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PAPER

Early Observations on Possible Defenses by the Emerging Threat Agent Project

Bruce W. Bennett, Jonathan Kaufman,
James Byrnes, Pamela L. Gordon, McRae Smith

Prepared for the Defense Threat Reduction Agency

RAND NATIONAL DEFENSE RESEARCH INSTITUTE

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Preface

The Defense Threat Reduction Agency's (DTRA's) Joint Science and Technology Office (JSTO) characterizes potential future chemical, biological, and radiological (CBR) threats and identifies potential means for countering them. The Threat Agent Science (TAS) Capability Area under the Basic and Supporting Sciences Division of the JSTO leads DTRA's efforts to rapidly respond to new chemical and biological (CB) agents. In late 2007, the director of TAS created the Emerging Threat Agent Project (ETAP), involving scientific, intelligence, and military operations experts from various agencies in examining the evolving CB threat and how best to respond to it. This occasional paper offers an early set of observations from members of this group. A more in-depth report of this group's work is in preparation but is not expected to change these observations.

Historically, U.S. efforts to counter military CB threats have focused on passive defenses, such as protective garments and detectors for U.S. military personnel. The U.S. efforts have sought to determine whether existing and developmental CB defense equipment needs to be improved to counter new threats as they appear. The ETAP sought to broadly characterize recent changes in CB threats and potential responses to those changes. It recognized that the pace of scientific advances applicable to the development of CB weapons has accelerated significantly, and it noted a growth in the number and diversity of potential U.S. adversaries.[1] The ETAP also determined that CB protection should be extended to include a significant number of civilians supporting U.S. military operations, as well as the military forces of U.S. allies.

The challenges presented by these changes suggest the need to enhance the roles of deterrence and dissuasion in the U.S. Department of Defense Chemical and Biological Defense Program (CBDP) against these evolving threats. This occasional paper argues that doing so requires a two-track science and technology (S&T) effort supporting the CBDP: (1) the current agent-specific approach and (2) a mechanistic approach to better understand underlying science. This paper explains the two approaches and provides many examples of how current CBDP efforts could be adjusted to enhance the deterrence and dissuasion potential of the program.

This research was sponsored by the Defense Threat Reduction Agency. RAND's part in the ETAP was conducted within the International Security and Defense Policy Center of the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Com-

[1] The growth in potential adversaries has been heavy in terms of nonstate actors, a number of which have sought CB weapons.

batant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community.

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Early Observations on Possible Defenses by the Emerging Threat Agent Project

by Bruce W. Bennett, RAND Corporation; Jonathan Kaufman, Defense Threat Reduction Agency; James Byrnes, Joint Research and Development; Pamela L. Gordon, Jennings International Corporation; and McRae Smith, Northrop Grumman[1]

The Defense Department is concerned about emerging chemical and biological (CB) weapon agents and the ability of U.S. defenses to counter them. Due to scientific advances that facilitate the development of new and novel CB agents and the fact that uncovering such work will be a difficult intelligence challenge, the Emerging Threat Agent Project (ETAP) undertook a study to examine the challenges of emerging CB agents and propose measures to reduce their risks.[2]

The authors conclude that the problem is comprised of two related components. Given the inherent secrecy with which states and other actors will conduct CB agent development, adversary programs could acquire new CB agents years before U.S. defense planners recognize those agents. And, after the U.S. intelligence community recognizes those CB agents as threats, the United States will probably need many more years to establish a comprehensive defense against them. Such gaps in CB agent defense capabilities pose a potentially serious risk to U.S. military operations.

To best mitigate this risk, the Chemical and Biological Defense Program (CBDP) of the U.S. Department of Defense needs to augment current work with enhanced efforts to dissuade adversary CB agent development and to deter adversary use of new CB weapons.[3] *Successful initiatives in dissuasion and deterrence will depend on CB defensive programs that appear dynamic, progressive, and integrated with other Defense Department and national-level efforts in counterproliferation. Many of these objectives can be met by adding a second track to the current agent-specific science and technology (S&T) effort, a track that focuses on the mechanisms of CB agent effects and interactions with the environment. The goal of the resulting robust combination of CBDP defense, dissuasion,*

[1] This summary paper reflects work done over the past two years by a committee that, over time, has included (besides the authors) Francis A. Handler, Syracuse Research Corporation; Holly Dockery, Department of Homeland Security; Bradley Dickerson, Department of Homeland Security; Richard A. Love, National Defense University; Sari Paikoff, Defense Threat Reduction Agency (DTRA); LTC Donald C. Kemp, U.S. Special Operations Command (USSOCOM); Christian J. Kazmierczak, Camber Corporation; Carol A. Demme, National Ground Intelligence Center; Jack M. Baggett, Bull & Associates, Inc.; Wendy Hall, Department of Homeland Security; Steve Harbeson, Triton Scientific; and several individuals from the intelligence community. This paper represents the views of the authors, based on their participation in the larger group's discussion, and does not necessarily reflect the opinions or policies of their organizations. The authors express their appreciation to Elaine Bunn of the National Defense University and John Parachini of RAND for providing a technical review of this paper.

[2] This paper is focused on developments in CB warfare and terrorism. The potential for the development of radiological weapons is acknowledged, although the study group determined that new radiological weapons are less likely to pose defense challenges than evolving CB weapons might. Consequently, the study group restricted its analysis to the evolving CB threat.

[3] U.S. counterforce, active defense, and arms control efforts plus retaliatory threats also support deterrence and dissuasion. These are briefly discussed in the text but are beyond the scope of the CBDP.

and deterrence is to induce great doubts in adversaries about the value of employing any CB agents or developing new CB agents.

This study effort began by examining historical U.S. defense responses to the sudden emergence of previously unidentified CB agents. It also explored how S&T investments address perceived vulnerabilities and how the CBDP currently translates those S&T efforts into CB defensive requirements and systems. The study then reviewed the acquisition and production processes required to field defense capabilities against CB agents. The four principal steps involved in capability development are as follows:

1. Develop and validate a list of potential new CB agent threats based on intelligence information.
2. Characterize specific agents and prioritize those agents to determine defense requirements.
3. Develop the means for defending against the use of those CB agents.
4. Acquire and field the defensive capabilities to counter those CB agents.

Results of the Initial Analysis

This analysis concluded that the current CBDP process will respond to new CB agents far too slowly. For example, the potential speed of adversary CB threat agent development,[1] coupled with adversary information denial, will tend to leave the United States surprised by adversary CB threats. Each of the subsequent steps can take years,[2] and, with its current resources, the CBDP can perform the latter three steps for only a small number of new CB agents at any one time.[3] Such slow responses will leave U.S. and allied forces vulnerable to emerging CB agents, with the potential to seriously jeopardize U.S./allied military operations.

Of course, existing defenses will often provide some level of defense against new CB agents: Masks, filters, and overgarments might provide physical protection against most CB agents. But what of new agents developed specifically to exploit limitations in the existing CB defenses?[4] What if detection is the trigger for donning protective gear, and U.S. detectors are incapable of sensing new categories of agents? These concerns pose real challenges for a program that delays the development of an operational defense strategy until potential CB threat agents are validated and well characterized.

Historically, the lag between CB agent development and fielding appropriate defenses has been due to a number of challenges associated with the four steps of defensive capability development mentioned above. By step, key challenges include the following:

1. Detecting the development of new agents has been problematic in the past.[5] In many cases, knowledgeable sources from adversary offensive CB agent programs have provided the ultimate tip about these programs. For example, the former Soviet scientists

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[1] Adversaries can potentially develop CB threat agents rapidly because of advances in science, information posted on the Internet, and the availability of human experts who have lost employment in Russia and elsewhere.

[2] For example, the United States spent roughly two decades seeking the best combination of medical responses to sarin and is still addressing medical responses to soman some 60 years after its discovery.

[3] Some related work has therefore sought to define means of prioritizing CB agents for defensive development once their general characteristics are known.

[4] According to William S. Cohen,

> There has been a great deal of publicity about Russian development of a new generation chemical warfare nerve agents, some of which are referred to as "Novichoks." . . . There is additional concern that the technology to produce these compounds might be acquired by other countries, amplifying the threat. (William S. Cohen, *Proliferation: Threat and Response*, Washington, D.C.: Office of the Secretary of Defense, January 2001, p. 4)

[5] Consider, for instance, the surprise discovery of a mature German nerve agent program at the conclusion of World War II. See U.S. Army Medical Research Institute of Chemical Defense, Chemical Casualty Care Division, *Medical Management of Chemical Casualties Handbook*, 3rd ed., McLean, Va.: International Medical Publishing, July 2000, p. 4.

who alerted the United States to the true extent of the Soviet biological weapon programs at the end of the Cold War provided their warnings almost two decades after the Soviets signed the Biological and Toxin Weapons Convention (BTWC).[6]

2. The U.S. defense and scientific communities might be aware of new CB agents years before they fully understand them. Consider, for instance, the World War I–era agent mustard. While scientists studied and feared the most obvious vesicant effects for most of the 20th century, mustard injuries caused genetic damages that the scientific community barely understood until the 1970s, and the community is still studying mustard-related cases today.[7] The rumored modification of Soviet-era anthrax strains poses similar challenges.[8]
3. Developing effective defense against agents typically takes years, if not decades. For example, the effects of soman, some 60 years after the agent was discovered, continue to drive a portion of the medical countermeasure program of the CBDP even today.
4. As with other military acquisition programs, fielding appropriate defensive technologies often involves extended time periods. The acquisition process can lead to a significant delay in comprehensive protection. For instance, how quickly could the United States produce and distribute medical countermeasures to U.S. forces if it determined that a previously unknown lethal chemical agent utilizing a non-cholinesterase mechanism posed a military threat?

The authors' initial analysis also assessed that the changing global threat environment further contributes to the likelihood that states and nonstate actors will pursue new CB agents in developing offensive capabilities. Among these changing threat factors are the following:

- The existing Chemical Weapon Convention (CWC)[9] identifies specific traditional agents and their standard precursors and forbids possession of them. It also prohibits all existing and future chemical agents used for offensive military purposes.[10] Still, some actors might try to avoid short-term treaty censure by pursuing agents and precursors not explicitly identified by the CWC and take similar action with biological weapons. The adverse economic and political repercussions of developing new CB agents will likely compel actors

[6] *Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction*, United Kingdom, Union of Soviet Socialist Republics, and United States, April 10, 1972.

[7] For a general overview, see Constance M. Pechura and David P. Rall, eds., *Veterans at Risk: The Health Effects of Mustard Gas and Lewisite*, Washington, D.C.: National Academy Press, 1993.

[8] See, for example, Peter Eisler, "U.S., Russia Tussle over Deadly Anthrax Sample," *USA Today*, August 19, 2002; and Nicholas Wade, "Tests with Anthrax Raise Fears That American Vaccine Can Be Defeated," *New York Times*, March 28, 1998.

[9] The CWC is described by Organisation for the Prohibition of Chemical Weapons, "Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (Chemical Weapons Convention)," undated web page. As of September 10, 2010: http://www.opcw.org/chemical-weapons-convention/

[10] The Hague Conventions of 1899 (*Convention [II] with Respect to the Laws and Customs of War on Land and Its Annex: Regulations Concerning the Laws and Customs of War on Land*, The Hague, July 29, 1899) and 1907 (*Convention [IV] Respecting the Laws and Customs of War on Land and Its Annex: Regulations Concerning the Laws and Customs of War on Land*, The Hague, October 18, 1907) prohibit the use of chemical weapons, and the Geneva Protocol that entered into force in 1928 (*Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare*, Geneva, June 17, 1925) prohibits the use of CB weapons. Nevertheless, subsequent to these agreements, many countries have prepared CB agents for use, and some have also used them in conflict.

to conduct their CB programs covertly, posing a range of problems for the international community.

- The Russians have apparently identified some chemical agents capable of overcoming standard Western detection and protection measures.[11]
- The development of new CB agents might be easier because international scientific capabilities are accelerating, in part due to Internet-based sharing of advances in engineering and science and the globalization of markets and industrial capabilities. Indeed, even within the United States, laboratories designed to work with biological agents (for defensive purposes) have been proliferating.
- Potential dual-use (military and commercial) industries are becoming more common.[12] Also, many of the toxic industrial chemicals (TICs) that they produce are not much less lethal than many chemical warfare (CW) agents, posing an expanded chemical threat.
- Small yet technically competent nations will continue to enhance their military capabilities; some of these countries might see a CB capability as an advantage over potential adversaries.[13]
- Recent publicity regarding pandemics has increased the fear of CB agents in the United States and elsewhere. The knowledge that a few envelopes of anthrax had such a profound impact on the United States in 2001–2002 could serve as a springboard for some nations (and nonstate actors) to pursue offensive CB programs to gain weapons of intimidation.[14]
- Potential proliferators are aware that the use of CW agents in the past (e.g., Italy in the 1930s and Iraq in the 1980s) did not result in the kind of swift punishment that supports deterrence.[15]

In the coming decades, these factors will likely increase the probability[16] that the United States will face "unknown" CB agent threats and CB agent threats against which existing CB defenses are inadequate even for U.S. military personnel.

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[11] Cohen, 2001, and others.

[12] Discriminating between the legitimate development of commercial products and malicious development of CB agents is increasingly difficult due to the expansion of dual-use industrial technologies. These technologies not only encourage potential dual-use research (both industrial and academic) but also minimize difficulties in transitioning between industrial and military production. The nature of many chemical agents also encourages dual-use facilities; common pesticides often share structural characteristics with recognized warfare agents.

[13] For example, Syria, Iran, and North Korea have apparently perceived such an advantage. (This is a revealed-preference argument: They have shown their interest through their spending on acquiring CB capabilities.)

[14] U.S. efforts since 2002 on antibiotics and vaccines might discourage adversaries from using anthrax and encourage them to seek alternative biological weapons not covered by U.S. efforts.

[15] We acknowledge that there are also factors that counter these threat environment factors and reduce the unbridled spread of traditional CB weapon agents. The arms control treaties intended to prevent CB threat development have contributed to a reduction in foreign efforts to cross CB capability thresholds. Our concern is primarily with those who deliberately defy both the letter and spirit of nonproliferation treaties.

[16] There are, however, counterexamples that suggest that some states may be more reluctant now to pursue CB warfare (CBW) capabilities. Iraq decided in the late 1990s to largely forgo CBW efforts, though it tried to maintain the appearance of making CBW efforts for deterrence purposes. Libya decided in 2004 to abandon its weapons of mass destruction (WMD) efforts, seeking a better relationship with the outside world. But later, Libyan leader Muammar Qadhafi expressed his disappointment with the meager rewards given him for his cooperation. See "Libyan Leader Qadhafi 'Disappointed' He Has Not Seen More Rewards for WMD Dismantlement," *Global Security Newswire*, November 24, 2004.

There have also been changes in the combat operational environment that suggest that adjustments are needed in the existing CBDP approach:

- The CBDP, with its focus on the development of CB defenses for active-duty military personnel, is not comprehensive enough to encompass the additional populations involved in U.S. military operations.
  - The U.S. military increasingly relies on civilian and contract personnel for a variety of mission-critical tasks (e.g., logistics and maintenance), few of whom are trained in or equipped for operations in a contaminated environment. Adversaries' employment of novel CB agents against the support personnel would dramatically complicate combat operations.
  - Coalition forces are important to U.S. military operations, both strategically and politically. Many of these coalition nations lack adequate CB defenses for their personnel, making their personnel more vulnerable to CB attack. An attack aimed at exploiting the vulnerability of a coalition partner (even by employing a well-characterized CB agent) will likely strain tactical and strategic cooperation. The surprise use of a novel CB agent might produce significantly greater casualties and psychological reactions than a conventional attack and could strain the coalition to the breaking point.
  - Adversaries could use asymmetric means, such as targeting rear areas and civilians during conflict. While the peacetime Tokyo subway attack in 1995 was not as deadly as it might have been, the accompanying short-term panic and fear had a dramatic effect on Japanese society and generated homeland security concerns internationally.[17] Similar psychological reactions have developed in response to some natural disease outbreaks, suggesting that panic and fear can occur in response to any serious disease.[18] The efficient dissemination of CB agents against the most vulnerable populations would impose additional political and medical burdens on operational commanders in the region.
- Adversaries might use CB agents in more limited quantities than historically assumed; for example, massive chemical weapon artillery barrages appear far less likely in the future than they were perceived to be in the 20th century. The most common CB agent uses may come from special operations forces or from ballistic missile attacks, creating much lower exposure levels but increasing the risk of tactical surprise. Lower challenge (or exposure) levels can put the protection of contractors, allies, and civilians more within reach.
- U.S. military systems are increasingly designed to require fewer but more specialized personnel. Individual casualties can thus have a far greater impact on the tactical or operational success of a mission.

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17 See, for instance, Robyn L. Pangi, *Consequence Management in the 1995 Sarin Attacks on the Japanese Subway System*, Cambridge, Mass.: Executive Session on Domestic Preparedness, discussion paper 2002-01, John F. Kennedy School of Government, Harvard University, Belfer Center for Science and International Affairs discussion paper 2002-04, 2002, which clearly differentiates between the number of truly injured and the number of "worried well."

18 For example, in 1994, a small outbreak of plague in Surat, India, caused more than half a million people to flee the city in one day (including many of the doctors), suggesting that psychological reactions might be a serious problem in the aftermath of a biological warfare (BW) attack. See V. Ramalingaswami, "Psychosocial Effects of the 1994 Plague Outbreak in Surat, India," *Military Medicine*, Vol. 166, No. 12 Suppl., December 2001, pp. 29–30.

Developing an Appropriate Response to Chemical and Biological Agent Threats

All of these factors underscore the assessment that the current CBDP approach has inherent limitations that adversaries can exploit in the future. The 2005 *U.S. National Defense Strategy*[1] suggested the basis for an enhanced approach. That strategy document introduced the four interlinked means for accomplishing U.S. objectives: Defeat adversary attacks, deter aggression, dissuade potential adversaries, and reassure allies.

The CBDP is currently focused on the first means of defeating adversary attacks by being able to protect U.S. military personnel against the damage caused by CB agent effects. The CBDP needs to augment its focus on defeating CB agent threats by adding components to deter CB agent use and dissuade CB agent development, seeking to protect U.S. military personnel, the civilians supporting them, and the militaries and civilians of U.S. allies. The United States also needs a more proactive and more dynamic approach to CB defense to address the unknown threats and other aspects of the changing environment. The current reactive approach will cause the United States to remain behind in the weapon-countermeasure cycle, without a commitment to leap-ahead solutions and with potentially significant vulnerabilities.

The U.S. *Deterrence Operations Joint Operating Concept* summarizes the U.S. military's current perspectives on deterrence: "Deterrence operations convince adversaries not to take actions that threaten U.S. vital interests by means of decisive influence over their decision-making. Decisive influence is achieved by credibly threatening to deny benefits and/or impose costs."[2] The CBDP passive defense serves deterrence by what is referred to as *deterrence by denial*: convincing an adversary not to use a capability because doing so will yield little benefit (while potentially costing a lot in terms of U.S. and international reaction and retaliation).[3] The CBDP can have a similar effect on dissuasion, though with more focus on future (and uncertain) benefits and costs.

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1 U.S. Department of Defense, *The National Defense Strategy of the United States of America*, Washington, D.C., March 2005, p. i.

2 U.S. Strategic Command, *Deterrence Operations Joint Operating Concept*, version 2.0, Offutt Air Force Base, Neb., August 2006, p. 8. This quote is simplified from the original; it does not mention adversary restraint, which can also be important.

3 Since the early 1960s, deterrence has been described as having two major components: deterrence by denial and deterrence by punishment. See, for example, Glenn Herald Snyder, *Deterrence and Defense: Toward a Theory of National Security*, Princeton, N.J.: Princeton University Press, 1961, pp. 14–16. In the 1960s, the United States concluded that denial of a Soviet strategic nuclear attack was too expensive and not very feasible, so it relied heavily on strategic nuclear deterrence by punishment, referred to at the time as *assured destruction*. Because of the primacy of assured destruction during the Cold War, many authors have assumed that deterrence flows entirely from threats of punishment, but that is not the case, especially when it is possible to significantly deny the effects of an adversary's attacks.

The CBDP's passive defense efforts are part of the overall U.S. effort against CB agent attacks; this effort also includes active defenses, U.S./allied counterforce attacks, arms control measures, and retaliation. Active defense and counterforce strengthen the CBDP protections by further reducing the likelihood that an adversary can execute a successful CB agent attack against the United States and its allies. Arms control agreements with verification provisions and trade sanctions against the domestic industries of countries that do not meet treaty provisions combine to help dissuade states from pursuing clandestine CBW capabilities.[4] U.S. threats of retaliation against CB attacks tell adversaries that they could pay very high costs for these CB agents' development and use.[5] The United States needs to take full advantage of all of these measures in dissuading adversary CB agent development and deterring CB agent use, though further analysis of the means outside of the CBDP are beyond the scope of this paper.

Figure 1 explains our deterrence and dissuasion concepts. Adversaries face a series of thresholds en route to the development of CB capabilities and the use of CB weapons. The four thresholds shown here are ones that adversaries (either states or nonstate groups) will tend to pass when they perceive that the benefits of moving to a higher level exceed the costs they may be forced to pay, including the probabilities of those benefits and costs. For example, the threat of a punishment with little chance of enforcement is actually a very weak cost and, thus, unlikely to deter or dissuade. In practice, adversary risk behavior may focus on comparing the most severe costs or the biggest benefits rather than comparing the expected costs and benefits.

Dissuasion works on the early decision thresholds of interest and intent and on the production/weaponization threshold. When faced with dissuasive measures, an adversary must consider the trade-offs between benefits and costs well into the future. The adversary also must consider the potential benefit of fielding CB weapons given all of its prospective opponents. For example, in the mid-1980s, Iran developed chemical weapons to counter the ongoing Iraqi chemical weapon attacks on Iran; its decision to produce chemical weapons had very little to do with the United States and U.S. abilities to defend against CBW.

Deterrence works on the use threshold, with more immediate consequences. An adversary is deterred from attacking U.S. forces with CBW if it thinks it has little to gain against the United States, though it simultaneously might not be deterred from CBW attacks on one or more of its neighbors. General deterrence seeks to prevent an adversary from planning to employ CBW; preventing employment of CBW—because of the risks involved—will often be easier than preventing an adversary from using CBW for coercive or deterrence purposes (causing no physical casualties). Immediate deterrence seeks to prevent an actor from using CBW in a particular situation for distinct goals.

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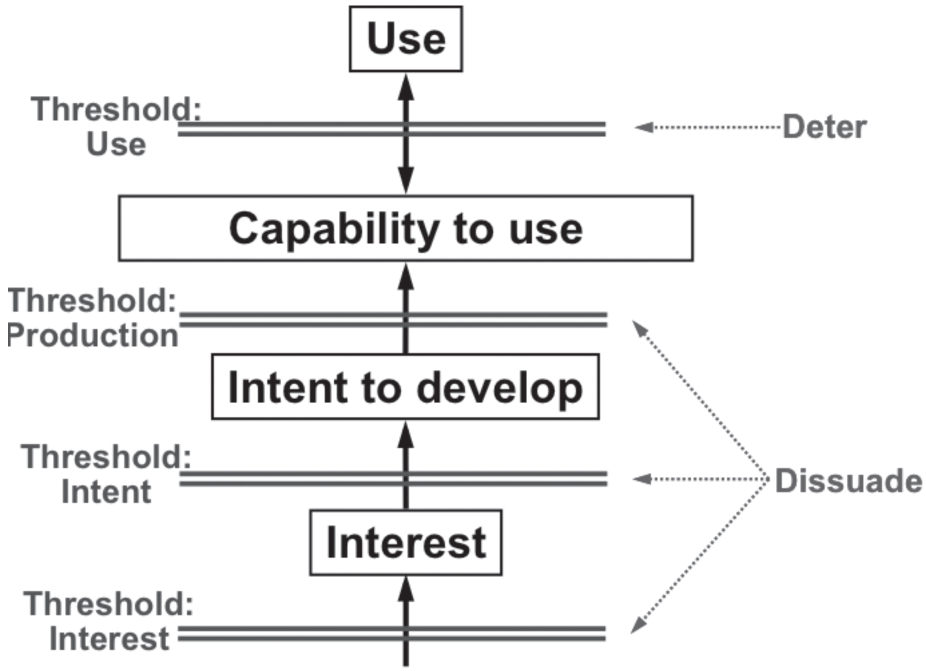
[4] The CWC provides for widely accepted and consistently enforceable verification and sanction provisions. The BTWC has similar provisions, but some of them are voluntary, and the treaty regime lacks an international treaty-implementation body. Because of its less-rigorous nature, the BTWC is not perceived to provide as robust a capability to dissuade and deter states from pursuing biological weapons.

[5] Historically, the United States has been vague in its retaliatory threats, leaving open the potential that even U.S. nuclear weapons could be used in retaliation for adversary CB agent attacks. But the recent *Nuclear Posture Review Report* says,

> With the advent of U.S. conventional military preeminence and continued improvements in U.S. missile defenses and capabilities to counter and mitigate the effects of CBW, the role of U.S. nuclear weapons in deterring non-nuclear attacks—conventional, biological, or chemical—has declined significantly. The United States will continue to reduce the role of nuclear weapons in deterring non-nuclear attacks. (U.S. Department of Defense, *Nuclear Posture Review Report*, Washington, D.C., April 2010, p. viii)

Figure 1
Chemical and Biological Weapon Thresholds



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Almost all of the costs and benefits of CBW development and use are highly uncertain. For example, an adversary usually will not be able to predict whether it will be successful in using CBW: The agents might or might not cause the desired effects, U.S. (or other) defenses might thwart CB agent use, the United States might retaliate against CB agent use in ways that seriously hurt the adversary, and the international community might act against CBW use. It will be even more uncertain when considering CBW development, having to also worry about whether a development effort will be successful, whether the CB agents can be meaningfully weaponized, whether delivery systems can be mastered, and whether U.S. defenses will have evolved into reasonable counters by the time the CBW can be fielded. In addition, the adversary must worry about whether its CBW development efforts will be revealed, subjecting it to international censure and punishment.

If an adversary is risk averse, it will want to make sure that its estimated benefits exceed costs by a fair margin before crossing a threshold. Risk-averse adversaries will also weigh possible U.S. retaliations (a major part of their costs) very heavily in their decisions. Those adversaries that tend to be risk-takers may actually exhibit more mixed behavior—willing to chance a U.S. retaliation but not to the point at which they appear reckless and ineffective in the eyes of their supporters. Dissuasion, in particular, exploits risk aversion.

Deterrence and dissuasion depend heavily on efforts to counter the threat from emerging CB agents, especially given the other changes in the CB defense requirements suggested above. Our analysis suggests that the best approach would involve the following:

- *Seek to* dissuade *adversary development of new CB capabilities.* Dissuasion seeks to affect the adversary's perception that the likely costs of developing, fielding, and eventually using new CB agents will be greater than the benefits it could obtain. In terms of benefits, CB capabilities have seldom had the peacetime influence that nuclear capabilities do.[6] Thus, dissuasion by denial focuses primarily on convincing adversaries that they will achieve minimal gains by fielding new CB agents for a future conflict or terrorist action. The United States can achieve this effect through a combination of proactive CB defensive S&T, vigorous and well-funded defensive system development, and strategic communications. If potential adversaries perceive the CBDP as a consistent U.S. priority that is both dynamic and progressive, they might doubt their ability to exploit gaps in U.S. defenses.[7] U.S. CB defense efforts should thus appear aware of and ahead of potential offensive developments. The CBDP can further contribute to adversary uncertainty by tailoring the CBDP information available to the public: Adversaries can monitor U.S. "open literature" but should know little of U.S. classified work. Conceptually, an adversary should have diminished expectations about gaining net benefits through CB agent development if it realizes that the United States is continually improving its and its allies' passive defense capabilities and if some enhanced defensive capabilities are protected as a "technological edge."[8] As a result, adversaries might perceive that the effective production threshold is too high, and even the interest and intent thresholds might be too high.

- *Seek to* deter *all prospective adversaries from planning to use CB agents.* General deterrence usually occurs when the costs of an action outweigh the likely benefits of that action. If adversaries feel that U.S. CB defense capabilities are dynamically improving and generally capable, they will tend to doubt that they can gain a major benefit from CB agent use (deterrence by denial).[9] U.S. policy can facilitate this effort through visible demonstrations of the *current* quality and amount of CB defense equipment, including coverage by the mainstream media as a form of strategic communications. The United States should target potential adversaries with a convincing information offensive suggesting that U.S. and allied military and supporting civilian personnel are well trained and equipped for any CB threats. This should force adversaries to consider the difficulty they will have trying to gain an operational advantage against U.S. forces by using CB agents. An effective information campaign should also create a level of certainty among most adversaries that the United States and its allies will impose major costs on any adversary using CB agents (deterrence by punishment, ranging from economic sanctions to military attack). The risks of low benefits and high costs should be sufficient to deter most adversaries from planning CB attacks.

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6 Adversaries regularly use nuclear weapons for influence and deterrence purposes in peacetime but tend not to use CB agents for such purposes, though a case can be made that the mistaken belief in Iraqi CB capabilities in 2001 through 2003 was highly influential. The possession of CB agents in peacetime tends to lead to international censure because of the CB weapon treaties.

7 Adversaries with mature CB programs are less likely to be fully dissuaded by these U.S. efforts, though they may be dissuaded from developing or using some specific offensive CB agents.

8 It is generally agreed that most existing CBW programs are not designed to "take on" the United States. The efforts outlined here are meant to keep it that way. However, to get the full benefit of this approach, much of the basic CB defense–related work might have to be shared so that other nations can benefit from it.

9 The CBDP deals with the passive defense aspects of denial. Denial can also be achieved by active defense (for example, ballistic missile defense) and by counterforce capabilities (for example, preemptive strikes against known CB weapon storage facilities), efforts that the United States should also pursue.

- *Seek immediate deterrence of specific adversary CB attacks and the ability to defeat such attacks, if necessary.* If dissuasion and general deterrence fail, the United States will want capable and affordable CB defenses to protect U.S. and allied military and civilian personnel. This requires broadening and adjusting the CBDP acquisition focus. The United States should develop an array of defense equipment to enhance U.S. and allied defense capabilities. This includes the production of replacement equipment, following through on preplanned product improvements and, when appropriate, providing leap-ahead new materiel capabilities. The United States should also maintain some defensive surprises to enhance immediate deterrence, being able to deploy protections that an adversary had not anticipated in order to force the adversary into rethinking CB use just before crossing the threshold.

If the United States is able to dissuade adversaries from developing new CB agents, it faces the least risks because adversaries would, at worst, possess just traditional CB agents, against which U.S. capabilities will continue to improve. Some adversaries might even abandon CB agents entirely. If dissuasion fails and some adversaries acquire new CB agents, deterrence reduces the chance that they will use such agents against the United States and its allies. Pursuing both alternatives and preparing to defeat CB attacks are worth the investment, as these efforts reduce the risks associated with operations in a contaminated environment.

Enhancing Dissuasion and Deterrence in the Chemical and Biological Defense Program

As outlined in the previous section, existing CBDP S&T efforts and CB defense capabilities already support dissuasion and deterrence. But both can and need to do more, especially to deal with emerging CB agents. The key to doing more is to enhance the CBDP S&T effort into a dual-track approach, adding to current efforts the scientific basis for promptly defending against emerging agents, and thereby enhancing deterrence and dissuasion by denial. The CBDP can also take a range of other actions to also enhance deterrence and dissuasion.

A Dual-Track Science and Technology Effort

The current CBDP S&T effort is an agent-specific approach. It focuses on specific CB agents or groups of agents and seeks to define counters to those agents. Against any given agent, initial work focuses on characterizing that agent—its lethality, solubility, persistence, and other factors. Research then proceeds in each of the CBDP "stovepipes" (e.g., detection, individual protection, medical countermeasures, and decontamination) to test that agent against existing countermeasures and, where the countermeasures are inadequate, to develop new countermeasures.

This agent-specific approach to S&T is the first of the two needed tracks. Track 1 is a necessary but insufficient approach because it takes a long time to develop the needed countermeasures to emerging CB agents—often decades. The U.S. military is thus left with a window of vulnerability to emerging agents that adversaries could exploit. Should adversaries do so, U.S. military operations against those adversaries might become impossible—an unacceptable situation.

Responding to emerging CB agents thus requires a second S&T track (track 2) that attempts to understand CB phenomena (e.g., dissemination, host response, environmental interactions, identification, detection) on a fundamental level, with the objective of producing generalized predictive models of CB agent behavior and effects. Achieving increased mechanistic understanding enhances the ability to predict agent behavior from known or projected physicochemical or biological properties. Developing such predictive models is envisioned to be an iterative process between theory and empirical data derived from studies involving a broad range of toxic and nontoxic chemicals and pathogenic and innocuous biological organisms. Validating these new models against known CB agents makes them highly useful tools to develop or adjust counters to a broader range of current or potential agents than existing processes can handle. Armed with this predictive capability, the CBDP and, by extension, the

U.S. operational responses to unanticipated threat agents will also be greatly enhanced by providing the means to respond much more quickly than is currently possible.

Specifically, modeled (and validated) behavior will include the following:

- Identify potential warfare agents, in part by conducting expansive reviews of newly introduced chemical and novel biological organisms, and determine the means to detect them. Resulting models will seek to anticipate introduction by adversaries of new chemical or biological agents useful for warfare purposes. In addition, such models could aid in identifying appropriate agent detection methodologies.
- Determine host response to these agents. Models will attempt to broadly characterize and predict physiological interaction with CB agents, including potential routes of exposure; exposure limits (e.g., LD_{50},[1] ED_{50},[2] NOAEL[3]); absorption, distribution, metabolism, and excretion (ADME); mechanisms of action; and subsequent physiological, psychological, or cognitive consequences. These models will also identify mitigation strategies to reduce or eliminate physiological effects, including diagnostics and medical countermeasures (e.g., vaccines, therapeutics).
- Characterize agent environmental interactions. Models will predict agent transport through the atmosphere and substrates (e.g., structural materials, soils, fabrics, filters), addressing such factors as interaction with surfaces (e.g., particulate resuspension), role of environmental contaminants (e.g., oil and dust on surfaces), and endogenous flora and fauna (including microorganisms). A major consideration will be predicting agent persistence under widely varying environmental conditions.

Examples of the value of this approach include the following:

- Developing diagnostic tools to distinguish between previously unknown (but actual) threat agents and innocuous chemicals or biological organisms depends on an a priori understanding of host response to challenge from these materials. Given that prior characterization is impossible for previously unknown threat agents, predictive capabilities are essential for diagnosing exposure to these agents. Likewise, developing advanced, broad-spectrum medical countermeasures would also greatly benefit from an a priori prediction of host response to agent exposure.
- In a similar vein, advanced detection, decontamination, and protection depend on understanding how agents interact with environmental substrates. For example, attempting to detect agents on substrates depends on surface (or near-surface) availability; this, in turn, is a function of transport through and CB interaction (e.g., reactivity) with the substrate. Having the ability to predict agent transport and substrate interactions enhances detector design and use. Once again, a priori characterization is impossible for unknown agents, and only predictive models based on a fundamental understanding can provide such insights.

[1] Lethal dose 50, or the amount of a toxic agent that could kill 50 percent of those exposed within a given period.

[2] Effective dose 50, or the amount of a drug required to cause a response in 50 percent of those exposed.

[3] No observed adverse-effect level.

Once these mechanisms are understood, the U.S. military would be able to approximate the threats posed by even previously unrecognized, novel CB agents. In many cases, broad-spectrum countermeasures already developed would provide full or at least partial protection against novel agents. Where protection was incomplete, the models could help expedite development of enhanced protective capabilities. The U.S. CBDP would become a vastly more dynamic program far more capable of broad responses. As such, the CBDP would have greater potential to significantly discourage adversaries considering CB agent efforts, likely dissuading and deterring most adversaries.

Establishing *grand challenges* (broadly stated complex and difficult-to-solve scientific questions) provides a strategic framework for integrating scientific efforts and strengthening the ability to respond to unknown threats. The intent is to identify the major questions that, upon resolution, define how to overcome the obstacles to achieving successful development of the predictive models previously discussed. Grand challenges are expected to be difficult, perhaps impossible, to fully answer. However, they provide a framework that can be reduced to smaller, more focused questions (subelements) amenable to solution by completing appropriate empirical studies.[4] Resolving subelements moves the level of understanding significantly forward and will steadily increase the CBDP's ability to respond to the use of unanticipated agents.

Examples of possible grand challenges include the following:

- time-dependent chemical percutaneous transport and role in host response and therapeutic intervention
- integrative host response to insult by chemical or biological pathogens
- quantitative understanding of liquid transport through heterogeneous porous media and resultant surface concentration
- understanding comparative physiology and scaling issues when comparing animal data with human response
- understanding what makes a biological organism virulent[5]
- understanding whether toxicity can be predicted a priori from chemical structure.

The term *grand challenges* clearly conveys the fact that these are major scientific endeavors. But these endeavors can draw on a wide body of research in nondefense areas and exploit some mechanistic models that already exist. Such an effort will require stable S&T funding to pursue these grand challenges and to integrate efforts across current 6.1 (basic research) and 6.2 (applied research) funding—for example, exploiting and generalizing work in the agent-specific track 1 described earlier. Because it might take some time for the mechanistic approach to bear significant fruit, it would be unwise in the short term to divert much funding from the agent-specific approach to the second track.

The track 2 mechanistic approach is a medium- to long-term research track that requires even greater continuity than current track 1 efforts. This continuity needs to be supported

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[4] This is similar to the approach used in subatomic physics, in which the goal is to fully understand the true nature of matter (and energy)—perhaps an unachievable goal. However, the pursuit of this goal has generated tremendous insight into the nature of mass and energy.

[5] As an example, community work on this topic is already reported in Committee on Scientific Milestones for the Development of a Gene-Sequence-Based Classification System for the Oversight of Select Agents, and National Research Council, *Sequence-Based Classification of Select Agents: A Brighter Line*, Washington, D.C.: National Academies Press, 2010.

by greater funding stability and more integration of efforts across performers (including the track 1 performers). Eventually, appropriate research centers should be formed to carry out the track 2 efforts.

Meanwhile, a number of efforts could enhance the track 1 approach:

- Devote part of the track 1 basic and applied S&T defense program efforts to those "dual-use" technologies that have long been the concern of futurist thinkers.[6] Some other areas of concern include many that have been anticipated for years but that, because of technological advances, are now achievable:[7]
  - genetic manipulation of traditional BW agents to enhance their effectiveness
  - genetic manipulation of innocuous (and perhaps ubiquitous) bacteria, viruses, or fungi to make them dangerous, if not lethal
  - protective surface treatments that increase pathogen persistence relative to the adverse effects of atmospheric chemistry and ultraviolet radiation.
- Categorize potential agents more in terms of the damage they could cause (including toxicity, transmissibility, and resistance to defenses) than the ability of intelligence to fully confirm adversary pursuit of specific CB agents. To keep this effort to manageable levels, the CBDP should set baseline damage thresholds (e.g., in toxicity and transmissibility) for including agents in this effort.
- Direct some track 1 research and development at a wider range of potential threats, and use scientific publications as a key means of strategic communications to prospective adversaries. This work might not have great depth in many areas but could support specific track 2 studies and might affect adversaries' decisions as they monitor the U.S. scientific literature for ongoing activities and recognize the breadth of U.S. efforts.[8]

Other Efforts to Enhance Deterrence and Dissuasion

In addition to adding a second track to the S&T effort, we suggest that other new initiatives, taken by CBDP managers in concert with other government agencies, can better prepare the CBDP to defeat emerging CB weapons. By doing so, the CBDP will be more likely to dissuade and deter adversaries, convincing them that the U.S. CB defense efforts are dynamic, proactive, and broad. For instance, the CBDP should do the following:

- Proactively work with intelligence agencies, the Defense Advanced Research Projects Agency, and academia to identify potential CB agent threats. While these organizations

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[6] This approach balances the inherent risks of spending defense dollars to prepare for threats that do not materialize against the much-greater risk of not anticipating the future threats in a timely manner, suffering technological surprise with no defense in sight.

[7] See, for instance, J. B. Petro, T. R. Plasse, and J. A. McNulty, "Biotechnology: Impact on Biological Warfare and Biodefense," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science*, Vol. 1, No. 3, 2003, pp. 161–168; and Office of the Deputy Assistant to the Secretary of Defense (Chemical Biological Defense), *Advances in Biotechnology and Genetic Engineering: Implications for the Development of New Biological Warfare Agents*, Washington, D.C.: U.S. Department of Defense, 1996.

[8] A classified, peer-reviewed, CB defense journal should be considered to better integrate S&T into acquisition and to maintain the technological edge.

already work together, this approach would focus on science-based toxicological screening of new compounds, toxins, and pathogens to determine which might pose a risk to U.S. or coalition forces; early discovery of such risks would minimize potential surprise. As the mechanistic approach develops the ability to predict potential toxicity from chemical structures, this effort would both provide a basis for validation of the proposed science and be accelerated by the toxicity predictions.

- Increase CBDP efforts on projects that take a "broad-spectrum" approach, leading to protection against a range of CB agents rather than agent-specific protection.
- Support CB defense capability development through more use of rapid prototyping and incremental fielding. New product lines and even limited acquisition efforts will not only give adversaries an impression of dynamic U.S. defense progress; they will complicate their ability to develop agents that target specific defense weaknesses. Incremental fielding will allow users to more quickly establish how new equipment can be made more effective, allow rapid integration of such enhancements, and demonstrate a commitment to a more dynamic defense development program. Incremental fielding will also create more capability to improvise against new threats. For example, an effort could be made to expand the detection capabilities of existing systems to address a wider range of viruses. Incremental fielding could allow for additions of agents and procedures over time. In the end, adversaries might be dissuaded from working on viruses, recognizing that it might only be a matter of time before the United States would be able to detect any virus they might develop.
- Use S&T to help characterize the tactics, techniques, and procedures (TTPs) that can counter CB threats. Exercise these TTPs to test them (including "red-teaming"):
  - To deal with chemical weapon threats, better characterize the trade-offs between standoff distances (downrange and cross-range) and the requirements of individual protection so that even relatively unprotected personnel can know where to go to avoid casualty-causing exposures.
  - With biological weapon agents, develop quarantine, isolation, and related TTPs that are compatible with ground force and airlift operations, including noncombatant evacuation, to prevent or limit the spread of a contagious disease.[9]
- Expand the CB defense "umbrella" by coordinating international efforts to provide better CB protection to coalition forces and operational support personnel (civilians and contractors). This protection may not be as robust or as expensive as that provided U.S. military personnel but could still provide a reasonable margin of protection in many cases and could be combined with appropriate TTPs to provide even more protection.
- Develop a strategic communication program for the CBDP that creates an image of dynamism without divulging so many of the S&T details that adversaries are able to identify weaknesses in the defense. The track 2 mechanistic approach will significantly assist in this process: As the United States better understands key mechanisms, much of this information will be more easily included in the open scientific literature to clearly demonstrate the advances in U.S. CB defense potential. The track 2 efforts could be fundamental to dissuading adversary pursuit of new types of CB agents.

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[9] Because contagious disease may pose the most severe CB agent threat, such TTPs, given current technical shortfalls in limiting contagious-disease spread, will be of significant importance.

One concern that has come up in the past is that other nations will interpret increased U.S. CB defensive activities as a signal of a renewed offensive program. The proposed effort must recognize this unfortunate tendency and be, whenever operational security allows, as transparent as possible to clearly demonstrate the defensive nature of the enhanced CBDP.

Although they are beyond the scope of the CBDP, U.S. efforts at active defense and counterforce also need to be included in appropriate strategic communications on the CBDP, illustrating the synergies between these efforts and the CBDP, such that adversaries will perceive reduced likelihood of successfully using CB agents.

The strategic communication program for the CBDP and other national counterproliferation efforts should herald the enhanced CBDP as reducing the risks of CB warfare while allowing the United States to have less reliance on nuclear deterrence.

The totality of the enhanced CBDP effort would result in enhanced force protection and a reduced risk of strategic surprise. The CBDP's S&T efforts should become the backbone of these enhancements.

Conclusions

A more dynamic CBDP will significantly increase the United States' ability to dissuade CB agent development and deter CB agent use against U.S. and allied forces and resources. In addition, adopting a proactive approach to CB threats will help break the cycle of the United States continuously pursuing solutions to older CB agents while adversaries seek newer CB agents with novel properties. The intent of the current work is not to prescribe a single new approach but to suggest several possible elements and open a discussion on this concept. What appears critical, however, is a reconsideration of the 90-year-old approach of reactive defense. Failure to rethink these issues places U.S. forces in an increasingly vulnerable position as adversaries surreptitiously explore new CB agents and consider their use.