Good Bugs, Bad Bugs:
A Modern Approach for Detecting Offensive Biological Weapons Research

Michael Moodie, Cheryl Loeb, Robert Armstrong, and Helen Purkitt

Center for Technology and National Security Policy
National Defense University

September 2008

Robert Armstrong (1948–2008) was a Senior Research Fellow with the Center for Technology and National Security Policy (CTNSP) at the National Defense University. He held a B.A. degree in psychology from Wabash College and an M.A. in experimental psychology from Oxford University, as well as an M.S. in biology and a Ph.D. in plant breeding and genetics, both from Purdue University. Dr. Armstrong retired as a chemical corps colonel in the U.S. Army Reserve. He held a variety of positions in both the National Guard and Army Reserve and was a graduate of numerous Army schools, including the Army War College. His last military assignment was as the commander of a separate chemical brigade. Prior to joining CTNSP, Dr. Armstrong served as a life sciences intelligence officer with the Central Intelligence Agency, where his work included analytical projects involving biological and chemical warfare.

Cheryl Loeb is a Research Associate at CTNSP and a Ph.D. candidate in the Biodefense Program at George Mason University. Prior to joining CTNSP, she was a Research Associate in the D.C. office of the Monterey Institute of International Studies, Center for Nonproliferation Studies. Ms. Loeb may be contacted via e-mail at loebc@ndu.edu or by phone at (202) 685-2397.

Michael Moodie is a consultant to CTNSP who has worked for more than 15 years on chemical and biological weapons issues in government and the policy research community. He headed the Chemical and Biological Arms Control Institute and served as assistant director for multilateral affairs at the U.S. Arms Control and Disarmament Agency.

Helen Purkitt is a Professor of Political Science at the U.S. Naval Academy. After earning a Ph.D. at the University of Southern California, she joined the Political Science faculty at Texas Tech University, where she was the Director of the International Relations Graduate Program. She has also worked as an analyst for the Office of the Secretary of Defense-African Affairs and served as a co-principal investigator for an experimental study of political decisionmaking funded by the National Science Foundation. She has served as editor for fifteen volumes of Dushkin/McGraw-Hill's *Annual Editions: World Politics* and has published several articles in social science journals.

Defense & Technology Papers are published by the National Defense University Center for Technology and National Security Policy, Fort Lesley J. McNair, Washington, DC. CTNSP publications are available online at http://www.ndu.edu/ctnsp/publications.html.

Contents

Executive Summary

Monitoring covert offensive biological weapons research from afar has always been a daunting task. The problems facing analysts today are even more difficult, as advances in life sciences and dual-use biotechnology are rapidly spreading the knowledge, equipment, and materials needed to produce crude and sophisticated biological weapons around the world. Unlike nuclear programs, a well-defined and limited set of equipment and material that can be controlled through various import/export controls does not exist. Future monitoring will become more challenging as the distinctions among military, civilian and dual-use research and applications continue to blur. Managing proliferation risks in this environment will constitute the greatest challenge to policymakers in the biological weapons arena over the next two decades.

One of the factors that make this new type of analysis challenging is that nearly every nation-state in the world today has some level of biodefense and biotechnology capability. Most government decisionmakers and planners view the life sciences as promising drivers fueling future economic growth. These common trends serve to create a lot of "noise" that makes it much more difficult than even a few years ago to identify signs of covert biological weapons research and development.

The major requirements for dealing successfully with biological challenges today, therefore, are to shape a new conceptual framework and analytical approach sophisticated and rich enough to capture current complexities and dynamics, and to create new policy tools that, taken together, improve the international community's ability to drive biological risks to the lowest possible levels. The search for good indicators of malicious intent, destructive capabilities, or a combination of the two, therefore, must continue. Such indicators need not provide evidence of a "smoking gun." Rather, they should be used to generate sufficient concern so that policymakers and analysts can pay closer attention to a given situation, intensify their scrutiny, attempt to prevent surprises, and mobilize the international community to address a gathering problem.

This report outlines a new framework to monitor countries in terms of their potential to engage in covert biological weapons research. This is an effort to develop an indirect approach to measuring a nation's capability to conduct offensive weapons research in both civilian and government or military settings. This report discusses eight possible indicators of illicit biological weapons activities. Through analyzing these indicators, one can indirectly identify areas of possible illicit BW activity. These indicators include:

- Known chemical or nuclear programs,
- Number and level of BSL 3-4 facilities in a country,
- Sophistication of civilian domestic biotechnology capabilities,
- Known manufacture of rare or unusual biological compounds,
- Mismatch between number of trained scientists and positions available,
- Level of business transparency,
- Number of publications compared to number of scientists, and

- Complexity of social networking among scientists (both domestically and with scientists from other countries).

While not a panacea for monitoring all types of biological proliferation threats, the framework may serve as a guide for government and industry analysts for the type of information that needs to be collected and assessed to make more informed judgments about the likelihood that a particular state is engaging in illicit biological weapons research.

Introduction

At the 2006 Sixth Review Conference of the Biological and Toxin Weapons Convention (BWC), Assistant Secretary of State for International Security and Nonproliferation John Rood argued that,

> [f]undamental to the success of the BWC and its goal of ridding the world of biological weapons is full and effective compliance by all States Parties. Noncompliance with the central obligation of the BWC poses a direct threat to international peace and security, and compliance concerns must be pursued vigorously…Noncompliance with the fundamental requirement not to develop biological weapons is of paramount concern. It would be irresponsible to strengthen the superstructure of the Convention and yet turn a blind eye to problems with the foundation itself.

He then went on to state publicly that the United States believed that Iran and North Korea probably had illegal offensive biological weapons programs (a charge immediately and vehemently denied by Iran), and to raise concerns about Syria's research and development for an offensive program as well. Secretary Rood concluded his observations on compliance by noting that the United States understands that the problem of noncompliance with the BWC is difficult, but that it must be faced head-on: "The international community must remain vigilant and steadfast, and root out violators that undermine the integrity of the Convention."[1]

The issue of identifying illicit efforts to pursue biological weapons has bedeviled the international community since it first began to worry about such capabilities almost a century ago. The problem has taken its most concrete form in the inability to verify compliance with the BWC, which was negotiated in the early 1970s and entered into force in 1975. From the beginning of the negotiations of the BWC, the United States argued that the agreement was not verifiable and that it knew of no way to make it so at an acceptable political, economic, or security cost. Although the Clinton administration took a somewhat different view, that position has largely characterized U.S. policy for most of the last three decades.

The challenge of verifying compliance has been a contentious issue among BWC States Parties, and it has been the object of often intense debate over the last thirty years. The most recent attempt to address the problem—the seven-year effort of the Ad Hoc Group (AHG) to negotiate a legally binding verification protocol to the BWC—collapsed in 2001 with the U.S. rejection of the draft protocol tabled by the AHG chairman. The process ended with hard feelings and bruised sensitivities, and no mechanism to ensure compliance with treaty obligations or identify noncompliant behavior.

---

[1] John C. Rood, Assistant Secretary of State for International Security and Nonproliferation, "United States of America Address to the Sixth Biological Weapons Convention Review Conference," Geneva, Switzerland, November 20, 2006.

The problem of verifying compliance with the BWC and identifying BW-related activity has been further complicated by two developments that, while ongoing for some time, have been thrown into sharper relief in recent years. First, the underlying life sciences and associated technologies are advancing at an incredible pace, propelled by strong legitimate scientific, health, and commercial interests. At the same time, this knowledge and related technology is diffusing widely around the world.

Second, the emergence of non-state actors, especially terrorists, with interest in biological weapons capabilities (among others) presents a new dimension to the challenge. The identification of large, military-oriented, state-sponsored BW programs has been difficult enough. Terrorists bring to their cost/benefit calculations regarding potential biological weapons capabilities different motivations and objectives, non-military standards of desired or needed operational effectiveness, and a wider range of possible options and targets for BW attacks. All of these factors mean that terrorists are likely to take a different approach to development and use of biological weapons, providing a significantly altered profile from that of possible state programs that is even harder to identify with any degree of certainty.

While the task is enormously difficult, it would nevertheless be irresponsible for policymakers or analysts to abandon efforts to find ways to detect illicit BW-related activity, whether by states or terrorists. After all, such behavior at times has been identified. The United States, for example, charged the Soviet Union with noncompliance with the BWC for over a decade, charges that were acknowledged in 1992 by then Russian President Boris Yeltsin to be correct (although the United States was surprised by how right it was in terms of the size and scope of the program). The United States did not use treaty-designated means to make its determination because there were none, and most other BWC States Parties were reluctant to support Washington's contentions (one exception was Britain which had access to the same defector sources as the United States), demonstrating that dealing with issues of noncompliance are as much about politics as they are about evidentiary and technical issues.

More importantly, meeting the challenge of biological capabilities in the hands of states or terrorists cannot be successful through preparedness alone. Prevention is also necessary, and prevention entails doing everything possible to identify potentially harmful activities before any harm occurs.

The search for good indicators of malicious intent, destructive capabilities, or a combination of the two, therefore, must continue. Such indicators need not provide a smoking gun, which is highly unlikely to be found in any case. Rather, they should generate sufficient concern so that policymakers and analysts can pay closer attention to a situation, intensify their scrutiny, attempt to prevent surprises, and mobilize the international community to address a gathering problem.

Meeting the challenge of identifying and dealing effectively with an illicit biological weapons program, however, demands an appreciation of how much the world has been transformed. Changes since the BWC was negotiated have altered the contours of the problem, and old paradigms and templates are no longer adequate to capture either the dynamics or complexity of the current situation. Change has also thrown into question the continuing utility and relevance of several of the traditional tools on which policymakers have depended to address the biological weapons issue. The major requirements for dealing successfully with biological challenges today, therefore, are to shape a new conceptual framework and analytical approach sophisticated and rich enough to capture current complexities and dynamics, and to create new policy tools which, taken together, improve the international community's ability to drive biological risks to their lowest possible levels.

This report will first discuss the complexities and issues surrounding biological weapons proliferation and then will discuss eight indicators of biological weapons development activities. These indicators are part of a new framework to monitor countries in terms of their potential to engage in covert biological weapons research. In the life sciences in particular, a legitimate business may mask prohibited research, be exploited to advance illegitimate efforts, or be integrated with other activities, which, seemingly innocent in isolation, when combined move an actor closer to a dangerous capability.

A New Environment

New thinking about the biological warfare challenge begins with understanding the evolving environment in which that challenge emerges and the changes that have occurred. Several characteristics of that new environment should be highlighted.

First is the rapid advance of the life sciences and associated technologies. What is known about life today—especially at the molecular level—is vastly greater than it was even ten years ago, and substantially less than what will be known a decade hence. Not only is it the nature of the discoveries that are remarkable, but the speed at which they are occurring. Many areas of the life sciences are moving forward at a rate faster than the frequently cited Moore's Law in information technology.[2] This explosion in knowledge is prompting significant growth in the number of legitimate applications in health, agriculture, the environment, and many other areas. These rapid advances are, in the eyes of many commentators, so profound that they are producing a "revolution" in the life sciences, so much so that they are hailing the 21st century as the "century of biology."

This development is important for security as it relates to the process of scientific innovation and discovery. A recent study by the National Academy of Sciences Institute of Medicine and National Research Council stresses that progress in science is rarely a linear process but is marked by serendipitous discoveries and developments. These innovations and unexpected discoveries yield sudden and occasionally dramatic changes with important impacts. Sometimes those implications are to combine progressive increases in performance and continually declining costs to push rapid technological growth. At other times, they result in a fundamental paradigm shift that alters the fundamental outlook of the entire scientific enterprise. The impact is to produce results that are unanticipated, unexpected, and even unknowable.[3] If such developments were to occur in areas with security implications, the results could be unwelcome surprises for which policymakers are unprepared.

Innovation beyond the scientific process is also important, particularly innovation in the use of technology in which scientific knowledge is embedded. Technology innovation can also yield surprise, that is, employment of technology in new ways or according to new concepts of operation. That technology need not be at the cutting edge, but could also be "sidewise technology," or older technology whose use is innovative with respect to processes, areas of application, or in hitherto unforeseen combinations.[4] The important point is that devastating harm need not come only from state-of-the-art biotechnology or

---

[2] Robert Carlson, "The Pace and Proliferation of Biological Technologies," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science*, 1, no. 3, 2003, 7.

[3] Institute of Medicine/National Research Council, *Globalization, Biosecurity, and the Future of the Life Sciences* (Washington, DC: National Academies Press, 2006).

[4] The term is Paul Bracken's. See Paul Bracken, "Sidewise Technologies: National Security and Global Power Implications," in *Technology Futures, and Global Power, Wealth, and Conflict*, edited by Anne G.K. Solomon, A Report of the Project on Technology Futures and Global Power, Wealth, and Conflict, Center for Strategic and International Studies, May 2005, 91–100.

techniques, but that even modest levels of capability can, especially if used in unexpected ways, foster considerable damage.

In the current environment, key scientific advances are rarely reported by individual scientists or companies, but by teams of collaborators. At the level of the firm, one of the key characteristics to have emerged is increasing specialization; it is hard to be successful if a company seeks to go it alone and do everything on its own. The same is true for research scientists. Therefore, alliances, partnerships, and other forms of collaboration are increasingly important. The number of technical cooperation agreements in biotechnology, for example, grew from near zero in 1970 to almost 700 in 1985 to 1989.[5] More and more of those cooperative relationships, whether they are among companies or scientists, are occurring across international borders. Myriad examples could be cited: Cuba has technical agreements with fourteen countries, including Algeria, Brazil, China, India, Iran, Malaysia, Mexico, and Tunisia; a trilateral forum with Brazil, India, and South Africa fosters dialogue on critical biotechnology issues;[6] the Economic Cooperation Organization, created initially by Turkey, Iran, and Pakistan, and extended to a number of other central Asian states, is creating an Agricultural Biotechnology Network hosted by Iran;[7] and the South African Bioinformatics Initiative not only seeks to connect researchers at national universities, government facilities, and startup private biotechnology firms, but to provide access to state-of-the-art bioinformatics throughout the African continent.[8]

This development reflects the second major trend shaping the new global security environment—the global diffusion of life sciences knowledge and technology. Many countries around the world see the life sciences and their commercialization as a key driver of future economic growth. As a result, they are investing heavily both in promoting indigenous development of such capabilities and attracting foreign life sciences research and commercial enterprises. China and India in particular have been identified as likely biotechnology leaders in the years to come, but many other countries outside the developed world, including Singapore, Malaysia, South Korea, Cuba, Brazil, and South Africa, are also committed to promoting commercial life sciences enterprises. The impact of this trend was summarized by Robert Erwin, CEO of the Large-Scale Biology Corporation, who argues that in this new environment, "Everything will be cheaper, faster, and in the hands of a vastly larger number of people who are competent to use it."[9] The result is that a breakthrough in the life sciences or related technology—

---

[5] NAS, *Globalization,* 82.

[6] "Science and Technology Minister Discusses Nuclear, Space, and Other Priorities," Open Source Center, original published in *Brasilia InfoReal* in Portuguese, April 6, 2006.

[7] "Experts Meet in Tehran for Establishment of ECO Agricultural Biotechnology Network," Islamic Republic News Agency, April 25, 2006.

[8] Helen E. Purkitt, *Biowarfare Lessons, Emerging Biosecurity Issues, and Ways to Monitor Dual-Use Biotechnology Trends in the Future*, U.S. Air Force Institute for National Security Studies, INSS Occasional Paper 61, September 2005, 40–41.

[9] Quoted in Gerald Epstein, *Global Evolution of Dual-Use Biotechnology,* A Report of the Project on Technology Futures and Global Power, Wealth, and Conflict, Center for Strategic and International Studies, April 2005.

possibly one with important security implications—could come from virtually anywhere in the world.

This expansion of life sciences and biotechnology capabilities around the world is the product of many factors: national decisions to make biotechnology an important driver of future economic development; relatively low costs of materials, equipment, facilities, and labor; growing use of cooperative agreements and other forms of international cooperation; and long- and short-term exchanges of life scientists. The important impact of these trends is that they contribute to a "deterritorialization" of life sciences technology development, application, and dissemination, making it almost impossible for any single government to exert control over commercial operations and activities.

The third key factor influencing the security environment in which the biological challenge must now be addressed is the decreasing significance of material and equipment and the increasing importance of knowledge. In this regard, the biological challenge stands in stark contrast to its nuclear counterpart. For nuclear proliferation to be successful, a proliferator—whether a state or non-state actor—must acquire weapons grade nuclear material. Hence, preventing such acquisition and securing access to nuclear materials remains a cornerstone of nuclear nonproliferation efforts. In the biological realm, however, access to materials and equipment is not a problem. Some traditional BW agents, such as anthrax and plague, are still found in nature. Increasingly, biological agents can also by synthesized from scratch in a laboratory as their genomes are identified. Moreover, the prospect has been widely reported that, as science continues to advance, new pathogens and other kinds of biological weapons, e.g., those affecting the body's natural bioregulators and thereby influencing human behavior, could be developed in the future.

At the same time, the spread of the relevant science and technology and its commoditization through biotechnology make available most of the equipment needed to formulate a biological agent. Even technology related to delivery of the agent—generally considered the most difficult aspect of developing an effective biological weapon—is increasingly widespread, as, for example, commercial efforts move forward to improve the aerosolization of agents for better drug delivery.

In an environment of virtually ubiquitous material and equipment, then, the key factors for proliferation become knowledge, the people who have that knowledge, and what they choose to do with it. From a scientific point of view, knowledge may be important for its own sake, but in the security realm its broader utility depends on how it is used. It is applied knowledge that is the source of leverage and influence. As more is known about the life sciences and the more that knowledge can be applied, the greater its potential impact. Indeed, biotechnology is one of the most knowledge-intensive activities in the contemporary global economy. A paper by the Organization for Economic Cooperation and Development (OECD), for example, argues that "knowledge churn" has become the motor for advances in the biosciences.[10]

---

[10] Organization for Economic Cooperation and Development, "The Bioeconomy to 2030: Designing a Policy Agenda," (Paris: OECD Futures Program, 2006), 5.

But science and technology are neutral; they can be used for beneficial or malevolent ends. The key is what the user chooses to do. If one opts for proliferation, greater knowledge will allow entry higher on the proliferation learning curve, make that curve less steep, and reduce the costs of making further advances.

Social network analysis has identified tacit knowledge—knowledge that can be gained only by doing, by trial and error—as especially important. In the context of BW proliferation, this insight has been reinforced by work done with BW scientists in the former Soviet Union. In the short-term, this reality may relieve some anxiety regarding biological proliferation, because the number of biological weaponeers—whether from the former Soviet Union, South Africa, or Iraq—is relatively small. Over the longer-term, however, it provides little comfort in the face of the declining scientific and technical barriers to proliferation made possible by advancing science and related technology, and by the number of life scientists, biotechnologists, and other experts in related work (even if not for proliferation purposes) around the globe.

This leads to the fourth factor making the security landscape related to biological proliferation more complex: the growth in the number and variety of potential players in the proliferation arena. Reflecting its global diffusion, the work force involved in the life sciences and biotechnology is growing both in terms of highly trained scientists and increasingly important, but less well trained, technicians.[11] Moreover, those workers are ever more mobile. A growing, increasingly capable, and highly mobile work force with elements of the critical knowledge needed for BW proliferation is a prospect that must cause severe headaches for nonproliferation officials, especially those seeking to discover noncompliance with treaty-based obligations. This is not to argue that members of this life sciences work force are likely proliferators. Far from it; the vast majority certainly are committed to the beneficent use of the life sciences to improve the human condition. But if knowledge is now the core of a BW proliferation program, it is the people with that knowledge who are key, and the statistical reality is that as the number of people with the necessary knowledge grows, the risk also goes up that someone will decide to use that knowledge for malevolent purposes. Moreover, managing the risks associated with this "people dimension" of the challenge is something with which policymakers have very little experience.

A further complication related to the issue of potential proliferation players is the fact that proliferation is not just the province of governments and terrorists or the scientists and technologists they might recruit. The problem now encompasses many more potential kinds of actors, as was well demonstrated in the nuclear realm by the activities of A.Q. Khan and his cohorts. Those who might now be involved in proliferation as providers, users, or facilitators include proliferation "entrepreneurs," rogue scientists, organized

---

[11] In the United States alone, industrial demand for skilled biotechnology workers has increased 14 to 17 percent per year for the last decade, with many workers coming from overseas. See, E.D. Sevier and A.S. Dahms, "The Role of Foreign Worker Scientists in the U.S. Biotechnology Sector," *Nature Biotechnology*, 20, no. 9, 2002, 955–956.

criminal groups, financiers, logisticians, ethnic separatists, tribes or other entities engaged in communal conflict, front companies, and multinational corporations.

It is not just the number and variety of possible participants in the proliferation process that is important to understand, but also the nature of their interactions. Traditionally, proliferation has been a top-down process initiated by a government interested in acquiring a specific capability. Today, the process is much more free-form. The operation of formal or informal networks is particularly important in this regard. The emergence of networks is one of the key factors empowering the wide array of potential proliferation players, and it has facilitated the flow and exchange of materials, equipment, and knowledge. In the past, because they existed at different levels or were geographically disparate, the nodes in many of these networks were isolated from one another. Moreover, they were without access or influence.

New technology has now made possible a mode of operation supported by a global infrastructure that changes all that. The impact of the growth and diversity of networks is to increase the number of channels within and among society through which action can be taken and influence exerted. More and more, these new and increasingly empowered networked non-state actors are able to express their singular interests through the tools and channels globalization provides. The point has been made with respect to business, but it is applicable to many other non-state actors, as well, that globalization is allowing them to operate beyond the control of any single government.[12] The result is that even relatively weak actors can have disproportionate impact.

Networks are decentralized and distributed, and their hallmarks are flexibility, adaptability, and resilience, the same factors that are likely to exacerbate the difficulties confronting those responsible for countering proliferation. The challenge of identifying illicit, noncompliant behavior in the face of networked activity among proliferation actors is especially difficult. The existence of increasingly complex global networks complicates management of the security challenge, because the significant and growing numbers of transactions among an increasingly diverse set of actors make it more difficult to identify transactions of concern. This is a problem in which, as bioterrorism expert Randy Murch has elaborated, the signs that would portend such a development are small, often unrecognizable, imperceptible and evolving signals in a vastly greater, more complex dynamic of naturally occurring and man-made noise which represents the advance of legitimate biology-related science and commerce.

A final factor defining the current environment relates to industrial processes that are being significantly revised by globalization. Globalization is changing the way individual facilities and broad industries do business. At the facility level, technology has increased the level of automation, thereby reducing the personnel needed for efficient operation. Practices such as just-in-time delivery have altered the extent to which stockpiles of

---

[12] Ronald F. Lehman and Eileen S. Vergino, "Unclear and Present Danger: Understanding and Responding to WMD Latency," presentation to the 2005/2006 CGSR Futures Roundtable, Center for Global Security Research, Lawrence Livermore National Laboratory, January 19–20, 2006.

materials and other former requirements are now necessary. An important aspect of these changing industrial processes is the eroding distinction between technology development and application. Today, rather than a process that leads from one to another in distinct stages, development and application are now both phases of a process that is ongoing simultaneously.[13]

Another key aspect of these new ways of organizing the conduct of business at the industry level is the practice of outsourcing. The reality of a global biological infrastructure for both science and commercialization drives outsourcing in the face of largely commercial desires to share business risk, take advantage of distributed expertise around the world, and get into new markets. This trend has led to what one assessment has described as "deinfrastructuralization,"[14] or a diminished reliance on an indigenous infrastructure, but instead on one that is more geographically decentralized and distributed. Those interested in exploiting biotechnology will be reliant on neither wholly indigenous nor wholly external resources.

Changes in industrial practices, such as decentralization and outsourcing, put a premium on the ability to integrate. The elements of a successful endeavor that have to be brought together will likely come from many different places. Advanced technology will be available not just to those who invent it. Those who will be successful will be those who are best able to put disparate pieces together. As the National Intelligence Councils projection of the world in 2020 argues, "benefits of globalization will accrue to countries and groups than can access and adopt new technologies. Indeed, a nation's level of technological achievement will be defined in terms of its investment in *integrating* and applying the new, globally available technologies" (emphasis added).[15]

What is true in the broad economic arena is also true for any attempt to apply biotechnology in the security sphere. Because the security sector now relies on the application of technologies emerging largely from the commercial sector, the advantage here also rests with those who can rapidly adapt, exploit, and integrate evolving technology.[16] With the global spread of biotechnology, the United States should be under no illusion that it or its friends and allies are the only places where innovation in the application of the technology to the security arena can occur.

A second important implication of this development is the prospect of pursuing multiple routes to the same end point. It is vital for those responsible for managing the security risks related to biology to recognize that future efforts to exploit the life sciences and biotechnology for malicious purposes could bear no resemblance to past efforts in terms of the pathways traveled to achieve success. Comparing past BW programs, such as those of the Soviet Union, Iraq, and South Africa, one can see that those efforts began at different points on the learning curve and took distinct forms. This difference is likely to

---

[13] J.D. Kenneth Boutin, "Technological Globalization and Regional Security in East Asia," Institute for Defence and Security Studies, Singapore, no. 65, May 2004, 5.

[14] Lehman and Vergino, "Unclear and Present Danger: Understanding and Responding to WMD Latency."

[15] NIC, *Mapping the Global Future*, 11.

[16] Ibid., 13.

become more pronounced with respect to security-related programs that might emerge in the years ahead. U.S. assessments, particularly those that focus on potential noncompliance, must guard against adopting the notion that the future will be like the past.

Implications of a Changing Environment

From the perspective of proliferation, why do such developments matter? The reason is obvious: these developments can have a profound effect on the potential for the misuse of the life sciences and biotechnology by those people who would wish to do harm to others. As one journalist put it, "the age of weaponeering is just dawning; almost all of the fields potential lies ahead."[17] The potential impact of these trends and patterns is likely to be felt in a number of ways:

- They will increase the range of options and possibilities for those who might seek to exploit them for malicious purposes;
- They will make it easier to acquire capabilities and to do so at a more rapid pace;
- Untoward activities will be harder to detect; and
- Those responsible for countering proliferation will have a diminished capacity to manage risks and respond to problems.

The accelerating pace of scientific and technological change and the surprise inherent in scientific discovery and technological innovation require addressing phenomena that are both unanticipated and, in a sense, unknowable. Current trends and patterns make it extremely difficult to predict or even identify the threat. David Relman of Stanford University's Department of Medicine and chair of several important National Academy of Science studies makes the point that history does not provide a particularly good guide in this regard for several reasons. First, the notion of only a few agents posing a plausible threat is largely an artifact of weapons programs that predated the current knowledge of molecular biology; moreover, it reflected the identification of agents on the basis of natural properties and limited technical expertise. Second, large-scale industrial processes are no longer necessary for development of potent biological weapons, because the means for propagating agents under controlled conditions are now more easily accessible. Third, the traditional concept of weaponization is misleading, given that nature provides mechanisms for packaging infectious agents that are increasingly understood and more and more subject to manipulation through genetic engineering. Moreover, scientific advances will yield new ways to package such agents. Relman's conclusion is that the full potential of programs of the past was never unleashed and the use of biological weapons by small groups historically was relatively unsophisticated (even the relatively well educated and well funded Aum Shinrikyo). They are "far from representative of what moderately well informed groups might do today."[18]

In such an environment, the proliferation dynamic is moving further and further away from the classic model of a government making a commitment to achieving a biological weapons capability and then moving through a series of steps to the eventual deployment of a full military system. This trend argues not only for an assessment of whether the

---

[17] Mark Williams, "The Knowledge," *Technology Review,* March/April 2006, 50.

[18] David A. Relman, "Bioterrorism – Preparing to Fight the Next War," *The New England Journal of Medicine*, 354, no. 2, January 12, 2006, 113–115.

current definition of "proliferation" appropriately captures the nature of the problem, but also whether efforts to identify proliferation—including noncompliance with nonproliferation obligations—are adequate. Do we have an effective analytical framework for making such determinations?

What Indicators?

A recent background paper prepared for the Weapons of Mass Destruction Commission, chaired by Swedish diplomat Hans Blix, argues that, "there is no single outstanding critical indicator of a state-funded chemical or biological weapons programme, rather multiple indicators or specific 'signatures' of indicators common for chemical and biological programmes have to be used."[19] Any weapons capability, including biological weapons, is the product of the desire for such a capability and the ability to produce it. This much is true whether the actor is a state or a terrorist. At the state level, a wide array of elements will shape any government decision to pursue a biological weapons capability, including policy (both foreign and national security) as well as bureaucratic and organization, economic, psychological, and cultural factors. Fewer factors may be involved in the choice by terrorists, but some of the same forces are in play. In terms of capability, for both states and terrorists, an understanding of the underlying science and an ability to translate that scientific knowledge into usable technology are needed.

The factors that might provide some indication of illicit efforts, then, are numerous. For analysts, such abundance is both positive and negative. On one hand, there are many places to look. On the other hand, because there are so many factors, much of the information relating to them inevitably will be partial and incomplete, yielding significant uncertainties. The critical element is to identify and understand how those different factors come together.

Policy and Leadership Factors

The Swedish researchers referenced above concluded that, "the most decisive signature components were found to be state leadership and political will."[20] While they may be the most important, they are also the most difficult to assess. This is the case in part because leadership and political will are the product of many factors. Among the most critical are, obviously, perceptions of national security interests, the perceived nature of the threats to those interests, and the national leadership's objectives with respect to those interests. The Swedish analysts noted as key indicators expansionistic ambitions, pursuit of regional hegemony, and what they called a "negative asymmetric position towards the [perceived] threat."[21] Few countries, however, are likely to be blatant about these kinds of ambitions. They are much more likely to cast the issue in terms of defense needs and cite an existential threat to their security—whether one exists or not—as a justification for considering actions of which the international community is likely to disapprove. They

---

[19] Ingrid Faengmark and Lena Norlander, "Indicators of State and Non-State Offensive Chemical and Biological Programmes," WMD Commission Paper 30, August 2005, 3, available at <www.wmdcommission.org>.

[20] Ibid., 9.

[21] Ibid., 6.

can make their case stronger if they convince the international community that a major gap exists between the threat and their ability to deter or respond effectively to it.

Similarly, few if any states will be open about their perception of the utility of "weapons of mass destruction," including biological weapons, in addressing their security deficit. Although some critical holdouts remain, most countries today are party to the major international arms control and nonproliferation agreements (the Nuclear Nonproliferation Treaty [NPT], the Chemical Weapons Convention [CWC], and the BWC). Given the importance that most of the world attaches to these agreements, a country interested in capabilities those treaties prohibit is unlikely to suggest it does not take its treaty obligations seriously, or that it is engaged in a cynical maneuver to cover illicit behavior.

States do get reputations regarding their willingness to abide by international treaty obligations. These reputations are earned not by what governments say, but by what they do. It is a reputation based on a pattern of behavior extending well beyond arms control and nonproliferation agreements to their observance of international norms, rules, and expectations embodied in treaty-based global commitments they assume, such as membership in the United Nations or the World Trade Organization (WTO). Suspicions may exist with respect to a country such as China, for example, not only because it has abetted proliferation through nuclear assistance to Pakistan, or because the United States has had to sanction Chinese companies for violations of export control norms, but also because China has been notorious in disregarding its obligations to protect intellectual property rights as a member of the WTO. The current view is that China is doing better in this regard, a view that is shaped less by the rhetoric of China's leadership and more by the actions the Chinese are seen to be taking to demonstrate the seriousness with which they view their international obligations.

A government's decision to pursue biological weapons, of course, is a product of much more than national security and foreign policy incentives. Analysts have discussed many other factors that contribute to such policy choices. These include the political psychology of the leadership on such questions as the extent to which it feels integrated with or isolated from those in the international community with whom they most want to associate. Another important factor is the influence of particular segments or organizations that are part of the domestic political dynamic, not least of which are the military and the scientific communities. Yet another cluster of factors is cultural influences, such as the extent to which the society values secrecy.

Complicating the assessment still further is the fact that none of these factors works in isolation; they interact with one another. Nor do they all necessarily work in the same direction (i.e., either promoting or impeding a decision to pursue BW); they can be reinforcing in some cases but cancel each other out in others. No methodology has yet been developed that establishes an analytical framework defining the nature of the relationships among these factors, weighs their respective values in influencing a decision, or accommodates the variability in their dynamics that will inevitably emerge as an analyst moves from one specific case to the next.

The best that can be done in evaluating intent in relation to the proliferation of biological weapons capabilities is for country, regional, nonproliferation, and scientific experts to work together to construct a convincing narrative regarding a particular country's perspective. The eight indicators proposed in this report can provide the basis for this narrative.

During the Cold War, the United States expended extraordinary resources—time, treasure, and talent—on understanding its adversaries in the Kremlin. By and large, it developed a reasonably sophisticated and thorough understanding of how the Soviet leadership operated and what made it tick. Even so, intense debates abounded within the U.S. policy, intelligence, and analytical circles about a range of Soviet-related issues. Moreover, some issues, such as the extent of the illicit Soviet BW program, were never fully grasped. No comparable security challenge today commands such assets. Analytic and policymaking resources must be spread more thinly across a wider variety of consequential but existential challenges.

Science and Technology

As the earlier discussion of the changing security landscape underlines, the challenges of finding useful indicators of a biological weapons capability is getting more difficult. It is certainly true that some combinations of capability, if seen in some contexts, would raise suspicions. One example is a capacity for large-scale cultivation, preparation of pathogenic materials for aerosol dissemination, and animal testing facilities (especially aerosol chambers). In general, however, it has been the traditional view that it was not until the later stages of a BW program—production, storage, deployment, and training—that more recognizable indicators emerge. In part this was the case because the BWC allows for biological defense activities that in some cases are virtually the same as those of an offensive program. The suspicious combination mentioned above, for example, could be explained away as part of a defensive program to enhance protection against airborne agents.

Thinking about capability indicators has its origins in concern about the original proliferation dynamic, that is, military programs aimed at producing biological weapons for use on the battlefield. Such thinking is increasingly outmoded for several reasons. First, the nature of conflict is changing, and how biological weapons could be used is changing with it. Large, set-piece battles, while they cannot be totally dismissed, are increasingly rare. Military forces now find themselves engaged in other forms of conflict, both military engagements of an unconventional character and "operations other than war." In such an environment, the perceived uses of biological weapons may change. One group of analysts, for example, suggests that biological agents could be used in situations in which the armed forces of the international community find themselves in an internal conflict.[22] In almost every case of community conflict in the world today, one side or the other, and often both, have accused the other side of using chemical weapons. Most of these charges have been made for political reasons or have mistaken other materials

---

[22] Ake Sellstronm and Anders Norqvist, "Comparison of States and Non-State Actors in the Development of a BTW Capability," WMD Commission Paper Number 16, 5, available at <http://www.wmdcommission.org/files/no16.pdf >.

(smoke, tear gas) for chemical weapons. Looking to the future, however, in light of current trends it would not be a big jump for them to consider the actual use of chemical or biological weapons.

The second reason for the questionable relevance of looking for traditional capability indicators is that advancing science and technology are changing the biological weapon model insofar as they are making some program elements that in the past might have provided indicators less necessary. It would be foolish in the extreme, for example, for any state to produce and store large stockpiles of biological weapons. Such stockpiles are not needed in the face of a growing just-in-time production capability. This would be especially the case if the concept of operation for BW use shifts away from its employment on the battlefield to other purposes.

Third, traditional capability indicators may become less relevant because a state might decide to proceed with a limited biological weapons program without necessarily committing to its ultimate implementation. The leadership might be intrigued, for example, by what advancing science and technology make possible, even if they have no clear vision at the outset of how capabilities can be exploited or commitment to carrying a program forward. This might be called the "Mount Everest syndrome" (that is, when asked why they climb mountains, climbers respond, "Because it's there"). In this variant, the question is why someone would push for the creation of a dangerous capability, and the response would be: "Because we could."[23]

The combination of what is interesting and what is doable could yield worrisome results. It could, in particular, make "dabbling" much more frequent. Such a decision could produce a program that focuses on research and development without scaling up to production or even significant testing. At the same time, it would provide a "warm capabilities base" or a latent or virtual capability on which the actor could build rapidly. In some ways, this situation may be the most difficult for the international community, because it suggests the creation of a capability that allows for rapid breakout if and when a leadership makes the decision that such a capability is worth having.

Some people may argue that such a latent biological capability is of little or no use without the training, doctrine, and equipment needed to exploit it. In a military context, this is true. Armed forces need to be trained in BW uses and protected against its effects. The argument here, however, is that such classical military applications need not be the sole or perhaps even the most likely use scenarios in the future. Limiting the applicable

---

[23] A mid-1990s scientific experiment involving the recovery of frozen tissues containing the agent that caused the 1918–1919 Spanish influenza pandemic that killed at least 40 million people provides an interesting example. In that case, the research team had recently developed a new technique to analyze DNA in preserved tissue. Looking for new applications, they decided on the Spanish flu. According to one description of the effort, "this work was not triggered by a search for flu treatments or the search for new biowarfare agents, but by a rather simple motivation: [the] team could just do it." According to the team leader, "the 1918 flu was by far and away the most interesting thing we could think of." In short, the work went ahead because the team was curious, the issue was interesting, and they could do it. See the Sunshine Project, "Emerging Technologies: Genetic Engineering and Biological Weapons," Background Paper Number 12, November 2003, 7, available at <http://www.sunshineproject.org/publications/ bk/bk12/html>.

use template leads to thinking that may be too narrow to identify the real problems that will arise.

The final reason that indicators related to military programs may be less germane now relates to the foregoing point. In today's world, it makes little sense for a determined BW proliferator to have its illicit program reside in its military sector. The non-military arena provides innumerable opportunities for activities that could contribute to an illegal offensive capability. Since many of the questions relating to the development and performance of agents and delivery systems are the same for civilian and military applications, significant understanding of fundamentals can be achieved in the commercial arena that would not likely be seen to be violations of international treaty obligations. Given the sensitivity of such a program, the leadership might want to put control of the critical function of integrating the dispersed efforts that are likely to characterize a modern program into hands other than the military's to achieve an additional layer of protection against discovery.

The Need for Innovative Thinking

The empowerment of individuals underlines an important shift that must be made in thinking about the problem of BW proliferation, whether pursued by state or non-state actors. More and more, the problem in the biological realm is one of potential misuses of knowledge. The focus of concern, therefore, should shift to the people who hold such knowledge. But almost no work—conceptual or policy-related—has explored the means by which this dimension of the risk can be managed.

Clearly, the policy and analytical communities need innovative thinking regarding both the nature of future biological proliferation and the tools needed to address them. That thinking must begin with the recognition that no single tool will be decisive, and no single indicator will be definitive. It is likely to be the quality of integrated assessment and analysis of information gathered from a growing number of sources that will provide the key to understanding what is happening. Such thinking will also require the contribution of a wider range of expertise than has traditionally been the case, which will, in turn, require the allocation of more resources to this task. It is well worth the investment, and it is time to begin.

Indicators to Monitor BW Trends Worldwide

Monitoring covert offensive biological weapons research in the future will be a difficult task for nonproliferation experts. Advances in life sciences and dual-use biotechnology are rapidly diffusing the knowledge, equipment, and materials needed to produce crude and sophisticated biological weapons around the world. Due to the dual-use nature of many of the products and materials associated with biological weapons development, it will grow increasingly difficult to distinguish an offensive weapons program from legitimate civilian research until the weapons program is in advanced stages, if at all. Unlike nuclear programs, there is not a well-defined set of equipment and material that can be controlled through import/export controls, further complicating the monitoring process and the ability to identify illicit activity (see table 1).

Table 1. Characteristics of Fissile Materials and Pathogens[24]

Fissile Materials	Biological Pathogens
Do not exist in nature	Generally found in nature
Nonliving, synthetic	Living, replicative
Difficult and costly to produce	Easy and cheap to produce
Not diverse; plutonium and highly enriched uranium are the only fissile materials used in nuclear weapons	Highly diverse; more than 20 pathogens are suitable for biological warfare
Can be inventoried and tracked in a quantitative manner	Because pathogens reproduce, inventory control is unreliable
Can be detected at a distance from the emission of ionizing radiation	Cannot be detected at a distance with available technologies
Weapons-grade fissile materials are stored at a limited number of military nuclear sites	Pathogens are present in many types of facilities and at multiple locations within a facility
Few nonmilitary applications (such as research reactors, thermo-electric generators, and production of radioisotopes)	Many legitimate applications in biomedical research and the pharmaceutical/biotechnology industry

The changing threat environment since the end of the Cold War, coupled with revolutions in the life sciences and the increasing impotence of international arms control agreements, begs that novel approaches to detecting illicit offensive biological weapons programs be developed.

This section discusses eight possible indicators of illicit biological weapons activities. Through analyzing these indicators as they relate to a specific country, an analyst can develop a narrative of a country's potential capability to engage in illicit bioweapons

---

[24] Jonathan Tucker, "Preventing the Misuse of Pathogens: The Need for Global Biosecurity Standards." *Arms Control Today*, 33, no. 5, June 2003, available at <http://www.armscontrol.org/act/2003_06/tucker_june03.asp>.

research. The indicators selected for this study are just a small sampling of indicators that can be chosen, depending on the nature and goals of the study being undertaken. These indicators were chosen because they provide a broad overview of the different types of indicators that can be used. Together, these indicators will not provide "smoking gun" evidence of a country's illegal biological weapons activities, but rather, a narrative of the potential or likelihood for a country to engage in illegal activity. These indicators are:

- Known chemical or nuclear programs,
- Number and level of BSL 3-4 facilities in a country,
- Sophistication of civilian domestic biotechnology capabilities,
- Known manufacture of rare or unusual biological compounds,
- Mismatch between number of trained scientists and positions available,
- Level of business transparency,
- Number of publications compared to number of scientists, and
- Complexity of social networking among scientists (both domestically and with scientists from other countries).

Other possible indicators not profiled in this study that could highlight potential offensive research include: the type or nature of state leadership (i.e., undemocratic state with limited transparency and no public insight into internal affairs), regional dynamics (i.e., one country may choose to pursue offensive BW program based on the perceived state of another country's unconventional and conventional weapons arsenal), membership and compliance with nonproliferation agreements, and mismatch between production capacity and stated production output in both civilian biotechnology facilities and known biodefense facilities.

Known Chemical and Nuclear Weapons Programs

While it may not be true in all cases, evidence indicates that countries that have pursued chemical and/or nuclear weapons programs have also pursued, or are likely to pursue, some level of biological weapons capacity. Historically, Germany, France, Japan, the United Kingdom, the Soviet Union, and the United States all pursued offensive biological weapons capabilities in parallel with development of their chemical and nuclear weapons arsenals. While these countries have publicly renounced their chemical and biological weapons programs, a number of other countries are suspected of pursuing illicit WMD programs, including Iran, North Korea, and Syria. One indicator of potential illicit BW activity would be to analyze which countries have had or are pursuing nuclear weapons capabilities and/or illegal chemical weapons programs, or are suspected of having such programs.

Iran, which has been accused by both the United States and the international community of illegally pursuing a nuclear weapons program, is also suspected of seeking production technology, dual-use materials, training, and expertise from foreign entities to develop indigenous biological and chemical weapons capabilities, even though it has ratified both the biological and chemical weapons conventions. Some analysts suspect Iran has small stockpiles of both mustard and cyanide, and, potentially the nerve agent sarin.[25] Of particular interest is the growing sophistication of Iran's biotechnology and pharmaceutical industries, and the potential to divert dual-use agents and materials for illicit weapons purposes. At a minimum, based on its biotechnology infrastructure, Iran has the capability to produce at least small quantities of offensive biological weapons. Some of the most common agents associated with the Iranian research in the open literature are anthrax, botulinum toxin, ricin toxin, T-2 mycotoxin, and Variola virus, the causative agent of smallpox.[26]

North Korea performed an underground nuclear weapons test on October 9, 2006, confirming long-held suspicions that the country was pursing a nuclear weapons capability. According to analysis done by the Nuclear Threat Initiative, North Korea is suspected of stockpiling, or has the capability of stockpiling, a number of chemical weapons, including phosgene, lewisite, mustard blister agents, and possibly sarin, as well as related delivery vehicles.[27] In regard to biological weapons, the country is believed to have the capability to produce traditional infectious biological warfare agents or toxins. In 2002, General Thomas A. Schwartz stated in testimony before the U.S. Senate that "… North Korea has the capability to develop, produce and weaponize biological warfare agents. They can deploy missiles with chemical warheads and potentially have the ability to weaponize biological agents for missile delivery."[28] Russian intelligence sources have also stated that North Korea has an offensive biological weapons program and may be conducting research on anthrax, cholera, bubonic plague, and smallpox.[29] North Korea also possesses a conventional munitions production infrastructure that could be used to weaponize BW agents, and is believed to be actively seek to acquire dual-use equipment, materials, and expertise that could be used to support an offensive BW program.[30]

Both India and Pakistan have detonated nuclear weapons and are capable of developing chemical and biological weapons. India, for example, has an advanced domestic biotechnology infrastructure, as well as a known defensive biological weapons program. Other countries that are believed to be pursuing nuclear and/or chemical programs and have the potential to pursue biological weapons capabilities include China, Egypt

---

[25] Nuclear Threat Initiative, "Iran Profile: Chemical Chronology 1998–1992," October 2003, accessed at <http://www.nuclearthreatinitiative.org/e_research/profiles/Iran/Chemical/2340_2960.html>.

[26] Nuclear Threat Initiative, "Iran Profile: Biological Overview," June 2007, available at <http://www.nti.org/e_research/profiles/Iran/Biological/index_2300.html>.

[27] Nuclear Threat Initiative, "North Korea Profile: Chemical Overview," February 2006, available at <http://www.nti.org/e_research/profiles/NK/index_1549.html>.

[28] Statement of General Thomas A. Schwartz, Commander in Chief United Nations Command/Combined Forces Command; and Commander, United States Forces Korea, before the 107th Congress, Senate Armed Forces Committee, March 5, 2002, available at <http://armedservices.senate.gov/statemnt/ 2002 / Schwartz.pdf>.

[29] Russian Federation Foreign Intelligence Service, "A New Challenge After the Cold War: Proliferation of Weapons of Mass Destruction," 99.

[30] Deputy Director of National Intelligence, "Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions, 1 January-31 December 2004," available at <ttp://www.dni.gov/reports/2004_unclass_ report_to_ NIC_DO_ 16Nov04.pdf>.

(chemical program, no nuclear program), Israel, Syria, and Taiwan (past, and foregone interest in nuclear weapons as well as chemical suspected).[31]

Number and Level of BSL 3-4 Facilities

Most countries operate a defensive biological weapons program, which is permitted under the Biological Weapons Convention. A potential indicator, however, lies in the size and sophistication of a country's defensive biological research and development program and the number of high containment biological safety level (BSL) facilities a country operates (both civilian and military). It is particularly important to look at how many of the identified facilities are run by the defense establishment, the biosecurity level at these sites (we recommend an analysis focus only on those facilities that are classed as BSL 3 and above, and the level of security at the facilities, such as armed guards, restricted access, fences, and cameras). A large number of BSL 3-4 facilities will increase a country's capability to quickly divert defensive research into offensive research.

While BSL guidelines are not universal, laboratories can typically be classed through levels 1-4, based on the type of agents researched on or stored in the laboratory, as well as the risk posed to personnel, environment, and surrounding community by research done at the lab (table 2).[32] BSL 4 labs, the highest classification in regard to risk, contain pathogens such as hemorrhagic fever viruses Ebola and Marburg, lassa fever, and smallpox. Agents located in BSL 4 labs are typically dangerous and/or exotic agents that pose a high risk of life-threatening disease, high individual risk of aerosol-transmitted lab infections, and for which vaccines or other treatments are *usually* not available.

As with the other indicators, determining a country's number and level of BSL 3-4 facilities alone will not provide a "smoking gun" of illegal activity. Rather, it gives more countries the capability to pursue offensive weapons research masked as benign defensive research or civilian vaccine or therapeutic research. Analyzed together with other selected indicators, the number and level of a country's BSL 3-4 facilities will provide a narrative of the capability and/or likelihood to engage in illegal activities.

Table 2 provides a general guideline on the differences between BSL levels 1-4. As noted, while BSL guidelines are not universal, similar requirements for laboratory safety exist throughout the international community, and even illegal programs must protect their workers from biohazards.

---

[31] Nuclear Threat Initiative, "Country Profiles," available at <http://www.nti.org/e_research/ profiles/ index.html>.

[32] For examples of existing BSL4 facilities, please see Interpol's "Biocontainment Laboratories," accessed at <http://www.interpol.int/public/BioTerrorism/links/biocontainmentLab.asp>.

Table 2. Biosafety Levels[33]

BSL	Agents	Practices	Safety Equipment (Primary barriers)	Facilities (Secondary barriers)
1	Not known to consistently cause disease in healthy adults	Standard Microbiological Practices	None required	Open bench top sink required
2	Associated with human disease, hazard = percutaneous injury, ingestion, mucous membrane exposure	BSL-1 practice plus: Limited access Biohazard warning signs "Sharps" precautions Biosafety manual defining any needed waste decontamination or medical surveillance policies	Primary barriers = Class I or II BSCs or other physical containment devices used for all manipulations of agents that cause splashes or aerosols of infectious materials; PPEs: laboratory coats; gloves; face protection as needed	BSL-1 plus: Autoclave available
3	Indigenous or exotic agents with potential for aerosol transmission; disease may have serious or lethal consequences	BSL-2 practice plus: Controlled access Decontamination of all waste Decontamination of lab clothing before laundering Baseline serum	Primary barriers = Class I or II BCSs or other physical containment devices used for all open manipulations of agents; PPEs: protective lab clothing; gloves; respiratory protection as needed	BSL-2 plus: Physical separation from access corridors Self-closing, double-door access Exhausted air not recirculated Negative airflow into laboratory
4	Dangerous/exotic agents which pose high risk of life-threatening disease, aerosol-transmitted lab infections; or related agents with unknown risk of transmission	BSL-3 practices plus: Clothing change before entering Shower on exit All material decontaminated on exit from facility	Primary barriers = All procedures conducted in Class III BSCs or Class I or II BSCs in combination with full-body, air-supplied, positive pressure personnel suit	BSL-3 plus: Separate building or isolated zone Dedicated supply and exhaust, vacuum, and decon systems Other requirements

---

[33] Centers for Disease Control and National Institutes of Health, "Biosafety in Microbiological and Biomedical Laboratories, 4th Edition," May 1999, available at <http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm>.

Sophistication of Civilian Domestic Biotechnology Capabilities

Nearly every country has some level of biotechnology capability. Rising science and technology powers, such as India and China, have made it a high priority to become leaders in biotechnology research, development, and commercialization. At the same time, other fields not traditionally viewed as biotechnologies, such as materials science, agricultural science, information technology, and nanotechnology, are becoming increasingly integrated with traditional biotechnologies. As a result, the capabilities to develop and produce BW are becoming available in both civilian industrial sectors and academic settings. Widespread access to the Internet has expanded the availability of the supplies, equipment, and specialized data bases, such as gene and protein libraries, needed to produce biological weapons to people beyond scientific and technical communities.[34]

The equipment needed to develop biological weapons is also decreasing in cost and size. Small fermenters capable of cultivation of pathogenic microorganisms, viruses, or toxins, protective and containment equipment, and other materials are available for purchase from hundreds of distributors around the world. Large-scale industrial processes are no longer necessary for development of potent biological weapons, because the means for propagating agents under controlled conditions are now easily accessible. This shift means that the research and development phase of a BW program does not need to be conducted through an offensive military program.

Australia, Brazil, China, India, Israel, Russia, Singapore, and South Korea are all expected to become “stronger economic, political, scientific, and technological global players in the future.”[35] India and China, for example, which are signatories to the BWC, have well-developed domestic biotechnology infrastructures that include numerous pharmaceutical production facilities and biocontainment laboratories (including BSL3) for working with lethal pathogens.[36] An industry analysis by Frost & Sullivan estimated India’s pharmaceutical market to be about $5.1 billion in 2004, ranking it 13th globally by value and 4th by volume.[37]

As mentioned above, China has also made strides in biotechnology in the past decade due to numerous reforms in science and technology. Over 500 biotechnology companies operate in China, employing over 5,000 people. China was the only developing country to participate in the Human Genome Project, is currently the world’s leading producer of genetically modified cotton, and, in 2003, became the first country to obtain a drug license for a recombinant gene therapy. Further, China has more than 150 health

---

[34] Author Helen Purkitt discovered a mobile, module field BL 3 laboratory for sale on the Internet. While this product had only been used by such agencies as the CDC in emergency situations as of 2005, the manufacturers indicated they were prepared to sell to any legitimate user via the Internet.

[35] National Academies of Science, “Globalization, Biosecurity and the Future of Life Sciences,” available at <http://www.nap.edu/catalog.php?record_id=11567>.

[36] Nuclear Threat Initiative, “India: Biological Overview,” October 2006, available at <http://nti.org/e_research/profiles/India/Biological/index.html>.

[37] National Academies of Science, “Globalization, Biosecurity and the Future of Life Sciences,” available at <http://www.nap.edu/catalog.php?record_id=11567>.

biotechnology products in clinical trial and has received approval to market a number of Chinese-produced vaccines, diagnostics, and therapeutics.[38]

Egypt also has begun to emerge as a biotechnology power. Among Arab states, Egypt is a scientific leader, with a strong biotech base in agricultural and health biotechnology. Because Egypt's biotechnology sector is largely dependent on foreign rather than indigenous innovation, the government has been channeling funds toward the building of multipurpose biotechnology pilot manufacturing plants (i.e., the Mubarak City for Scientific Research and Technology Applications, the National Research Centre, and El Monoufiya University). They have also begun introducing biotechnology educational programs into Egypt's higher education system.[39]

Within this indicator, one could also look at large quantities of dual-use materials and technology within the civilian biotechnology and defensive research fields and any discrepancy in declared activities and/or production at a site and the types of technologies known to be located at the site. The Australia Group, an informal forum of countries which, through the harmonization of export controls, seeks to ensure that exports do not contribute to the development of chemical or biological weapons,[40] has identified equipment and materials that have dual-use potential. Such equipment includes:

- Fermenters capable of cultivation of pathogenic micro-organisms, viruses, or toxin production, without the propagation of aerosols, having a capacity of 20 liters or greater.
- Cross (tangential) flow filtration equipment capable of separation of pathogenic micro-organisms, viruses, toxins, or cell cultures, without the propagation of aerosols, having a total filtration area equal to or greater than 1 square meter and capable of being sterilized or disinfected in-situ.
- Chambers designed for aerosol challenge testing with micro-organisms, viruses, or toxins and having a capacity of 1 cubic meter or greater.
- Steam-sterilizable, freeze-drying equipment with a condenser capacity of 10 kg of ice or greater in 24 hours and less than 1,000 kg of ice in 24 hours.
- Complete spraying or fogging systems, specially designed or modified for fitting to aircraft, lighter than air vehicles, or UAVs, capable of delivering, from a liquid suspension, an initial droplet of less than 50 microns at a flow rate of greater than two liters per minute.[41]

Even though the existence of large amounts of such equipment and materials alone is not an indicator of illicit activity, it allows the analyst to identify and determine the capabilities of production.

---

[38] Ibid.

[39] Ibid.

[40] Australia Group, "The Australia Group," 2007, available at <http://www.australiagroupnet /en/index.html>.

[41] The Australia Group, "Control List of Dual-Use Biological Equipment and Related Technology," September 2007, available at <http://www.australiagroup.net/en/dual_biological.html>.

As mentioned, however, the challenge in examining the implications of the global spread of biotechnology is that it presents a high noise-to-signal ratio. With many countries around the world investing heavily in biotechnology on the bet that it will be a future economic driver, it is very difficult indeed to distinguish developments that have little or no bearing on BW prospects (noise) from those that do (signals). As biotechnology continues to advance, a country will come ever closer to the line that separates legal from illegal activities. The critical factor then becomes whether that country chooses to exploit that capability for weapons purposes. We have come full circle back to intent.

Known Manufacture of Rare or Unusual Biological Compounds

If traditional capability indicators are less useful today, a sense of a country's biological weapons capability—or at least its potential—can still be achieved by examining its life sciences activities and its ability to translate its scientific knowledge into useful products and technologies.

As described earlier, the basic level of the life sciences around the world is improving significantly. While much of this scientific knowledge is applicable to biological weapons, analysts have identified research in the life sciences that has particular relevance and could trigger greater attention if identified. A report of the National Academy of Sciences, for example, lists seven classes of experiments that illustrate the types of endeavors or discoveries that should require review and discussion because of their potential implications for biological weapons development. These include experiments that would:

- Demonstrate how to render a vaccine ineffective,
- Counter resistance to therapeutically useful antibiotics or antiviral agents,
- Enhance the virulence of a pathogen or render a non-pathogen virulent,
- Increase transmissibility of a pathogen,
- Alter the host range of a pathogen,
- Enable the evasion of diagnostic/detection modalities, and
- Enable the weaponization of a biological agent or toxin.[42]

A second NAS committee took a different approach. It identified four major categories of advances in the life sciences that will have high-impact, near-term consequences for the life sciences and could enhance or alter the nature of future biological threats. These categories of activities include:

- Acquisition of novel biological or molecular diversity (e.g., DNA synthesis, DNA shuffling, bioprospecting, and high-throughput screening),
- Direct design (e.g., rational drug design, synthetic biology, or genetic engineering of viruses),

---

[42] National Research Council, *Biotechnology Research in an Age of Terrorism* (Washington, DC: National Academies Press, 2004), also known as the "Fink Report," after Dr. Gerald Fink, who chaired the committee that produced it.

- Understanding and manipulation of biological systems (e.g., RNA interference, computational biology and bioinformatics, systems biology, and genomic medicine), and
- Production, delivery, and packaging (biopharming, mirofluidics and mircrofabrication, bionanotechnology, mircroencapsulation technology, aerosol technology, and gene therapy technology).[43]

Sponsorship of work in these areas—especially related to the first set of seven experiments—would certainly raise a warning flag about a country's possible BW plans, especially if it is less than transparent about such work.

A second area at which to look to achieve some sense of a country's biological weapons potential is its ability to exploit scientific advances. This is largely the province of life sciences industry, a large and expanding economic sector. Key applications of life science discoveries that take the form of new technology potentially relevant in the military area will come from the civilian sector. A country with a strong biotechnology base would be able to begin a BW program much higher on the learning curve than was the case for past programs. Advances in aerosolization technology, for example, driven by non-military factors, such as potential for drug delivery, would assist in overcoming what had been a major technical barrier in past BW programs.

Mismatch Between Number of Trained Scientists and Positions Available

Analyzing the number of trained scientists working for a defense establishment and the number of positions available/required for a defensive only program is a useful guide to possible illicit activity. Within this indicator, analysts should also look at foreign-trained scientists located within the establishment.

A historical example of a large mismatch between the number of trained scientists working for a defense establishment and the number of positions available/required for a defensive only program is the Soviet biological weapons program. From 1972 to 1992, Biopreparat, an ostensibly state-owned Soviet pharmaceutical organization was, in reality, carrying out an extensive illicit offensive biological weapons program. By the early 1990s, more than 60,000 people were estimated as involved in the research, development, and production of biological weapons, making it the largest offensive biological weapons program ever created.[44]

Another related factor is the number of indigenous foreign-trained scientists participating in a domestic BW program. Scientists who train or study in countries with significantly advanced life sciences capabilities and return to work in domestic programs could provide the knowledge or expertise needed to develop offensive biological weapons. This is particularly relevant for countries that do not have advanced life sciences capabilities. In its Unclassified Report to Congress on the Acquisition of Technology Relating to

---

[43] NAS, *Globalization*.

[44] National Research Council, Committee on Advances in Technology and the Prevention of Their Application to Next Generation Biowarfare Threats, *Globalization, Biosecurity, and the Future of the Life Sciences* (Washington, DC: National Academies Press, 2006).

Weapons of Mass Destruction and Advanced Conventional Munitions, 1 January-31 December 2006, the CIA stated it believed that Syria continued to seek dual-use technology and expertise from foreign sources and had a basic capability of biological agent development. In regard to Iran, they stated that their assessment of Iran's biotechnology infrastructure:

> indicates that Iran probably has the capability to produce large quantities of some Biological Warfare (BW) agents for offensive purposes, if it made the decision to do so. Iran continues to seek dual-use biotechnology materials, equipment, and expertise consistent with its growing legitimate biotechnology industry but these components could also advance Tehran's BW capability.[45]

The report also stated that countries of concern continued to contact Russian entities as a source of dual-use biotechnology equipment and related expertise. Russia's well-known biological expertise may make it an attractive target for countries seeking assistance that could be applied to biological warfare programs.[46]

Finally, one must be concerned with the phenomenon known as "brain drain," whereby weapons experts provide biological related materials and expertise to a suspected proliferant country or terrorist organization. This is particularly relevant in the case of former weapons scientists from South Africa and the Soviet Union. From 1981—1993, South Africa's apartheid chemical and biological weapons program known as "Project Coast," collected hundreds of strains of microbes, including forty-five types of anthrax, and strains of cholera, brucellosis, and plague. Dr. Wouter Basson, the former head of the project, is known to have traveled to China, Iraq, and Libya under the guise of business, and is believed to have sold cultures of these deadly pathogens, including genetically engineered varieties, on the black market for profit.[47]

Another serious risk of brain drain stems from scientists of the former Soviet Union's vast BW program. Since the breakup of the USSR, it is unknown how many Soviet weapons scientists have attempted to sell WMD-related technologies, materials, and knowledge to countries or terrorists suspected of pursuing offensive programs. While programs such as the Nunn-Lugar Cooperative Threat Reduction Program have attempted to find alternate employment for former weapons scientists to limit this threat, cases exist of weapons scientists either emigrating to suspected proliferant countries or attempting to sell their knowledge and expertise on the black market. The Government of Iran, for example, has been reported to have attempted to recruit Russian scientists to help it develop its biological weapons program, and has hired several scientists once associated with institutes that were part of the Soviet Union's germ warfare program.[48]

---

[45] CIA, "Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions, 1 January-31 December 2006," available at <http://www.dni.gov/reports/Acquisition_Technology_Report_030308.pdf>

[46] Ibid.

[47] Jonathan Tucker, "Preventing the Misuse of Pathogens: The Need for Global Biosecurity Standards," *Arms Control Today,* available at <http://www.armscontrol.org/act/2003_06/tucker_june03.asp#notes>

[48] Judith Miller, "Russian Biologist Denies Work in Iran on Germ Weapons," *The New York Times*, January 19, 1999, available at <http://query.nytimes.com/gst/fullpage.html?res=9D00E7D91430F93AA25752C0A96F958260>.

Through analyzing the number of trained scientists working for a defense establishment, the number of positions available/required for a defensive only program, and the number of foreign-trained scientists within the establishment, one might develop a realistic indicator of potential illegal bioweapons activity.

Business Transparency

A variable that could indicate potential illicit dual-use BW activity is the relative transparency of a country's business practices. The United States, for example, has a very transparent business culture, where information on research, sales, and other activities are easily accessible to the public, both inside and outside the United States. The biotechnology, pharmaceutical, health, medical, and other industries are subject to not only licensing, importation, and exportation rules, but also Federal regulatory standards and government oversight.

A high level of transparency in a nation's business culture provides a window through which one can gain insight into potential illicit or dual-use BW related activities. A transparent business culture makes possible the identification and tracking of purchases of dual-use materials and equipment, cutting edge research, allocation of government resources in the private sector, and other types of important information.

The opposite is true for countries characterized by opaque business practices—weak business regulations, impenetrable business cultures, and limited controls on the importation and exportation of dual-use materials. This lack of transparency raises the risk that illegal activity will go undetected. Analysts looking for potential BW activity should look at business transparency of a country and ask questions such as: What kind of information is made public regarding relevant commercial activity? In what quantities? Of what quality? How frequently? By whom? Based on such information, what kind of research are they undertaking? To whom are they selling their products? What safeguards are being used? Could terrorists could gain access to the materials?

Number of Publications Compared to Number of Scientists

Scientists, for the most part, need to publish their work to be recognized for their achievements by the scientific community. Analyzing the type of research being published as well as the number of publications, or lack thereof, coming from a country could provide indicators of illicit activity. One facet is to look at the number of publications in a country's academic community and compare them against the number and types of publications coming out of a military or defense establishment. A key indicator is if a large number of employed scientists working for a government or military biodefense program are publishing their scientific research in limited quantities only. A country that is capable of performing "red flag" research but produces no record of it, therefore, should be the subject of concern; it may be trying to hide ongoing work by its scientists, whom they refuse to let publish. If a government does not allow them to publish their research, it may be because it does not want the rest of the world to know its current priorities. Such was the case in the early 1990s with Iraq's burgeoning biological weapons program. In March 1990, the Defense Intelligence Agency stated in a memo:

> The Nuclear Research Center (NRC) at Tuwaitha has not only continued, but increased the procurement of media for cell cultures and material for molecular biology and genetic engineering. The Center is also procuring a centrifuge suitable for viruses, bacteriophage cell nuclei…Even though the NRC has been procuring materials associated with genetic engineering and virology, there have been no publications in these areas from this facility. For that reason it is speculated that the facility is affiliated with BW.[49]

Another indicator is to look at the type of research, regardless of quantity, published in scientific journals. Research that could raise red flags and indicate capabilities to produce offensive biological weapons, or hidden offensive research already being undertaken, include those kinds of efforts identified in the National Academy study previously mentioned, such as research on how to render a vaccine ineffective; countering resistance to therapeutically useful antibiotics or antiviral agents; and enhancing the virulence of a pathogen or rendering a non-pathogen virulent.

Complexity of Social Networking Among Scientists

Monitoring the social networking of scientists could provide signs of potential intent. Questions to be asked include: Are the scientists attending international meetings and conferences? What type of meetings and events do they attend? What are the topics of the meetings? With whom are they meeting? Are they actively seeking out specialists in areas they are not experts in?

Through analyzing social exposure and networking, one can identify a variety of potential patterns that might be indicative of dual-use or offensive weapons research. In particular, analysts could identify scientists interested in specific cutting edge or “gray area” research. Noticeable interest in topics relating to increasing transmissibility of a pathogen or altering the host range of a pathogen can act as a red flag, especially if the scientists’ home country does not have particular expertise in these or other related dual-use areas.

Analysts also need to monitor patterns of inactivity, where gaps show that groups of scientists are not interacting but should be. Similar to a citation index, such a pattern poses the question of whether they might be hiding illicit activities and are not attending international scientific symposia in order to keep their illicit research secret.

---

[49] GulfLink, “The Nuclear Research Center,” March 1990, available at <http://www.gulflink.osd.mil/declassdocs/dia/19961031/961031_950719_22010629_90a.html>.

Conclusion

A global revolution is underway in the life sciences, transforming the way the international community must deal with biological weapons proliferation. Traditional tools of arms control and nonproliferation are no longer adequate in an ever-changing security environment of increasingly complexity and uncertainty. Accelerating advances in life sciences and the availability of materials, equipment, and technical know-how, have vastly increased the number of actors who are capable of producing biological weapons and significantly increased the playing field in which they can operate.

The framework identified in this paper is the first step in an effort to develop an analytical approach to identify possible proliferation in an era in which the risks turn increasingly on the proliferator's intent, smoking guns to demonstrate maleficent designs will be few and far between, ambiguities will prevail, and the line between legal and illegal activities will become ever harder to draw with any brightness. These indicators are offered in the hope that when they are examined, not individually, but in terms of how they might interact, we can indirectly measure a country's capability to engage in illicit BW activity. Armed with those insights, more attention and resources can be directed toward an uneasy situation with the goal that more intensive efforts and the brighter glare of continuing analyses will reveal more of the true nature of a disturbing confluence of developments.