors, corpsmen, clinicians, and commanders working with modern diagnostic tools will allow early medical interventions to save lives and preserve warfighting strength. Recognition of symptoms and pre-incident intelligence should be the earliest input into efficient, distributed disease reporting and analysis systems to allow effective and timely medical defensive measures to be taken.

In this chapter, the committee presents findings and recommendations that run the spectrum from near-term, nontechnical initiatives, to technical and operational shortfalls, to interdepartmental, policy-level issues that can only be addressed through initiatives by the Secretary of the Navy and above. These findings and recommendations focus on three general areas:

1. *Medical training.* Medical training remains a critical determinant of success in medical defense and an area in which senior leadership can be most effectively applied. It is also an area in which Navy medical personnel are significantly lagging behind their counterparts in other Services. *Enhanced training of naval personnel, medical and—as noted for operations—non-medical, represents the highest-payoff, near-term investment that can be made by the naval Services, and the committee urges that it be done now.* Training is not without costs, but the costs are relatively low. Moreover, without better training, the equipment and medical countermeasures provided by the technology developers cannot provide the levels of effectiveness for which they are designed.

2. *Technical and operational shortfalls.* Many of the technical and some of the operational shortfalls in naval medical capabilities are the result of overreliance on the Joint Chemical and Biological Defense (CBD) Program.[1] The committee's leading recommendation for addressing these issues is to define the nature of the shortfalls in terms of naval-specific requirements. This analysis involves the full range of developmental activities, as discussed for operations: doctrine, organization, training, materiel, leadership, personnel, and facilities (commonly referred to as "DOTMLPF" analysis). This kind of analysis and

[1]Due to their expanded scope of chemical and biological defense associated with the war on terrorism, the Department of Homeland Security and the Department of Health and Human Services, especially in the area of vaccines, may impact the Joint CBD Program. The committee believes, however, that its recommendations remain applicable, although the Department of the Navy should follow closely and leverage these activities as much as possible.

formalization of naval requirements should be undertaken by the naval Services doctrine and warfare development centers, the Navy Warfare Development Command (NWDC) and the Marine Corps Combat Development Command (MCCDC), informed and supported by qualified medical personnel. (Specific information with respect to drugs and vaccines, diagnostics, and disease reporting is provided later in this chapter.)

3. *Medical policy issues.* Embedded in the acquisition programs of DOD and the Joint CBD Program for both vaccines and laboratory diagnostics is the requirement for Food and Drug Administration (FDA) certification of drugs, devices, and vaccines. According to current DOD policy, the FDA provides the standards for the safety and efficacy of systems that are used to protect military personnel. FDA certification for BW and CW medical systems is problematic because objective clinical trials involving humans cannot be conducted on the diseases or injuries produced by CW or BW agents. The committee noted two major shortfalls in the development programs of the Services and the Medical Defense part of the Joint CBD Program: (1) the certification of critical laboratory reagents and (2) the slow progress toward certification of drugs and vaccines against BW pathogens. These shortfalls continue despite evidence that the FDA commissioner has shown increasing willingness to modify the certification systems unique to BW and CW. He has recently provided relief from some of the documentation requirements on "orphan" drugs or vaccines that are only effective against BW pathogens. The commissioner has also recently signed a letter authorizing the use of adequate animal studies to meet the efficacy rule. Yet the Joint CBD Program has been slow to act on those "openings" to shorten development and approval times. Liaison and cooperation between the Department of Health and Human Services and the Department of Defense must be continuously exercised to facilitate ways of establishing safety and efficacy in systems designed for military use. This kind of dialogue cannot be assumed to represent the Navy's interests or needs. The committee recommends that the Secretary of the Navy champion those issues within which large gaps in capabilities expose sailors and Marines to unnecessary risk.

The committee's findings and recommendations are presented in four sections: "Medical Training for Casualty Management," "Technical and Operational Shortfalls: Drugs and Vaccines," "Technical and Operational Shortfalls: Medical Diagnostics," and "Disease Reporting and Analysis." Medical policy issues specific to each area are addressed in the respective sections.

MEDICAL TRAINING FOR CASUALTY MANAGEMENT

Medical training is an important basis for successful defense against chemical or biological attack. Training needs are broad: how to recognize the signs of an attack, how to protect medical forces from contamination, how to contain

contagious infections, including when and how to quarantine personnel, how to diagnose and manage patients, and how to maintain and access records of personnel exposed to CW or BW on a long-term basis. This section deals with the comprehensive training of Navy health care providers in the medical aspects of chemical or biological attacks. Because there are important differences between chemical and biological attacks with respect to procedures and health impacts, comprehensive training in both areas is essential. For the purpose of this section, CW and BW are discussed together except for topics in which distinctions need to be drawn.

Medical Chemical and Biological Countermeasures Finding: Navy Deficiencies in Chemical and Biological Medical Defense Training

While specific medical training needs vary, overall the Navy is severely deficient in many areas of chemical and biological medical defense training. Several changes will be needed to rectify the problems. Some of these changes will run counter to current Navy culture and practices and will therefore require directives or orders from the Chief of Naval Operations (CNO) or other appropriate authority to implement them.

Training Requirements

As stated in a recent General Accounting Office report, "There is no mechanism—either joint or within a service—for defining the medical NBC [nuclear, biological, and chemical] training requirements to support medical readiness."[2] It is difficult to establish what medical resources and facilities will be needed to respond to CW or BW situations that have not been previously encountered. Thus, tools are limited for estimating numbers of expected casualties, the mixes of medical specialty skills needed to treat casualties, and the types of equipment and facilities to handle, decontaminate, and treat casualties. Planning instruments, such as the Medical Analysis Tool (software used by the combatant commanders for identifying medical requirements to support war plans), do not adequately estimate the types of injuries and illnesses that a chemical or biological warfare attack would generate. Therefore, the estimated personnel needs generated by the software may not reflect the true mix of skills required to meet a specific situation. For this reason there is a greater requirement for military medical personnel to possess a diverse set of skills so that they can cope with many different possible scenarios. This need is especially relevant to the situation faced by Navy ships at sea, since importing new expertise in a given set of

[2]General Accounting Office. 2001. *Chemical and Biological Defense: DOD Needs to Clarify Expectations for Medical Readiness,* GAO-02-38, Washington, D.C., October 19.

circumstances in any timely way may not be possible. The only effective way to meet the needs for an extensive set of specialized CW and BW medical skills with a limited number of individuals is to invest these skills in the available medical personnel by placing a high priority on chemical and biological casualty diagnosis and management training and by making this training mandatory.

Available Chemical and Biological Medical Defense Courses

The Navy does not have a comprehensive chemical or biological casualty management training program, although there is ample opportunity for the training of Navy Medical Corps officers and health care providers through other organizations. The Army has the most extensive set of such training programs of any of the Services. The Chemical Casualty Care Division of the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD) provides training in chemical weapons casualty care. The U.S. Army Medical Research Institute for Infectious Diseases (USAMRIID) provides extensive instruction in biological weapons casualty care. These two institutes jointly administer and teach courses under the sponsorship of the Army Medical Department Center and School. The flagship course is titled Medical Management of Chemical and Biological Casualties (MCBC).

The MCBC course was designed to train physicians, but it is open to physician's assistants, nurses and, with instructor approval, senior medics and Medical Corps officers for all of the Armed Services. The course and selected components of the course are available in several formats. The most intensive version is a $6^1/_2$-day on-site course covering the principles, management, and treatment of chemical and biological warfare injuries. It combines lectures with clinical laboratory and hands-on field training. A limited number (560) of training slots per year is currently available. To meet a growing demand both within and outside the Services, off-site training options that are exportable on CDs have been developed or, at selected locations, are available for distance learning via satellite broadcast.

A new course, Field Management of Chemical and Biological Casualties (FCBC), began in 1999. The focus of this course is on pre-hospital emergency treatment and casualty decontamination. It is available in both on-site and off-site versions.

The USAMRICD television course Medical Response to Chemical Warfare and Terrorism has been viewed (at least in part) by about 3,500 military personnel who registered for the course. The institute has also developed several distance learning products in this area.

In FY 1999, the Navy began offering a 1-day course, Navy Familiarization Course in the Medical Management of Chemical, Biological, Radiological and Environmental Casualties, that focuses on first-responder and medical support personnel. The course provides informatinon the chemical, biological, radiologi-

cal, and environmental (CBRE) threat and appropriate medical response. The Navy also has a 3-day Chemical, Biological, Radiological and Environmental Casualty Care Management Course. This 3-day course is designed specifically for clinical providers, including physicians, nurses, physician's assistants, nurse practitioners, dentists, and independent-duty hospital corpsmen who might provide front-line or rear-echelon treatment to CBRE casualties. The course covers CBRE medical management and includes an interactive tabletop exercise involving one or more of the potential agents. The courses are conducted at the Naval Environmental and Preventive Medicine Units at Norfolk, Virginia; San Diego, California; Pearl Harbor, Hawaii; Sigonella, Italy; or on-site at the requesting command.

In contrast to the limited time allocated for medical chemical and biological training, the Navy provides a 12-day course for non-medical chemical and biological issues, entitled Shipboard Chemical, Biological and Radiological Defense Operations and Training Specialist. This course provides basic to advanced chemical, biological, and radiological defense (CBR-D) training for enlisted personnel (E5 through E9, source ratings of damage controlman, hull maintenance technician, and hospital corpsman). Graduates of the course are prepared to conduct CBR-D training at commands and aboard ship and to advise on the integration of CBR-D operations into a normal command organization. This course is conducted by the Naval Construction Training Center Detachment at Fort Leonard Wood, Missouri.

Readiness of Medical Personnel

The availability of training courses does not by itself ensure that the Navy has reached an adequate level of chemical and biological medical defense readiness. The measure of readiness should include whether or not sufficient medical personnel have received training and provide objective evidence that this training has been effective. Navy doctrine provides for the regular evaluation of ships' operational readiness and training. However, within this framework, the chemical and biological medical defense training requirement to support medical readiness is inadequately defined. The Navy does require that personnel deploying to field hospitals learn decontamination procedures, but little else in the way of chemical and biological medical defense training is mandatory for physicians, physician's assistants, nurses, medics, or corpsmen.

Chemical and biological medical defense training courses are largely voluntary. This lack of required training is reflected in the relatively small numbers of Navy health care providers who have received chemical and biological medical defense training. In some cases, individual health care personnel can augment formal training by taking personal initiative and studying the many resources available for self-instruction, as exemplified by a corpsman aboard the USS *Kauffman* who demonstrated this level of bottom-up initiative during a visit by members of the committee. Such initiative and interest are not universal, however.

On the basis of data provided to the committee by both Army and Navy medical record holders, the committee estimates that overall participation by Navy health care providers in any training is poor.

The MCBC course provides the most comprehensive training of all the available courses and should represent the minimum acceptable level of training for medical corps officers. From the same data, only a small percentage of Navy active duty officers have taken this course in comparison to a much larger percentage of the Army active duty officers.[3]

Reporting

There is no centralized internal training and competency database for the Navy analogous to the one maintained by the Joint Commission on Accreditation of Health Care Organizations for civilian medical care. Consequently, there are no available accurate data on medical personnel trained in chemical and biological defense to support the development of compilations of medical skill availability for war planning and ship staffing. The staffing of a ship's medical department will therefore be uneven with respect to training and competency.

The committee's findings can be summarized in three succinct statements:

1. Participation by Navy Medical Corps officers in training for chemical and biological casualty treatment is unacceptably low, although training courses are available. Chemical and biological casualty training is not mandatory for Navy health care providers and is voluntary or discretionary on the part of commanders.

2. The Navy has no objective tests for skills proficiency after training. The Army has tested its medics and found that NBC skills were unacceptably low.[4] In the absence of Navy data, the readiness of Navy personnel to treat chemical and biological casualties is unknown but suspect.

3. The Navy does not track the chemical and biological medical defense training or proficiency of health care providers. This lack of information limits the ability of the combatant commanders to accurately forecast medical skills needed and availability of trained personnel to support war plans. This limitation translates to the possibility that poorly prepared personnel will have life-and-death responsibilities aboard ship in the event of a chemical or biological attack.

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[3]U.S. General Accounting Office. 2001. *Chemical and Biological Defense, DOD Needs to Clarify Expectations for Medical Readiness,* GAO-02-38, Washington, D.C., October.

[4]The Army conducted an evaluation of the proficiency of its medical first-responders (medics). Their readiness to treat NBC casualties was lowest of all the skills evaluated (16 percent passed a cognitive test with a grade of 70 percent or better). Hands-on skills were not tested in this evaluation. There are no equivalent data for the Navy.

Medical Chemical and Biological Countermeasures Recommendation: Improving Medical Readiness

In parallel with the recommendations of Chapter 3 in this report for achieving operational readiness, the Navy should establish a training and exercise program and an accompanying reporting system in order to achieve chemical and biological medical defense readiness.

Since the Navy does not have its own comprehensive training program for the medical management of chemical and biological warfare casualties, Navy health care personnel should be directed to enroll in and complete the CW and BW courses on medical management offered by USAMRICD and USAMRIID, respectively. This direction should apply to all Navy health care providers, from corpsmen to physicians. The Navy should provide scheduling and funding for this training. The committee recommends that specific goals leading to at least 60 percent trained personnel within 2 years be adopted. The CNO should direct that training in chemical and biological medical defense and casualty management be mandatory and that no corpsman or physician should be deployed prior to completion of the appropriate course(s). Compliance can be ensured by incorporating requirements for proficiency in medical chemical and biological training in operational-readiness inspections prior to deployment.

The Navy's health care providers should be regularly tested for proficiency in the diagnosis and treatment of chemical and biological warfare casualties. To implement this requirement, fleet commanders should be directed to include the medical readiness of ships with regard to CW and BW medical defense into the periodic reports of readiness and training (i.e., Status of Resources and Training System (SORTS)) so that the capacity of a ship to handle the consequences of chemical or biological attack can be evaluated. A capably trained and proficient health care provider will save lives. The Navy should develop a program to track chemical and biological medical defense training and proficiency to allow medical personnel and skills to be adequately accounted for in war planning and ship staffing.

TECHNICAL AND OPERATIONAL SHORTFALLS: DRUGS AND VACCINES

This section reviews chemical and biological medical defense products currently available to naval and Marine forces. In addition, it discusses future products in advanced development and the medical technology base. The process used for military medical product development is reviewed, and a critical assessment of the process is presented.

Medical Chemical Defense

Current Treatments

With the exception of toxic industrial chemicals (TICs) and a small number of novel chemical agents, there is a limited number of chemical warfare agents (see Appendix B, "Agents and Effects," for a summary description). Some of these agents have been weaponized by potential adversaries and, in some cases, used in warfare. Much is known about their physical and toxicological properties. The effective employment of these classical agents produces nearly immediate pathophysiological effects by relatively well-understood mechanisms. Physical protection is the first and most important line of defense, followed by decontamination, antidote therapy, or both. There are no plans to replace physical protection with a broad-spectrum, pre-exposure drug. In reality, there are only five military CW medical products fielded for U.S. forces. Four are for use as nerve agent therapeutics and one is a skin decontaminant resin device. Each is known to be safe and effective. All Navy personnel should be familiar with and trained in the use of these products and, when deployed, should have access to them in adequate quantity. Box 5.1 describes currently available medical products.

BOX 5.1
Current Medical Treatments for Chemical Warfare Agents

Nerve Agents

The treatment for nerve agent poisoning recommended by the U.S. military involves the use of three therapeutic drugs: atropine, pralidoxime, and diazepam. Atropine counteracts many of the effects caused by the inhibition of acetylcholinesterase. Pralidoxime chloride (2-PAM), one in a family of drugs that reactivates the nerve agent-inhibited cholinesterase, is administered with atropine. Diazepam, an anticonvulsant, is administered in severe cases of nerve agent intoxication to control seizures and thereby minimize brain injury. Atropine, 2-PAM, and diazepam are packaged in autoinjectors issued to U.S. military personnel for self- or buddy-aid. Atropine and 2-PAM by themselves have limited efficacy against the nerve agent soman (GD); thus, naval personnel are supposed to be provided supplies of the nerve agent pretreatment pyridostigmine bromide (NAPPB). PB is administered on the orders of the commanding officer when a creditable future threat of exposure to GD exists. As is the case with other nerve agents, atropine and 2-PAM are administered post-exposure.

Vesicants

Included in the category of vesicants are sulfur mustard, lewisite, and phosgene oxime. Mustard has been used on modern battlefields—for example, in the Iran–Iraq conflict—and it is considered a likely chemical agent to be employed

continues

against U.S. forces in a future war. Currently there is no effective antidote or treatment for mustard injury. Chemical protective ensembles are effective barriers if worn properly, and the chemical filters in the current mask are effective against mustard vapor. Should skin exposure occur, immediate decontamination of exposed skin areas is the only means of preventing tissue injury. For skin decontamination, U.S. military doctrine prescribes the use of 0.5 percent sodium hypochlorite followed by soap and water. The resin-based M291 kit is effective for small-area skin exposures. The Food and Drug Administration considers this product, developed by the Army Medical Department in cooperation with a commercial partner, a medically regulated product. One of the major problems associated with skin exposure to mustard is that signs of exposure such as pain and redness often do not appear for hours. By the time signs appear, the damage is done and the resulting injuries to the skin, eyes, and airways can only be treated with conventional supportive therapy.

The clinical effects of lewisite are similar to those of mustard. However, unlike mustard, lewisite liquid or vapor produces irritation and pain upon contact. As with mustard, immediate decontamination will limit lewisite's damage to skin or eyes. A specific antidote for the systemic effects of the agent exists in the form of British Anti-Lewisite (BAL). BAL must be used under medical supervision owing to its own toxic properties. There is no need to have this antidote far forward, and it can be kept in modest quantities because of the minimum threat from lewisite.

In both liquid and vapor forms, phosgene oxime is highly corrosive and penetrates clothing and rubber readily; and, like lewisite, it produces severe pain upon contact. Like mustard, phosgene oxime has is no antidotal therapy.

Cyanide

Amyl nitrite, sodium nitrite, and sodium thiosulfate are commercially available in standard doses in the Pasadena Cyanide Antidote Kit. This kit is not widely distributed in Department of Defense medical channels. No antidote kits are provided to naval personnel far forward. However, should a person be exposed to a lethal dose of the agent and not receive therapy immediately, death is certain.

Phosgene

Although phosgene is not currently believed to be a significant threat to naval personnel, it is still a ubiquitous toxic industrial chemical. Pulmonary edema is the most serious consequence of inhalation exposure. At present, there are no proven pharmacological interventions for phosgene-induced pulmonary injury. As with the vesicants, rapid removal from the source is essential. Physical exertion during the latent period following exposure may precipitate signs and symptoms; thus, rest and airway management are essential in the medical management of phosgene exposure.

Treatments Under Development

Two new medical products are currently in advanced stages of development in the Joint Service Medical Chemical Defense Science and Technology Program: a topical skin protectant and a multichambered autoinjector. The topical skin protectant is a barrier ointment that will significantly delay the penetration of

chemical agents to the skin. This item is neither to be used on large areas of the body nor designed to take the place of gloves; rather, it is designed to improve the efficiency of the current chemical protective ensemble. Specifically, it is to be used around the neck, wrists, and ankles where there are weaknesses in the seals owing to body movement. This medical device is regulated by the FDA.

The multichambered autoinjector is simply a device that will allow a nerve agent victim to administer both the atropine and the 2-PAM through a single needle. This medical device is also FDA-regulated and while each of the drugs contained in the device is approved separately, the combination delivery system requires additional FDA testing. Both of these products have spent at least a decade in development but are not expected to be fielded during the next several years.

A number of potential advances in medical chemical defense are being pursued in the science and technology base. Some research efforts are looking at commercially available pharmaceuticals, such as an advanced anticonvulsant, that may be useful for the purpose of stopping and preventing nerve agent–induced seizures. It is important to point out that while a number of currently approved drugs may be effective, many years of research are required to meet FDA standards for an indication, or use, that the drug was not originally approved for. The best example of this problem is PB (pyridostigmine bromide). This drug, used safely in humans for another indication, requires that DOD request a special exception from FDA to allow its use as an investigational drug. Additionally, FDA requires that the efficacy of the product be shown in human subjects. This, of course, is impossible with chemical agents and requires enormous efforts to find surrogate endpoints for efficacy in animals that can be extrapolated to humans receiving the drug.

Also within the Joint Service Medical Chemical Defense Science and Technology Program technology base are programs to develop broad-spectrum enzyme scavengers that will provide pre-exposure protection against CW agents. These scavengers are forms of human cholinesterases and will require the administration of a non-self-generated protein or gene therapy to develop levels that are protective. This next-generation antidote for nerve agents and for many of the other CW agents will not be available for at least a decade or more. Another next-generation medical product, the reactive topical skin protectant discussed above, has the potential to be developed more rapidly once the first iteration of the product currently in advanced development meets all regulatory requirements and is acceptable to operational forces.

Medical Biological Defense

Medical countermeasures to biological agents include pre-exposure vaccination and pre- or post-exposure drug therapy.

TABLE 5.1 Vaccines Against Selected Biological Warfare Threat Agents

Agent	Current Product	Date of Next-generation Candidate Licensure
Anthrax	Licensed	2011
Smallpox	Licensed	2005
Botulism	IND	2011
Plague	Licensed	2011
Tularemia	IND	2009
Venezuelan equine encephalomyelitis	IND	2016

Vaccines

Currently, the Armed Services have only two FDA-licensed vaccines suitable for use in military populations—those for anthrax and smallpox.[5] Other stocks of vaccine are held by the military and could be used widely in the military if needed, under an FDA-approved Investigational New Drug/Vaccine (IND) research protocol. However, because of the current age of these stocks, these vaccines cannot be used under an IND protocol until they are retested and pass standard FDA quality-testing requirements. A limited discussion of the current status of approved medical countermeasures is presented in Box 5.2. Table 5.1 demonstrates the status of most current DOD BW vaccines.

Post-exposure Therapy

Several therapeutics are approved for post-exposure treatment. For anthrax, current military doctrine calls for initiating treatment with oral ciprofloxacin or doxycycline as soon as exposure to spores is suspected, and introducing intravenous ciprofloxacin at the earliest signs of infection or disease. The vaccination series should also be administered to victims not immunized in the previous 6 months. Antibiotic treatment should be continued for at least 4 weeks, during which time the victim should also receive a series of vaccinations.

Plague pneumonia is almost always fatal if treatment is not initiated within 24 hours of the onset of symptoms. A number of readily available, broad-spectrum antibiotics have shown efficacy. Specific broad-spectrum antibiotics are also recommended for post-exposure treatment against tularemia and Q fever. A licensed trivalent equine antitoxin available from CDC is the only approved therapy for airborne botulism.

[5]A previously licensed vaccine for plague was no longer produced after 1998, and its license expired shortly thereafter.

BOX 5.2
Approved Biological Warfare Medical Countermeasures

Anthrax

A licensed anthrax vaccine is available for use by U.S. military forces from BioPort Vaccine Corporation. This vaccine is administered intramuscularly in a series of six doses at 0, 2, and 4 weeks, and 6, 12, and 18 months, followed by annual boosters. Studies are under way to determine if fewer immunizations in the initial series will provide protection. Owing to delays in gaining approval from the Food and Drug Administration for release of stocks at the only U.S. manufacturer of this vaccine, the Secretary of Defense has had to delay the implementation of a comprehensive anthrax immunization plan for U.S. forces. Currently, only limited numbers of forces being deployed to high-threat areas are receiving vaccinations. The inventory of approved vaccine is limited at this time. Recently, the Department of Defense (DOD) Joint Vaccine Acquisition Program (JVAP) has commenced an effort with Avant Immunotherapeutics to develop an oral combination vaccine against anthrax and plague.

Smallpox

At the time of the study committee's research, the only vaccine available in the United States was a live vaccinia virus preparation, and the Centers for Disease Control and Prevention (CDC) held a stock of several million doses. Subsequently, a larger stockpile of frozen vaccine was found in the storage facilities of a U.S. pharmaceutical company. The federal government has initiated a program to vaccinate key public health and emergency medical personnel throughout the country with these stores, although suspected cardiac complications in some cases have slowed progress. In the meantime, the JVAP has given the go-ahead to its prime contractor, DynPort Vaccine Company, to initiate clinical trials on its new smallpox vaccine for DOD. In addition, the British pharmaceutical company Acambis announced its new version of a smallpox vaccine, which is currently in clinical trials and expected to be available in 2004. Vaccination induces good immunity and will give protection to an exposed individual if it is administered within a few days of exposure. Unfortunately, rare adverse reactions, including neurological disorders, can occur. Also, the live virus in the vaccine is transmissible, and it is hazardous to individuals with compromised immune systems. Recent testing of the stockpile of smallpox vaccine by CDC has demonstrated that the doses of vaccine in these stocks can be diluted while retaining potency, thus expanding the potential number of doses available for the U.S. population. Additionally, new contracts have been established that will provide millions of additional doses of this vaccine. Current stocks of the licensed vaccine are not dedicated for military use.

Botulinum Toxin

The currently available toxoid protects against botulinum toxin types A through E, but is available only as an Investigational New Drug/Vaccine product, with the administration of the toxoid controlled by CDC. A series of three vaccinations must be started 12 weeks before exposure. Most recipients show positive evidence of protective titers at 14 weeks, and yearly boosters are required to maintain protection.

There is no drug with proven effectiveness against smallpox in humans. However, some promising candidates are emerging. Recent in vivo results with cidofavir are showing good results as a therapeutic. Vaccinia-immune globulin (VIG) might be of use if given soon after exposure to variola (smallpox) or at the time of an adverse vaccination reaction, but this potential is based on laboratory results of its interactions with the vaccinia virus. The availability of VIG came long after the eradication of the disease, so affirmation of its effectiveness has been precluded. There is limited availability of VIG from CDC. The antiviral drug ribavirin is recommended for therapy for some viral hemorrhagic fevers.

Joint Service Vaccine Development

In addition to having responsibility for existing stocks of DOD vaccines, all DOD BW vaccine development efforts are managed through the Joint Vaccine Acquisition Program (JVAP) and through the prime system contactor, DynPort Vaccine Company. JVAP is a subordinate organization of the Joint Program Office for Biological Defense. JVAP also manages and monitors progress on vaccine development efforts that are in the Joint Service Medical Biological Defense Science and Technology Program technology base. Vaccine candidates that are mature enough for small-scale production and testing under FDA guidelines are transitioned to DynPort Vaccine Company for advanced development, regulatory compliance, testing, production, and fielding.

Table 5.1 illustrates the current JVAP time lines for several next-generation vaccine candidates. The dates of next-generation candidate licensure presented in this table should give the reader a sobering vision of our expectations with regard to future vaccine protection. These time lines are established by JVAP and are supported by the related DOD-level working committees.

While there are legitimate scientific hurdles in the science of vaccine development, this committee cannot find any civilian business model that parallels the DOD development plan. This may be because in industry, economic pressures drive the developer to "move it or kill it" when it comes to a drug or vaccine product. To this committee, it seemed from numerous briefings that the officers responsible for drug development were not fully engaged in the kind of drug and vaccine development programs that emphasize rapid screening, testing, and early regulatory agency engagement on "best of breed" candidate drugs and vaccines. In fact, the committee sensed that DOD's working business model is characterized by single-product, risk-averse plans with little early assessment from the perspective of regulatory approval. There are no effective partnerships with industry or FDA that emphasize the need to produce a product or stop the candidate development program.

Medical Chemical and Biological Countermeasures Finding: Shortfalls in Both Navy and Joint Drug and Vaccine Programs

On the basis of the committee's visit with deployed shipboard personnel in Norfolk, Virginia, and the collective knowledge of current and former Navy medical personnel, the committee found that a number of inventory shortages exist in preparedness for medical defense against chemical warfare agents. These shortcomings include out-of-date antidote kits, insufficient antidote kits for all who might be exposed, and an absence of convulsant antidote for nerve agent (CANA). Further, the committee was given the impression that training on self- and buddy-aid with training sets was not part of individual training requirements. At the same time, the available treatments for CW agent exposure are reasonably effective, so such deficiencies point to low priority within ongoing operations and maintenance programs and practices as opposed to technical shortcomings.

The Joint Vaccination Acquisition Program suffers from a number of shortcomings, many of which can be remedied with efforts from the affected Services:

- There is currently only one source of FDA-approved anthrax vaccine for U.S. forces, and current stockpiles are limited.
- DOD has stockpiles of vaccines against many important BW agents, but it is estimated that it would take 2 years and $6-8 million to test each vaccine in the stockpile to FDA standards for release and use under IND protocols.
- In the absence of adequate vaccines, large stockpiles of broad-spectrum antibiotics, antivirals, antisera, and supportive medical material will be required to treat mass casualties from a BW attack. A wide range of broad-spectrum antibiotics is approved and available, but not stockpiled for emergency military use.
- Within DOD and the Army, as the DOD executive agent for military drug development, the current system of identification and maturation of candidate systems has no parallel in the commercial pharmaceutical and vaccine industry. The system is risk averse and likely to achieve results in decades rather than years. Regulatory issues surrounding FDA approval of DOD chemical or biological defense drugs in combination with the application of DOD development and acquisition guidelines compound the problem, but FDA has indicated its willingness to create an approval protocol tailored to military needs. JVAP needs to act on that opening.

Medical Chemical and Biological Countermeasures Recommendation: Needed Practices and Reforms for Adequate Protection

At a minimum, the Navy should ensure that all deployments include adequate stores of current chemical and biological medical defense countermeasures. It should also push the JVAP into a more aggressive development path for new and more effective vaccines and drugs. The current DOD time line for the

fielding of vaccines and therapeutics will provide at least a decade lag in force protection with the current investment and cautious approach. Therefore, the Navy should not rely on vaccinations to be effective protection against BW agents in the short to mid-term, nor should it await more effective antidotes to CW agents. Deployment with adequate stores—with respect to both quantity and shelf life—of chemical agent countermeasures and known antibiotics to mitigate BW effects should be an operational requirement.

To accelerate the introduction of more effective medical countermeasures, there needs to be an overhaul of the DOD drug and vaccine management structure. The new structure and processes should mimic best commercial practices and allow for risk tolerance in product development. To ensure that this issue receives the attention needed, the Chief of Naval Operations needs to champion an effort through the Secretary of the Navy to accelerate those efforts that are of the highest interest to naval forces.

TECHNICAL AND OPERATIONAL SHORTFALLS: MEDICAL DIAGNOSTICS

Medical diagnostics are usually bounded by those activities that result in clinical confirmation of disease or injury. This report divides this activity into laboratory diagnostics and clinical diagnostics. While both activities lead to the confirmation of disease, they have distinctly different doctrinal and technical characteristics.

Laboratory diagnosis is the activity that confirms the presence and identity of a pathogen in samples from humans who are either showing signs of clinical illness or, in some instances, are identified as having been exposed to pathogens. While a laboratory analysis provides the final confirmation of disease-causing organisms in a human sample, the actual diagnosis of disease (or exposure to disease-causing organisms) is made by correlating these supporting laboratory data with the clinical findings. Accordingly, a diagnostic laboratory is only as good as the people interpreting the data.

Clinical diagnosis is the high-level activity conducted by clinicians that results in decisions being made that affect the lives of crews and the missions of warfighters. This activity is heavily dependent on training, on the level of awareness of the threat (field intelligence, situation awareness), and on the skills of the clinician.

Because chemical warfare casualties have a short lag time between exposure and the onset of symptoms and since the distinction between different warfare agents is fairly straightforward, the committee focused on the diagnosis of biological warfare–related disease, which can be easily confused with naturally occurring (“background”) infections. The more technical findings and recommendations of laboratory diagnostics are addressed first, followed by the broader and less technical area of clinical diagnosis.

Laboratory Diagnostics

Pathogen identification and characterization systems are dominated by the same two technological approaches as those used for environmental sensors supporting contamination avoidance: (1) antibody-based systems in which the identification of a pathogen is made by a characteristic reaction between the pathogen and a protein product of the immune system, or (2) nucleic acid methods in which a pathogen's DNA is amplified and detected.

The first process is exemplified by the enzyme-linked immunosorbent assay (ELISA) common to a wide range of clinical laboratory products. ELISA is the basis for almost all of the handheld and fixed installation biodetection systems currently under development or fielded. ELISA is characterized by a reaction between a specific component of the pathogen (often the cell wall) and a specifically engineered immunity molecule (immunoglobulin). This reaction is transduced, in a variety of ways, to provide the operator with an "on-off" indication of the presence of the target pathogen. The actual transduction process varies among systems and can be as simple as a color change on a piece of paper or as complicated as a method of reading the amount of light emitted from a test system. The laboratory diagnostic systems differ from field sensors only in the higher level of specificity and sensitivity engineered into their design.

The other dominant technology is the polymerase chain reaction (PCR) system, which is a means of amplifying (i.e., rapidly growing) small quantities of bacterial DNA to reach "critical mass" for analysis. Since characteristic segments of DNA are a form of "fingerprint" for a microbe, this system is used to expand the quantity of a test substance to a level at which it can be assayed by DNA-sensing technology.

Neither of these systems is unique to biological warfare. Both technologies are used in a wide range of clinical and research applications. FDA certifies both the reagents and the laboratory technology used to manage the care of humans.

Medical Chemical and Biological Countermeasures Finding: Both Operational and Technical Shortfalls in Laboratory Diagnostics

Operational Capabilities

The committee's review of a limited number of operational-readiness directives (specifically, instructions from the Commander, Naval Air Force, U.S. Atlantic Fleet (COMNAVAIRLANT), and the Commander, Naval Air Force, U.S. Pacific Fleet (COMNAVAIRPAC), that define medical readiness) suggests that formal requirements for capabilities in a ship's medical department lag behind the availability of technology. The Navy's Bureau of Medicine and Surgery and the fleet have begun efforts to develop training packages and medical concepts of operations and to field improved equipment to Navy ships, but these changes

have not yet been reflected in formal instructions and directives governing the readiness status of Navy ships.

The committee also found that there is an excellent resource available through the Navy forward-deployable medical laboratories that are assembled and maintained by the forward-deployable, environmental and preventive medicine units (FD-EPMUs). These laboratories are expeditionary, hardened for field use, and represent the first step toward a minimal equipment set for advanced laboratory diagnostics. It is the sense of this committee that these laboratories have not been fully exploited as platforms for experimentation in training, doctrine, equipment, and disease surveillance.

Technical Directions

The Joint CBD Program's development plans for laboratory diagnostics are too narrowly focused on ELISA and PCR sciences. ELISA laboratory diagnostic systems, while more sensitive and specific than their environmental sensor counterparts, still can produce disruptive false-positive reports by cross-reacting with common benign organisms found in the soil or the atmosphere. Further, ELISA will fail to provide a positive response below a certain level of organisms in the sample. In some cases, this means that a lethal concentration of pathogens may be present in a sample but fail to be detected on the ELISA assay. While skilled practitioners understand these limitations and can look for corroborating diagnostic signals, not all medical technicians are so trained. Thus, the Navy may be dependent on systems that alarm too frequently—or that may fail "quietly" in circumstances in which the microbe concentration in a sample is low. Although significant progress has been made, PCR is not yet widely fielded because significant resources must be committed to the upkeep of equipment, operator training, and a supply of calibration reagents to keep the system fidelity up to standards.

As noted at the beginning of this section, the committee's findings suggest that practically all of the laboratory diagnostics systems either under development or fielded for the military are based on one or both of these technological approaches. The committee believes that this represents an overly narrow investment in core technology.

There are other technological approaches to pathogen identification currently employed or under development by other federal agencies, although most are aimed first at the environmental sensing problem. Other scientific approaches with less dependence on immune-system reactants have recently been shown to be useful in discriminating "nearest neighbor" species with sufficient fidelity to offset the nagging problem of false alarms. Pathogen identification by mass spectrometry—traditionally a tool of large laboratories—may offer advances in miniaturization and durability that make it attractive to combat developers. These systems may offer some relief from the limitations of the existing technology.

Recognizing the challenges that any of these alternative approaches faces, the committee believes that some assessment of different approaches should nonetheless be made.

The committee's review of the Joint CBD Program's Critical Reagents Program suggests that FDA certification of the reagents used in many of the advanced military diagnostic systems lags behind technological development. There remains an impression with the committee, gained from looking into this area and into the vaccine programs, that the level of dialogue with the FDA is below a level at which efficient pathways to certification are going to be realized any time in the near future.

Finally, the current systems under development, with rare exceptions, assume that the role of laboratory diagnostics is to provide *confirmation* of the clinical patterns observed by the physician or hospital corpsman. It assumes that sufficient clinical evidence exists to warrant laboratory sampling and that sufficient pathogen load exists to make the individual clinically ill. A priori, this assumption gives away much of the initiative to the perpetrator of biological warfare. The committee's findings suggest that there is an opportunity to redirect some of the Navy's basic research into investigating technologies that can identify incipient infection in individuals exposed to a BW pathogen *before* they manifest symptoms of infection. Given the suspicion of exposure (from warning sensors or an index case), this "pre-clinical" (or pre-symptomatic) phase represents a window of opportunity for making early treatment decisions that may be affected by mission requirements, limited supplies, or other non-medical issues that impact on the commander's decision-making processes.

Medical Chemical and Biological Countermeasures Recommendation: Operational Diagnostic Improvements at Hand

Implement existing instructions and make use of environmental and preventive medicine units for introducing new equipment.

The Chief of Naval Operations should require that fleet commanders review relevant instructions governing the medical readiness of ships with regard to biological warfare diagnostics. Ideally, this readiness review should result in new periodic reports of readiness and training (i.e., Status of Resources and Training System (SORTS)) and be more reflective of the capacity of a ship to handle the consequences of biological warfare. *This recommendation is a low-cost, high-payoff action with a short implementation schedule.*

In addition, fleet commanders, wherever possible, should exercise the forward-deployable medical laboratories and direct that the lessons learned be incorporated into fleet instructions governing the equipping of medical facilities afloat and the training of their personnel. This laboratory represents an ideal testbed for defining the utility and "fieldability" of new diagnostic technologies.

Medical Chemical and Biological Countermeasures Recommendation: Current and New Technical Developments in Diagnostics

Assess current equipment against naval requirements and establish research and development efforts where gaps in effectiveness exist.

A number of actions are recommended both for assessing the direction of the current Joint CBD Program with regard to the specific needs of naval forces and for focusing some basic research in more promising directions. More specifically:

- The Chief of Naval Operations should direct a review of Joint Chemical and Biological Defense Program and Department of Defense lead agent investments in existing technologies and modify, as necessary, Navy operational requirements documents to serve the needs of the fleet and naval station end users. As is apparent from other parts of this report, there is a downside in assuming that joint systems will result in robust Service capabilities. Navy ships and marine operating environments can place unique demands on the design of equipment. A piece of laboratory equipment that would be entirely compatible with an Army table of organization and mission has more than a small chance of failing to become an operational capability on a Navy vessel.
- The Chief of Naval Operations should direct the chief of the Bureau of Medicine and Surgery to report on the status of the Critical Reagents Program and to make recommendations for CNO action for accelerating the regulatory activity surrounding the reagents that are necessary for the laboratory diagnostic gear earmarked for the fleet.
- The Chief of Naval Research (CNR) should consider Navy funding of technologies for laboratory diagnostics that support a broader technology base for ELISA (immunoassay) and polymerase chain reaction to drive down cross-reactivity and false positives and to assess alternative techniques that may not have the inherent shortcomings of these approaches.
- The Chief of Naval Research should assess the adequacy of investigations into the means of identifying individuals who have been exposed to but are not yet clinically ill from a biological warfare pathogen. This task will require the investment of basic science dollars in the fundamental biology of pathogen invasion, infection, and host response. If gaps are identified, the CNR should champion increased investment by the Joint CBD Program in such research tailored to BW agents. While this is a potentially large scientific endeavor, the DOD program can build on significant investment by the National Institutes of Health and others on pre-symptomatic diagnosis techniques and tailor the most promising approaches to BW agents.

Clinical Diagnostics

Clinical diagnostics traditionally represents the activity of physicians who must make the diagnosis of disease and injury on the basis of history, physical examination, and supporting laboratory data (in this case laboratory diagnostics). In the case of ships at sea, this role is often assumed by independent duty corpsmen. For disease outbreaks, the process consists of physical observation and correlation of data.

Historically, the public health model of disease identification and mitigation has often been characterized by full laboratory confirmation of the putative pathogen before effective countermeasures are instituted. Less common, where public health is affected on a large scale, officials use "warnings or indicators" of disease and act early (often without the time for confirmation of findings) to head off the spread of dangerous diseases. The most common example of this proactive stance toward disease is the periodic surveillance of Far East stocks of chickens and waterfowl that may represent a reservoir of Asian influenza virus. Any change in the health of these animals that indicates the likelihood of spread to humans results in immediate actions (culling and slaughter) to prevent the spread of a contagion that could result in a human influenza pandemic. In this instance, the public health officers "get out in front" of more conservative means of human disease monitoring to lower the threshold for effective action to mitigate or eliminate the disease.

The point to be made is that traditional clinical diagnosis, unless modified and advanced to a set of early, fundamental indicators of incipient disease, is likely to be "too little, too late" to prevent casualties and loss of life from biological warfare attacks.

Medical Chemical and Biological Countermeasures Finding: The Lack of Practice of Clinical Diagnosis

Training programs are available through the Department of the Army for both physicians and paramedical personnel in the diagnosis and management of CW and BW casualties. As noted in the section "Medical Training for Casualty Management," above, there is no evidence that a minimum standard has been set for the training of fleet medical departments. Of equal importance for taking action, there was no evidence presented to the committee that efforts have been made to train commanders in the common language of epidemiology. The process of gaining some level of understanding of the language of infectious diseases (or chemical casualties, for that matter) currently depends on the interest and experience of the commander and the skill of those Navy Medical Department personnel who provide advice and counsel. The development of a more robust and widely useful approach for the fleet is hampered by the fact that there is no medical officer representation at the Navy Warfare Development Command.

This lack, in turn, limits progress in the development of concepts of operation and experimentation in areas in which emerging threats or new operational doctrines have a medical diagnostic component.

Medical Chemical and Biological Countermeasures Recommendation: CONOPS Development Coupled with Clinical Diagnosis

The Navy Warfare Development Command should develop gaming and operational concepts, coupled with clinical diagnosis, for biological warfare attacks.

This recommendation further expands the recommendation in Chapter 3 (see the section "Operational Recommendation: Roles for NWDC and MCCDC"). The Commander, Fleet Forces Command, should define a role for NWDC in the development of war games or seminars that exercise decision making by commanding officers faced with the consequences of biological warfare attack. The exercise of these war games should include ways to further refine the relationship between medical diagnostics (the detection of clinical disease) and the decision-making process of the ship's commanding officer or the battle group commander. Said another way, medical diagnostics is another piece of information flowing to the operational commander. If the data supplied to the commander are not helpful in making decisions about the best employment of the unit, the systems need to be reengineered to fit the need. Assigning a senior medical officer who has fleet experience to serve as the principal originator of new concepts in medical diagnostics would be a minimal step. In fact, the Navy Medical Department has made considerable investment in physicians trained in epidemiology and infectious diseases. It is recommended that such an officer with sufficient fleet experience and training in infectious diseases be selected by the Bureau of Medicine and Surgery so that he or she can provide the nexus for concept generation and experimentation.

Medical Chemical and Biological Countermeasures Finding: Consequences and Impact of Exposure

A serious and generally overlooked issue is that of long-term consequences for the health care system of victims exposed to chemical or biological weapons. Lacking an understanding of any long-term or recurring symptoms of exposure, health care professionals in the military are not in a position to provide adequate treatment or post-injury support. The committee raises the issue as a general concern but does not have a particular recommendation to make beyond raising the need for the Department of Defense to invest in the research necessary to characterize such effects in order to provide both immediate and longer-term treatments.

DISEASE REPORTING AND ANALYSIS

A near-real-time disease reporting process coupled to an efficient and automated epidemiological analysis system would significantly improve the Navy's ability to defend and operate under chemical and, especially, biological warfare conditions.

Medical Chemical and Biological Countermeasures Finding: Lack of Disease Reporting System Among Naval Forces

The Navy does not have a comprehensive health incident reporting system. The committee did not receive any information suggesting that the Navy has advanced beyond the "daily report of the sick" for naval vessels. There may be some ad hoc arrangements, particularly in amphibious ready groups, by which data are collected and shared, but there is no evidence of a system to facilitate sharing medical data within the battle groups. During a visit to Norfolk, Virginia, the committee was given the impression that each ship commander independently establishes his or her requirements for medical disease reporting. In some instances the captain is notified within 24 hours of any encounters in the sick bay, and in other instances the reports may be weekly or only at the discretion of the corpsman providing the first-line health care. Indications were that the larger the ship and hence the more sophisticated the medical capability, the more likely that the medical contingent functioned relatively independently of the ship captain unless an emergent situation developed. Many medical facilities ashore participate in local community disease reporting systems, but this too is not uniform practice. Thus, the current level of health surveillance in the Navy, especially among its surface ships, is insufficient to detect early symptoms of biological and/or chemical exposure.

There is evidence that a few Marine bases have achieved some level of a civilian–military joint venture in health service support, particularly in disaster situations. Such practices are also followed by other naval installations (notably, nuclear shipyards) in regard to radiation health and by a few Navy hospitals. However, even if put in place, a health surveillance system will only be effective if its health care providers are properly trained in its use and interpretation—and the committee has already noted the shortcomings in medical training in general.

Such variations in reporting are not acceptable in an era of significant and ongoing threats of biological or chemical attack. In this environment, it is essential that the ship or base commander and the medical personnel be aware of the threat and mutually supportive of one another in dealing with the threat.

Medical Chemical and Biological Countermeasures Recommendation: Establishing a Disease Reporting System

Implement a routine disease reporting system.

The committee recommends that the Navy implement a system of disease reporting which requires that any complex of signs and symptoms occurring in shipboard personnel above a predetermined threshold of indications be reported to the captain within hours. It is the committee's view that such a system should be implemented if the Navy is to meet its responsibilities to protect, consistent with mission accomplishment, the lives of Navy personnel. The ultimate goal should be a single system of disease reporting that encompasses all aspects of Navy operations, deployed and shore-based.

The elements of such a system need to include the initial capture of data in real time by monitoring key indicators gathered from patient encounters on a daily basis. All reported signs and symptoms that fit criteria indicating possible chemical or biological attack should be immediately reported to a unit commander. The commander should report data to a larger database at the battle-group level, which collects data from several units on a daily basis. At the battle-group level there should exist not only additional collection and analysis capability, but the expertise to provide consultation to individual units to confirm diagnoses. The battle group would, in turn, transmit the data to a Navy-wide CONUS-based database monitoring global developments. At the CONUS level, additional analysis and intervention capability would be available to address the situation. Ideally, the Navy system would then communicate the data and analysis to a single national registry, which would correlate developments from the military and civilian communities.

Medical Chemical and Biological Countermeasures Finding: Successful Reporting Systems

There are examples of successful military and civilian initiatives to identify fundamental warnings and indicators, collect the data, and analyze and merge them into systems capable of assessing the significance of seemingly random clinical observations. Beyond these, the Navy's particular development needs should be minimal. The best military example of such an initiative that the committee is aware of is the Air Force's progress in monitoring diseases in Southwest Asia. Originally developed as a project of the Defense Advanced Research Projects Agency, Desert Care One uses database management systems to log data from individual clinic visits to Air Force field medical units in Southwest Asia. Data such as presenting complaint, temperature, time to onset of disease, and initial laboratory findings are recorded into the central database. Computer analysis establishes a "normal" background activity level. Any specific findings above

the background level are analyzed for their significance. If a predetermined threshold of activity is exceeded, the Air Force dispatches a medical contact team to investigate the cause of the change. The result of these efforts has been some surprisingly early interventions in the course of human disease. In one instance, the system led investigators to a source of contaminated food before illness progressed to the level of deterioration in mission readiness. In the civilian community, large city health departments are beginning to use similar real-time analysis of visits to emergency rooms and clinics to gain some time advantage over the outbreak and spread of disease.

Another successful system has been established in the commercial cruise industry. In that industry, the guideline is that any recurring symptom complexes be reported promptly to the ship captain. Further, any time that similar signs or symptoms occur in 1 percent of the ship's population, the situation must be reported immediately to the corporate office. The corporate office is responsible for providing the needed range of medical and risk management consultation to deal effectively with the problem. Should the level of similar signs and symptoms exceed 2 percent of the presumed at-risk population, the cruise ship company is required to report the findings to the Centers for Disease Control and Prevention of the Department of Health and Human Services. (See also footnote 29 in Chapter 2.)

Medical Chemical and Biological Countermeasures Recommendation: Standards for Disease Reporting

Build a routine disease reporting system based on the Air Force prototype and adopt "best practices" from the commercial world.

In the case of deployed naval forces, it is the committee's recommendation that the Navy build on the Desert Care One prototype developed by the Air Force and implement the system with guidelines similar to those of cruise industry. In a deployed situation, the medical contingent with the most personnel and expertise in the battle group, usually on the aircraft carrier, should replace the corporate office and be notified at a predetermined threshold. The carrier medical department would maintain the registry of all suspicious occurrences within the battle group and would be staffed and equipped to provide consultation and sophisticated diagnostic and treatment advice to the smaller units. To assist in this responsibility, a large ship's medical department could be the keeper of a forward-deployable, preventive medicine unit that would be used to help confirm the presence of a biological warfare pathogen.

Marines afloat should be managed in the same way, with the same reporting requirements as those for Navy personnel. Once Marines are deployed on shore, guidelines for reporting medical conditions should be maintained insofar as possible, depending on the intensity of combat.

The committee both appreciates that it is recommending significant changes to the traditional Navy concept of each ship's functioning independently in the medical arena and takes seriously the difficult nature of cultural and behavioral change. The committee is convinced, however, that the recommended changes are fully justified by the serious nature of biological and/or chemical attack. Particularly in the case of biological attack, time is of the essence. For example, describing a biological attack on a U.S. Navy guided-missile destroyer, the morbidity and mortality rate increases rapidly with each passing day between exposure and diagnosis. In order to preserve life, there must be made every effort to make a diagnosis before the onset of clinical disease. To accomplish this task, the Navy must ensure that adequate preventive medicine and detection capabilities are made available in order to strengthen laboratory capabilities and integrate information collection. In addition, epidemiological resources will be required to facilitate appropriate analysis, investigation, and consultative feedback to deployed units.

The Navy should also take responsibility for transmitting information to larger national and, if developed, international data collection and analysis centers. In the United States, the Centers for Disease Control and Prevention is taking the lead for homeland security in this area, and it would be a logical referral site for analysis and further consultative help. As noted above, commercial cruise lines are mandated to report to the CDC when an incidence rate reaches 2 percent of the presumed at-risk population. Thus, the CDC would become the ultimate national registry of suspicious medical data for both the civilian and military communities.

Medical Chemical and Biological Countermeasures Recommendation: Shore Installations and Bases

Ensure that all shore installations and bases are included in the disease reporting system.

The disease reporting and analysis system outlined above should be mirrored in the ports, at shore installations, and at bases. Depending on the size of the base and the sophistication of the health care contingent, any recurring signs and symptoms should be reported promptly to the base commander. Early reporting should be at the discretion of the concerned provider, but mandatory reporting at the 1 and 2 percent incidence levels, as described above, should be accepted procedure. It is important that the information flow to the base commander despite the fact that, particularly on larger bases, the medical commander also reports to the Navy's Bureau of Medicine and Surgery and ultimately to the Surgeon General of the United States.

In a scenario involving a biological or chemical attack, the base and the surrounding civilian community are inseparable. In order to provide the best

protection and care to both base and civilian communities in such circumstances, there need to be seamless reporting, analysis, and mobilization of resources. It seems to the committee that having the integration effort led by the base commander makes the most sense, since the base is a more likely target for attack. It should therefore be the responsibility of the base commander to assure that the base and civilian response to a biological or chemical attack is maximally coordinated. In the case of disease reporting, information should be shared when the first report is made to the base commander and regularly thereafter, until the crisis has passed. Communication should be continuous and efforts coordinated throughout the crisis. For that to happen, a concerted effort must be made to bring together the leadership from both sides of the base fence in a series of regularly scheduled meetings to plan the reporting and response system and then to regularly exercise it.

The committee was made aware of the significant progress in fielding such a system at the Marine Corps base at Camp Lejeune and its surrounding community, Onslow County, North Carolina. The system was initiated because of concern for the possibility of an explosive release of toxic material. It effectively coordinates first-responders and those providing backup medical intervention. A similar system is being developed between the Marine Corps base at Camp Pendleton, California, and the surrounding communities in San Diego County. The committee sees no reason why similar programs tailored to community needs should not be developed at every CONUS Navy or Marine Corps base.

A FINAL WORD ON TRAINING

Although a more extensive discussion of training appears earlier in this chapter and in Chapter 3, the committee emphasizes here that it does not see any scientific or technological breakthroughs in the near term that will significantly alter current capabilities for diagnosing and treating biological or chemical attack victims. Therefore, the system will remain highly dependent on the performance of alert and well-trained individuals who have taken part in exercises focused on what can and should be done when a biological or chemical attack is suspected. To underpin the current system, it is important that biological and chemical attack scenarios be used in training exercises and war games to raise awareness of these threats. Further, the Navy should institutionalize training in risk communication for all commanders and health personnel. Since it is imperative that all personnel have heightened awareness, the Navy should introduce training in selected aspects of the chemical and biological threat, risk awareness, and risk communication to all Navy personnel within a short time of their induction into the Service.

SUMMARY

Box 5.3 provides a summary of the findings and recommendations in this chapter. Recommendations are directed to the Navy's operational medicine leadership (Bureau of Medicine and Surgery) to prioritize and enlist key support organizations, both within the Navy and in the Joint CBD Program, for implementation.

BOX 5.3
Summary of Findings and Recommendations on Medical Chemical and Biological Countermeasures

Drugs and Vaccines

Findings

- There are five fielded products for medical chemical warfare (CW) defense—four nerve agent therapeutics and one skin decontaminant.
- A topical skin protectant and a multichambered autoinjector are close to being fielded. Less mature are broad-spectrum enzyme scavengers and reactive topical skin protectants to provide pre-exposure protection against a wide range of agents.
- Two vaccines are approved for use against biological warfare (BW) agents—smallpox and anthrax—but both have limited availability.
- With the exception of smallpox, next-generation candidates to replace the two current vaccines (smallpox and anthrax), and vaccines for botulism, tularemia, and Venezuelan equine encephalomyelitis will not be approved and available until the end of the decade at the earliest, hampered in part by the normal process for new drug approval and by the risk-averse nature of lead agencies within the Department of Defense.
- Post-exposure antibiotic therapies for plague and anthrax are generally effective if administered within a day or so after exposure. There is no approved therapy for smallpox, but cidofavir and possibly vaccinia-immune globulin (VIG) are showing some promise.
- Stores of chemical antidote kits and antibiotics may be out of date and/or insufficient to treat all who might be exposed onboard ships, according to anecdotal evidence provided to the committee. Stocks at shore installations tend to suffer the same—or worse—shortfalls.

Recommendations for the Navy

- Ensure that all deployments include adequate stores of current chemical and biological medical countermeasures.
- Push the Joint Vaccination Acquisition Program into a more aggressive development path for new and more effective vaccines and drugs (e.g., smallpox therapeutics).
- Even with aggressive engagement, do not rely on vaccinations or more effective chemical warfare agent antidotes to become available in the near term to midterm.

Medical Diagnostics

Findings

- The Navy's Bureau of Medicine and Surgery and the fleet have begun efforts to develop training packages and medical concepts of operations and to field improved equipment to Navy ships, but these changes have not yet been reflected in formal instructions and directives governing the readiness status of Navy ships.
- An overlooked resource to support experimentation, doctrine development, training, and disease surveillance are the forward-deployable medical laboratories that are assembled and maintained by the forward-deployable, environmental and preventive medicine units (FD-EPMUs). These laboratories are expeditionary, hardened for field use, and represent the first step toward a minimal equipment set for advanced laboratory diagnostics.
- Almost all of the clinical diagnostics systems either under development or fielded for the military are based on one or both of two relatively well-understood technologies. Both need further work to drive down false-positive indications.
- Almost all clinical diagnostics systems are based on confirmation of the clinical patterns observed by the diagnostician as opposed to approaches that identify incipient infection before symptoms are manifested (anthrax spore inhalation being an exception). Success with pre-symptomatic diagnosis would greatly reduce the treatment regimen and negative mission impacts.

Recommendations for the Navy

- Implement existing instructions and make use of environmental and preventive medicine units for introducing new equipment.
- Review all Joint CBD Program efforts to assess how well they will meet operational requirements in the maritime environment.
  - —Assess the status of the Critical Reagents Program for fielded diagnostic equipment to accelerate approvals.
  - —Pursue development paths for advanced diagnostics to reduce false positives characteristic of the two leading approaches.
  - —Undertake fundamental research in developing the basis for pre-symptomatic diagnosis.
- Develop gaming and operational concepts, coupled with clinical diagnosis, for biological warfare attacks.

Disease Reporting And Analysis

Findings

- The Navy lacks a comprehensive health incident reporting system. Some ad hoc systems may exist, but they will not serve either fleet or shore installation operations well in the event of a major chemical or biological attack.
- Examples of successful reporting systems can be found in both civilian (e.g., the commercial cruise industry) and other military (e.g., the Air Force) communities.

Recommendation for the Navy

- Develop and implement a routine disease reporting system, built on the Air Force prototype and best practices from the commercial world—for the fleet, shore installations, and bases.

6

The Longer Term—Leadership to Sustain the Commitment

The recommendations elaborated in the preceding chapters are aimed at institutionalizing the Navy's approach to chemical and biological warfare defense and at improving the posture of the Marine Corps. These recommendations describe a number of fairly dramatic shifts in the ways that naval forces organize, train, and equip themselves to combat adversaries armed with chemical and biological weapons. They also promise a series of payoffs for the Navy in the short, mid-, and long term. These payoffs and anticipated gains in effectiveness will not be won through short-term interest from Navy leadership. This is a long-term problem requiring organization, focus, and commitment at the top that extends beyond the normal cycle of leadership turnover.

This problem is more challenging than just staying the course. The Navy, like the rest of the nation, has a lot to learn about chemical and biological threats, risks, vulnerabilities, and responses. As naval leaders become better informed, they will choose to make some midcourse adjustments. There are, however, parts of the problem that are inherently uncertain—the tactics of asymmetric strategies and the unpredictable and potentially far-reaching nature of "attacks" as is the case with biological weapons that may not produce the immediately visible results associated with conventional forms of warfare. Moreover, even as the U.S. military gets smarter, so too does the adversary. Both state and nonstate adversaries are climbing their own learning curves about chemical and biological weapons. They will draw on rapidly evolving technologies widely available in the commercial realm rather than on the slowly evolving technologies in the defense industry. They will watch and learn from what the United States does, and vice versa. This interaction between defender and aggressor is inherently dynamic.

For the United States to come out on top requires more than simply staying the course—it requires an ability to learn and to respond in an agile way to new understandings of the problem.

It is conceivable that a crisis will come along to galvanize this kind of sustained but agile leadership on the issue. Historically, the Navy has demonstrated a very strong capability to study mission failures for the lessons they yield. In this case, however, the Navy should not await a crisis or calamity with chemical and biological weapons to begin to learn the necessary lessons. Given the weaknesses in the current posture of naval forces and the utility of chemical and biological weapons in asymmetric strategies, such an encounter could be costly in terms of lives lost, missions compromised, and confidence to re-engage. There are sufficient lessons in the experience of the past decade to chart a more productive course to the desired posture than that so far being navigated.

If the Navy implements this longer-term strategy, what payoffs can it expect in terms of the ability of naval forces to meet mission requirements in a chemical or biological threat environment? In other words—

- *Can the Navy get better at chemical and biological defense?* Absolutely. Existing efforts will generate incremental improvements to existing capabilities, perhaps at a more rapid pace in the wake of the concern generated by the attacks of September 11, 2001, and in the preparations for the recent war with Iraq. Implementation of the more comprehensive strategy elaborated in this study promises further progress in coming to terms with the chemical and biological weapons challenge.
- *Does progress equate with success?* As the Navy gets better, will it also get "good enough"? What is good enough? The answer would seem to be that "it depends" on the intentions and capabilities of U.S. adversaries.

Against an adversary willing to make limited use of small quantities of chemical or biological agents largely in order to generate fear as a way to coerce or deter, "good enough" equates with an ability to sustain the warfighter in the face of such limited attacks—and also to reassure those made fearful, at least within the forces themselves. It would appear that even evolutionary improvements in operational capabilities will promise this level of performance.

Against an adversary willing and able to use chemical or biological warfare aggressively in campaign-style attacks for its theater-strategic purposes, "good enough" requires a more elaborate description. It requires the operational ability to project power and prevail against such an adversary at casualty levels acceptable to the public and political leadership. It requires an ability to protect local U.S. allies and coalition partners so that they are not paying an extreme share of the cost and risk. All of these requirements can be met by U.S. naval forces, but they demand the comprehensive—and sustained—approach that this report has presented.

Against an adversary willing, at the extreme, to exploit the full mass casualty potential of chemical and especially biological weapons to kill millions, "good enough" equates with an ability to sustain combat operations and to terminate those attacks before they reach that potential. The kinds of operational and other adjustments elaborated in this study do not promise this level of capability. An aggressor willing to wage a war of mass annihilation is an aggressor willing to confront the United States not at the conventional, but at the strategic level.

Appendixes

A

Committee and Staff Biographies

Miriam E. John, *Chair,* is vice president for the California Division at Sandia National Laboratories. Dr. John has served in a number of managerial and technical roles for the laboratories, including assignments in the areas of nuclear weapons development, chemical and biological weapons defense program development, systems analysis, and thermal analysis/fluid mechanics research and development; experimental and theoretical studies in heterogeneous catalysis, thermodynamics, and multiphase reacting flow; and postdoctoral work in alternative energy concepts analysis and simulation. She has participated in numerous defense community efforts, including the Department of Defense's Threat Reduction Advisory Committee, the Defense Science Board's summer and task force studies, and the Air Force Scientific Advisory Board, as well as serving on the National Research Council's Board on Army Science and Technology. She was a member of the Department of Energy's National Commission on Science and Security. Dr. John has served on the California Council for Science and Technology, the Technical Division Advisory Board of the Jet Propulsion Laboratory, and the executive advisory committee for the National Science Foundation's Science and Technology Center for Environmentally Responsible Solvents and Processes at North Carolina State University/University of North Carolina. She is also a member of the board of directors of ANSER. She is currently a member of the National Research Council's Naval Studies Board.

Robert S. Carnes is vice president and cofounder of Biosciences International, Inc., a biomedical consulting firm with operations in the United States and the United Kingdom. Following service as a naval aviator, Dr. Carnes embarked on a

career in medicine, serving in a variety of clinical roles including that of director of surgical services, as well as being chair and program director of the Anesthesiology and Critical Care Divisions of the Naval Hospital, Portsmouth, Virginia. Capping a 32-year Navy career, he served successive tours with the Marine Corps, including assignments as brigade surgeon, assistant chief of staff, Marine Forces Pacific; and as director, Deep Future Division, Marine Corps Warfighting Laboratory. Following retirement from the Navy, Dr. Carnes joined the faculty of Georgetown University, where he was detailed to the Defense Advanced Research Projects Agency (DARPA) as a program manager in the Defense Sciences Office. During his tenure at DARPA, Dr. Carnes developed and ran the Metabolic Engineering Program, a basic science venture in the management and control of cellular metabolism in human cells. Dr. Carnes received a B.S. degree in biology from the University of California at Irvine, and an M.D. from the University of Southern California. He is board certified in anesthesiology, critical care medicine, and aerospace medicine. He completed a fellowship in anesthesia and critical care at Harvard Medical School and Massachusetts General Hospital. His firm's consultancy spans the spectrum of government, industry, and private foundations with interests in the advancement of the human condition through innovations in the biological sciences.

John D. Christie is a senior fellow at the Logistics Management Institute. His background is in Department of Defense acquisition policy and program analysis. From 1989 to 1993, Dr. Christie served as director of Acquisition Policy and Program Integration for the Office of the Under Secretary of Defense (Acquisition); in that position he directed the preparation of a comprehensive revision of all defense acquisition policies and procedures, resulting in the cancellation and consolidation of 500 prior separate issuances. (He also prepared comprehensive acquisition program alternatives for the Secretary of Defense that resulted in multibillion-dollar budget reductions.) As a former member of Army Science Board, Dr. Christie was called upon to direct reviews of the Army analytical community and operations research activities for the vice chief of staff; included were reviews of the support of the overall Army acquisition process and its integration with the programming and budgeting process. Dr. Christie has served on numerous scientific boards and advisory committees, including the Commission on Roles and Missions of the Armed Forces, which provided recommendations to improve defense management. With regard to chemical and biological programs, he participated in a review of chemical warfare by the Army Science Board in the 1980s and was responsible for reviewing chemical warfare and biological programs from 1968 to 1971 as director of the Nuclear Weapons and Materials Division in the Office of the Assistant Secretary of Defense (Systems Analysis). Dr. Christie is a member of the National Research Council's Naval Studies Board.

Robert P. Currier is a research scientist with the Physical Chemistry and Applied Spectroscopy Group at Los Alamos National Laboratory (LANL). Dr. Currier's background is in physical chemistry and chemical engineering. His research interests include gas hydrate production, decontamination and destruction of chemical and biological agents (counterterrorism and battlefield applications), carbon dioxide fixation, and clean coal technology. Prior to joining LANL, Dr. Currier was a process engineer at Cities Service Company and a software development engineer at ChemShare Corporation. His professional affiliations include the American Institute of Chemical Engineers, the American Ceramic Society, and Sigma Xi Research Society.

Ruth A. David is president and chief executive officer at Analytic Services Inc. (ANSER), a not-for-profit public service research institute that provides solutions to national and international issues. Dr. David, a member of the National Academy of Engineering, has a background in intelligence and threat assessment. Prior to joining ANSER, she was deputy director for science and technology at the Central Intelligence Agency, where she had leadership responsibilities for supporting and improving the collection, processing, analysis, and dissemination of intelligence through the research, development, and application of technology. Previously, Dr. David had served in several managerial positions at Sandia National Laboratories. Her technical experience has included digital and microprocessor-based system design, digital signal analysis, adaptive signal analysis, and systems engineering and integration. Dr. David is a member of the National Security Agency Advisory Board, the Defense Science Board, and the Technical Advisory Group of the Senate Select Committee on Intelligence. She is currently a member of the National Research Council's Naval Studies Board.

Joseph "Pat" Fitch is program leader for chemical and biological national security at Lawrence Livermore National Laboratory (LLNL). Dr. Fitch has a background in genomics, biophysics, and electrical engineering. He has also served as LLNL deputy associate director for biology and biotechnology programs and as LLNL director of the Center for Healthcare, in addition to serving as an independent consultant to private industry for medical, computing, and imaging devices. Dr. Fitch holds a Ph.D. in electrical engineering from Purdue University and two B.S. degrees, in physics and engineering sciences, from Loyola College.

Frank A. Horrigan retired from the technical development staff for sensors and electronic systems at Raytheon Systems Company. Dr. Horrigan has a background in technologies relevant to military systems, in particular, radar and sensor technologies. A theoretical physicist, he has more than 37 years' experience in advanced electronics, electro-optics, and advanced information systems. In addition, he has experience in planning and managing industry research and

development investments and in projecting future technology growth directions. Dr. Horrigan once served as a NATO fellow at the Saclay Nuclear Research Center in France and has served on numerous scientific boards and advisory committees, including as chair of the National Research Council's (NRC's) Panel on Sensors and Electronic Devices. He is a member of the NRC's Naval Studies Board and Army Research Laboratories Technical Advisory Board.

Harry W. Jenkins, Jr., retired major general, U.S. Marine Corps, is director of business development and congressional liaison for ITT Industries, where he is responsible for activities in support of airborne electronic warfare and tactical communications systems between the Navy, Marine Corps, National Guard, and appropriate committees in Congress. His operational background in expeditionary warfare is extensive. During Operations Desert Storm and Desert Shield, General Jenkins served as the commanding general of the Fourth Marine Expeditionary Brigade, directing operational planning, training, and employment of the ground units, aviation assets, and command and control systems in the 17,000-person amphibious force. General Jenkins's last position before retirement from the U.S. Marine Corps was as director of expeditionary warfare for the Chief of Naval Operations; during that assignment he initiated a detailed program for command, control, communications, computers, and intelligence (C4I) systems improvements for large-deck amphibious ships and reorganized the Navy's unmanned aerial vehicle efforts for operations from aircraft carriers and amphibious ships. General Jenkins has served on numerous scientific boards and advisory committees; he is the current chair of the National Defense Industrial Association Expeditionary Warfare Division.

Michael T. Kleinman is associate director of the Air Pollution Effects Laboratory and adjunct professor at the Department in Community and Environmental Medicine at the School of Medicine, University of California at Irvine. His background is in environmental effects and air pollution toxicology. Dr. Kleinman's research interests include the mechanisms by which inhaled toxic chemicals, alone and in mixtures, interfere with the cardiopulmonary system and with respiratory system defenses, using both laboratory animals and human subjects. Dr. Kleinman has served on numerous scientific boards and advisory committees, including the California Environmental Protection Agency's Air Quality Advisory Committee, the U.S. Environmental Protection Agency's Science Advisory Board Health and Economic Effects Subcommittee, and the Human Subjects Research Committee and the Biosafety Committee at the University of California at Irvine. Dr. Kleinman was the co-principal investigator for the National Research Council report entitled *Strategies to Protect the Health of Deployed U.S. Forces: Force Protection and Decontamination* (2000).

John B. LaPlante, retired vice admiral, U.S. Navy, is an independent consultant and former manager of Department of Defense Business Development at

McDermott International, Inc., a worldwide energy services company. His background is in naval (and joint) military operations, particularly in regard to operational logistics. Before retiring from the Navy in 1996, Admiral LaPlante served as director for logistics, J-4, Joint Staff. His military experience also included assignments as commander of Naval Logistics Command Pacific and head of the Amphibious Warfare Branch in the Office of the Chief of Naval Operations. During Operations Desert Storm and Desert Shield, he commanded all amphibious forces in the Gulf region, a force of some 43 ships and 34,000 men and women.

Joshua Lederberg is the Sackler Foundation Scholar at the Rockefeller University. Dr. Lederberg, a member of the National Academy of Sciences and the Institute of Medicine, has an extensive background in biological and physical sciences, including bacteriology, biochemistry, biophysics, epidemiology, genetics, microbiology, molecular biology, toxicology, and virology. He is a leading geneticist and microbiologist who received the Nobel Prize in 1958 for his work in genetic structure and function in microorganisms (he was also awarded the U.S. National Medal of Science in 1989). Prior to serving as president of the Rockefeller University from 1978 to 1990, Dr. Lederberg served on the faculty at the University of Wisconsin and at the Stanford School of Medicine. He has served on numerous scientific boards and advisory committees, including the World Health Organization's Advisory Health Research Council, the President's Cancer Panel, and the Congress Technology Assessment Advisory Council. Dr. Lederberg is currently serving on the Committee on International Security and Arms Control.

David W. McCall[1] retired as director of the Chemical Research Laboratory at AT&T Bell Laboratories (now Bell Laboratories, Lucent Technologies), where he was responsible for the research, development, and engineering of materials and processes employed in the production of communications systems. Included were a variety of insulating materials and advanced structural materials essential to the long-term integrity of equipment produced. Dr. McCall, a member of the National Academy of Engineering, had a background in physical chemistry and materials engineering. He served on numerous scientific boards and advisory committees, including as chair of the National Commission on Superconductivity. Dr. McCall was a former member of the National Research Council's Naval Studies Board.

James W. Meyer is retired senior vice president, director of research and development/chief technical officer at the Eastman Kodak Company. Dr. Meyer's

[1]Deceased.

background is in advanced technologies. At Kodak, the career of Dr. Meyer, a chemist by training, included research on novel color imaging systems, fundamental studies of image structure and color reproduction, and pioneering work on one-time-use cameras. In addition, he led laboratory efforts in optical and magnetic recording technologies, electronic materials, and novel manufacturing technology. Since retiring from Kodak in 1998, Dr. Meyer has created and led the Technical Advisory Group for the Rochester Museum and Science Center. He is a member of the American Chemical Society, the American Association for the Advancement of Science, the Society for Imaging Science and Technology, and the Materials Research Institute.

William C. Miller, retired rear admiral, U.S. Navy, is academic dean and provost at the U.S. Naval Academy. Dr. Miller returned to his alma mater in 1997 after having served as associate provost for research and economic development at West Virginia University; there he was responsible for providing institution-wide leadership for the university's research program and for developing and guiding the university's contribution to economic development throughout the state. In addition, he was a member of the university's teaching faculty. Before his arrival at West Virginia in 1993, Dr. Miller served in a variety of assignments in the U.S. Navy, the most prominent of which were in the areas of research and development. From 1990 to 1993, Admiral Miller served as the chief of naval research in Washington, D.C., and chief executive of the Office of Naval Research, where he was responsible for the Department of the Navy's $1.5 billion annual investment in science and technology through universities, industry, and government laboratories. Dr. Miller's other significant naval assignments included serving as chief executive of the Navy's corporate laboratory, the Naval Research Laboratory; founding director of both the Navy's low observables (stealth) technology office and the Department of Defense counter low observables office; captain of two naval vessels; and service on the electrical engineering faculty and as executive assistant to the superintendent at the U.S. Naval Academy.

David H. Moore is director of medical toxicology programs for the Aerosol and Bio-Defense Sciences Division at Battelle Memorial Institute. His background is in chemical warfare defense. A retired Army colonel, Dr. Moore received his D.V.M. from the University of Georgia College of Veterinary Medicine and his Ph.D. in physiology from Emory University School of Medicine. He is a member of the Committee on Toxicology and serves on the Subcommittee on the Toxicity of Diisopropyl Methylphosphonate. Dr. Moore served as a member of the advisory group for the National Research Council report entitled *Strategies to Protect the Health of Deployed U.S. Forces: Analytical Framework for Assessing Risks* (2000). He also served as a panel member on the Institute of Medicine report *Chemical and Biological Terrorism: Research and Development to Improve Civilian Medical Response* (1999).

John H. Moxley III is managing director at North American Health Care Division, Korn/Ferry International. Dr. Moxley, a member of the Institute of Medicine, has a background in internal medicine, military medical issues, health science policy, and cancer research. Prior to joining Korn/Ferry, he held a number of senior positions in academia, government, and commercial industry, including that of dean of both the University of Maryland and the University of California (San Diego) Medical Schools, assistant secretary of defense for health affairs, and senior vice president at American Medical International. He has served on numerous scientific boards and advisory committees, including the American Hospital Association board of trustees, the California Medical Association, the American Medical Association, the National Fund for Medical Education, and the Henry M. Jackson Foundation for the Advancement of Military Medicine. Dr. Moxley is a member of the National Research Council's (NRC's) Board on Army Science and Technology and served as chair for the NRC report entitled *Protecting Those Who Serve: Strategies to Protect the Health of Deployed U.S. Forces* (2000).

Bradley H. Roberts is a research staff member of the Strategy, Forces, and Resources Division at the Institute for Defense Analyses (IDA). His background is in macroscale systems and policy. Dr. Roberts has written widely on the subject of chemical and biological warfare and terrorism, and prior to working with IDA he served as a research fellow at the Center for Strategic and International Studies. He is an adjunct professor at the George Washington University Elliott School of International Studies and is chair of the Research Advisory Council and member of the board of trustees of the Chemical and Biological Arms Control Institute. In addition, Dr. Roberts is a member of the International Institute for Strategic Studies and the Council on Foreign Relations.

Charles H. Sinex is a member of the Joint Warfare Analysis Department at the Applied Physics Laboratory (APL) of Johns Hopkins University. His recent assignments have been in the development of methodologies for the Office of Naval Research and the Deputy Under Secretary of Defense (Advanced Systems and Concepts) for assessing the value of technology investments and in the design and conduct of future warfighting experiments for the U.S. Joint Forces Command. He has also participated in an APL Counter-Proliferation study room to identify critical challenges for the military and civilian counterproliferation programs. Dr. Sinex has also been the logistics program manager for improving linkage models between military forces and logistics systems. Prior to that, he served as supervisor of the Environmental Group, where he was responsible for numerous environmental survey design efforts.

Joseph J. Vervier is an executive with ENSCO, Inc., a technology systems engineering, research, and information management company serving both pub-

lic and private industries. Mr. Vervier has a background in detection devices, particularly in regard to chemical and biological sensors. Prior to joining ENSCO, Mr. Vervier held numerous high-ranking positions in the Department of the Army, including that of technical director at the Edgewood Research, Development and Engineering Center, where he directed research and development on chemical and biological agent detectors, protections systems, and decontamination methods. He has served on numerous scientific and advisory boards, and is a current member of the Board on Army Science and Technology.

Richard L. Wade is president of Risk Management Sciences, a private consulting firm; his current clients include the Princess, Norwegian, and Orient Cruise Lines, as well as many industrial clients. Dr. Wade's background is in risk mitigation and threat assessment. His career has included work as a regulator, a professor, and a consultant. Dr. Wade has served as the head of public health agencies (Seattle, Washington; State of Minnesota; and State of California), and taught at the University of Minnesota and the University of California. His work has also included local, state, federal, and international environmental and health issues. Currently, Dr. Wade is an adjunct associate professor of medicine at the University of California at San Francisco Medical Center and maintains an active international private practice in environmental health. In 1990, he received the American Public Health Association's lifetime achievement award.

Michael A. Wartell is chancellor at Indiana University–Purdue University-Fort Wayne. His background is in defense issues relating to chemical and biological defense and Department of Defense policies and doctrine. In the 1980s he was involved in the Army Science Board, where issues of chemical and biological defenses were part of ad hoc and summer study groups in which he participated. In 1997, he rejoined the Army Science Board and is an ex officio member of the Defense Science Board. He also serves as chair of the Defense Intelligence Agency Science and Technology Advisory Board. Dr. Wartell was the co-principal investigator for the National Research Council report entitled *Strategies to Protect the Health of Deployed U.S. Forces: Force Protection and Decontamination* (2000).

George M. Whitesides is Mallinckrodt Professor of Chemistry at Harvard University. Dr. Whitesides, a member of the National Academy of Sciences, has a background in biological and physical sciences, including materials science, organic chemistry, and biochemistry. He is a leading chemist who received the U.S. National Medal of Science in 1998. His research interests include surface chemistry, materials science, self-assembly, capillary electrophoresis, organic solid state, molecular virology, directed ligand discovery, and protein chemistry. Dr. Whitesides has served on numerous scientific boards and advisory committees,

including most recently, a biological warfare defense study for the Department of Defense. He is currently a member of the Committee on Challenges for the Chemical Sciences in the 21st Century.

Staff

Ronald D. Taylor currently is on assignment to the Department of Homeland Security (DHS). In July 2003, Dr. Taylor became director of the Office of Studies and Analysis in the Science and Technology Directorate at DHS. He also serves as the executive secretary for the Homeland Security Science and Technology Advisory Committee. Dr. Taylor has been director of the National Research Council's Naval Studies Board since 1995. In 2002 he assumed collateral duties coordinating National Research Council work with the intelligence community as well as coordinating NRC work on homeland security. He joined the National Research Council in 1990 as program officer, then senior program officer, with the Board on Physics and Astronomy and in 1994 became associate director of the Naval Studies Board. During his tenure at the National Research Council, Dr. Taylor has overseen the initiation and production of more than 40 studies focused on the application of science and technology to problems of national interest. Many of these studies address national security and national defense issues. From 1984 to 1990 Dr. Taylor was a research staff scientist with Berkeley Research Associates working on-site at the Naval Research Laboratory on projects related to the development and application of charged particle beams. Prior to 1984, he held both teaching and research positions in several academic institutions, including assistant professor of physics at Villanova University, research associate in chemistry at the University of Toronto, and instructor of physics at Embry-Riddle Aeronautical University. Dr. Taylor holds a Ph.D. and M.S. in physics from the College of William and Mary and a B.A. in physics from Johns Hopkins University. In addition to a specialty in science policy, Dr. Taylor's scientific and technical expertise is in the areas of atomic and molecular collision theory, chemical dynamics, and atomic processes in plasmas. He has authored or coauthored numerous professional scientific journal papers and technical reports. In 2002 Dr. Taylor received the National Academies Individual Distinguished Service Award and Group Distinguished Service Award for his role as study director of the report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* (2002). In 2003 he received the Department of the Navy Superior Public Service Award from the Chief of Naval Operations for his service since 1995 as director of the Naval Studies Board.

Charles F. Draper is acting director of the National Research Council's Naval Studies Board. He joined the National Research Council in 1997 as program officer, then senior program officer, with the Naval Studies Board and in 2003

became associate director. During his tenure with the Naval Studies Board, Dr. Draper has served as the responsible staff officer on a wide range of topics aimed at helping the Department of the Navy with its scientific, technical, and strategic planning. His recent efforts include topics on network-centric operations, theater missile defense, mine warfare, and nonlethal weapons. Prior to joining the Naval Studies Board, he was the lead mechanical engineer at Sensytech, Inc. (formerly S.T. Research Corporation), where he provided technical and program management support for satellite Earth station and small-satellite design. He received his Ph.D. in mechanical engineering from Vanderbilt University in 1995; his doctoral research was conducted at the Naval Research Laboratory (NRL), where he used an atomic force microscope to measure the nanomechanical properties of thin-film materials. In parallel with his graduate student duties, Dr. Draper was a mechanical engineer with Geo-Centers, Inc., working on-site at NRL on the development of an underwater x-ray backscattering tomography system used for the nondestructive evaluation of U.S. Navy sonar domes on surface ships.

B

Chemical and Biological Agents and Their Effects

The tables in this appendix are reprinted from a previous National Research Council report, *Strategies to Protect the Health of Deployed U.S. Forces: Force Protection and Decontamination*.[1] They provide brief descriptions of both chemical agents (Tables B.1 through B.3) and biological agents (Tables B.4 through B.7), as follows:

- Table B.1 Inhalation/Respiratory Agents
- Table B.2 Dermal Absorption Agents
- Table B.3 Dermal Necrotic Agents
- Table B.4 Inhalation/Respiratory Agents
- Table B.5 Ingestion Agents
- Table B.6 Agents Absorbed via Mucous Membranes or the Skin
- Table B.7 Arthropod Vectors

[1]National Research Council. 2000. *Strategies to Protect the Health of Deployed U.S. Forces: Force Protection and Decontamination,* Board on Army Science and Technology, National Academy Press, Washington, D.C., Tables 2-5 through 2-11.

TABLE B.1 Inhalation/Respiratory Agents

Agent	Mode of Delivery	Effect	Effective Dose (mg-min/m^3 except where otherwise noted)	Rate of Action
Phosgene	Vapor	Causes fluid buildup in the lungs that can cause drowning	ICt_{50} = 1,600	Delayed, although immediate irritation in high concentrations At low concentrations, no effects for three hours or more
Diphosgene	Vapor	Causes fluid buildup in the lungs that can cause drowning	ICt_{50} = 1,600 (at rest)	Delayed, although immediate irritation in high concentrations At low concentrations, no effects for three hours or more
Tabun	Vapor	Cessation of breath	ICt_{50} = 300 (at rest) ECt_{50} = no existing estimates ECt_{50} = no existing estimates (severe effects)[a] ECt_{50} = 0.9 (mild effects)[a] ECt_{50} = 2-3[b]	Very rapid
Sarin	Vapor	Incapacitation; cessation of breath	ICt_{50} = 75 (at rest); 35 (mildly active) ECt_{50} = no existing estimates (threshold)[a] ECt_{50} = 35 (severe effects)[a] ECt_{50} = 2 (mild effects)[a] ECt_{50} = 3[b]	Very rapid

Soman	Vapor	Incapacitation; cessation of breath	ICt_{50} = 75-300 (at rest) ECt_{50} = no existing estimates (threshold)[a] ECt_{50} = 35 (severe effects)[a] ECt_{50} = no existing estimates (mild effects)[a] ECt_{50} = 1-2[b]	Very rapid
GF	Vapor	Incapacitation; cessation of breath	ECt_{50} = no existing estimates (threshold) ECt_{50} = no existing estimates (severe effects) ECt_{50} = no existing estimates (mild effects)	Very rapid
VX	Vapor	Incapacitation; cessation of breath	ICt_{50} = 50 (at rest); 24 (mildly active) ECt_{50} = no existing estimates (threshold)[a] ECt_{50} = 25 (severe effects)[a] ECt_{50} = 0.09 (mild effects)[a] ECt_{50} = 1-2[b]	Very rapid
Hydrogen cyanide	Vapor	Interferes with the body's utilization of oxygen; accelerates rate of breathing	ICt_{50} varies with concentration ECt_{50} ≈1,500	Very rapid; incapacitation can occur within 1 to 2 minutes of exposure to an incapacitating or lethal dose, and death can occur within 15 minutes of receiving a lethal dose

continues

TABLE B.1 *(continued)*

Agent	Mode of Delivery	Effect	Effective Dose (mg-min/m^3 except where otherwise noted)	Rate of Action
Cyanogen chloride	Vapor	Choking, irritation, slows breathing	ICt_{50} = 7,000	Very rapid
Arsine	Vapor	Damages blood, liver, and kidneys	ICt_{50} = 2,500	Effects delayed from 2 hours to 11 days
Distilled mustard	Vapor	Inflammation of the nose, throat, trachea, bronchi, and lungs	ICt_{50} = 150 ECt_{50} = no existing estimates (threshold)[a] ECt_{50} = 200 (moderate temperature, severe effects)[a] $ECt_{50} \geq 50$ (mild effects)[a] ECt_{50} = 10-1,000[b]	Effects delayed for 4 to 6 hours
Nitrogen mustard	Vapor	Incapacitation	N/A[c]	Effects delayed for ~12 hours
Mustard-T mixture	Vapor	Incapacitation	N/A[c]	Delayed action not well known
Lewisite	Vapor	Incapacitation	ECt_{50} = 1,500	Rapid acting
Mustard-lewisite mixture	Vapor	Incapacitation	N/A[c]	Rapid acting skin irritation, blisters in 13 hours

Phenyldichloroarsine	Vapor	Incapacitation	N/A[c]	Rapid acting
Ethyldichloroarsine	Vapor	Incapacitation	ICt_{50} = 5-10	Rapid acting nose/throat irritation, blisters in 12 hours
Methyl-dichloroarsine	Vapor	Incapacitation	ICt_{50} = 25	Rapid acting nose/throat irritation, blisters in several hours
Phosgene oxime	Vapor	Coughing, choking, chest tightness on exposure; possible cyanosis following pulmonary edema	ICt_{50} = unknown; lowest irritant concentration after a 10-second exposure is 1 mg/m^3; effects of the agent become unbearable after 1 minute at 3 mg/m^3	Rapid acting

[a]NATO, 1996; NRC, 1997.
[b]Ali et al., 1997.
[c]Exposure via this route is unlikely; no information was found.

SOURCES: Boyle, 1998; U.S. Army, 1995; Army et al., 1990.

TABLE B.2 Dermal Absorption Agents

Agent	Mode of Delivery	Effect	Effective Dose (mg-min/m^3 except where otherwise noted)	Rate of Action
Tabun (GA)	Liquid; vapor	N/A[a]	ED_{50} = no existing estimates	Very rapid
Sarin (GB)	Liquid	N/A[a]	ED_{50} = no existing estimates	Very rapid; may be lethal within 15 minutes after absorption
Soman (GD)	Liquid	N/A[a]	ED_{50} = no existing estimates	Very rapid; may be lethal within 15 minutes after absorption
GF	Liquid	N/A[a]	ED_{50} = no existing estimates	Very rapid
VX	Liquid	N/A[a]	ED_{50} = 5 mg/70-kg man[b] ED_{50} = 1 mg[c]	Very rapid; may be lethal within 15 minutes after absorption
Distilled mustard	Liquid	Inflammation of the nose, throat, trachea, bronchi, and lungs	ID_{50} = 2,000 by skin; 200 by eye ED_{50} = no existing estimates[b] ED_{50} = 10 Tg[c]	Effects delayed for 4 to 6 hours
Nitrogen mustard	Liquid	Incapacitation	ID_{50} = 200 by eye; 9,000 by skin	Effects delayed for ~12 hours

Mustard-T mixture	Liquid	Incapacitation	ID_{50} = very low	Delayed action not well known
Lewisite	Liquid	Incapacitation	ID_{50} = less than 300 by eye; more than 1,500 by skin ED_{50} = 15 Tg	Rapid acting
Mustard-lewisite mixture	Liquid	Incapacitation	ID_{50} = 200 by eye; 1,500-2,000 by skin	Rapid acting skin irritation; blisters in 13 hours
Phenyldichloroarsine	Liquid	Incapacitation	ID_{50} = 16 as vomiting agent; 1,800 as blister	Rapid acting
Ethyldichloroarsine	Liquid	Incapacitation	N/A[a]	Rapid acting nose/throat irritation; blisters in 12 hours
Methyldichloroarsine	Liquid	Incapacitation	N/A[a]	Rapid acting nose/throat irritation; blisters in several hours

[a]Unlikely exposure via this route; no information found.
[b]Ali et al., 1997.
[c]NRC, 1997.

SOURCES: Boyle, 1998; NATO, 1996; U.S. Army, 1995; U.S. Army et al., 1990.

TABLE B.3 Dermal Necrotic Agents

Agent	Mode of Delivery	Effect	Effective Dose	Rate of Action
Distilled mustard	Liquid	Incapacitation	ID_{50} = 2,000 by skin; 200 by eye ED_{50} = no existing estimates[a] ED_{50} = 10 μg[b]	Effects delayed for 4 to 6 hours
Nitrogen mustard	Liquid	Incapacitation	ID_{50} = 200 by eye; 9,000 by skin	Effects delayed for ~12 hours
Mustard-T mixture	Liquid	Incapacitation	ID_{50} = very low	Delayed action not well known
Mustard-lewisite mixture	Liquid	Incapacitation	ID_{50} = 200 by eye; 1,500-2,000 by skin	Rapid acting skin irritation; blisters in 13 hours

[a]NATO, 1996; NRC, 1997.
[b]Ali et al., 1997.

SOURCES: Boyle, 1998; U.S. Army, 1995; U.S. Army et al., 1990.

TABLE B.4 Inhalation/Respiratory Agents

Agent	Mode of Delivery	Effect	Effective Dose	Onset Time (days)
Anthrax (*Bacillus anthracis*)	Aerosol	75% morbidity; 80% mortality	8,000-50,000 spores	1-5
Plague (*Yersinia pestis*)	Aerosol		100-500 organisms	2-3
Tularemia (*Francisella tularensis*)	Aerosol	80% morbidity; 35% mortality	10-50 organisms	2-3
Q fever (*Coxiella burneti*)	Aerosol	70% morbidity; <1% mortality	1-10 organisms	14-21
Smallpox	Aerosol	30-35% mortality	10-100 organisms	12
Venezuelan equine encephalitis	Aerosol	90% morbidity; <5% mortality	10-100 organisms	1-5
Dysentery (*Shigella dysenteriae*)	Aerosol	25% mortality	10-100 organisms	1-7
Cholera (*Vibrio comma*)	Aerosol	15-90% mortality	1,000,000 organisms	1-5
Brucellolis (*Brucella suis*)	Aerosol	2% fatality	10-100 organisms	5-21

SOURCES: Ali et al., 1997; Boyle, 1998; U.S. Air Force, 1997; U.S. Army et al., 1990.

TABLE B.5 Ingestion Agents

Agent	Mode of Delivery	Effect	Effective Dose	Onset Time (days)
Anthrax (*Bacillus anthracis*)	Ingestion	75% morbidity; 80% mortality	1,000 spores	1-7
Cholera (*Vibrio comma*)	Ingestion	15-90% mortality	$>10^7$ organisms	1-5
Dysentery (*Shigella dysenteriae*)	Ingestion	25% mortality	10-100 organisms	1-7
Q Fever (*Coxiella burneti*)	Ingestion	70% morbidity; <1% mortality	1-10 organisms	14-21
Tularemia (*Francisella tularensis*)	Ingestion	80% morbidity; 35% mortality rate	N/A[a]	2-3

[a]Information, if known, was not readily available during the course of the study.

SOURCES: Ali et al., 1997; Boyle, 1998; U.S. Air Force, 1997; U.S. Army et al., 1990.

TABLE B.6 Agents Absorbed via Mucous Membranes or the Skin

Agent	Mode of Delivery	Effect	Effective Dose	Onset Time
Anthrax (*Bacillus anthracis*)	Direct contact with contaminated material	25% mortality	N/A[a]	N/A[a]
Tularemia (*Francisella tularensis*)	Inoculation of skin or mucous membranes with blood or tissue fluids of infected animals	80% morbidity; 35% mortality rate	10-50 organisms	N/A[a]
Brucellosis (*Brucella suis*)	Through abraded and possibly intact skin	N/A[a]	N/A[a]	N/A[a]
Ebola/Marburg	Through abrasion or via conjunctiva; possibly direct contact with blood or other tissues	N/A[a]	N/A[a]	N/A[a]
Crimean-Congo hemorrhagic fever	Direct contact with animal or human tissues and blood	N/A[a]	N/A[a]	N/A[a]

[a]Information, if known, was not readily available during the course of the study.

SOURCES: Ali et al., 1997; Boyle, 1998; Johnson, 1990; LeDuc, 1989; Johnson, 1990; Mikolich and Boyce, 1990; U.S. Air Force, 1997; U.S. Army, 1990.

TABLE B.7 Arthropod Vectors

Agent	Mode of Delivery	Effect	Effective Dose	Onset Time (days)
Plague (*Yersinia pestis*)	Fleas	25-100% mortality	$1\text{-}10^3$ organisms	2-7
Tularemia (*Francisella tularensis*)	Bites of infected deerflies, mosquitoes, or ticks	80% morbidity; 35% mortality	$1\text{-}10^3$ organisms	1-10
Rocky Mountain spotted fever (*Rickettsia rickettsi*)	Ticks	7-20% fatal	N/A[a]	3-10
Yellow fever	Ticks	<5% mortality	N/A[a]	3-6
Rift Valley fever	Mosquitoes	<1% mortality	N/A[a]	3-12
Venezuelan equine encephalitis	Variety of mosquitoes	90% morbidity; <5% mortality	$1\text{-}10^3$ organisms	4-20
Crimean-Congo hemorrhagic fever	Ticks	N/A[a]	N/A[a]	N/A[a]

[a]Information, if known, was not readily available during the course of the study.

SOURCES: Ali et al., 1997; Boyle, 1998; LeDuc, 1989; U.S. Air Force, 1997; U.S. Army et al., 1990.

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C

Additional Information on the Five Commodity Areas

This appendix expands on the information presented in Chapter 4 about the five commodity areas of the Joint Chemical and Biological Defense (CBD) Program: contamination avoidance, individual protection, collective protection, decontamination, and modeling and simulation.

CONTAMINATION AVOIDANCE

Consistent with the Joint CBD Program's organization of the science and technology associated with contamination avoidance, the following discussion is divided into subsections on chemical and biological point detection and standoff detection. Point and standoff detection require mostly distinct science and technology, albeit with some overlaps. For instance, optical spectrometry may be useful in both point and standoff applications. Within those divisions, sensors for chemical and biological agents are discussed separately because each one usually requires different science and technology.

Chemical Point Detection

Modern chemical warfare (CW) agents are produced as solids or liquids, depending on the application. Liquids can be volatile, such as sarin (GB), which converts to vapor form quickly, or nonvolatile, such as VX (O-ethyl S-diisopropylaminoethyl methylphosphonothiolate), which emits almost no vapor at standard temperatures. Liquids can also be sprayed into the air as aerosols or fixed on a solid matrix such as silicone particles (dusty agents), or perhaps be fixed on soil particles. In these cases, volatile agent droplets or volatile agents

loaded on inert particles will still emit a vapor signature. Solid agents, such as BZ (3-quinuclidinyl benzilate), will often be aerosolized as an inhalable powder. Many of the techniques for delivering solids are designed to defeat the standard vapor-detection devices used by most military forces. Liquid agents can also leave ground contamination. Agents such as mustard and VX are designed for use in terrain denial; they persist in the environment because of their low volatility. Precursors and by-products can be found in any of these physical forms.

Unfortunately, because the response to direct exposure to CW agents is typically very fast and violent, humans are excellent detectors for the presence of such substances in the immediate environment. It is certainly preferable to be able to detect the presence of CW agents through some other form of interaction. There are numerous other physical mechanisms that can be exploited to produce robust detection, classification, and identification signatures. Although CW agents can appear in many different physical forms—vapors, solids, or liquids, with or without inert co-components—such chemical substances typically have distinctive mass, chemical, and electromagnetic (EM) properties that can be measured.

The electromagnetic interactions, which probe the energy-level structure of the chemical molecules, are particularly useful, leading to various forms of classical spectrometry, which are known to be capable of both excellent sensitivity and specificity. In addition, because of the propagation properties of EM waves, spectroscopic approaches can be successfully applied both locally, for point detection, and remotely, for standoff detection.

The mass and chemical and physical interaction properties of CW agents are also quite distinctive and can permit sensitive detection, classification, and identification. Sensors based on such properties require that physical samples of the suspected agent be placed into intimate contact with the measurement equipment, however, and so they are suitable only as point detectors.

The two popular forms of mass-based CW point detection—ion mobility spectrometry (IMS) and mass spectrometry (MS)—utilize similar principles. The unknown CW agent is collected and ionized in some way, and the ions are allowed to propagate under the influence of an electric field to a collector. Ions with different mobilities arrive at the collector at different times, and the time-dependent collection current provides a signature which depends both on the specific ions that are present (i.e., position time of arrival peaks) and the numbers of each (i.e., signal level). The fundamental difference between the two techniques lies in the properties of the propagation medium. IMS uses local ambient air at atmospheric pressure, while MS uses a vacuum. As compared with the MS technique, the atmospheric pressure ion chemistry associated with the IMS technique greatly modifies the distribution of ion fragments or clusters that are generated by the ionization process, as well as the mobilities of the resulting fragments. As a result, the signatures and sensitivities of the two approaches are typically quite different—although signatures unique to individual CW agents can be obtained from each. Typically, the IMS approach is less sensitive, but it can be

significantly less expensive and provide faster response without the vacuum requirements of MS, and is better suited for the generation of compact designs. IMS is a well-developed point detection technology used in most recently fielded battlefield point CW detectors.

A summary of Department of Defense (DOD) programs in chemical point sensing is provided in Table C.1.

TABLE C.1 Chemical Point Sensing Programs of the Department of Defense

Name	Description
ABC-M8 ABC-1-58	ABC-M8 chemical agent detector paper detects liquid chemical agents. It is used whenever chemical agents are suspected. Every soldier carries a booklet of ABC-M8 paper in the mask carrier. Each booklet contains 25 sheets of paper. This paper turns colors when it touches a chemical agent. V-type nerve agent turns the paper dark green, G-type nerve agent turns it yellow, and a blister agent turns it red. Night operations cause problems, because ABC-M8 paper must be read in white light. Since ABC-1-58 paper is used to check suspected surface areas for contamination, it can be brought into a white light area for reading. During night reconnaissance operations, the monitor can take several samples, marking each one, and then bring them back to the vehicle for reading. The paper is used by blotting it on the suspected contaminated surface.
ACADA	The automatic chemical agent detector/alarm (ACADA) is an advanced point-sampling, chemical agent alarm system capable of detecting, warning, and identifying standard blister and nerve agents simultaneously. The ACADA is man-portable, operates independently after system startup, and provides an audible and visible alarm. It is used by Army, Navy, Air Force, and Marine Corps units. ACADA replaces the M8A1 alarm as an automatic point detector and augments the improved chemical agent monitor (ICAM; see below) as a survey instrument. It provides its warning automatically, using the multiple integrated chemical agent alarm, to communicate with battlefield data transfer and warning systems. ACADA does not require a specific military operator. Weight: 24 lb (complete with carrying case, battery pack, and M42 remote alarm). Size: 7 in. × 7 in. × 14 in. detector and battery box (14 lb). Detection capability: Nerve and blister agents. Battery life: Approximately 15 hours at 70°F. ACADA uses the IMS technology of Graseby Dynamics, Ltd., and operates continuously.
Beaglette	The Beaglette is a Naval Research Laboratory (NRL) program outside the Joint Chemical and Biological Defense (CBD) Program. The concept is based on the larger point chemical agent detector (pCAD; see below) and offers the potential for a disposable, matchbox-sized system (with polymer-coated surface acoustic wave (SAW) sensors) with true real-time agent detection capabilities with subsecond equilibrated agent responses; robust performance for distributed, or personnel, or miniature unmanned aerial vehicle (UAV) applications in an environment with dynamically changing humidity/temperature; fabricated with

TABLE C.1 *(continued)*

Name	Description
	commercial off-the-shelf components; and having low-power operation with no consumables. Current or projected system capabilities include these: • Chemical agent vapor detection with low parts per billion limits; • High discrimination for diesel, gasoline, and the like; • System power: 0.1 W continuous; • Weight: 0.1 lb (palm-sized system); • Zero warm-up time for efficient intermittent operation; • Wireless link; and • Compatibility with other sensors.
CAAS	The chemical agent alarm system (CAAS; also known under the designation M8A1), through IMS techniques, detects the presence of nerve agents (tabun (GA), sarin (GB), soman (GD), O-ethyl S-diisopropylaminoethyl methylphosphonothiolate (VX)) and supplies visible and audible alarms. This mature system has been available for a long time. More than 40,000 M8A1 systems have been fielded by the U.S. Army and many foreign countries.
CAM	The chemical agent monitor (CAM) is a product of Graseby Dynamics, Ltd. It is a handheld, portable detector specifically designed to assess the extent of chemical dispersal and the contamination of personnel, vehicles, and equipment, and to confirm when an area is clear of contamination. It is based on Graseby's mature IMS technology; detects nerve, blister, blood, and choking agents; is programmable to cover other agents or simulated agents for training; and is capable of 14-hour continuous battery operation. More than 50,000 units are in service worldwide. A few vapors present in the atmosphere can, in some circumstances, give a false response in CAM. The situations most likely to give a false response are those in enclosed spaces or when sampling is done near strong vapor sources (dense smoke). Some of the types of vapors that have been found to give false readings include these: • *Aromatic vapors*. Included in this category are groups of materials such as perfumes and food flavorings. Some brands of aftershave and perfume can give a response in G mode (for detecting nerve agents) when CAM is held close to the skin—for example, as in casualty-handling procedures. Some sweets, such as peppermints and cough lozenges, and menthol cigarettes can cause a response in G mode if the breath is exhaled directly into the CAM inlet. • *Cleaning compounds*. Some cleaning compounds and disinfectants contain additives that give them a pleasant smell. Some of these additives, such as menthol and methyl salicylate can give false responses in the H mode (for detecting blister agents). Ammonia gives a false response in the G mode. Many cleaning materials are spread over large surface areas and therefore provide a considerable vapor source, particularly in enclosed spaces. • *Smoke and fumes*. The exhaust from some rocket motors and the fumes from some munitions can give responses. Since monitoring with CAM in these situations is unrealistic, few problems should arise.

TABLE C.1 *(continued)*

Name	Description
ICAD	The Marine Corps-issued individual chemical agent detector (ICAD) includes two electrochemical sensors, each of which is covered by a thin diffusion membrane. One sensor is sensitive to nerve agents (GA, GB, GD: 0.5 mg/m^3 in 120 seconds); blood agents (cyanide (AC): 250 mg/m^3 in 120 seconds); and choking agents (CG: 25.0 mg/m^3 in 15 seconds). The other sensor detects blister agents (H, lewisite (L): 10.0 mg/m^3 in 30 seconds). Chemical agents in the air diffuse through the membranes on the faces of the ICAD sensors and are collected by the electrolyte behind the membranes. The chemical agent concentrations in the electrolyte are measured by multiple-electrode electrochemical sensor systems. When the concentration reaches a preset threshold level, an audio alarm sounds and a light-emitting diode comes on.
ICAM	The improved chemical agent monitor (ICAM) is a product of the Joint CBD Program. Based on IMS technology, the ICAM upgrades the CAM with improved reliability and maintainability. It is a handheld device for real-time detection of low levels of nerve and mustard vapors and is capable of both day and night operation. More than 6,000 ICAMs have been procured to date.
ISCAD	The IMS/SAW chemical agent detector (ISCAD) is an NRL program outside the Joint CBD Program. It strives for ultralow false-alarm rates by integrating two CW point detection technologies (IMS and SAW) that have orthogonal principles of operation. The objective is a handheld chemical detector with subsecond equilibrated chemical detection at threat levels for survey mode and vehicular applications. The ISCAD incorporates NRL's pCAD, which dramatically improves SAW signal kinetics and tolerance to environmental effects.
JCAD	The joint chemical agent detector (JCAD) is a handheld, pocket-sized detector capable of automatically detecting, identifying, and quantifying chemical agents onboard ships and aircraft and for individual warfighter applications. Its operating principles are based on NRL's pCAD SAW-based detector. Production is scheduled for FY 2004 and beyond.
M256	The M256 series chemical agent detector kit is capable of detecting both liquid and vapor concentrations of chemical agents. It detects chemical agents in the following concentrations—nerve (G series: 0.005 mg/m^3; VX: 0.02 mg/m^3 within 15 minutes), blister (H: 2 mg/m^3 to 12 mg/m^3 within 10 minutes), and blood agents (AC: 7 mg/m^3 within 10 minutes). The M256 kit is issued at the squadron level, so every squadron has the capability of detecting and classifying chemical agents. The M256 series contains ABC-M8 chemical agent detector paper for liquids and samplers/detectors for vapors. An improved M256 detector kit will also be capable of detecting T2 mycotoxin. M256 series samplers/detectors are used primarily to determine the type of chemical agents present. For example, a unit may have noticed an attack or the alarm may have sounded; the M256 series is then used to check if there is a chemical agent present and to identify the agent. The M256 series also causes operational security problems during hours of limited visibility. A white light is needed to read both the ABC-M8 paper and

TABLE C.1 *(continued)*

Name	Description
	the sampler/detector. The light must be shielded from enemy observation using a poncho or other suitable covering.
M272	The M272 water-testing kit for chemical agents is a lightweight portable kit that will detect and identify harmful amounts of chemical warfare agents when present in raw and treated water. The kit will detect AC to 20 mg/liter, mustard (HD) to 2.0 mg/liter, L to 2.0 mg/liter, and nerve agents (both G and V series) to 0.02 mg/liter. Water containing agents in less than these concentrations is permissible for short-term (up to 7 days) use, in cold or warm regions, with up to 5 quarts per person per day usage. These kits are usually found in chemical reconnaissance units, medical units, and units with water-purification or transportation missions.
M8A1	M8A1 is another designation for the CAAS.
M9	Chemical agent detector paper M9 is the most widely used method of detecting liquid chemical agents. It is more sensitive and reacts more rapidly than ABC-M8 paper does. M9 paper reacts to chemical agents by turning a red or reddish-brown color. To use M9 detector paper, it is put on opposite sides of the body: if one is right-handed, a strip of M9 paper is put around the right upper arm, left wrist, and right ankle; if one is left-handed, the M9 paper is put around the left upper arm, right wrist, and left ankle. It is also attached to large pieces of equipment (e.g., air-conditioning systems, shelter or van entrances, or vehicles). When attached to equipment, it must be placed in an area free from dirt, grease, and oil. This is especially important, since petroleum products and DS_2 (decontaminating solution containing diethylenetriamine, 2-methoxyethanol, and sodium hydroxide) also cause the paper to change color. M9 paper is especially useful in detecting on-target attacks and in keeping soldiers from entering contaminated areas. Whenever a pink, red, reddish-brown, or purple color appears on the paper, the presence of chemical agents is suspected. As soon as M9 paper indicates the presence of chemical agents, soldiers and units must take protective action to keep from becoming grossly contaminated. The results of the M9 paper should be confirmed with the M256 kit. Night operations present some problems when using M9 paper. Color changes do not show up when a flashlight with a red filter is used to read the paper; white light must be used. This could cause some serious operations security problems, especially for front-line troops. Commanders must realize that there is a risk if they do not establish procedures for checking M9 paper for color changes. To check it, soldiers can be rotated into a white-light area, or the M9 paper can be collected periodically for reading.
MIME	The metal-insulator metal-ensemble (MIME) chemi-resistor is an NRL project outside the Joint CBD Program. It represents a new development in solid-state chemical vapor sensors and is still in an early phase of research and

TABLE C.1 *(continued)*

Name	Description
	development (R&D). The MIME chemical sensor is composed of nanometer-sized gold particles encapsulated by a monomolecular layer of an alkanethiol surfactant. These nanoclusters are self-assembled onto a micron- or nanometer-scale electrode. This sensor operates by reversible absorption of vapors into the organic monolayer, which causes a very large modulation in the tunneling current between clusters in the deposition. Response times are controlled by vapor diffusion, which is extremely fast for monolayers. Selectivity depends on an array of variably responding sensor elements, which are produced by chemical functionalization of the alkanethiol. Current or projected capabilities include these: • "Electronic nose" chemical vapor detection, • Parts per billion chemical agent simulant detection, and • Response and recovery times <1 sec. An entire detection system may be packaged within the volume of a wristwatch.
pCAD	The point chemical agent detector (pCAD) represents the pioneering NRL SAW-based CW-agent point-sensor concept that is being incorporated into the JCAD sensor of the Joint CBD Program. The pCAD provided for the first time true real-time agent detection capabilities with subsecond equilibrated agent responses. It offers robust performance for ground and unmanned aerial vehicle applications in an environment with dynamically changing humidity and temperature; a palm-sized system fabricated with commercial off-the-shelf components; and low-power operation with no consumables. The operating principle is based on polymer-coated SAW devices that selectively and reversibly absorb chemical agents. The resulting shift in SAW signal frequency provides detection capability. SAW-array pattern analysis provides identification of the agent. Novel system design provides accelerated signal kinetics and immunity from environmental effects due to humidity and temperature. Current or projected system capabilities include these: • Chemical agent vapor detection with low parts per billion limits; • High discrimination for diesel, gasoline, and the like; • System power: 0.5 W continuous; • Weight: 0.5 lb (palm-sized system); • Zero warm-up time for efficient intermittent operation; • Wireless link; and • Successful preliminary ground and UAV flight tests.

Chemical- and physical-reaction-based point detectors exploit several different principles. Perhaps the most basic, and the first to be exploited in the context of CW agent detection, is the change in color of various solutions and substrates when they interact with the agents. Detection papers (e.g., ABC-M8 and M9) have reagent coatings that selectively change color when exposed to specific CW agents. Color-change detectors can detect nerve, blister, and blood agents.

Chemoselective hydrogen-bonded acid polymers are at the heart of many "electronic nose" chemical point detection sensor systems. These polymers selectively adsorb chemical agents or explosives over extended periods of time (minutes, hours, days). Relatively thick polymer films and/or hyperporous structures allow rapid vapor sorption. Material properties are selected to allow vapor sorption, but not desorption, at ambient conditions. Heating allows the trapped agent to be released for analyses.

The adsorption of the agent into the polymer can have a number of measurable physical effects, the simplest of which is an increase in overall mass of the element. If these polymer elements are coated on the surface of a surface acoustic wave (SAW) oscillator, the changes in mass can be detected as changes in frequency of the SAW signal. The use of multiple polymers, which respond in different ways to a given chemical agent, permits agent identification through pattern-matching techniques. This is the principle of operation behind a series of CW point detection sensors. SAW technology was, in fact, pioneered by the Naval Research Laboratory (NRL) and has been selected for the next-generation chemical point detector (the joint chemical agent detector, or JCAD).

Another approach commonly used in the civilian and academic worlds is chromatography. Chromatography involves dissolving a sample in a so-called mobile phase, which may be a liquid or a gas. The mobile phase is then forced over a static component known as the stationary phase. Generally the sample will have differing solubilities in each phase. A component that is quite soluble in the stationary phase will take longer to travel through the apparatus than a component that is not. As a result of these differences, sample components will become separated from each other. Techniques such as high-performance liquid chromatography and gas chromatography use columns—narrow tubes packed with the stationary component through which the mobile component is forced. The sample is transported through the column by the continuous addition of the mobile phase; the different components of the sample emerge at different times.

Chromatographic separations can be carried out using a variety of transport and stationary phases, including liquids, volatile gases, paper, and immobilized silica on glass plates. Coupling a detection scheme at the exit of the separation produces the sensor. Such sensors have found wide application in the laboratory and for environmental measurements. As does mass spectrometry, chromatography offers high sensitivity and good specificity for the detection of CW agents in many forms.

Work on systems using microfabricated columns to implement miniature gas and liquid chromatography sensors for the detection of pollutants (e.g., toxic industrial chemicals or CW agents) has been going on for some time, but it has been historically challenged by difficult implementation issues. Recent progress, however, is suggesting that microchromatographic techniques may form the basis for the next-generation detector after JCAD.

Biological Point Detection

As noted in Chapter 4 of this report, at least six approaches are being used for the detection and identification of biological agents:

1. Nucleic acid sequence detection and identification,
2. Binding affinity and specificity using natural antibodies to target antigens,
3. Ligands and artificial antibodies for binding affinity and specificity,
4. Response of living cells or tissue to pathogen or toxin exposure,
5. Chemical analysis, and
6. Culture-based approaches including microscopy.

Numerous measurement approaches use these basic six "signatures." For instance, a binding event between the target agent and the test probe can be measured using the differences in mass among the individual molecules and the bound complex. Alternatively, an optical label can be attached to the probe and detection achieved after separation of the molecular complex by physical filtering from the labeled probe. Each of the six basic signatures has resulted in numerous instrument prototypes and concepts for detection and identification.

Immunological approaches (i.e., antibody assays) have been available for some time. Their principal limitation is the lack of specificity of the antibody; that is, very few antibodies bind exclusively to one target molecule. This can lead to false positives from the detector. Several approaches are being investigated to improve the performance of immunological sensors, including the design of artificial antibodies with greater specificity, the use of multiple antibodies that bind to different parts of the target molecule, and the use of a network of detectors that allow spatial comparisons among the sensors to help discriminate between a false positive and the presence of a biological agent.

Nucleic acid–based approaches are both sensitive and specific, and have been fielded as part of demonstrations and tests. Nucleic acid approaches cannot detect purified biological toxins but may be able to identify associated residues from the organism. The time required to perform a nucleic acid test is decreasing, and for some instruments it is now less than 10 minutes. Instrument packaging is also being dramatically reduced; currently, suitcase-sized systems can be purchased. A nucleic acid approach to medical diagnostics is also showing promise

(see Chapter 5). On the other hand, inhibition from metals, salts, and other factors affect detection and can lead to significant sample preparation issues in various environments. Nucleic acid detection instrumentation can be expensive.

Ideally, a single sensor would be available to detect and identify both chemical and biological threats. The potential for integrating chemical and biological point detection was presented to the committee for a system based on mass spectrometry (signature 4 in the list at the beginning of this section). Mass spectrometry is arguably the "gold standard" for chemical testing. Even though the mass spectrometer approach has promise, progress for biodetection has been limited such that the near-term potential to perform both types of tests in one sensor should not be expected. Even if the detection capability can be developed, the mass spectrometer will require different "front ends" with separate optimization for chemical and biological targets.

In the near term, a single instrument will not be able to adequately detect and identify both chemical and biological agents. Mass spectrometry has some promise in this area but will require a long-term investment. It is likely that different sample preparations will be required for chemical and biological samples.

The sensors proposed and used for contamination avoidance should have utility in decontamination. The committee is not aware, however, of any assessment aimed at finding out how well the sensors developed for contamination avoidance can support decontamination and resumption of operations. There are also opportunities to leverage sensor investments with water and food safety. The DOD development of a sensor for water safety (joint chemical/biological agent water monitor) is at an early stage, with planned entry into development in FY 2005. Several references provide descriptions and status reports of biological point detection systems within the DOD.[1] Table C.2 offers a summary.

There are significant investments and progress being made in similar sensors in other parts of the government—for example, the National Science Foundation, Department of Energy (DOE), and National Aeronautics and Space Administration—and in industry (HAZMAT and medical diagnostics). The committee did not attempt a catalog of all of these activities, but acknowledges that the Joint CBD Program is continuously monitoring progress in these other efforts and is importing promising technologies when appropriate.

[1]National Research Council. 2000. *Strategies to Protect the Health of Deployed U.S. Forces: Detecting, Characterizing, and Documenting Exposures*, Board on Army Science and Technology, National Academy Press, Washington, D.C.

TABLE C.2 Biological Point Detection Systems of the Department of Defense

Name	Description
BAWS	The bio-aerosol warning sensor (BAWS) is an ultraviolet (UV) fluorescence detector using laser illumination. BAWS units are planned to be integrated into the joint biological point detection system (JBPDS) as a trigger for the presence of a 1- to 10-micron-sized biological particle.
BIDS	The Biological Integrated Detection System (BIDS) is a vehicle-based collection of components with upgrade capacity. Integration into JBPDS is planned toward fully automated, broad-spectrum biological detection and identification.[a] Tens of units were produced for the Chemical Company.
BSPS	The Biological Sample Preparation System (BSPS) for biological identification is two different approaches: proteomic and genomic. The proteomic approach uses sonication and high-performance liquid chromatography separation as a front end to mass spectrometry. In FY 2000, about 2-ft^3-size implementations of the front end were demonstrated. Enzymatic digests have been used to do protein-based identification. The genomic approach uses polymerase chain reaction (PCR) as the detection mechanism and has shown a 100 colony-forming unit/ml limit of detection for several threat organisms in less than 20 minutes.
CASPOD	The Contamination Avoidance at Sea Ports of Debarkation (CASPOD) advanced concept technology demonstration (ACTD) has been newly initiated by the Joint CBD Program.
CBIS	The Chemical and Biological Individual Sampler (CBIS) ACTD has begun with chemical detection only, using commercial off-the-shelf technology. The scenario for the ACTD has not yet been determined.
CBMS	The chemical biological mass spectrometer (CBMS) uses infrared pyrolyzer followed by tandem mass spectrometry.[b] The CBMS was originally intended for the next-generation BIDS. It is being evaluated as a joint chemical/biological agent water monitor.
IBAD	The interim biological agent detector (IBAD) is composed of a particle-size sorter/counter, a wet cyclone sampler, a manual identifier, and a flow-through colorimetric ticket assay. Agent identification occurs within 20 minutes.
JBAIDS	The Joint Biological Agent Identification and Diagnosis System (JBAIDS) has demonstrated PCR-based systems to quickly and reliably identify multiple (at least 8) biological organisms. It is moving to the acquisition phase. Smart Cycler™ XC and Rapid/LightCycler were part of Block I concept technologies.
JBPDS	The Joint Biological Point Detection System (JBPDS) is in development to replace and outperform the Army BIDS and Navy IBAD systems. It is planned to enter development of Block II in FY 2004. JBPDS comprises trigger, sampler, detection, and identification subsystems to meet Joint Operational Requirements Document (JORD) specifications. It is designed to be able to identify multiple BW agents in less than 15 minutes, at 1 ACPLA sensitivity, and have less than 2 percent error in identification.[c] Generic UV laser-induced fluorescence detection capability (BAWS) improves system performance while reducing operations and support costs.

TABLE C.2 *(continued)*

Name	Description
JBREWS	The Joint Biological Remote Early Warning System (JBREWS) ACTD was completed in FY 2000 and considered BW missile with BW warhead attacks on a ground maneuver force in an assembly area. It used point and standoff detection sensors with information links.
JCBAWM	The joint chemical/biological agent water monitor (JCBAWM) is proposed (should enter development in FY 2005) to be a portable device for detection and identification. Market surveys are being done, and requirements and exit strategy are in planning stages. Testing protocols are being exercised.
JMCBD	The joint modular chemical/biological detector (JMCBD) will be capable of detecting, identifying, quantifying, and warning personnel of the presence of chemical and biological agents and toxic industrial chemicals and biological hazards. It is scheduled to begin development in FY 2008. It will be lightweight and handheld (target size: about 40 $in.^3$), may be used singly or in a network of detectors, and may include a biological/chemical detector module or separate biological and chemical detector modules, a communications/alarm module, a battery, and a command/communications module. It is intended to be employed in various modes, including but not limited to these: on individuals, vehicles, perimeters; set up in a detection grid; attached to UAVs; on the interior and exterior of aircraft, fixed sites, and naval ships designated to operate in or transit a chemical or biological threat area.
JSLNBCRS	The Joint Services Lightweight NBC Reconnaissance System (JSLNBCRS) is proposed as a vehicle-mounted point and standoff nuclear, biological, and chemical (NBC) system. The vehicle includes collective protection and unspecified biological sensors.

continues

Chemical Standoff Sensors

Active approaches to chemical standoff detection use a laser source that can illuminate the suspect cloud or surface with several different wavelengths of laser light. The light, through several possible mechanisms, is differentially absorbed and/or scattered and ultimately reflected back to the receiver, which is typically in the immediate neighborhood of the transmitter. A high-power tunable laser source is required to achieve sensitive performance at the desired ranges of many kilometers. The technique is commonly referred to as lidar (light detection and ranging), and the different interaction techniques are identified as differential absorption lidar (DIAL) and differential scattering (DISC). Lidar systems are currently expensive and complex because they require relatively large optical configurations. To detect and identify CW agents, the system must operate in the far-infrared region, limiting the choices of laser sources that can be employed primarily to the carbon dioxide (CO_2) laser—a reasonably mature laser system

TABLE C.2 *(continued)*

Name	Description
MAGI Chip	The micro-array of gel-immobilized compounds (MAGI) Chip is planned to identify nucleic acid signatures aimed at virulence factors associated with pathogenic strains.
NBCRS	The M93A1 FOX Nuclear, Biological, Chemical Reconnaissance System (NBCRS) is a vehicle system capable of detecting, identifying, marking, sampling, and reporting NBC contamination on the battlefield. The nuclear and chemical systems are more mature than the biological. The biological sensors are unspecified.
Portal Shield ACTD	The Portal Shield ACTD focuses on air bases and ports for the automatic detection and notification of aerosol attacks. The ACTD was completed in FY 1999, and Portal Shield was transitioned into procurement.
RESTOPS	The Restoration of Operations at Fixed Sites ACTD integrates and demonstrates tools to mitigate adverse effects and restore operations at a fixed site before, during, or after a CW or BW attack on an airfield or seaport. Preliminary demonstrations were scheduled for FY 2002.

[a] Johnson-Winegar, Dr. Anna, Deputy Assistant to the Secretary of Defense for Chemical/Biological Defense. 2000. *Joint Services Chemical and Biological Defense Program, FY00-02 Overview,* Washington, D.C.

[b] Berry, Patrick L., Edgewood Chemical and Biological Command. 1998. *Biological Integrated Detection System (BIDS),* U.S. Army Soldier Biological Chemical Command, Aberdeen Proving Ground, Md., p. 221.

[c] Department of Defense. 2000. *Chemical and Biological Program, Annual Report to Congress,* Washington, D.C., March.

capable of emitting a large number of wavelengths in the 9- to 10-micron range with high powers and efficiencies. However, CO_2 laser lifetime, ruggedness, and power requirements remain practical challenges. Several lidar systems have been flown and successfully demonstrated over the past two decades.

Passive optical techniques exploit the natural illumination in the environment (e.g., thermal radiation from the elements in the scene, the Sun, the cloud itself) to replace the active laser beam. In the infrared spectral region, where CW agents have the most characteristic spectral properties, solar radiation contributes little compared with thermal self-emission. As long as the suspect cloud or surface is not in complete thermal equilibrium with the environment, that is, as long as there is a temperature difference between the "target" and elements in the scene, there are measurable spectral differences between emissions from elements (pixels) on and off the target.

Passive remote sensing systems are categorized by the degree of spectral detail measured, as well as by the degree of imaging achieved—that is, whether the

spectrum is measured from one or many pixels at the same time. If high-resolution spectral data are collected across a multipixel image, the system is known as a hyperspectral imaging (HSI) system. HSI has been a popular research area in recent years in many contexts other than CW, since the more information that is collected, the better the chance to detect and recognize objects in the scene. The disadvantage is that the amount of data collected grows rapidly as the product of the number of pixels in the image and the number of wavelength bands measured in the spectrum. In practice, both image and spectral resolutions have to be kept modest to stay within the bounds of existing signal/data communication and processing equipment. At present, spatial and spectral resolution of HSI sensors is not adequate for most CW agent detection missions, but the technology is promising and should be monitored. Performance calculations done by both the Army and DOE suggest that HSI systems will be feasible for many applications in the future.

It is more common to address the hyperspectral data overload by keeping fairly high spatial resolution in the image while confining the spectral information to only a few broad wavelength bands, chosen to maximize the difference expected between the radiation from the background and the candidate targets of interest (CW clouds or contaminated surfaces, in this case). Such systems are known as multispectral imaging (MSI) systems.

If the proper wavelength bands are selected, multispectral imaging systems can be a powerful tool for detecting events or scene characteristics of interest. Many MSI sensors are now operational on Earth-orbiting satellites for resource monitoring, atmospheric studies, and some military applications, where it has proven to be a good technique to defeat camouflage. Unfortunately, the existing MSI technology does not provide adequate spectral resolution to make it attractive for detecting CW agents and related chemicals except in limited scenarios.

Standoff chemical sensing programs related to DOD are summarized in Table C.3.

TABLE C.3 Chemical Standoff Detection Systems of the Department of Defense

Name	Description
AIRIS	The adaptive infrared imaging spectroradiometer (AIRIS) is a commercial product that provides for the passive imaging of chemical clouds in the thermal infrared (IR) (8 to 12 μm) spectral region. It uses a tunable etalon (Fabry-Perot bandpass filter) with computer control of selected wavelengths combined with a HgCdTe IR focal plane array to generate multi- and hyperspectral images. The Army has conducted field tests of AIRIS for the investigation of target phenomenology.
AN/KAS-1	AN/KAS-1 is the field designation for the chemical warfare agent directional detector (CWDD). It is a two field of view, forward-looking infrared (FLIR) device utilized by the Navy for the passive optical standoff detection of nerve agents. Three spectral band filters enable the operator in principle to distinguish the presence of nerve agents. More than 1,000 AN/

TABLE C.3 *(continued)*

Name	Description
	KAS-1 systems have been manufactured. When the JLSCAD (see below) becomes available, it will replace the AN/KAS-1.
Artemis	Artemis is the continuation of the former Joint Service Warning and Identification LIDAR System (JSWILD) program, which was renamed in FY 2001. Artemis will be a CO_2 LIDAR system for the long-range (10 to 20 km) detection, identification, and mapping of CW agent vapors, aerosols, and droplets. Among the technical challenges are issues of tunable CO_2 laser sources, real-time discrimination algorithms, laser-induced optical damage issues, and difficulties in shifting the CO_2 laser outputs into the 8-mm range for enhanced mustard detection. An advanced brassboard LIDAR with these features is under development. This program is in an early phase of development and, in spite of the relative maturity of CO_2 laser technology and the Army's frequency agile laser (FAL) developments, still has major practical implementation issues to resolve before the intended FY 2007 operational capability can be realized.
CATSI	The compact atmospheric sounding interferometer (CATSI) is a commercial product utilizing Fourier Transform infrared (FTIR) spectrometry in the 3- to 18-μm IR spectral range for the detection and discrimination of gaseous chemical air pollutants. This sensor has been used by the Army for the measurement of agent phenomenology.
CIS	The Chemical Imaging System (CIS) is an advanced hyperspectral passive optical system that uses a novel spinning plate interferometer to implement high-speed FTIR spectrometry in the 8- to 12-μm IR spectral range. The current hardware, which is ruggedized for field use, is capable of collecting spectra on 16 image pixels at rates up to 100 scans/s. Successful field tests were carried out in FY 1999 and FY 2000 at the HAZMAT Spill Center of the Nevada test site where simultaneous releases of multiple (4) chemicals were successfully detected and discriminated at ranges of 1.5 km. The technology seems extremely promising.
CWDD	Chemical warfare agent directional detector (CWDD) (see AN/KAS-1 above).
FAL	The frequency agile laser (FAL) is a flexible CO_2 laser transmitter that represents the evolution of work begun in the mid-1980s. The current system holds the lifetime record for sealed CO_2 gas lasers and is capable of sending out a burst of 20 wavelengths in 1/10 s at 4 bursts/s. The laser has been fully engineered with stringent temperature/vibration/shock/life tests. Edgewood Chemical and Biological Command (ECBC) has had an in-house testbed using FAL technology from 1992 to the present, and several other programs (MIRELA and N-ABLE; see both below) have used the FAL technology. It provides the starting point transmitter technology for the Artemis/JSWILD program.
JSLSCAD	The joint service lightweight standoff chemical agent detector (JSLSCAD) is a passive optical CW agent detection system using FTIR techniques. It represents a second-generation improvement of the M21 RSCAAL sensor (see below). Significant testing and program decisions for JSLSCAD were

TABLE C.3 *(continued)*

Name	Description
	expected to take place in FY 2001. However, it was not possible to determine from the information supplied to the committee if these events took place and what the decisions were.
JSWILD	The Joint Service Warning and Identification Lidar System (JSWILD) has been renamed Artemis.
M21 RSCAAL	The M21 remote sensing chemical agent alarm (RSCAAL) was the first standoff CW agent detection system developed and fielded that was capable of detecting agents at distances of up to 5 km using passive IR spectrometry. The system provides early warning of the presence of nerve agents (GA, GB, GD) and blister agents (HD and L) in vapor form. More than 300 units have been produced, and the system has been fielded by both the Army and the Marine Corps.
MIRELA	This U.S./French prototype lidar, 1993-1999, used FAL laser technology.
N-ABLE	The ECBC/Air Force Research Laboratory/Los Alamos National Laboratory airborne lidar, 1996-1997, used FAL laser technology.
SHREWD	The standoff handheld real-time early warning detector (SHREWD) is an Army system under development by ECBC; it is intended to provide a compact, standoff detection capability for manned applications (warfighter/first-responder, Future Combat System helicopter) and unmanned applications (UAV/UGV, static emplacement); 3 to 5 km maximum range. SHREWD is a differential absorpton lidar (DIAL) concept based on advanced tunable CO_2 and solid-state, diode-pumped optical parametric oscillator (OPO) laser technology. The program is still in early development and faces substantial challenges in the technology of the lasers. The program plans to build and field-test a brassboard version in FY 2002, with improved prototypes demonstrated in the field by FY 2005.
WILDCAT	The warning and identification lidar detector for countering agent threats (WILDCAT) is an advanced lidar brassboard. Utilizing the FAL technology, the program seeks to increase CO_2 laser pulse energy from 100 mJ (i.e., FAL) to 1 J for aerosol/rain detection at ranges longer than 1 km. It will be wavelength-tunable at 100 Hz. WILDCAT demonstrated good signal-to-noise ratio for long-range detection in field tests in August 2001.

Biological Standoff Sensors

The major points regarding standoff detection of biological agents are discussed in the main body of the report (see Chapter 4). Here it is simply added that the use of ultraviolet (UV) irradiation, while promising in many respects, still presents many obstacles. In the first place, efficient generation of UV laser radiation is difficult. Some gas laser systems, such as the argon laser, can produce various UV wavelengths, but the equipment is large and the power efficiency extremely poor. More commonly, a solid-state laser that emits in the near IR is

TABLE C.4 Standoff Biodetection Systems of the Department of Defense

Name	Description
LR-BSDS	The Long Range Biological Standoff Detection System (LR-BSDS) is an Army corps-level asset that provides early warning and aerosol cloud detection and tracking to enhance contamination avoidance efforts and cue other biological detection assets (e.g., the Biological Integrated Detection System). However, the system has no integral biological warfare (BW) agent discrimination capability and measures only the presence of aerosols. The system employs lidar laser technology and will detect and track aerosol clouds (with particles larger than 1 micron) at ranges up to 30 km (50 km for the objective system). These systems are mounted and operated from an unmodified UH-60 Blackhawk helicopter platform and ground vehicles. The LR-BSDS system provides information about cloud configuration (size, shape, and relative intensity) and cloud location (range, width, height, height above ground, and drift rate). A two-operator crew allows for human discrimination between man-made and naturally occurring aerosol clouds. The interim system saw limited procurement in 1995, and has been fielded as the XM94. A counterproliferation version (CP LR-BSDS) is under development using improved (i.e., eye-safe) laser technology.
SR-BSDS	The Short Range Biological Standoff Detection System (SR-BSDS) is under development by the Army. It uses laser-induced fluorescence to distinguish BW agents from nonbiological clouds at ranges of 1 to 3 km. Some field testing has been done, but the concept is still in development.

used and the output frequency doubled several times to achieve outputs in the 300- to 400-nm range. Such solid-state lasers can be compact and reasonably efficient. The range of UV wavelengths that can be usefully applied to standoff detection is limited severely by the absorption properties of the atmosphere. Below 400 nm the attenuation of the atmosphere rises steeply, and long-range propagation rapidly becomes impossible. Since fluorescence of biological materials tends to decrease as the exciting wavelength approaches the visible region of the spectrum, the design of a UV lidar fluorescence system involves difficult trade-offs between laser wavelength availability, range of propagation, and strength of the resulting fluorescence signals.

The difficulties associated with standoff biodetection are illustrated by the small number of programs in DOD (Table C.4).

INDIVIDUAL PROTECTION AND COLLECTIVE PROTECTION

Currently fielded individual protective equipment includes the MK-V, MCU-2P, M40-A1, and M4-2 masks. Protection is provided by high-efficiency filtration (BW agents) and chemisorption onto activated charcoal filters (CW agents). Future technology may include the use of reactive and regenerative filters in masks. Similar technology is employed in the collective protection units to cap-

ture or remove contamination from the air. Individual protective garments currently fielded include the chemical protective overgarment (CPO), battle dress overgarment (BDO), and Saratoga suits. Technology development efforts for outerwear focus on enhanced, semipermeable fabrics to reduce heat and respiratory loads; toughening of garments; and development of self-decontaminating, or reactive, fibers.

The Joint CBD Program currently funds research, development, and testing for both individual and collective protection. This includes the Joint Services Program mask with end-of-service-life indication and limited protection against toxic industrial chemicals; the next-generation general-purpose mask intended to reduce respiratory and thermal stress while offering enhanced protection and comfort; and the joint services chemical environment survivability disposable mask that offers up to 6 hours of protection. New-generation garments are also under development in the Joint CBD Program. These include the lighter-weight and lower-thermal-stress suit (JCE-I); the JCE-II suit that promises even lower weight, lower thermal stress, and a self-decontaminating feature; and the JSCESS suit that is a single-use, minimum-weight and -volume garment. Collective protection systems under development include the chemical/biological protective shelter, which is a lightweight, truck-mounted shelter that provides a clean working area for medical, combat service, and support personnel for up to 72 hours. The chemically protected deployable medical system is a chemically hardened, air-transportable hospital unit. Collective protection retrofits and the shipboard collective protection equipment (SCPE) project are focused on extending the lifetime of shipboard high-efficiency particulate air filters for protection systems based on overpressurization with clean air.

DECONTAMINATION

In the committee's opinion—and as stated many times throughout this report, attacks with chemical or biological agents or toxic industrial chemicals (TICs) will occur, and some of them will be successful. It is a nearly impossible problem to protect fully against contamination by a determined adversary armed with a chemical or biological weapon in many asymmetric scenarios. Although improved CW or BW detection sensors have value for providing an increased warning capability, they should not be relied upon as an effective defensive strategy to avoid attack. Similarly, the nature of many of these scenarios is such that it would be impossible to avoid contamination by quickly fleeing the area. Because of these limitations, the probability of contamination resulting from an asymmetric attack is far from zero. Attacks with CW or BW agents or TICs will occur, and some of them will be successful. The operational goal then becomes achieving a quick recovery to operational status, which in turn requires well-planned decontamination operations, which in turn will require significant im-

provements in decontamination agents, methods, technical understanding, training, and doctrine.

Methods and Materials

Some currently fielded decontamination materials and equipment are described in detail in a separate National Research Council/Institute of Medicine publication.[2] A brief description of current decontamination programs under the auspices of the Joint CBD Program is provided in Box C.1. (The associated time lines for testing, acquisition, and fielding can be found in the publication entitled *Joint Service Chemical and Biological Defense Program—FY00-02 Overview*.[3]) Box C.1 also includes a listing of other federally funded research and development efforts related to decontamination.

Standards

In addition to the decontamination approaches themselves, effective decontamination requires reducing exposure to the toxic compound or biological agent to a level that is considered safe for personnel. In managing the consequences of an attack, it is important to distinguish between the two agent types. Chemical agents can have both acute, immediate effects and more chronic (long-term) effects that may not manifest themselves for months or years. Some biological agents create morbidity within hours, while others take days or weeks. It is critical to have expert advice as to the range of possible effects as well as the chemical and biological nature of the agents in question. Little is known about the effects of long-term exposure to low levels of chemical or biological agents. Understanding this is important for those target areas that have large in-place populations such as harbors and bases, where return to a safe level may mean safe for long-term exposure or a level dictated by civil regulations. These facilities depend on a continuous and complicated free flow of people and materiel for effective naval operations. A return to normal operations may require a more thorough and possibly more complex decontamination process than that required in battlefield scenarios.

In most situations, rapid resumption of operations will depend on effective decontamination of installations, personnel, and equipment. This is especially true for persistent chemical agents and spore-forming bacteria and some viruses.

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[2]Institute of Medicine and Board on Environmental Studies and Toxicology, National Research Council. 1999. *Chemical and Biological Terrorism: Research and Development to Improve Civilian Medical Response,* National Academy Press, Washington, D.C., pp. 239-240.

[3]Johnson-Winegar, Dr. Anna, Deputy Assistant to the Secretary of Defense for Chemical/Biological Defense. 2000. *Joint Services Chemical and Biological Defense Program, FY00-02 Overview,* Washington, D.C.

BOX C.1
Joint Service and Other Agency Programs in Decontamination

Joint Service Programs

- *Joint Services Fixed Site Decontamination (JSFSD).* This effort is geared toward ports of entry, airfields, logistics nodes, and command and control centers. The goal is removal, neutralization, or elimination of chemical/biological agents and toxic industrial materials by employing a family of decontamination reagents and applicator systems. Decontamination of wide areas, facilities, key equipment, and personnel are all considerations. The program focuses on the use of new decontamination reagents that can be employed with existing applicators. A second aspect deals with the development of new applicators. The third aspect of the program is concerned with applicators for use on skin and in open wounds.
- *Joint Services Sensitive Equipment Decontamination (JSSED).* This effort primarily focuses on nonaqueous decontamination technologies for chemical/biological agents. Three separate capabilities are under development. First, techniques for decontamination of small, high-value, sensitive equipment or components are being examined. Included are examination of supercritical solvents, glow discharge plasmas, catalyst (nanoparticle) solvent wash systems, and thermally accelerated weathering. Second, vehicle interiors that house sophisticated electronic materials (aircraft, tanks, and so on) are to be examined. Included are exterior surfaces that cannot be subjected to the more aggressive decontamination solutions currently fielded, such as DS_2. Third, in the out years, the issue of "on-the-move" decontamination will be addressed. Included is the decontamination of vehicles while they are in operation or flight.
- *Modular Decontamination System (MDS).* This technology development program has as a primary goal minimizing the spread of contamination on the battlefield through the use of small, modular decontamination stations. The system under development includes a decontamination reagent pump and high-pressure applicators. This unit is essentially a compact, high-pressure washer unit capable of delivering a limited set of liquid-phase decontamination reagents (DS_2, common bleach, formalin, or even diesel fuel, should that be the only liquid available).
- *Sorbent Decontamination.* The sorbent program includes development of personal wipedown systems and spraydown operations. The objective is to improve upon the carbonaceous and ion exchange mixes in current use and to eliminate DS_2 from the spraydown operations. A stable, environmentally acceptable, noncorrosive sorbent that is effective over a wide temperature range will permit decontamination of personal equipment, key areas of vehicles, and weapon systems. Short-term objectives include development of carbon cloth technology for the removal of contamination from skin. Longer-term objectives include testing and procurement of sorbent-based decontamination kits for field use.

Other Decontamination Programs

In addition to the joint service programs listed above, current research and development efforts are being undertaken through 6.1 efforts supported by the Army Research Office, through the Technical Support Working Group, as part of the biodefense program at the Defense Advanced Research Projects Agency, and at the Department of Energy national laboratories. These efforts are listed below.

- Army Research Office—Chemical Sciences Division
  - —Novel Surfactants and Microemulsions (Menger, Emory University)
  - —Simultaneous Signal and Decontamination (Jaeger, University of Wyoming)
  - —Polyoxometalates (Hill, Emory University)
  - —Nanoparticles (Klabunde, Kansas State University)
  - —Artificial Metallo-phosphoesterases (Chin, McGill University)
  - —Ester Metathesis (Gagne, University of North Carolina)
  - —Metal Catalyzed Degradation (Moss, Rutgers University)
  - —Solar-driven Photooxidation (Yates, University of Pittsburgh)
  - —Chemistry of Mild Wide Spectrum Decontamination (Bunton, University of California, Santa Barbara)
  - —Enzyme Catalysis (Leblanc, University of Miami, Coral Gables)
  - —Meso and Microporous Materials (Landry, University of Vermont)
  - —New Chemical Catalysts (Chen, University of South Carolina)
- Technical Support Working Group
  - —Mass Decontamination Protocols (Technical Support Working Group/ Public Health Service)
  - —Mass Decontamination Protocols (Technical Support Working Group/ Public Health Service)
- Defense Advanced Research Projects Agency
  - —Antimicrobial Nanoemulsions (Baker, University of Michigan)
  - —Enzymatic Decontamination (Maxygen)
- Department of Energy
  - —Gel-based Catalytic Oxidant System (Raber, Lawrence Livermore National Laboratory)
  - —Foam-based Oxidant/Additive System (Tucker, Sandia National Laboratories)
  - —Atmospheric Pressure Plasma Jet (Herrmann, Los Alamos National Laboratory)
  - —Gas Phase Decontamination (Currier, Los Alamos National Laboratory)
  - —How Clean Is Safe (Sorenson, Oak Ridge National Laboratory)
  - —How Clean Is Clean (Raber, Lawrence Livermore National Laboratory)

For biological attacks, there currently are no guidance documents or performance standards that could be used by the Navy to decontaminate its operations to levels suitable for resuming its operations and protecting its human and material resources. Guidance for chemical agent exposure has been recently addressed by the Joint Staff[4] ; it admits to a limited understanding of safe exposure levels and to the need for the individual commander to accept some level of risk appropriate for his or her own situation. In the commercial world, the acceptable risk levels that are used by regulatory agencies for setting standards for managing chemical and biological disease outbreaks are small, but not zero—typically on the order of 1 casualty in 10^5 or 10^6 (i.e., a fatality rate of 1 in 100,000 or 1 in 1 million.)

In military operations, it is impossible to have zero risk, and indeed, the acceptable risk level in most cases may well be higher than that set for civilian operations. Determining the appropriate level of decontamination for a situation is the result of assessment and decision making based on all of the risks. Setting the appropriate risk levels and decontamination specifications is an area in need of Navy doctrine. Once established, that doctrine could then lead to the development of testing and performance standards to be used for field decontamination, as well as to base and long-term equipment decontamination procedures. The Navy must be able to provide doctrine, guidelines, and expertise in this area.

Agent Fate Studies

The test protocol established by Edgewood Chemical and Biological Command (ECBC) for establishing chemical agent interactions with substrates is summarized in Box C.2.

MODELING AND SIMULATION

Chemical Modeling

The emphasis in chemical agent modeling appears to be on using plume models to predict the spread and concentration levels of a chemical release. However, the accuracy of such predictions is highly dependent on knowledge of the precise location and magnitude of the chemical release, the physical characteristics of the plume (e.g., the initial particle-size distribution), and detailed knowledge of the stochastic nature of local atmospheric dispersion. In reality, these parameters are likely to be poorly known in any cleverly executed asym-

[4]Hawkins, MAJGEN James A., USAF, Vice Director, Joint Staff. 2002. Memorandum for Distribution List re: Chemical Warfare (CB) Agent Exposure Planning Guidance (with two enclosures), MCM-0026-02, Office of the Chairman, Joint Chiefs of Staff, Washington, D.C., April 29.

BOX C.2
Test Protocol for Chemical Agent Fate Studies

The standard Edgewood Chemical and Biological Command (ECBC) testing protocol for chemical warfare agents includes three levels of tests: (1) laboratory tests are performed using live agents and/or surrogates, (2) larger-scale chamber tests are performed with either live agents and/or surrogates to correlate the live agent and surrogate results, and (3) final field tests are performed using surrogate agents. During these final tests, operational assessments of applicator performance and techniques, tactics, and procedures are made. Whenever possible, international and ASTM (American Society for Testing and Materials) standards are employed. Internationally accepted standards do not presently exist for biological agent testing.

At the laboratory scale, tests may be performed in stirred reactor vessels typically involving 1 g of agent and 50 ml of decontamination reagent. These tests provide basic kinetics data and an indication of the product suite. Panel testing, offgassing, and contact hazard testing may also be performed to determine the ease with which contamination can be removed from a specified surface. The Department of Defense (DOD) standard challenge, developed during the Cold War, is still employed, namely, 10 grams of agent per square meter of surface. Adherence to this protocol is by DOD decree. Agent is typically allowed to dwell on the surface for 60 minutes prior to application of the decontamination reagent. This is a historical artifact related to the time required either to set up a field decontamination unit or to return from the field to an established decontamination site. Decontamination reagents are typically applied to the surface and rinsed off following a 30-minute contact time. The contact time may vary with specific customer requirements. ECBC personnel indicated that there is a current push toward reagents that will be effective following a 15-minute contact time. Analytical methods typically include nuclear magnetic resonance, gas chromatograph/mass spectrometer (GC/MS), flame photometric detector (FPD), and so on for CW work, while classical growth-based microbiological assays are employed for assessing decontamination efficacy for biological agents and surrogates.

metric attack. The inaccuracies introduced from these poorly known sources may prove to be the limiting factor in making detailed, spatially resolved predictions.

A common perception exists that chemical attacks appear to require large amounts of chemical materials to have significant, long-term effects over large areas. This increases the likelihood of an opponent's employing industrial chemicals (TICs/TIMs (toxic industrial materials)) as the agent. This also suggests that commercial chemical installations near Navy bases or carried by commercial transportation (e.g., trucks, rail cars, freighters) may present the more significant chemical threat near bases and ports. Such sources could be remotely triggered by attacks with man-portable weapon systems, such as small rockets or placed charges, effectively providing a remote capability to generate a significant chemical attack. Such

attacks would require that the industrial facilities or transportation routes be upwind of the base. In addition to open-air dispersion at shore installations and bases, the Navy needs models to help understand dispersion around and within vessels.

Efforts are under way to include recent results on agent fate in the models. However, there is a significant controversy regarding chemical agent fates. The Air Force approach estimates practical limits for operational decisions rather than pursuing an exhaustive study of detailed chemical fates. In principle this is an intriguing approach, as it adopts a more "operational" perspective on testing and evaluation. However, there are lingering questions in the community about the extent and accuracy of the data gathered in the Air Force-led study. Even if the inherent variability between substrate materials ultimately dictates that an in-depth and detailed study be conducted, there is merit to the operational perspective that the Air Force adopted which should not be overlooked.

Biological Modeling

Biological modeling of agent transport and fate has apparently not received nearly the same level of attention as chemical agent modeling. The same considerations for open-air and enclosed-vessel/facility transport of agent are needed, but in addition, the biological problem introduces some unique requirements.

Since people act as "amplifiers" for infectious biological agents, the concentrations of biological agents that raise concern can be much lower than the levels of chemical agents that cause concern. Consequently, the accuracy requirements for biological modeling may be much higher than those necessary for chemical modeling. The prediction problem is further complicated by the fact that low biological concentrations can occur over much larger geographic areas than are typically affected in chemical attacks.

People and/or animals can also act as dispersion mechanisms (vectors) for the spread of biological agents. For infectious agents spread initially in an aerosol cloud, exposed personnel act as dispersive cells, moving randomly in many different directions and over great distances. This situation takes the modeling problem beyond simple physics, since personnel movement is driven by many factors, most of which cannot be modeled in any sort of predictive sense.

The time lag between exposure to a biological agent and the appearance of symptoms is usually measured in days or more, in contrast to minutes to hours for chemical agents. This lag increases the uncertainty in the source term (location and time of release), further complicating the biological modeling problem even as it offers leeway for therapeutic intervention.

Agents that settle, like anthrax spores, are more easily resuspended by various activities; again, these are processes that are not well understood and cannot therefore be modeled in any predictive sense.

There are currently no highly reliable in situ biological detectors that could be used to increase the accuracy of dispersion models in the early phases of an incident as there are with the chemical problem.

Effectively, a biological attack is likely to be recognized following a disease outbreak. Because of the unpredictable, dispersive spread of biological agents by affected people, biological dispersion models may be applicable only in the early phases of an attack, to narrow the set of personnel likely to have been exposed during the initial release. The growing use of computers in the military and the trend toward using biometrics to identify legitimate military users will lead to a growing capability to "track" the movement of military personnel back in time. This ability to track, at least in a general sense, the movement of military and support personnel might aid in identifying the origin of an outbreak and the region of exposure. A few cases of symptoms appearing in a diverse group of personnel whose movements had coincided in a particular region a few days earlier might help provide an indication of an attack sooner than waiting for more widespread symptoms to appear. Such a "detect to track" capability based on modeling could help identify and confirm that a biological attack had occurred.

Another concern for biological modeling is the use of genetically altered agents, or the introduction of harmful genes into normally occurring, innocuous organisms. Even if we were to develop robust biodetectors for the dangerous biological agents likely to be used as weapons today, such sensors may prove of little value against genetically altered agents in the future.

To illustrate the many factors to be included in a model to aid in decision making in the event of an attack, the committee provides an example of the elements that might be a part of a discrete simulation of the event. The example is illustrative only and not necessarily exhaustive in the factors it includes, but serves to make the point.

Consider a case in which an adversary releases a biological agent against a naval base in CONUS, with the goal of delaying the deployment of a task force. Here the parameter that best determines the effectiveness of the attack would likely be how long the deployment is delayed. Deployment delays can occur because key personnel are injured or killed and are deterred from working and time is required for their recovery or their replacement, or because time is required to decontaminate equipment. In this scenario, a major branch point occurs at the beginning of the attack. If sensors detect that an attack is occurring, personnel can take advantage of individual and collective protection with a concurrent reduction in casualties. Alternatively, sensors may fail to detect that an attack is under way, delaying detection until personnel start falling sick. Along this second branch, personnel losses and resulting deployment delays might be much higher. Since even technically sound sensor systems can fail to detect an attack for any number of reasons, there is always the possibility that a real event could follow either branch of this scenario.

Figure C.1 outlines how a simulation might be constructed to explore this scenario. The goal is to calculate delays that would be introduced into a deployment. The simulation begins with the question of whether any indications and warnings (I&W) of an attack are available before the attack actually begins. Questions related to where such I&W might originate are discussed below. Sensors will produce a finite number of false alarms, which require some time, t_{FA}, to resolve. One can anticipate that there will invariably be some time delay, t_5, associated with the total number of false alarms and the time needed to resolve them. For sensors with high false-alarm rates, t_5 goes up.

I&W might allow an attack to be stopped in progress, resulting in no delay to the deployment. Otherwise there is a major branch point designated as "Detect attack under way." One possibility is that this detection occurs at time t_1, based on the sensor capabilities, allowing personnel to get into individual and collective protection by some time t_2, which is a function of when they get the warning, their proficiency from training, and the ease of obtaining and using protective equipment. Some number of personnel are exposed, P_e, and some fraction of these personnel become infected, P_i, which depends on the number exposed, the agent, and the effectiveness of any vaccines. The notional graph at the bottom indicates that there is some recovery time, *trec*, required for these infected personnel to be either cured and returned to duty or to be replaced by transfers. There is probably some minimum number of losses, P_{min}, which would not stop deployment. Beyond that, there are time delays for recovery or replacement, which can be expected to accelerate at a rate greater than linear for a period of time as more and more personnel become incapacitated. Whether replacement is by recovery or transfer, there is also some minimum time delay, t_{trans}, that would be introduced. Of course, there may be different curves for transfer and recovery. Along this same branch, equipment has to be decontaminated and returned to operational status. This total time t_4 depends on how much equipment is contaminated, the decontamination techniques used, and the ease with which personnel can work in protective equipment. The net result, if the simulation goes down this branch, is a delay, which is the maximum of either the personnel delay, $t_2 + t_{rec}$, or the equipment delay, t_4.

The other possibility occurs when the sensors fail to detect the attack, because of sensor system failure or because they had been deactivated due to high false-alarm rates, and so on. For infectious agents, the number of exposed personnel, P_e, now depends on the initial number of people exposed to the agent and the number of additional people that they infect as they move around. Eventually enough personnel fall sick that the occurrence of an attack is recognized at time t_3, which is probably days later than t_1. As a result, the recovery time, t_{rec}, is much higher, as is the decontamination time, t_6. Along this branch, the delay is the maximum of the personnel delay, $t_3 + t_{rec}$, or the equipment delay time, t_6. In this case, the personnel delay will likely be the controlling factor.

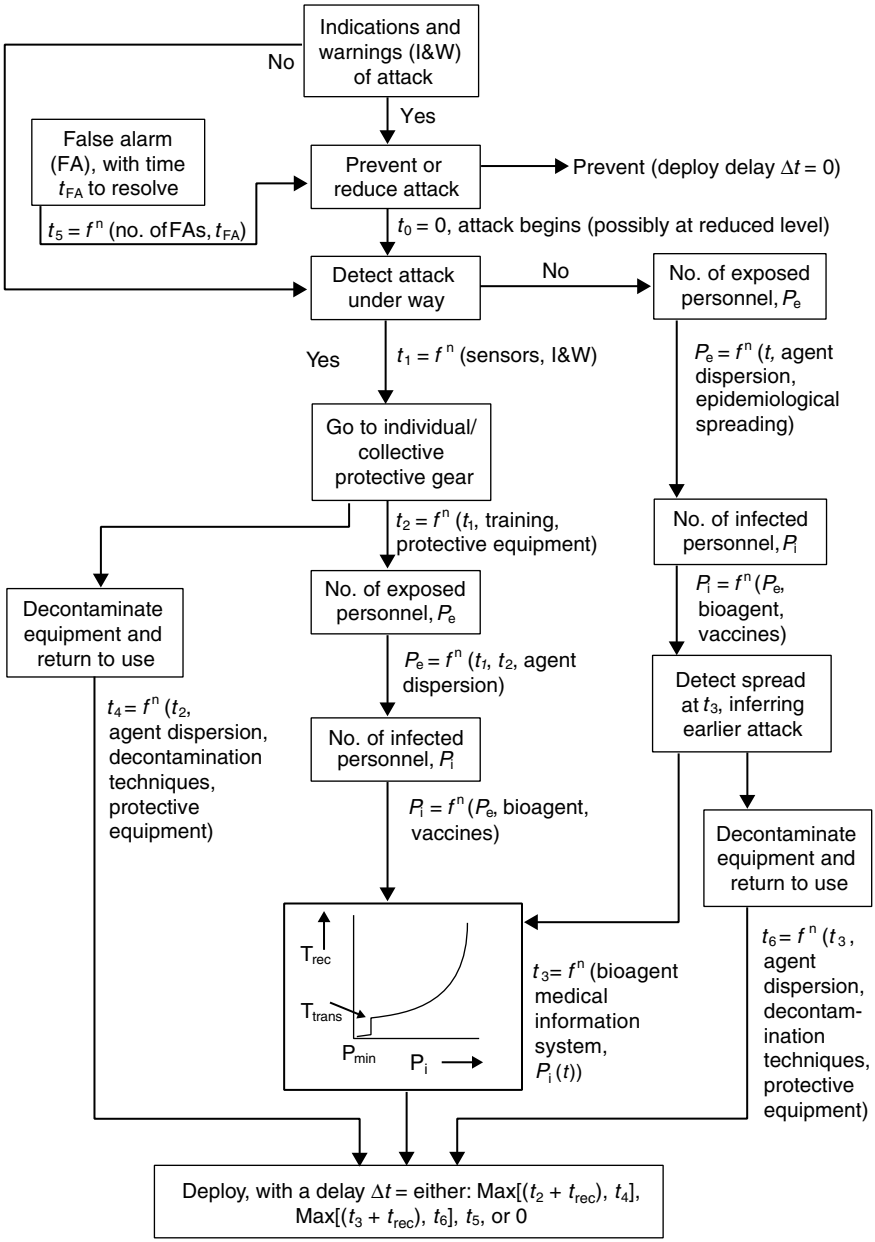

FIGURE C.1 Stochastic simulation for naval deployment delays caused by a biological attack. (See discussion in text.)

It should be noted that many of these times and the numbers of personnel exposed or infected are statistical in nature themselves and would vary from scenario to scenario. For example, there is likely to be significant variability in time t_3 for inferring an attack by recognizing groups of infected individuals. As shown in the box at the bottom of the figure, one pass through the simulation will result in a deployment delay time that is one of the four possibilities. Running the simulation many times then gives a distribution of deployment delay times and an indication of where bottlenecks exist in restoring operational capability.

This example has concentrated on a single parameter as the goal—minimizing deployment delays. Other end-goal parameters, such as minimizing the number of casualties, could also be simulated with only minor modifications. One could also explore coupled goals, such as minimizing deployment delays *and* minimizing casualties. Because these two factors are probably interrelated, some technique such as multiattribute decision theory is needed to combine them. For example, if decision makers can weight the relative importance of reduced casualties versus reduced deployment delays, a slightly modified simulation could be used which has this weighted combination of factors as the end goal.

D

Acronyms and Abbreviations

AC	cyanide
ACADA	automatic chemical agent/detector alarm
ACPLA	agent-containing particle per liter of air
ACTD	advanced concept technology demonstration
AOR	area of responsibility
BAL	British Anti-Lewisite
BDO	battle dress overgarment
BW	biological warfare
BZ	3-quinuclidinyl benzilate
C3	command, control, and communications
CA	contamination avoidance
CANA	convulsant antidote for nerve agent
CB	chemical and biological
CBD	Chemical and Biological Defense (Joint Program)
CBIRF	Chemical and Biological Incident Response Force
CBR-D	chemical, biological, and radiological defense
CBRE	chemical, biological, radiological, and environmental
CBRNE	chemical, biological, radiological, nuclear, or high yield explosive
CBW	chemical and biological warfare
CDC	Centers for Disease Control and Prevention
CFFC	Commander, Fleet Forces Command

CNAC	Center for Naval Analyses Corporation
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
COMNAVAIRLANT	Commander, Naval Air Force, U.S. Atlantic Fleet
COMNAVAIRPAC	Commander, Naval Air Force, U.S. Pacific Fleet
COMUSNAVCENT	Commander, U.S. Naval Forces Central Command
CONOPS	concept of operations
CONUS	continental United States
COTS	commercial off-the-shelf
CPO	chemical protective overgarment
CPS	Collective Protection System
CST	civil support team
CTF 73	Commander, Task Force 73
CW	chemical warfare
CWDD	chemical weapon directional detector
DARPA	Defense Advanced Research Projects Agency
DDG	U.S. Navy guided-missile destroyer (designation)
DIAL	differential absorption LIDAR
DISC	differential scattering
DOD	Department of Defense
DOE	Department of Energy
DOTMLPF	doctrine, organization, training, materiel, leadership, personnel, and facilities
DS_2	diethylenetriamine, 2-methoxyethanol, and sodium hydroxide
DSB	Defense Science Board
DTRA	Defense Threat Reduction Agency
ECBC	Edgewood Chemical and Biological Command
ELISA	enzyme-linked immunosorbent assay
EM	electromagnetic
ExCEL	*Ex*cellence through *C*ommitment to *E*ducation and *L*earning
FBE F	Fleet Battle Experiment Foxtrot
FCBC	Field Management of Chemical and Biological Casualties
FDA	Food and Drug Administration
FD-EPMU	forward-deployable, environmental and preventive medicine unit
FMF	fleet Marine force
FTIR	Fourier transform infrared
FY	fiscal year

GAO	General Accounting Office
GB	sarin
GD	soman
GF	cyclosarin
GPS	Global Positioning System
HAZMAT	hazardous material
HD	mustard
HEPA	high-efficiency particulate air (filter)
HQMC	Headquarters, U.S. Marine Corps
HSI	hyperspectral imaging
I&W	indications and warnings
IMS	ion mobility spectrometry
IND	Investigational New Drug/Vaccine
IPDS	improved point detection system
IPE	individual protective equipment
IR	infrared
JBPDS	joint biological point detection system
JCAD	joint chemical agent detector
JCBAWM	joint chemical/biological agent water monitor
JCE	joint chemical ensemble
JPO-BD	Joint Program Office for Biological Defense
JSCESS	joint Service contaminated environment survival suit
JSFSD	Joint Services Fixed Site Decontamination
JSLSCAD	joint service lightweight standoff chemical agent detector
JSPGM	Joint Services Program
JSSED	Joint Services Sensitive Equipment Decontamination
JTF/CS	Joint Task Force/Civil Support
JVAP	Joint Vaccine Acquisition Program
JWARN	Joint Warning and Reporting Network
L	lewisite
lidar	light detection and ranging
MARCORSYSCOM	Marine Corps Systems Command
MCBC	Medical Management of Chemical and Biological Casualties
MCCDC	Marine Corps Combat Development Command
MCM	mine countermeasures

MEB	Marine expeditionary brigade
MEB(AT)	Marine Expeditionary Brigade (Anti-terrorism)
MEU(SOC)	Marine Expeditionary Unit (Special Operations Capable)
MOPP	mission-oriented protective posture
MS	mass spectrometry
MSI	multispectral imaging
NAPPB	nerve agent pretreatment pyridostigmine bromide
N095	OPNAV, Director of Naval Reserve
N3	OPNAV, Deputy Chief of Naval Operations (Plans, Policy & Operations)
N4	OPNAV, Deputy Chief of Naval Operations (Logistics)
N70	OPNAV, Warfare Integration
N70CP	OPNAV, Office of Counter-Proliferation
N91	OPNAV, Director of Navy Test and Evaluation and Technology Requirements
NATO	North Atlantic Treaty Organization
NAVCENT	Navy Component, Central Command
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NBC	nuclear, biological, and chemical
NIH	National Institutes of Health
NMRC	Naval Medical Research Center
NOAA	National Oceanic and Atmospheric Administration
NORTHCOM	U.S. Northern Command (Homeland Security)
NRL	Naval Research Laboratory
NSF	National Science Foundation
NWDC	Navy Warfare Development Command
OCONUS	outside the continental United States
OJCS	Office of the Joint Chiefs of Staff
ONI	Office of Naval Intelligence
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
OSD	Office of the Secretary of Defense
2-PAM	pralidoxime chloride
PB	pyridostigmine bromide
PCR	polymerase chain reaction

QDR	Quadrennial Defense Review
R&D	research and development
RADIAC	radiation detection, indication, and computation
RDA	research, development, and acquisition
RDT&E	research, development, testing, and evaluation
RSCAAL	remote sensing chemical agent alarm
S&T	science and technology
SAW	surface acoustic wave
SCPE	shipboard collective protection equipment
SECNAV	Secretary of the Navy
SORTS	Status of Resources and Training System
SRBSDS	short-range biological detector system
SWAT	special weapons and tactics team
T&E	testing and evaluation
TARA	Technology Area Review and Assessment (panel)
TIC	toxic industrial chemical
TIM	toxic industrial material
TRAC	Threat Reduction Advisory Committee
TTPs	tactics, techniques, and procedures
UAV	unmanned aerial vehicle
UGV	unmanned ground vehicle
USAF	U.S. Air Force
USAMRICD	U.S. Army Medical Research Institute of Chemical Defense
USAMRIID	U.S. Army Medical Research Institute for Infectious Diseases
USD(AT&L)	under secretary of defense for acquisition, technology, and logistics
USJFCOM	U.S. Joint Forces Command
UV	ultraviolet
VIG	vaccinia-immune globulin
VX	O-ethyl S-diisopropylaminoethyl methylphosphonothiolate
WMD	weapons of mass destruction
YAG	yttrium aluminum garnet