THE CENTRE CANNOT HOLD: IMPACT OF THE SCIENTIFIC AND INFORMATION REVOLUTIONS ON THE NONPROLIFERATION REGIME

Amanda Moodie
Submitted to Professor Robert Pfaltzgraff
In fulfillment of the MALD Thesis Requirement
The Fletcher School of Law and Diplomacy
Spring 2011

THE FLETCHER SCHOOL

TUFTS UNIVERSITY

TABLE OF CONTENTS

ACKNOWLEDGMENTS

I was lucky enough to benefit from the assistance and support of Dr. Robert Pfaltzgraff, under whose guidance this thesis was written. His suggestions gave this paper its shape and direction, and it is difficult to overstate the encouragement I received from his belief that the topic was worthy of attention and research.

I am extremely grateful for the generous support from many individuals who provided insightful recommendations and invaluable assistance at various stages. Amy Smithson and John Overcash offered feedback on an early version of the section on microreactors and chemical technologies. Jeff Schneider shared his expertise on terrorist groups' use of the internet and the training manuals available online. Jeremy White lent his thoughts on a draft of this project, and I owe him thanks for his editing and proofreading work as well as his extremely helpful insights. I reserve special thanks to Adam Willis, who served as a constant source of encouragement and support as well as an on-call scientific advisor, and to Michael Moodie, who provided inspiration through long discussions, feedback on countless drafts and iterations, and reassurance when the going got tough. This paper reflects the work of all these individuals, though the errors are mine alone.

LIST OF ACRONYMS

AG	Australia Group
BWC	Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (1975) / Biological Weapons Convention
CBW	Chemical and biological weapons
CDC	Centers for Disease Control and Prevention
CTR	Cooperative Threat Reduction program / Nunn-Lugar program
CWC	Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (1997) / Chemical Weapons Convention
GICNT	Global Initiative to Combat Nuclear Terrorism
IAEA	International Atomic Energy Agency
ITT	Intangible Technology Transfers
MEMS	Microelectromechanical systems
MTCR	Missile Technology Control Regime
NAM	Non-Aligned Movement
NATO	North Atlantic Treaty Organisation
NBC	Nuclear, biological, and chemical
NPT	Treaty on the Non-Proliferation of Nuclear Weapons (1968)
NSG	Nuclear Suppliers Group
NWS	Nuclear weapons states
NNWS	Non-nuclear weapons states
OPCW	Organisation for the Prohibition of Chemical Weapons
PSI	Proliferation Security Initiative
UN	United Nations
UNSCR	United Nations Security Council Resolution

EXECUTIVE SUMMARY

The basic assumption of the nonproliferation regime – that proliferation can be limited by controlling access to materials and equipment as well as securing sensitive information and data – is increasingly erroneous. What people know is becoming more critical to whether they develop a chemical, biological, or nuclear capability than what they possess. The materials and equipment necessary for proliferation are now more readily available than ever before; therefore, access to equipment, particularly with regards to chemical and biological weapons, is no longer the main barrier to proliferation. At the same time, the scientific expertise necessary to develop such a weapon is far more common and readily available than it has been at any point in the past.

The shifts and developments in science and technology demand a new framework for conceptualizing proliferation risks and formulating policy, one that de-emphasizes control of materials or so-called "sensitive" information, and instead emphasizes the will or lack thereof of states or other actors to develop weapons of mass destruction and focuses on how to shape choices regarding proliferation. This paper will examine the assumptions and thinking of the traditional nonproliferation regime, as well as the ways in which the scientific advances and the information revolution of the late twentieth and early twenty-first centuries might undermine these assumptions. It suggests that there needs to be a corresponding shift in the way that policymakers and scholars think about proliferation and the means of preventing it, in order to address these new challenges effectively.

INTRODUCTION

In the twenty-first century, policymakers and analysts who hope to counter the dangers posed by the proliferation of nuclear, biological, and chemical (NBC) weapons[1] face an evolving and increasingly complex threat. What people know is becoming more critical to whether they develop a chemical, biological, or nuclear capability than what they possess – and no one has yet managed to develop a way to monitor proliferation by tracking what people know.

As the NBC proliferation challenge emerged in the years following World War II, the central premise of the nonproliferation regime – as enshrined in the Nuclear Nonproliferation Treaty (NPT), the Biological and Toxin Weapons Convention (BWC), and, later, the Chemical Weapons Convention (CWC) – was that certain materials and technologies were critical to the proliferation process and therefore inherently dangerous. Moreover, the majority of these key technologies belonged to a small group of like-minded states who hoped to limit proliferation of NBC weapons. As a result, the nonproliferation regime was designed to deny and control access to these materials and technologies, in the hope that proliferation could be controlled by extension as well. Additionally, for most of the post-war era, the knowledge necessary to develop a nuclear, chemical, or biological weapon was limited to scientists with highly specialized knowledge who were generally employed by the government or perhaps the academic sector; the small number of these individuals meant that the propagation of such expertise was easily tracked.

1 For the purposes of this paper, the terms "NBC weapons" or "nuclear, chemical, and biological weapons" will be used, rather than the more popular "weapons of mass destruction" or "WMD." The term "WMD" is in some ways a misnomer for NBC weapons, because some, particularly chemical gases, might not in fact cause mass destruction, while other weapons that could cause massive chaos or disruption are not usually included in this category. Moreover, the term "WMD" has become so ubiquitous in recent years that its actual meaning has become obscured: some scholars include radiological weapons, explosives, incendiary devices, landmines, or even small arms in discussions of WMD, while others do not. Thus this paper will use the term "NBC weapons" to clarify the scope of the discussion.

The world of science and technology has changed dramatically and continues to transform rapidly and pervasively, however. The materials and equipment necessary for proliferation are now more readily available than ever before. Extraordinarily rapid developments in laboratory tools have meant that older, yet still powerful instruments have found their way into wide distribution. Protocols and prepackaged kits to modify the sequence of a gene or replace genes within a microorganism are widely available and can be used by anyone with a high-school education. Small, disposable, self-contained bioreactors for propagating viruses and microorganisms and chemical microreactors slightly larger than a penny are sold on the open market. Technology intended to promote scientific discovery that can be used for legitimate and peaceful purposes can also be used by actors with malevolent intent to create highly destructive and dangerous weapons, and it is very difficult to ascertain the end-goal of an individual or program seeking to acquire such technology until that goal has been reached. Access to equipment, particularly with regards to chemical and biological weapons, is no longer the main barrier to proliferation; instead, the scientific know-how and willingness to acquire weapons of mass destruction present the main obstacles.

At the same time, the scientific expertise necessary to develop such a weapon is also far more common and readily available than it has been at any point in the past. Two major factors have led to this development: First, the internet and information revolution have ensured that the dissemination of knowledge occurs more quickly and easily and reaches more people than ever before. Individuals who are interested in developing chemical weapons, for example, can easily find articles describing how to produce nitrous oxide and other chemical gases in scientific publications or on the websites of universities' chemistry departments. Formulas for classic chemical weapons, such as sarin, are also posted on the internet. Second, the scientific revolution has meant that the amount of knowledge to be disseminated has also increased exponentially. There are more people than ever to keep track of in monitoring proliferation trends because so many people now possess the critical information necessary for producing weapons. These developments change the nature of the challenge to those fighting proliferation from controlling materials and equipment – the traditional approach underlying many of our current tools for counterproliferation – to managing risks associated with what people know.

WHY IS THIS NEW?

Some might suggest that there is nothing new in these threats. The concept of knowledge as a potential proliferation threat is not a recent development; concern about the possibility of scientists sharing their expertise with countries and individuals interested in developing and acquiring NBC weapons dates back to World War II, when U.S. attorneys granted immunity on charges of war crimes to scientists involved in the Japanese biological warfare program because the United States wanted to prevent the Soviet Union from acquiring the data these scientists possessed.[2] After the Cold War, the Nunn-Lugar Cooperative Threat Reduction program spent $250 million over 13 years on “redirection” programs designed to shift former bioweaponeers toward peaceful scientific livelihoods and to pay them a reasonable wage so that they would refrain from aiding others with proliferation interests.[3] Two additional brain-drain programs were launched by the State Department biosecurity initiative in 2004 and 2006, respectively supporting Iraqi bioweapons scientists and civilian biological scientists in other countries of the Middle East and Southeast Asia.[4] In fiscal year 2008, Congress designated $26 million for the U.S. Department of State to fund global biosecurity engagements with scientists possessing ‘‘dual-use’’ biological skills who had never worked in an offensive bioweapons program. Another $27 million was added for fiscal year 2009.[5]

2 Hal Gold, *Unit 731 – Testimony* (Singapore: Yenbooks, 1996).
3 Sonia Ben Ouagrham-Gormley and Kathleen Vogel, “The Social Context Shaping Bioweapons (Non)Proliferation,” *Biosecurity and bioterrorism: biodefense strategy, practice, and science* 8, no. 1 (March 2010): 10, doi: 10.1089=bsp.2009.0054
4 Ibid.
5 Ibid.

Clearly, the possibility has always existed that weapons scientists who have lost their jobs or who desire money or fame will seize the opportunity to sell their skills and knowledge. Nor is it a new development that this information is readily accessible to those who desire to find it. Many of the "poisoners' handbooks" available on jihadist websites today contain material taken from American sources, primarily texts written by neo-Nazi survivalists in the 1980s and passed around by sympathizers in the 1990s. The Smyth Report, an administrative history written about the Manhattan Project whose stated purpose was to give information to citizens regarding atomic weapons so that they could make informed policy decisions regarding their use, was used extensively by Soviet scientists to tailor the Soviet Union's bomb project.

Yet today, several factors compound this problem, making it all the more salient. In addition to the newly ubiquitous materials and equipment and the diffusion of scientific expertise, the dynamics of globalization have profoundly altered the landscape of proliferation. Biotechnology, chemical, and civilian nuclear energy industries around the world have exploded, which means that even small facilities can be global in their operations. This profusion is driven in part by economic factors and in part by environmental and health concerns. Thus the proliferation problem is but one critical dimension of the interaction between security, economics, and science. Additionally, these new enterprises provide a wider range of legitimate dual-use covers for malevolent activities. The rapid changes of science and technology are being driven in part by the incredible number of potential benefits that such innovations can create. This makes it much more difficult for governments to oversee and control actors' behavior, because by regulating the actions of these industries, they risk infringing upon the creativity of scientists and engineers that could lead to critical advances.

WHY IS THIS A PROBLEM?

All of the above suggests that a new framework for nonproliferation efforts is necessary. The basic assumption of the nonproliferation regime – that proliferation can be limited by controlling access to materials and equipment as well as securing sensitive information and data – is increasingly erroneous. The possibility that a state or non-state actor will develop NBC weapons is now based on a combination of the availability of materials and the presence of scientific expertise, as well as the will to do so. In short, the assumption underpinning the nonproliferation regime – that proliferation can be controlled through denying technology to certain states – no longer holds true. Current policies and measures based on this assumption may no longer be useful or relevant. The shifts and developments in science and technology demand a new framework for conceptualizing proliferation risks and formulating policy, one that de-emphasizes control of materials or so-called "sensitive" information, and instead emphasizes the will or lack thereof of states or other actors to develop weapons of mass destruction and focuses on how to shape choices regarding proliferation.

It is important to note that the challenges facing the nuclear, biological, and chemical nonproliferation regimes are not necessarily the same. Nuclear, biological, and chemical weapons development and use require different types of scientific expertise and different materials. Not all of these fields are equally problematized as a result of these shifts. In this respect, the key outlier is nuclear weapons, whose proliferation does still remain dependent on the acquisition of certain materials to a much greater degree than biological or chemical weapons. Nevertheless, the dimensions of the nuclear field are changing, and some aspects of the information and scientific revolutions that have affected the proliferation of chemical and biological weapons may also bear on nuclear weapons. The nonproliferation regimes for the different types of weapons therefore share some of the same challenges, although the extent to which each has been affected thus far varies.

This paper will examine the assumptions and thinking of the traditional nonproliferation regime, as well as the ways in which the scientific advances and the information revolution of the late twentieth and early twenty-first centuries might undermine these foundations. It suggests that there needs to be a corresponding shift in the way that policymakers and scholars think about proliferation and the means of preventing it, in order to address these new challenges effectively. Chapter I of this paper discusses the current nonproliferation regime's history and structure. It looks at the existing measures and programs that act as the basis for this regime, focusing particularly on the three central treaties as well as export control measures and newer initiatives such as the Cooperative Threat Reduction program and the Proliferation Security Initiative. This section of the paper will explore the assumptions that underpin these policies and programs in order to understand their relevance and utility in the current context. Chapter II will discuss in more detail the changes mentioned above and expand on this concept of knowledge-based proliferation. It will provide evidence of this shift and will discuss the ways in which the assumptions of the traditional nonproliferation regime have been undermined. Finally, Chapter III will attempt to answer the question, "What is to be done?" Without providing policy recommendations, which are beyond the scope of this paper, this section will provide a new conceptualization of proliferation risks in terms of knowledge. It will explore how proliferation can be disincentivized and choices can be shaped through policy and what types of frameworks exist to do this. Finally, it will discuss how international cooperation can be leveraged to confront the new proliferation challenge and how this cooperation might differ from other initiatives designed to challenge proliferation.

CHAPTER 1

THE WAY WE WERE: THE TRADITIONAL NONPROLIFERATION REGIME AND STRATEGY

As mentioned above, ever since its origins in the post-World War II era, the nonproliferation regime has rested on the assumption that by controlling the materials and supplies necessary for the development of a nuclear, biological, or chemical (NBC) weapon (for example, highly enriched uranium, chemical precursors, or large-scale fermenters), states could also control the proliferation of these weapons. The key equipment and technology necessary to create such weapons belonged to only a handful of states; moreover, they were largely the products of government-supported or -controlled research and development. Consequently, experts came to believe that the spread of these materials – and, by extension, the spread of NBC weapons – could be controlled through a series of treaties and export controls.

TREATIES AND CONVENTIONS: BINDING NONPROLIFERATION COMMITMENTS

NUCLEAR WEAPONS CONTROL

The belief that controlling highly enriched uranium would decrease the likelihood of proliferation dates back to the earliest effort to control the spread of nuclear weapons. In June 1946, less than a year after the bombings of Hiroshima and Nagasaki, the United States submitted a formal proposal known as the Baruch Plan to the United Nations (UN). The plan proposed that the United States turn over control of all its enriched uranium to a new UN body over which the United States and the other permanent members of the Security Council would have a veto, and that all countries in the world should be prohibited from possessing their own nuclear weapons.[1] Additionally, the plan suggested that the new UN body – the "Authority" - should have control over all uranium and thorium,[2] all plants that produce fissionable materials, and all research into atomic explosives, because these activities and stockpiles were "intrinsically dangerous."[3] The Soviet Union opposed this plan, arguing that negotiations could not proceed fairly as long as the United States maintained its weapon and could therefore use its atomic monopoly to coerce others into accepting its proposal. It argued that the United States must first agree to ban the bomb before a discussion could occur, whereas the United States claimed that international agreement must be reached before it would consider abolishing its weapon. As a result of this standoff, the plan failed to gain any real momentum in the United Nations.[4]

In December 1953, U.S. President Dwight D. Eisenhower gave his famous "Atoms for Peace" speech to the United Nations General Assembly, in which he called for governments to "make joint contributions from their stockpiles of normal uranium and fissionable materials to an international atomic energy agency."[5] Eisenhower's plan led to the creation of the International Atomic Energy Agency (IAEA). In the same year, the Soviet Union had become concerned about the United States' deployments of nuclear artillery in Europe for use by North Atlantic

---

1 George Bunn and John B. Rhinelander, "Looking Back: The Nuclear Nonproliferation Treaty Then and Now," *Arms Control Today*, July/August 2008, accessed 12 January 2011, http://www.armscontrol.org/act/2008_07-08/lookingback.

2 Thorium is a slightly radioactive metal that can be used in reactors. In the 1950s, a number of experiments were performed at Oak Ridge National Laboratory in Tennessee that proved the efficacy of thorium reactors. However, the government chose to build uranium-fueled reactors as the foundation for the nuclear power industry instead, in part because they produce plutonium that can also be used for nuclear weapons – an important consideration after the Soviet Union developed its own nuclear capability. Interest in thorium continues today, as industry players and governments consider whether it could be used to solve the problem of climate change, but because it leaves behind minimal amounts of waste and is far less radioactive than uranium or plutonium, it is not a major security concern.

3 "The Baruch Plan," Presented to the United Nations Atomic Energy Commission, June 14, 1946, atomicarchive.com, accessed 12 January 2011, http://www.atomicarchive.com/Docs/Deterrence/BaruchPlan.shtml.

4 Ibid.

5 "Atoms for Peace," IAEA, accessed 12 January 2011, http://www.iaea.org/About/history_speech.html.

Treaty Organisation (NATO) forces. The Soviet Union became concerned that the United States did not have sufficient control over these weapons, particularly those stationed in Germany. As a result, it proposed a ban on the deployment of nuclear weapons of any sort in Central Europe.[6] A number of states, including Ireland and Sweden, proposed nonproliferation resolutions, but the United States opposed any effort that could potentially jeopardize nuclear-sharing arrangements with its NATO allies.[7]

By the mid-1960s, five nations – the United States, the Soviet Union, Britain, France, and China – possessed nuclear weapons. Numerous other nations, including Argentina, Brazil, Egypt, India, Israel, Pakistan, South Africa, and West Germany, were giving serious consideration to going nuclear.[8] Both the United States and the Soviet Union became concerned that the nuclear arms race was spiraling out of control. At the same time, the United States had had little success in negotiating an agreement to have its nuclear weapons placed under the control of a multilateral NATO force.[9] By 1965, therefore, the United States was ready to negotiate on a nonproliferation treaty. Both it and the Soviet Union submitted draft treaties to the UN General Assembly in the fall.[10] Subsequently, U.S.-Soviet negotiations began in earnest.

Most states agreed that they had an inherent right to develop nuclear weapons and that non-nuclear states should therefore receive some benefit for not exercising their right to an atomic bomb. Many, such as Tunisia and Sweden, felt that they could be truly secure only in a disarmed world and therefore argued that nuclear disarmament by the major superpowers was

---

6 Henry Sokolski, "What Does the History of the NPT Tell Us about Its Future?" in *Reviewing the Nuclear Nonproliferation Treaty*, Henry Sokolski, ed. (Carlisle, PA: U.S. Army War College, Strategic Studies Institute, 2010), 31-32.

7 Ibid., 31-38.

8 Lawrence S. Wittner, "The Nuclear Non-Proliferation Treaty, Past and Present," *History News Network*, 26 April 2010, accessed 12 January 2011, http://hnn.us/articles/125933.html.

9 Bunn and Rhinelander, "Looking Back."

10 Wittner, "The Nuclear Non-Proliferation Treaty, Past and Present."

necessary before they would consider signing a nonproliferation agreement.[11] Thus the final version of the treaty, which was presented at the Geneva-based Eighteen-Nation Disarmament Committee and the UN General Assembly in 1968,[12] was designed to provide mutual obligations on the part of non-nuclear and nuclear nations. The non-nuclear signatories pledged "not to make or acquire nuclear weapons," as well as to accept a safeguard system that would prevent diversion of nuclear material from nuclear reactors to nuclear weapons development. In exchange, nuclear signatories pledged to "pursue negotiations in good faith at an early date on effective measures regarding cessation of the nuclear arms race and disarmament."[13] Finally, both the nuclear and non-nuclear states agreed to cooperate with respect to civilian nuclear energy, and concurred that any country that is a party to the NPT had the right to have capabilities associated with civilian nuclear energy. This is sometimes referred to as the "third leg" of the NPT.

The NPT recognizes five nuclear weapons states (NWS) – the United States, the United Kingdom, France, China, and Russia – which are required to pursue general and complete disarmament. Other states parties, known as non-nuclear weapons states (NNWS), may develop peaceful nuclear technology, but are prohibited from developing or possessing nuclear weapons. To verify that NNWS are not diverting nuclear materials for weapons purposes, the IAEA implements safeguards for the transfer of materials between NWS and NNWS and conducts inspections of the NNWS' nuclear facilities. Non-nuclear signatories also must conclude

---

11 Sokolski, "What Does the History of the NPT Tell Us about Its Future?," 43.
12 Bunn and Rhinelander, "Looking Back."
13 Wittner, "The Nuclear Non-Proliferation Treaty, Past and Present."

comprehensive safeguards agreements with the IAEA.[14] The treaty provides for a review conference every five years; in 2005, it was extended indefinitely.

BIOLOGICAL WEAPONS CONTROL

The concept of controlling materials or equipment as a method of nonproliferation has always been more complicated with regard to biological (and chemical) weapons than nuclear arms, because so many of these materials and technologies are dual-use items that can be used for peaceful purposes as well as military efforts. Moreover, it is easier to access basic materials for a biological weapon because, unlike highly enriched uranium or plutonium, these materials are found in nature. Thus a competent scientist could get soil samples from a farm and use them to extract and cultivate anthrax, for example. This ability to access materials from nature has only increased in recent years. Yet unlike nuclear weapons, there is "a uniquely wide array of societal constraints on CBW [chemical and biological weapons] armament...so that damaging opprobrium is likely to fasten on any future users of CBW."[15]

Like the chemical weapons regime, the law against use or production of biological weapons has its origins in the 1925 Geneva Protocol, more formally known as the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare. This treaty, which was negotiated during a League of Nations conference in Geneva and was signed on June 17, 1925, prohibits states parties from using CBW against one another.[16] The United States failed to ratify the treaty immediately. However, in 1969, U.S. President Richard Nixon announced that the United States would

14 Twenty-six of the 185 NNWS still do not have these agreements in place, although none of these states are of proliferation concern.

15 Julian Perry Robinson, "Chemical & Biological Weapons," in *Combating Weapons of Mass Destruction: The Future of International Nonproliferation Policy*, Nathan E. Busch and Daniel H. Joyner, eds. (Athens, GA: University of Georgia Press, 2009), 77.

unilaterally and unconditionally renounce biological weapons. He ordered the destruction of the considerable U.S. biological weapons stockpile and the conversion of all production facilities for peaceful purposes, and sought ratification of the Geneva Protocol.[17] The Nixon administration advocated a treaty banning germ warfare, and in 1971, the Eighteen-Nation Disarmament Committee completed negotiations on the text of the Biological and Toxin Weapons Convention (BWC).[18] The treaty, which drew on the norm established by the Geneva Protocol and which was signed by the United States in 1972, prohibited the possession of deadly biological agents except for the purpose of research into defensive measures. It was the world's first treaty to ban an entire category of armaments[19] – unlike the NPT, which maintained the nuclear status quo.

Yet the BWC was a deeply flawed treaty – really no more than a pledge of good faith by its signatories.[20] It had no provisions for monitoring or enforcing compliance with its prohibitions, no prescription for an international organization to assist with these tasks or to help states parties to meet their obligations, no procedures for implementing its rules.[21] No limits or standards governed the exception made for research pathogens, and no forms of consultation were specified.[22] The loophole protecting biodefense research also proved to be particularly problematic. This was an issue even as the treaty went into force in March 1975: in the two years since the treaty had been signed, scientists had managed to merge the genes of wholly unrelated organisms, creating the possibility that new biological weapons could be created using genetic

---

16 Ibid., 78.
17 Joseph Cirincione, *Bomb Scare* (New York, NY: Columbia University Press, 2007), 35.
18 Ramesh Thakur and Ere Haru, *The Chemical Weapons Convention* (Tokyo: United Nations University Press, 2006), 7.
19 Judith Miller, Stephen Engelberg, and William Broad, *Germs: Biological Weapons and America's Secret War* (New York, NY: Simon & Schuster, 2001), 63.
20 Ibid., 64.
21 Robinson, “Chemical & Biological Weapons,” 78.
22 Miller et al., *Germs*, 64.

engineering techniques. Despite the military implications of such advancements, the treaty could not address them, since the stated purpose of this research was defensive.[23]

The problem posed by scientific advancement continues to be an issue today. Two analysts comment, "The weaknesses [of the BWC] reflect the scientific state of the world in 1972, when biological weapons did not have a high utility. Production barriers, such as problems concerning the preservation and dissemination of biological agents and the protection of troops handling them, had not yet been overcome. Moreover, production required large fermentation facilities, which were easily detectable by outsiders."[24] Since then, of course, a number of these constraints have dissolved: large-scale production and storage of pathogens are relatively easy; in some cases, such storage may not even be necessary since an agent can be produced and dispersed fairly quickly; agents can be produced with equipment that is also used for legitimate medical, pharmacological, or scientific purposes; and large-scale facilities are no longer necessary for production.[25]

In 1995, a white supremacist named Larry Wayne Harris requested three vials of *Yersinia pestis*, the plague-causing bacteria, from the American Type Culture Collection. To prove to them that his purposes were legitimate, he sent them a document on letterhead from the Small Animal Microbiology Laboratory, a non-existent organization, and gave them a stolen Environmental Protection Agency identification number for the laboratory. The American Type Culture Collection sent him the vials, but became suspicious and tipped off the Centers for Disease Control and Prevention (CDC) when he called the next day to see why his order had not arrived. Harris was sentenced to eighteen months' probation, a $50 fine, and two hundred hours

23 Ibid., 71.
24 Thakur and Haru, *The Chemical Weapons Convention*, 5-6.
25 Ibid.

of community service.[26] As a result of Harris's actions, the U.S. Congress passed the Anti-Terrorism and Effective Death Penalty Act of 1996, which led to basic regulations on the transfer of dangerous pathogens. The law states that anyone shipping or receiving agents on a list of 36 microbial pathogens and toxins, known as “select agents,” must register with the CDC and declare a legitimate scientific or medical use for the material. In 2001, Congress passed additional legislation requiring all laboratories that work with or possess select agents to register with the CDC as well. The Agricultural Bioterrorism Protection Act of 2002 requires that anyone who works with biological agents and toxins that pose a severe threat to animal and plant health register with the CDC.[27] Other countries have passed similar legislation regulating laboratory security, and some international organizations such as the World Federation for Culture Collections and the Organization for Economic Coordination and Development have launched initiatives to negotiate global standards.

Such measures fall under the heading of biosecurity, which “involves technologies, procedures, and protocols to secure the exchange of highly infectious pathogens and to control access to those pathogens within a defense, research, industrial, or storage facility.”[28] One analyst of chemical and biological weapons notes that “The institution of biosecurity precautions presupposes the determination of which pathogens would pose a significant risk to security and to public and environmental health if they were stolen or diverted” and that “Biosecurity is such

26 Harris was arrested again in 1998 for possession of anthrax, but because the pathogen he possessed was a nonlethal strain of anthrax used to create vaccines, authorities were unable to prosecute him for possession of a biological agent for use as a weapon, and he received a five-month probation extension and an additional fifty hours of community service. For more, see Amy E. Smithson and Leslie-Anne Levy, *Ataxia: The Chemical and Biological Terrorism Threat and the US Response*, (Washington, DC: Henry L. Stimson Center, October 2000), 41-2.

27 Jonathan B. Tucker, “Preventing Terrorist Access to Dangerous Pathogens: The Need for International Biosecurity Standards,” *Disarmament Diplomacy* 66 (September 2002), accessed 14 January 2011, http://www.acronym.org.uk/dd/dd66/66op2.htm.

a new field that in the United States and some other countries the benefits and costs of various biosecurity measures are still being evaluated."[29] While the biosecurity legislation passed by Congress and the lawmakers of other countries did much to reduce the risk that rogue actors such as Larry Wayne Harris could acquire certain pathogens from laboratories and collections, it failed to address the possibility that those seeking to commit murder with biological weapons could develop new agents using genetic engineering techniques. Nor does it deal with the possibility that attackers could conceivably extract and cultivate agents from natural sources.

CHEMICAL WEAPONS CONTROL

As was true for biological weapons, the 1925 Geneva Protocol played a critical role in the development of the existing chemical warfare governance regime. Like the BWC, the Chemical Weapons Convention originated in intergovernmental talks on CBW that began in 1968.[30] Yet efforts to limit the use of chemicals in war far predate those relating to biological weapons. France and Germany agreed to prohibit the use of poison bullets in the Strasbourg Agreement of 1675; in 1874, the Brussels Convention on the Law and Customs of War banned the use of poison and arms, projectiles or material to cause unnecessary suffering.[31] In 1899, the Hague Convention of 1899 banned its signatories from using projectiles whose object was "the diffusion of asphyxiating or deleterious gases."[32] These agreements, however, were largely hypothetical, as states had signed on to them before any significant wartime use of chemical

28 Amy E. Smithson, "The Biological Weapons Threat and Nonproliferation Options: A Survey of U.S. Decision Makers and Policy Shapers," *CSIS Report*, November 2006, accessed 14 January 2011, https://csis.org/files/media/csis/pubs/061129_biosurvey.pdf, 6.

29 Ibid.

30 Robinson, "Chemical & Biological Weapons," 79.

31 Thakur and Haru, *The Chemical Weapons Convention*, 6-7.

32 Declaration on the Use of Projectiles the Object of Which is the Diffusion of Asphyxiating or Deleterious Gases; 29 July 1899, The Avalon Project, accessed 16 January 2011, http://avalon.law.yale.edu/19th_century/dec99-02.asp.

weapons had taken place. Moreover, they were reciprocal agreements, meaning that states were still free to use chemical weapons against non-signatories of these conventions.[33]

Thus it was not until the horror of chemical weapons was revealed during World War I that an impetus grew for a ban on chemical use, hence the signing of the Geneva Protocol of 1925. However, the treaty did not ban the production and stockpiling of chemical weapons, and many states reserved the right to respond to a chemical attack with chemical warfare themselves. Consequently, a number of states maintained chemical weapons programs and developed new and more lethal compounds.[34] The negotiations on the CWC thus began as a result of concern about the escalating chemical arms race. However, efforts to negotiate a global treaty banning the production as well as the use of chemical weapons in war proved difficult. The BWC included a clause committing countries to begin negotiations on an international treaty banning chemical weapons,[35] but the CWC was not opened for signature until 1993.

The CWC prohibits developing, producing, acquiring, stockpiling, and directly or indirectly transferring chemical weapons; it also prohibits the use of riot control agents for military purposes. It also requires states parties to declare their chemical stockpiles and to destroy them according to a series of specific deadlines. The international arms control community had clearly learned a number of lessons from its experience with the BWC; the CWC includes a comprehensive verification and inspection scheme. Because "far more facilities produce, ship, or use chemicals than are involved in peaceful nuclear activities"[36] and "[t]oxic chemicals are integral to modern industry and medicine on a daily and routine basis, for example

---

33 Eric Croddy, Clarissa Perez-Armendariz, and John Hart, *Chemical and Biological Warfare: A Comprehensive Survey for the Concerned Citizen* (New York, NY: Copernicus Books, 2006), 170.

34 Pål Aas, Monica Endregard, Hans Christian Gran, and Bjørn Arne Johnsen, "Improved Countermeasures against chemical weapons are needed," Norwegian Defence Research Establishment (FFI), June 2007, 3.

35 Thakur and Haru, *The Chemical Weapons Convention*, 7.

as fumigants, herbicides, insecticides and printing ink,"[37] the CWC is careful to spell out activities that are forbidden and to permit the peaceful use of chemicals; the mandate of the Organisation for the Prohibition of Chemical Weapons (OPCW) is clearly defined.

Analyst Jessica Stern points out that the CWC focuses less on materials than does the NPT and other elements of the nuclear nonproliferation regime:

> First, it focuses on both facilities and materials in selecting sites for routine inspection. It targets not only sites at which specific materials are present but also those considered to pose a risk to treaty objectives. Any facility that could be converted to manufacturing chemical weapons is subject to routine inspection, even if no chemical covered under the CWC has ever been processed there. And second, if any CWC party becomes suspicious about activities at *any* site – including undeclared sites where no chemical manufacturing has ever taken place – it can demand a challenge inspection. The nuclear ban, by contrast, focuses principally on materials.[38]

Yet the very language used in the CWC does suggest that materials and equipment are essential components for the creation of chemical weapons. Stern points out in the same article that the CWC does not "provide for ongoing research into the types of chemical agents actually sought by proliferants or the types of technologies, precursors, or equipment proliferants actually use."[39]

36 Randall Forsberg, William Driscoll, Gregory Webb, and Jonathan Dean, *Nonproliferation Primer* (Cambridge, MA: MIT Press, [no date given]), 68.
37 Thakur and Haru, *The Chemical Weapons Convention*, 7-8.
38 Jessica Eve Stern, "Lethal Compounds: The New Chemical Weapons Ban," *Brookings Review*, 12, no. 3 (Summer 1994): 33-34.
39 Ibid., 34-35.

EXPORT CONTROLS: VOLUNTARY ARRANGEMENTS

Treaties, however, are not the only means by which states have sought to practice arms control and limit proliferation. Governments have also sought to exert restrictions through export controls. Export control regulations are federal laws that prohibit the unlicensed export of certain commodities or information for reasons of national security or protections of trade.[40] The rationale for such controls is that the proliferation programs of states such as India, Iraq, Iran, Libya, North Korea, and Pakistan that in the past relied heavily on foreign military assistance and dual-use items for many key elements today acquire such items by using legitimate commercial channels as cover for illicit transfers.[41]

According to one Argonne National Laboratory export control specialist quoted in a *Science Daily* article, "People now understand the importance of nonproliferation, but often don't understand how it works. Export control is where nonproliferation becomes real. We try to prevent controlled technology, equipment or materials from getting into the wrong hands."[42] Lynn Davis, who served as Under Secretary of State for International Affairs during the Clinton administration, made a statement in 1994 arguing for the continued relevance of export controls in the post-Cold War world:

> In the past, we and our allies had a clear understanding of the need for export controls. The Warsaw Pact countries, as well as other communist countries, posed a serious and clearly defined threat to the United States and to the West generally. We undertook to deny them access to weapons, dual-use items, and technologies. We and our allies agreed upon procedures for controlling exports to these destinations, including allowing for any nation to veto a specific export. Now we face a very different threat. There are still serious dangers, but there are more uncertainties...Our export control system for the post-Cold War world needs to respond to these new security threats...we will focus our export

---

40 "What Is Export Control?" Office of Research, University of Tennessee, 2006, accessed 17 January 2011, https://my.tennessee.edu/portal/page?_pageid=43,618777&_dad=portal&_schema=PORTAL.

41 Richard T. Cupitt, Suzette Grillot, and Yuzo Murayama, "The Determinants of Nonproliferation Export Controls: A Membership-Fee Explanation," *Nonproliferation Review* 8, no. 2 (Summer 2001): 70.

42 Argonne National Laboratory, "Export Control Helps Prevent WMD Proliferation," *ScienceDaily*, 10 February 2005, accessed 17 January 2011, http://www.sciencedaily.com /releases/2005/02/050210003119.htm.

> controls on those items which lead to the development of weapons of mass destruction, missiles, and dangerous conventional arms.[43]

Each export control arrangement is a means by which states can coordinate their own export controls and ensure that they are working together to prevent the proliferation of materials and equipment.[44] In other words, the Australia Group (AG), the Missile Technology Control Regime (MTCR), the Nuclear Suppliers Group (NSG), and the Wassenaar Arrangement,[45] set out guidelines that states can use in determining their own export control legislation. They also provide opportunities for states to share their experiences with export controls and information about denials of exports or countries or materials of concern. Unlike the treaties discussed above, these are informal and non-binding arrangements.

Despite the beliefs held by Davis and other officials that export controls continue to be important even in a post-Cold War world, states have struggled to adapt the four major export control arrangements to the new security environment. According to one analyst, "Consequently, the four major export control arrangements entered into an era of stagnation without their

---

43 "Export Controls and Non-proliferation Regimes in the Post-Cold War World," testimony of Under Secretary for International Security Affairs Lynn E. Davis before the Senate Subcommittee on International Affairs and Monetary Policy, 24 February 1994.

44 The AG's export controls cover chemical weapons precursors, dual-use chemical manufacturing equipment, dual-use biological equipment, biological agents, plant pathogens, and animal pathogens. The NSG Guidelines cover nuclear material, nuclear reactors, non-nuclear material for reactors, reprocessing and enrichment equipment, and nuclear-related dual-use items and technologies.

45 Like the NSG and AG, the MTCR is a non-binding political arrangement intended to control exports of items related to rocket and unmanned air vehicle systems capable of delivering nuclear, chemical, and biological weapons. However, there is currently no multilateral treaty regulating possession, development, or trade in missile technologies, primarily due to the fact that it is virtually impossible to distinguish between legitimate materials and technologies and those which can be used for NBC-related purposes. It will not be discussed in greater detail in this paper. For more on the MTCR, see Daniel Joyner, *International law and the proliferation of weapons of mass destruction* (Oxford, UK: Oxford University Press, 2009), 40-42. The Wassenaar Arrangement relates only to conventional weapons and to dual-use equipment that can be used for civilian or military purposes, but is not usually included in discussions of control regimes related to NBC weapons; therefore it too is beyond the scope of this paper.

members having resolved several critical deficiencies in the multilateral system."[46] Experts acknowledge that export controls were never intended to entirely prevent NBC proliferation; their role is to make acquisition of materials and equipment more difficult, more expensive, and more time-consuming, factors that can dissuade some actors from acquiring these items.[47] Export controls, in other words, are intended as a stopgap measure to buy time. Nevertheless, they are an essential component of the nonproliferation regime as conceived in the post-World War II era.

NUCLEAR EXPORT CONTROLS

The NPT requires that its states parties maintain safeguards and export controls on the international supply of nuclear materials for peaceful purposes, but does not provide specific guidance on the goods and technologies to be controlled. Shortly after the entry into force of the NPT in 1970, multilateral consultations on nuclear export controls led to the establishment of two separate mechanisms for dealing with nuclear exports: the Zangger Committee and the Nuclear Suppliers Group (NSG).

The Zangger Committee was formed in the early 1970s to establish guidelines for implementing the provisions of Article III.2 of the NPT, which requires states parties to undertake "not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes, unless the source or special

46 Richard Cupitt, Statement to the United States Senate, Committee on Governmental Affairs, Subcommittee on International Security, Proliferation, and Federal Services, *Current and Future Weapons of Mass Destruction Threats*, Hearing, 7 November 2001, accessed 17 January 2011, . http://www.bioterrorism.slu.edu/bt/official/congress/cupitt110701.pdf

47 Ibid.; see also David Albright, Statement to the United States Senate, Committee on Governmental Affairs, Subcommittee on International Security, Proliferation, and Federal Services, *Nuclear Non-Proliferation Concerns and Export Controls in Russia*, 6 June 2002, accessed 17 January 2011, .http://www.exportcontrols.org/testimony.html

fissionable material shall be subject to the safeguards required by this article."[48] Between 1971 and 1974, 15 states, some of whom were already parties to the NPT and some of whom were considering becoming states parties, held a series of meetings in Vienna chaired by Professor Claude Zangger. Because the NPT did not define what constituted "equipment or material especially designed or prepared for the processing, use or production of special fissionable material," the goal of these meetings was to reach consensus on this definition, as well as to agree on conditions and procedures to govern the exports of these materials.[49]

In 1972, they spelled out the consensus they had reached in two memos known as the Zangger Committee Understandings. These Understandings enumerate three conditions of supply:

> (a) For exports to non-nuclear-weapon States, source or special fissionable material either directly transferred, or produced, processed, or used in the facility for which the transferred item is intended, shall not be diverted to nuclear weapons or other nuclear explosive devices;
> (b) For exports to non-nuclear-weapon States, such source or special fissionable material, as well as transferred equipment and non-nuclear material, shall be subject to safeguards under an agreement with the International Atomic Energy Agency (IAEA);
> (c) Source or special fissionable material, and equipment and non-nuclear material shall not be re-exported to a non-nuclear-weapon State unless the recipient State accepts safeguards on the re-exported item.[50]

These two memos became known as the "trigger list," since the items "trigger" IAEA safeguards. Examples of materials included on the trigger list include plutonium, highly enriched uranium (HEU), reactors, and reprocessing and enrichment plants, as well as equipment and components for such facilities.[51] The member states formally accepted these memos, in effect

---

48 "Treaty on the Non-Proliferation of Nuclear Weapons," 1 July 1968, accessed 18 January 2011, http://www.un.org/en/conf/npt/2005/npttreaty.html.
49 The Zangger Committee, "History," 13 January 2010, accessed 18 January 2011, http://www.zanggercommittee.org/History/Seiten/default.aspx.
50 Ibid.
51 Federation of American Scientists, "Zangger Committee," accessed 18 January 2011, http://www.fas.org/nuke/control/zangger/index.html.

making unilateral declarations that they would enforce the Understandings through domestic legislation.[52] Today, new members, who join by invitation, must do the same.[53]

The Nuclear Suppliers Group, also sometimes referred to as the "London Group," was created in 1974 following India's nuclear test, which had made suppliers realize that nuclear technology transferred to non-nuclear weapons states, even for peaceful purposes, could be diverted to unsafeguarded nuclear fuel cycle or nuclear explosive activities.[54] As a result, several Zangger Committee members joined forces with France and Japan – which were not yet states parties to the NPT – to build on the Zangger regulations.[55] In 1977, these countries established a set of criteria for exports that became known as the "London suppliers guidelines," which identified two additional conditions of supply:

> a. To apply physical protection measures on nuclear material; and
> b. To agree that any facility that was built on the basis of the know-how of supplied technology ("know-how clause") would be put under safeguards.[56]

Additionally, the NSG introduced the term "sensitive facilities," which identified facilities to which a transfer of technology should be handled especially carefully. These included reprocessing facilities and isotope separation facilities, both of which were categories included in the trigger list.[57] The NSG adopted the trigger list for its own guidelines, but also added a few additional items and technologies, such as heavy water production plants, and clarified some

52 The Zangger Committee, "History."
53 Federation of American Scientists, "Zangger Committee."
54 Federation of American Scientists, "Nuclear Suppliers Group," accessed 18 January 2011, http://www.fas.org/nuke/control/nsg/index.html; Nuclear Suppliers Group, "History of the NSG," accessed 18 January 2011, http://www.nuclearsuppliersgroup.org/Leng/01-history.htm.
55 The original meetings of nuclear suppliers, which took place in London in 1975, included the United Kingdom, Canada, France, the Federal Republic of Germany, Japan, the Soviet Union, and the United States. As an ad hoc arrangement, the NSG could include states that were not parties to the NPT, and because the discussions that took place were not directly associated with the NPT, participants could take a more flexible approach in developing a list of items and guidelines.
56 Fritz W. Schmidt, "The Zangger Committee: Its History and Future Role," *Nonproliferation Review* 2, no. 1 (Fall 1994): 39.
57 Ibid.

entries.[58] Furthermore, the Group agreed to apply its trade restrictions to all states, not just those outside the NPT.[59] These guidelines were published in 1978 as IAEA Document INFCIRC/254.[60] Other than the above additions, they were largely identical to the Zangger Committee's Understandings.

For many years following the adoption of the guidelines, the NSG did not meet, choosing instead to rely on the amendments to the trigger list made by the Zangger Committee in its meetings. This was due in part to the concerns of some parties to the NPT that the NSG operated as a "supplier cartel" and undermined the NPT's bargain between nuclear weapons states and non-nuclear states.[61] Several states, particularly France and the Federal Republic of Germany, regarded meetings of the NSG as an unnecessary provocation to non-aligned states.[62] However, the Gulf War led many to believe that there were a number of gaps regarding the implementation of Article III, particularly in terms of dual-use items and the lack of regulation regarding their export; consequently, the NSG stepped up its activities. In 1991 and 1992, the members of the NSG revised the guidelines that had been set out in 1977 to take into account technical developments. They also declared that non-nuclear weapons states, whether or not they were NPT members, would be required to complete an agreement with the IAEA implementing full-scope safeguards as a condition for transfers.[63]

---

58 Ibid.

59 Fact Sheets, "The Nuclear Suppliers Group (NSG) at a Glance," Arms Control Association, July 2009, accessed 18 January 2011, http://www.armscontrol.org/factsheets/NSG.

60 Nuclear Suppliers Group, "History of the NSG."

61 Ian Anthony, Christer Ahlström, and Vitaly Fedchenko, *Reforming Nuclear Export Controls: The Future of the Nuclear Suppliers Group*, SIPRI Research Report No. 22, Stockholm International Peace Research Institute (Oxford, UK: Oxford University Press, 2007), 17; Joyner, *International law*, 29-30.

62 Harald Müller, "Reform of the System of Nuclear Export Controls," in Harald Müller and Lewis A. Dunn, *Nuclear Export Controls and Supply Side Restraints: Options for Reform*, Programme for Promoting Nuclear Non-Proliferation Study Number Four (October 1993), 4.

63 Anthony et al., *Reforming Nuclear Export Controls*, 18; Joyner, *International law*, 32.

The NSG's major accomplishment, however, was to draw up new guidelines on the exports of dual-use items. The Zangger Committee's trigger list had only dealt with items with a major nuclear use,[64] and during the 1980s and 1990s, proliferators' procurement strategies had evolved away from a model in which capabilities or facilities would be diverted and into an illicit procurement model relying on dual-use equipment and exploiting the gap in export controls on these items.[65] Many dual-use materials could be used for indigenous production of items on the trigger list, thus enabling proliferators to evade the safeguards that they would encounter if they attempted to import these items.

CHEMICAL AND BIOLOGICAL EXPORT CONTROLS

The Australia Group (AG), according to its official website, is "an informal forum of countries which, through the harmonisation of export controls, seeks to ensure that exports do not contribute to the development of chemical or biological weapons."[66] Members aim to coordinate their national export control measures in order to better fulfill their obligations under the CWC and BWC.[67] Because the Group is an "informal forum," it has no charter or constitution; members are under no legally binding obligations as a consequence of their membership. Rather, according to the AG's promotional materials, "the effectiveness of their

64 Schmidt, "The Zangger Committee," 40-41.

65 Pete Heine, "Export Controls and the Problem of Secondary Proliferation Networks for APEC Economies," Lecture presented at the Effective Elements of Export Control for APEC Economies Conference, Honolulu, HI, 1-3 November 2005.

66 The Australia Group, "Main page," 2007, accessed 6 May 2010, http://www.australiagroup.net/en/index.html.

67 Both the BWC and the CWC ban the transfer, whether direct or indirect, of weapons. Article III of the BWC also bans the transfer of agents, toxins, equipment, and delivery systems. Article VI of the CWC bans states parties from transferring any Schedule 1 or 2 chemicals or precursors to non-parties, and they must get an end-use certificate from the non-party in order to transfer Schedule 3 chemicals. In the case of the CWC, these restrictions were originally intended to give countries an economic reason to join the treaty. In order to comply with these obligations – in particular, to avoid "indirect" transfers" – member states must adopt effective systems of export controls.

cooperation depends solely on a shared commitment to CBW non-proliferation goals and the strength of their respective national measures."[68]

The group's origins can be found in March 1984, when a United Nations investigation found that Iraq had used chemical weapons (CW) – specifically sulfur mustard and tabun – in its war with Iran, and was seeking chemical precursors from Western companies to develop other nerve agents such as sarin and VX.[69] Iraq was also believed to be developing an indigenous chemical weapons production capability through its partnerships with Western engineering companies, which assisted Iraq in the development of its chemical industry.[70] Officials were concerned that this trend could spread from the Middle East to other regions and that the use of CW by Iraq would weaken the norm against the use of chemical warfare agents and jeopardize the negotiations on the CWC that were occurring in Geneva at the time.[71] To address the issue of Iraq's acquisition of chemical precursors, fifteen countries, including the United States, Canada, Japan, New Zealand, Australia, and the then-ten countries of the European Union placed export controls on a number of chemicals that could be used as chemical weapon precursors. However, these controls suffered from a lack of uniformity in scope or application, and Iraq continued to successfully acquire the precursors it needed and to produce chemical weapons. Evidence suggests that Iraq had been shopping around international markets for some time, hoping to take advantage of the variations in the different countries' control lists.[72] Consequently, in early 1985,

68 Ibid.

69 Robert J. Mathews, "Chemical and Biological Weapons Export Controls and the 'Web of Prevention': A Practitioner's Perspective," in *A Web of Prevention: Biological Weapons, Life Sciences and the Governance of Research*, eds. Brian Rappert and Caitríona McLeish (London, UK: Earthscan, 2007), 164; see also Inventory of International Nonproliferation Organizations and Regimes, "Australia Group (AG)," James Martin Center for Nonproliferation Studies, 29 January 2010, accessed 6 May 2010, http://cns.miis.edu/inventory/pdfs/ag.pdf; "The Origins of the Australia Group," The Australia Group, 2007, accessed 6 May 2010, http://www.australiagroup.net/en/origins.html.

70 Mathews, "Chemical and Biological Weapons Export Controls and the 'Web of Prevention,'" 164.

71 Ibid.

72 The Australia Group, "The Origins of the Australia Group."

Australian officials conducted bilateral discussions with the other fourteen countries with export controls in which they suggested that the fifteen countries meet informally in order to harmonize their national export-control lists.[73] At the June 1985 meeting, the fifteen countries agreed that there was value in exploring the coordination of their export controls, and set up another meeting for September 1985 in Brussels, after which they met yet again in December 1985. At that meeting, it was decided to hold AG conferences annually in May at the Australian Embassy in Paris.[74]

Over the next several years, the Australia Group developed two lists of CW precursor chemicals – a core list and a warning list – over which member countries were expected to exercise some form of control. States are not necessarily required to control items on the warning list through licensing measures, but the purchase of these items could indicate possible proliferation-related procurement activities.[75] Following the discovery that Iraq was seeking to obtain dual-use chemical production equipment to enhance its chemical weapons stockpile, the Group also developed a dual-use chemical production equipment warning list.[76] Concern about biological issues as well as chemical weapons grew throughout the late 1980s;[77] as a result, the AG also developed export control lists for pathogens, toxins, and equipment that could be of interest to states seeking a BW capability.[78] The AG also continued to refine its lists of chemical weapons precursors and chemical production equipment, which were of all the more concern

73 Ibid.
74 Ibid.
75 James I. Seevaratnam, "The Australia Group: Origins, Accomplishments, and Challenges," *Nonproliferation Review* 13 (July 2006): 404.
76 Mathews, "Chemical and Biological Weapons Export Controls and the 'Web of Prevention,'" 164.
77 Elisa Harris, "Chemical and Biological Weapons: Prospects and Priorities After September 11," Brookings Institution, Summer 2002, accessed 6 May 2010, http://www.brookings.edu/articles/2002/summer_defense_harris.aspx.
78 Mathews, "Chemical and Biological Weapons Export Controls and the 'Web of Prevention,'" 166. Specifically, the lists dealing with biological materials are the List of Biological Agents for Export Control, the List of Plant

given Saddam Hussein's large-scale use of nerve agent against civilians in Halabja in March 1988.[79] In 1993, for the first time, the Australia Group adopted a full range of lists covering chemicals, dual-use chemical production equipment, and biological weapons-related items. The technological issues were thus settled, and all that remained was to maintain and consolidate the lists and to defend the activities of the group.[80]

The Australia Group meets annually to discuss participants' national-level export licensing measures and how they can be made more effective to ensure that would-be proliferators cannot obtain necessary inputs for a CBW program. In short, members of the Australia Group have interpreted their obligations under the CWC and BWC to mean that they have a responsibility to control the export of certain materials and technologies that could be dangerous from a proliferation perspective; as members of the AG, they share information with each other about their methods for doing so and have agreed to streamline and coordinate these methods as much as possible. The AG is currently comprised of forty-one members, including the European Commission.[81] A number of states, such as Russia and China, abide by the export control standards set out by the Australia Group, despite the fact that they have not officially applied for membership and do not attend AG meetings.

Pathogens for Export Control, the List of Animal Pathogens for Export Control, and the List of dual use Biological Equipment for Export Control.

79 Ibid.

80 Ibid., 167.

81 The European Commission, or EC, acts as the official representative of the European Union (EU) in the international arena and is responsible for negotiating international trade agreements and cooperation. An EU member state that is also a member of the AG must "implement the Guidelines in the light of its commitments as a member of the Union." See The Australia Group, "Main page." Some critics have remarked that the EU member states effectively act as a voting bloc, since the participation of the EC leads to the exclusion of individual dissent, ensuring that even EU members who support strong regulation will not vote for certain controls. See Seevaratnam, "The Australia Group," 413.

The development of the AG's export control list was originally seen as a short-term solution pending the conclusion of the CWC.[82] Although Australian Ambassador Paul O'Sullivan stated in 1992 at the CWC negotiations that the AG participants would "review…the measures that they take to prevent the spread of chemical substances and equipment…with the aim of removing such measures for the benefit of States Parties of the convention acting in full compliance with their obligations under the convention,"[83] the "short-term solution" persisted even after the CWC came into force, and the AG continued to develop and expand its control lists. It is important to note that O'Sullivan's statement was part of an ongoing effort to resolve the split between Western countries and the Non-Aligned Movement (NAM) with respect to obligations on sharing technology, a split that has continued to this day. Most NAM members were and are opposed to any export control measures outwith the treaty regime itself, arguing that such arrangements hamper their economic development. They contend that export control arrangements represent efforts of the technological "haves" to retain their economic, commercial, and scientific dominance and prevent those without access to such technology from changing their "have-not" status. In response, countries participating in such export control arrangements argue that treaty-based export control regimes are not sufficiently developed, that many state parties do not have adequate national export control systems, and that such arrangements are needed given the overall lack of attention to proliferation-related issues in many NAM member countries.[84] It is possible that resentment of export control regimes or the

82 Hassan Mashhadi, "Biological Warfare and Disarmament Problems, Perspectives, and Possible Solutions: Complementary Measures Inside and Outside the Framework of the BWC," *Politics and the Life Sciences* 18 (March 1999): 100.

83 Paul O'Sullivan, "Statement Made on Behalf of the Australia Group by the Representative of Australia," 629th Plenary Meeting of the Conference on Disarmament, CD/1164, 7 August 1992, quoted in Mathews, "Chemical and Biological Weapons Export Controls and the 'Web of Prevention,'" 167.

84 For more on this political debate, see Amanda Moodie and Michael Moodie, "Alternative Narratives for Arms Control: Bringing Together Old and New," *Nonproliferation Review* 17, no. 2 (July 2010): 301-321, doi: 10.1080/10736700.2010.485430.

acrimony surrounding this debate might lead some NAM countries to ignore their obligations under the treaties and transfer technologies to other states in some sort of solidarity with their fellow "have-nots."

Members are allowed to implement the AG's export controls as they see fit; for example, the United States exempts other AG members from licensing requirements for controlled chemicals on the condition that the recipient agrees not to re-export the chemicals to a third destination that would require a license for direct export.[85] Countries often create stricter controls than are suggested by the group,[86] as evidenced by the "catchall" provision, which allows a member to control a non-listed item if it is suspected of contributing to chemical and biological weapon development. The controls are *erga omnes*, meaning that decisions on exports are made on a case-by-case basis and there is no automatic blanket ban on exports to certain states.[87] The United States, however, identifies countries of proliferation concern, and approval or denial of license applications for export of AG-listed commodities is end-user driven: applications are denied whenever the credentials of the recipient are deemed to be unsatisfactory.[88]

AG members report which export licenses they have denied, but not those they have approved, in order to protect proprietary commercial and other information.[89] Members have a no-undercut policy, instituted in 1996, which means that if an AG participant has denied someone a license, another participant can only grant a request for the same item after

---

85 Jonathan B. Tucker, "Strengthening the CWC Regime for Transfers of Dual-Use Chemicals," Pugwash Meeting no. 324 (17-18 March 2007): 6.

86 Daryl Kimball, "The Australia Group at a Glance," Arms Control Association, November 2007, accessed 6 May 2010, http://www.armscontrol.org/taxonomy/term/46.

87 Jez Littlewood, "Export Control and the Nonproliferation of Materials: National Boundaries in International Science?" in *A Web of Prevention: Biological Weapons, Life Sciences and the Governance of Research*, Brian Rappert and Caitríona McLeish, eds. (London, UK: Earthscan, 2007), 152.

88 Seevaratnam, "The Australia Group," 405.

89 Tucker, "Strengthening the CWC Regime," 6.

consultation with the original license-denier.[90] Furthermore, industry exporters within member states must inform their governments if they are aware that an importer intends to use any import in a chemical or biological weapons program. In such a case, the government will decide whether to control the export.[91]

In order to deal with the rising threat of terrorism, the AG adopted a number of new measures in June 2002, including the "catchall" provision mentioned above, the addition of eight new toxins to the biological control list, and newly rigorous controls on the export of fermenters, which are central to the production of both biological and chemical weapons.[92] The group has recently expressed concern over the spread of technology by "intangible means" (Intangible Technology Transfers or ITT), and has sought to prohibit the transmission of CBW technologies by e-mail, phone, or fax, such as requiring a company to obtain government authorization to fax a "cookbook" for growth media.[93] It has also sought to provide a response to the emerging field of synthetic biology, and has made an effort to deal with the problem of secure electronic communications for information-sharing among members.[94] The Group also has made an attempt to deal with brokering and other intermediary activity, since it is possible that terrorists would rely on front companies or middlemen to acquire equipment or materials. In 2005, it agreed to conduct a survey on members' current controls relating to brokers,[95] and in 2007, the members

90 Seevaratnam, "The Australia Group," 411; Tucker, "Strengthening the CWC Regime," 6.

91 Seth Brugger, "Australia Group Concludes New Bio-Chem Measures," Arms Control Today, July/August 2002, accessed 6 May 2010, http://www.armscontrol.org/print/1076.

92 The Australia Group, "New measures to fight the spread of Chemical and Biological Weapons," 2002 Australia Group Meeting Summary, Paris, 3-6 June 2002, accessed 10 May 2010, http://www.australiagroup.net/en/agm_june2002.html.

93 Kimball, "The Australia Group at a Glance."

94 Rajiv Nayan, "Australia Group," Institute for Defence Studies and Analyses *CBW Magazine* 1 (July 2008), accessed 10 May 2010, http://www.idsa.in/cbwmagazine/AustraliaGroup_rnayan_0708.

95 The Australia Group, "2005 Australia Group Plenary," Sydney, 18-21 April 2005, accessed 10 May 2010, http://www.australiagroup.net/en/agm_april2005.html.

agreed that the activities of brokers and intermediaries should be factors of consideration in determining whether an export license should be granted.[96]

NEW INITIATIVES: ACTIVITIES, NOT ORGANIZATIONS

Many concerned with arms control and nonproliferation have observed that the existing regime, as exemplified through the three cornerstone treaties and the corresponding controls on trade in materials and equipment, has not kept pace with the evolving global security environment. As a result, a number of new approaches have been promoted. The initiatives below are examples of attempts to think about counterproliferation in innovative ways and to expand beyond the treaties and export controls. Yet these new approaches are based in the same assumptions that form the foundation of the traditional nonproliferation regime – that materials and equipment are essential components of proliferation, and that by controlling these items, states and non-state actors who desire to acquire and possess NBC weapons can be prevented from doing so.

PROLIFERATION SECURITY INITIATIVE

The administration of President George W. Bush was particularly concerned about failings of the treaty regime; many officials in the administration believed that the entire process of negotiating and implementing nonproliferation treaties was unnecessary and that the treaty regime was outdated and should be modified.[97] Consequently, in December 2002, the United States released its National Strategy to Combat Weapons of Mass Destruction. This document

96 The Australia Group, "2007 Australia Group Plenary," Paris, 4-7 July 2007, accessed 10 May 2010, http://www.australiagroup.net/en/agm_june2007.html.

detailed the government's plan for protection and response regarding NBC weapons, and outlined a strategy consisting of three pillars: counterproliferation (essentially, deterrence and defense against NBC employment); strengthened nonproliferation (including "new measures of prevention"); and consequence management (to reduce the impact of NBC attacks).[98] Most of the effort and funding, however, focused on the first pillar.[99] The National Strategy specifically identified interdiction as an essential component of the counterproliferation pillar.

To assist with this renewed effort on interdiction, the PSI was announced by George W. Bush on May 31, 2003 at Wawel Royal Castle in Krakow, Poland. President Bush stated, "The United States and a number of our close allies, including Poland, have begun working on new agreements to search planes and ships carrying suspect cargo and to seize illegal weapons or missile technologies. Over time, we will extend this partnership as broadly as possible to keep the world's most destructive weapons away from our shores and out of the hands of our common enemies."[100] John Bolton, then the U.S. Under-Secretary for Arms Control and International Security, stated that the PSI "reflects the need for a more dynamic, proactive approach to the global proliferation problem."[101]

The initiative's goal is to stop shipments of biological, chemical, and nuclear weapons, as well as missiles and goods that could be used to deliver or produce such weapons, to terrorists and countries suspected of trying to acquire such items. The PSI Statement of Interdiction Principles, which participants are required to endorse, calls on PSI participants, as well as other

97 Cirincione, *Bomb Scare*, 112; see also George Perkovich, "Bush's Nuclear Revolution: A Regime Change in Nonproliferation," *Foreign Affairs* 82, no. 2 (March/April 2003).
98 National Strategy to Combat Weapons of Mass Destruction, December 2002, accessed 24 January 2011, http://www.state.gov/documents/organization/16092.pdf: 2.
99 Cirincione, *Bomb Scare*, 113-114.
100 Joyner, *International law*, 299.
101 Statement by John R. Bolton, US Under-Secretary for Arms Control and International Security, before the House of Representatives Committee on International Relations (4 June 2003).

countries, to not engage in WMD-related trade with countries of proliferation concern and to permit their own vessels and aircraft to be searched if suspected of transporting such goods.[102] The initiative focuses mostly on training military and law enforcement personnel from PSI member states; it also allows states to share information regarding their domestic laws on counterproliferation. Most importantly, perhaps, it allows a country that has a concern about a particular shipment to notify other relevant nations, who can track the shipment and intercept it if necessary. Unlike the export controls enshrined in the Australia Group and NSG arrangements, which are not country-specific, PSI focuses on particular countries: Bolton indicated that PSI participants would not target the trade of countries perceived as U.S. allies or friends, such as India, Israel, and Pakistan, and would instead focus on countries viewed as threats by the participants.[103]

The PSI is a more flexible initiative than previous arrangements; its members view it as an "activity rather than an organization,"[104] and it is a voluntary partnership without a charter or any permanent staff. This loose affiliation has won it a number of supporters who might otherwise have been concerned about participating. Robert Joseph, who succeeded Bolton as Under-Secretary for Arms Control and International Security, told a Washington conference, "PSI has transformed how nations act together against proliferation...]It] is not a treaty-based approach involving long, ponderous negotiations that yield results only slowly, if at all. Instead it is a true partnership."[105] It is true that the PSI has arguably had some success in strengthening relationships between countries and fostering communication. Yet beyond this, it is difficult to

102 "Proliferation Security Initiative," U.S. Department of State, accessed 24 January 2011, http://www.state.gov/t/isn/c10390.htm.
103 John Bolton, quoted in "The Proliferation Security Initiative (PSI) at a Glance," Arms Control Association, October 2007, accessed 24 January 2011, http://www.armscontrol.org/factsheets/PSI.
104 Ibid.
105 Quoted in Cirincione, *Bomb Scare*, 116.

gauge the overall success of this effort. There is little data publicly available on interdictions; in 2005, then-Secretary of State Condoleezza Rice claimed that the United States and its partners in the PSI had carried out eleven interdictions in the previous nine months,[106] but there is no way to verify this. Nor is it possible to ascertain how many of these interdictions would have occurred had the PSI not been created. Moreover, while officials have often expressed a desire to use the PSI to interdict financial support for proliferation efforts, the available information does not suggest that it has moved beyond its initial focus on intercepting NBC materials.

GICNT

In contrast with the PSI, which focuses primarily on interdicting materials bound for states of proliferation concern, another major initiative of the Bush administration, the Global Initiative to Combat Nuclear Terrorism (GICNT), developed out of concerns regarding non-state actors' interest in acquiring nuclear weapons. The GICNT was launched by the United States and Russia on July 15, 2006, to expand and accelerate the development of their partnership capacity to combat the global threat of nuclear terrorism. In their initial statement, Bush and Russian President Vladimir Putin called on national governments to "ensure that law enforcement takes all possible measures to deny safe haven to terrorists seeking to acquire or use nuclear materials" and to adopt additional measures to deal with the threat of nuclear terrorism.[107]

Despite its bilateral origins, the Initiative is also open to other partner nations, which currently number 75. Participants have adopted a core set of principles designed to prevent, manage, and respond to attacks involving nuclear or radiological materials. An Implementation

106 Eben Kaplan, "The Proliferation Security Initiative," *Backgrounder*, Council on Foreign Relations, 19 October 2006, accessed 25 January 2011, http://www.cfr.org/publication/11057/proliferation_security_initiative.html.

107 "Joint Statement by U.S. President George Bush and Russian Federation President V.V. Putin Announcing the Global Initiative to Combat Nuclear Terrorism," Office of the White House Press Secretary, 15 July 2006, accessed 25 January 2011, http://www.whitehouse.gov/news/releases/2006/07/20060715-2.html.

and Assessment Group (IAG), which is responsible for coordinating the GICNT's activities, provides assistance to governments seeking to implement this GICNT Statement of Principles; it also helps to develop the work plan and measures of effectiveness for GICNT-sponsored activities.[108] Thus far, these activities seem to consist of briefings, workshops, and demonstrations to improve participants' law enforcement capabilities, although the Initiative members have agreed on an extensive list of projects to undertake in the future.

Like the PSI, the GICNT is organized to encourage broad participation; in theory, all a country has to do to join is to endorse the GICNT Statement of Principles, thereby avowing its commitment to combat the proliferation of nuclear materials and reduce the risk of nuclear terrorism. China joined the GICNT in its first year and hosted an emergency response workshop for Initiative participants. The Chinese government's participation was notable, given that it had refused to join the PSI. Some analysts have suggested that one reason for this may be because China saw the GICNT as a joint effort between the United States and Russia, rather than an exclusively U.S.-initiated initiative that reflects Washington's security priorities as does the PSI.[109] In any case, China's involvement is particularly important because the GICNT is one of the only forums in which the international community can engage with China on the subject of its nuclear materials.

The GICNT's activities are designed to "protect nuclear material, detect illicit nuclear trafficking, interdict and recover diverted nuclear items, and respond to nuclear terrorist incidents through measures focused on emergency response, consequence management, and identifying

108 Richard Weitz, "Global Initiative to Combat Nuclear Terrorism: Steady, but Slow Progress," *WMD Insights,* August 2008, accessed 25 January 2011, http://www.wmdinsights.com/I26/I26_G2_GlobalInitiative.htm.
109 Ibid.

and bringing to justice those responsible for actual or attempted nuclear terrorism."[110] Again, the emphasis is almost entirely on controlling materials and equipment.

UNSCR 1540

One of the most important measures to fall into this category of new initiatives is UN Security Council Resolution (UNSCR) 1540, a striking example of an innovative break with the past. Adopted by the Security Council on April 28, 2004, and twice renewed, the resolution mandates that all UN members must pursue a number of measures to ensure that terrorists do not succeed in acquiring or using NBC weapons or technologies. Resolution 1540 represents a unique step in the annals of arms control and nonproliferation, and it has been widely hailed for its potentially profound contribution to the fight against proliferation.[111]

All states have three primary obligations under UNSCR 1540: to prohibit support to non-state actors seeking chemical, biological, or nuclear weapons, means of delivery, and related materials; to adopt and enforce effective laws prohibiting the proliferation of these items, as well as assisting or financing such proliferation, to non-state actors; and to take and enforce effective measures to control these items.[112] Essentially, these requirements demand that states implement domestic legislation to prevent non-state actors from manufacturing, acquiring, or transporting NBC weapons within their territory. An ad hoc Committee which reports to the Security Council, known as the 1540 Committee, was established to monitor implementation of this legislation at

110 Ibid.
111 See, for example, Olivia Bosch and Peter van Ham, eds., *Global Non-proliferation and Counter-Terrorism: The Impact of UNSCR 1540* (Washington, DC: Brookings Institution Press, 2007).
112 UN Security Council Resolution 1540," U.S. Department of State, accessed 24 January 2011, http://www.state.gov/t/isn/c18943.htm.

the national level; states were required to submit a report on their implementation efforts to this Committee within six months of the resolution's passage.[113]

The novelty of the resolution stems from the fact that this was the first time that binding obligations on all UN member states to take and enforce measures against the proliferation of NBC weapons had been established. Additionally, it represents a new role for the Security Council in efforts to prevent proliferation. Because many states are concerned about the issue of terrorist access to NBC weapons, and because the resolution is intended to complement rather than replace the three major nonproliferation treaties, it was generally well-received. Several states sought advice on implementation of the requirements and on reporting, and cooperated with each other and with the 1540 Committee. States began to give serious consideration to their export controls as well.[114]

Yet despite these early signs of progress, the resolution has been plagued by controversies and challenges. Today, Resolution 1540 has a relatively low priority among many nations, perhaps because it has been deemed yet another example of "the heavy-handed imposition of 'one size fits all' Western security agendas on the developing countries of the South."[115] Developing countries argued at the time of the resolution's adoption that the Security Council overstepped its authority, excluding others from participating in negotiations and

113 "United Nations Security Council Resolution 1540," NTI Databases: UN Resolution 1540, Nuclear Threat Initiative, December 2010, accessed 24 January 2011, http://www.nti.org/db/1540/. As of December 2010, the 1540 Committee website lists 164 countries who have submitted their national implementation reports. There are therefore 28 members who have not submitted reports to date.

114 Merav Datan, "Security Council Resolution 1540: WMD and Non-State Trafficking," *Disarmament Diplomacy* 79 (April/May 2005), accessed 24 January 2011, http://www.acronym.org.uk/dd/dd79/79md.htm.

115 Tanya Ogilvie-White, "Facilitating Implementation of Resolution 1540 in South-East Asia and the South Pacific," in *Implementing Resolution 1540: The Role of Regional Organizations*, ed. Lawrence Scheinman (Geneva: UNIDIR, 2008): 46.

effectively behaving as a global legislator rather than an enforcer.[116] Certain members, including India, were critical of the fact that the resolution bound all of the UN member states, yet was adopted by a Security Council that consists of only fifteen members.[117] What was especially galling to many countries was their sense that the Security Council's five permanent members, who are also the five nations recognized as nuclear weapon states by the NPT, used their unique status to require other states to take action against proliferation without fulfilling their own treaty-based disarmament obligations.[118] Although the Security Council passed another resolution, UNSCR 1810, in April 2008 reaffirming the UN's commitment to 1540 and directing the 1540 Committee to "intensify" its efforts, states remain uncertain and skeptical about its legitimacy and their own compliance. During voting on Resolution 1810, Ambassador George Nene of South Africa, for example, stated that the language of the resolution is "far from ideal and does not fully reflect the view of the overwhelming majority of countries who believe that all weapons of mass destruction are illegitimate and that there is no grounds for claiming that these weapons are safe in some hands, but not in others."[119]

In 2011, the 1540 Committee must submit a report to the Security Council regarding overall implementation and compliance with UNSCR 1540. It is unclear at this point whether that report will be able to claim that the resolution has been successfully implemented. Moreover, while the passage of the resolution has been touted as an innovative step forward and

116 Johan Bergenäs, "Beyond UNSCR 1540: The Forging of a WMD Terrorism Treaty," James Martin Center for Nonproliferation Studies, 23 October 2008, accessed 24 January 2011, http://cns.miis.edu/stories/081022_beyond_1540.htm.

117 For example, India's representative stated: "We are concerned that the exercise of legislative functions by the Council, combined with recourse to Chapter VII mandates, could disrupt the balance of power between the General Assembly and the Security Council, as enshrined in the Charter." For more, see Nuclear Threat Initiative, "United Nations Security Council Resolution 1540."

118 Joseph C. Bristol et al., "A New Urgency for Nonproliferation: Implementing United Nations Security Council Resolution 1540," Woodrow Wilson School, Princeton University, January 2007: 12.

an important contribution to the field of arms control, it, like the other programs discussed above, is grounded in the same assumptions that put materials and equipment at the center of the nonproliferation and counterproliferation regime.

THREAT REDUCTION PROGRAMS: CTR AND THE G-8 GLOBAL PARTNERSHIP

Unlike the PSI and GICNT, the concept of cooperative threat reduction programs did not originate with the Bush Administration. Yet partner assistance programs designed to reduce the number of NBC-related materials and to secure those that remain have increased in number and scope over the past decade.

When the Soviet Union collapsed in the early 1990s, the United States no longer faced the threats of the Cold War; instead, it was confronted with a new set of security challenges. The Soviet Union had disintegrated into a number of independent countries, several of which were now in possession of the nuclear, chemical, and biological arsenals that had belonged to the Soviet government, and all of which had different levels of security. In response, at the instigation of Senators Sam Nunn and Richard Lugar, the United States Congress authorized $400 million in Department of Defense funds in 1991 to help Russia and other former Soviet states dismantle its weapons and delivery systems.[120] This Nunn-Lugar Act paved the way for

119 Quoted in Aaron Arnold, "UN Security Council Resolution 1540, PART I: Resolution 1810: Progress since 1540," *WMD Insights*, August 2008, accessed 24 January 2011, http://www.wmdinsights.com/I26/I26_G4_UNSCR1540_1.htm.

120 National Institute for Public Policy, "The Proliferation Security Initiative: A Model for Future International Collaboration" (National Institute Press: August 2009), 10.

the Cooperative Threat Reduction (CTR) program; since 1991, Congress has provided more than $1 billion per year to support CTR efforts.[121]

CTR program activities generally fall into four categories: dismantlement and destruction (specifically, providing leverage to encourage former Soviet countries to dismantle their weapons and providing them with equipment and training to do so); chain of custody (bolstering security around existing materials); demilitarization (which aims to decrease the long-term threat by reducing the economic pressures that might lead states to maintain their programs); and other programs (such as assisting in the development of civilian control of military departments).[122] CTR assistance helped Kazakhstan, Ukraine, and Belarus become non-nuclear weapons states and accede to the NPT. In recent years, the Department of Defense has focused its efforts on biological arsenals through the Biological Threat Reduction Program (BTRP), which is allocated about $250 million per year to help partners enhance biosecurity and to detect and respond to disease outbreaks. While BTRP focuses on the former Soviet Union, a corresponding, smaller program at the State Department called the Biosecurity Engagement Program conducts projects on biosecurity and surveillance outside this region.[123]

In 2009, the National Academy of Sciences' Congressionally-mandated report "Global Security Engagement: A New Model for Cooperative Threat Reduction," recommended an expanded Nunn-Lugar model of global security engagement to counter the 21st century terrorist threat.[124] The program is therefore now known as the Nunn-Lugar Global Cooperation Initiative, although it is still sometimes known as CTR or as Global Threat Reduction (GTR); its

---

121 Ibid.; see also "Cooperative Threat Reduction," Federation of American Scientists, accessed 25 January 2011, http://www.fas.org/nuke/control/ctr/index.html.
122 "Cooperative Threat Reduction," Department of Defense, accessed 25 January 2011, http://www.dod.gov/execsec/adr95/ctr_.html.
123 National Institute for Public Policy, "The Proliferation Security Initiative," 56.

administrators and supporters have begun to consider ways in which its model could be exported to countries outside of the former Soviet Union. In June 2002, at the G-8 summit at Kananaskis, President Bush called on the leaders of the other G-8 countries to contribute to this effort. He proposed that the G-8 contribute $20 billion, half of which would come from the United States, to CTR and other nonproliferation projects in the former Soviet Union over the next ten years.[125] The result was the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction. By 2004, 13 additional countries had joined the Global Partnership and added their resources.[126] Here again, the initiative relies on the commitments of sovereign states acting separately and in concert to eliminate and secure sensitive materials. Like PSI, the Global Partnership is an activity, not an organization.

To be fair, the threat reduction programs do go further than many of the other newer initiatives in attempting to move beyond an exclusive focus on materials. In 1998, as part of CTR, the United States launched an initiative to engage former Soviet biological weapons scientists;[127] today that effort continues through the Bio-Chem Redirect and Bio-Industry Initiative Programs, both of which are administered by the State Department.[128] State also oversees a number of other programs that focus on the knowledge-as-risk element of proliferation, including the Chemical Security Engagement Program (which implements scientific engagement capacity-building projects to deter terrorists from acquiring chemicals and chemical expertise), the Partnership for Nuclear Security (which aims to establish cooperative

124 "Nunn-Lugar Global Cooperative Initiative," Defense Threat Reduction Agency, accessed 25 January 2011, http://www.dtra.mil/missions/NunLugar/NunLugarHome.aspx.

125 National Institute for Public Policy, "The Proliferation Security Initiative: A Model for Future International Collaboration" (National Institute Press: August 2009), 10.

126 John R. Bolton, Remarks to the Chicago Council on Foreign Relations, 19 October 2004, accessed 26 January 2011, http://www.nti.org/e_research/official_docs/dos/dos101904.pdf.

127 Ouagrham-Gormley and Vogel, "The Social Context Shaping Bioweapons (Non)Proliferation," 9.

128 "Office of Cooperative Threat Reduction (ISN/CTR)," U.S. Department of State, accessed 26 January 2011, http://www.state.gov/t/isn/58381.htm.

partnerships related to the peaceful use of nuclear energy in support of global nuclear security and related safety and nonproliferation objectives), and the Science Centers Program (which supports two international science and technology centers that assist the global scientific and business community to engage with scientists and engineers in the former Soviet Union).[129] The Department of State also runs scientist engagement programs in Iraq and Libya.

These science engagement programs have met with some criticism as there seem to be few metrics to assess their success in achieving nonproliferation goals. Most programs measure performance by tracking the annual number of former Soviet weapons scientists, engineers, and technicians engaged in those programs' civilian projects,[130] but there is no way to prove that these scientists are not selling their expertise as well. Indeed, critics point out that given the ubiquity of internet access, there is a real danger that Soviet scientists will set themselves up as online consultants offering biological weapons expertise in exchange for money, and these programs do nothing to confront that challenge.[131] Others worry that the funding for such programs may enable states to save their money and resources to develop new bioweapons capabilities.[132] Still others are concerned that these programs appear to lack an exit strategy; they do not appear to provide an incentive for the former Soviet states to set up the infrastructure that would allow them to fund such civilian projects on their own. Moreover, there seems to be little integration between these initiatives on the part of the State Department and the other

---

129 In August 2010, Russian President Dmitri Medvedev signed a decree to pull Russia out of the International Science and Technology Center, which is located in Moscow and was formed in 1992 as part of the CTR program. Medvedev's government did not offer an explanation for the decision, but some have speculated that it may be due to the changing outlook for scientists in Russia. The decree is scheduled to go into effect in February 2011. For more, see David E. Hoffman, "Where will Russia's scientists go now?" *The World of Threats* blog, Foreign Policy, 18 August 2010, accessed 27 January 2011, http://hoffman.foreignpolicy.com/posts/2010/08/18/russia_pulls_out_of_program_for_post_soviet_scientists.

130 U.S. Government Accountability Office, *Weapons of Mass Destruction: Nonproliferation Programs Need Better Integration*, GAO-05-157 (Washington, DC: U.S. Government Accountability Office, 2005), 12.

131 Ouagrham-Gormley and Vogel, "The Social Context Shaping Bioweapons (Non)Proliferation," 11.

132 Ibid.

components of CTR, which are administered by the Defense Threat Reduction Agency, the Department of Energy, and other branches of the government.

CONCLUSIONS

Some readers may not be surprised that the treaties which are the bedrock of the nonproliferation regime are based on the assumption that policymakers could control proliferation by controlling the transfer or spread of materials and equipment. After all, they may argue, these treaties were written at a time when the relevant equipment and technology were largely the products of government-conducted or –supported research and development, and the scientists and technical experts who could work with such technology were virtually all employed by government-related enterprises. However, these readers overlook two facts: First, not all of these treaties date from an age when this expertise was the sole province of the government. While this assumption may have been correct when the NPT was concluded in the 1960s, it was no longer accurate when the CWC entered into force in the late 1990s. Thus the conceptual foundations of the most basic elements of the nonproliferation regime were shaky at best, even at the time of their creation. Second, changes and adaptations have been made to this regime, building on the basic norms and regulations enshrined by the treaties and, by extension, on the assumptions that form the basis for the treaties themselves. Yet while some policymakers have attempted to adapt the treaties to new scientific developments and capabilities, they have so far failed to acknowledge that these fundamental assumptions may no longer hold.

What is clear from an exploration of the existing regime is that it is entirely based on the assumption that proliferation can be limited by controlling access to materials and equipment. This is the origin of the safeguards requirement for non-nuclear weapons statements in the NPT;

of the prohibition of possession of biological weapons in the BWC; of the verification and inspection scheme of the CWC. This assumption undergirds the Zangger Committee, the NSG, and the AG, and the export controls which these groups aim to coordinate, as well as the requirements of UNSCR 1540 and the GICNT that countries maintain these controls. It led to a preoccupation with interdictions, which in turn led to the creation of PSI; to a lesser extent, it can even be seen in the Cooperative Threat Reduction program and the corresponding Global Partnership initiative. For over sixty years, policymakers and analysts have developed and built upon this nonproliferation regime without ever questioning its most fundamental assertion.

CHAPTER 2

CHANGES IN THE CONTEXT: THE NEW GLOBAL SECURITY ENVIRONMENT AND THE RISE OF KNOWLEDGE-BASED PROLIFERATION

Over the past sixty years, a number of challenges to the proliferation regime have arisen. The rapid changes wrought by globalization have meant that there are far more actors who can potentially pose a threat; the newly global reach of terrorists and other non-state armed groups means that these organizations are more relevant to national security than ever before, and these actors may have new interests in NBC weapons. Technology, meanwhile, has become far more domesticated and accessible, as a result of the rise of biotechnology and the development of new fields of science. Scientific advancements have become more geographically widespread, and thanks to online publications of scientific journals as well as terrorist "handbooks," the knowledge necessary for making an NBC weapon is now readily available. Policymakers therefore face the challenge of increasing diffusion of capabilities and knowledge, which makes it far more difficult for them to identify threats and presents them with the prospect that key scientific or technological advancements – or a proliferation threat – could come from anywhere and from any type of actor in the world.

EVOLUTION OF THE THREAT

Today, the United States and the rest of the world faces a new security paradigm and, consequently, new challenges to global security. Over the past several decades, non-state armed groups have become increasingly empowered; as conflicts between and among states have diminished in frequency, conflicts among sub-state groups and between such groups and governments have become increasingly important for the international security environment. In May 2008, at the fifth anniversary meeting of PSI partners, then-National Security Advisor Stephen Hadley described the differences between Cold War and post-Cold War proliferation threats:

> Then: One technology, nuclear weapons, was our primary proliferation concern. Now: We face increased threats from state and non-state actors seeking nuclear, chemical, biological, and radiological weapons—and many more methods of delivery.
> Then: Knowledge to make these weapons was a state secret. Now: Extremists can learn how to make a dirty bomb on the Internet.
> Then: Only states had the infrastructure necessary to manufacture weapons. Now: Dual-use or multi-use technologies are commercially available—and proliferation often hides behind legitimate commerce.
> Then: Only states had the missiles or bombers needed to deploy weapons of mass destruction. Now: A truck is the only delivery system a terrorist needs.
> Then: Arms control agreements and the IAEA seemed sufficient to meet the proliferation challenge. Now: Cold War institutions remain necessary, but not sufficient. And we need a new approach.[1]

The nature of warfare in the twenty-first century has changed dramatically from that of the early twentieth century. The traditional state-centered model of conflict has given way to a new security paradigm. Rupert Smith argues that this paradigm shift is driven by the end of the Cold War, as the latent intrastate struggles that had previously been held in check by the superpowers rose to the surface.[2] Many states whose borders had been arbitrarily drawn as a result of colonization and whose populations had thus been configured with no regard for shared values or identity suffered legitimacy problems as a result.[3] While Soviet Union officials claimed that communism was able to "eradicate" this problem by "eroding" the differences among states'

1 Quoted in National Institute for Public Policy, "The Proliferation Security Initiative: A Model for Future International Collaboration."

2 Rupert Smith, *The Utility of Force* (New York, NY: Penguin, 2006).

populations, in reality these problems remained beneath the surface. When these states regained their independence, their governments were plagued by structural weaknesses as a result of their lack of legitimacy. At the same time, globalization has empowered the non-state armed groups that engage in these intrastate struggles. As a result of the integration and increased interconnectedness of economies, non-state armed groups can more easily maneuver and move across borders. They can move and distribute resources more quickly to achieve their strategic goals, and it is more difficult than ever before to monitor this movement.[4] Additionally, the rise in information technology has made strategic communication within groups easier; it has altered the ways in which groups recruit and spread propaganda, as well as how they carry out attacks.[5] Finally, networks have enabled groups to become more decentralized and dispersed, thus making it more difficult for governments to find them and hinder their operations.

Analysts differ on whether terrorist groups, insurgents, criminal organizations, and other sub-state groups are likely to turn to NBC weapons to achieve their goals; it does seem clear that some groups are actively seeking to acquire such weapons. The best-known example of a sub-state group's interest in acquiring chemical and biological weapons is that of Aum Shinrikyo. The Japanese doomsday cult, described as "a wired, hi-tech, designer-drug, billion-dollar army of New Age zealots, under the leadership of a blind and bearded madman" whose ambition was to "paralyze the Japanese state and begin its historic mission of world domination,"[6] recruited scientists from the top Japanese universities to create biological weapons, including anthrax and

3 Kalevi J. Holsti, *The State, War and the State of War* (New York, NY: Cambridge University Press, 1996).

4 Querine H. Hanlon, "Globalization and the Transformation of Armed Groups," in *Armed Groups: Studies in National Security, Counter-terrorism, and Counterinsurgency,* Jeffrey Norwitz, ed. (Newport, RI: Naval War College Press, 2008), 137-147.

5 John Mackinlay, "Globalization and Insurgency," *Adelphi Papers* (No. 352, November 2002): 1-27.

6 David E. Kaplan and Andrew Marshall, *The Cult at the End of the World* (London, UK: Random House, 1997), 2-3.

Ebola, and chemical weapons such as sarin, mustard gas, and VX.[7] On March 20, 1995, Aum released sarin gas in the Tokyo subway in an attempt to trigger Armageddon. Although the group hoped to inflict mass casualties, the lack of an effective delivery system limited the impact to 12 deaths and a few hundred serious injuries.

Analysts have been concerned for some time that al Qaeda may also attempt to acquire chemical or biological weapons: numerous reports have claimed that Osama bin Laden has attempted to acquire unspecified chemical weapons from entities in Iraq and Sudan, as well as biological agents from suppliers in the Czech Republic, Kazakhstan, and Indonesia, although these claims have not been verified.[8] The group did launch a CW development program in the late 1990s in eastern Afghanistan, in which it experimented with several World War I-era chemical agents, including hydrogen cyanide, chlorine, phosgene, and mustard gas, at the Darunta training camp. Evidence suggests that local al Qaeda cells have also sought to acquire chemical weapons. In the buildup to the Iraqi war in early 2003, dozens of Algerians and other North Africans were arrested in Britain, France and Spain on charges of preparing ricin and other chemical weapons.[9] Also in 2003, an al Qaeda cell of five men in Saudi Arabia were found with plans for a home-made chemical dispersal device called a mubtakkar, intended to disperse hydrogen cyanide gas.[10]

---

7 Senate Committee on Governmental Affairs, Testimony by Jonathan B. Tucker before the Subcommittee on International Security, Proliferation, and Federal Services of the U.S. Senate Committee on Governmental Affairs, "The Proliferation of Chemical and Biological Weapons Materials and Technologies to State and Sub-State Actors," 7 November 2001, accessed 7 December 2010, http://cns.miis.edu/archive/cbw/ttuck2.htm.

8 Ibid.

9 "Ricin Fever: Abu Musab al-Zarqawi in the Pankisi Gorge," Jamestown Foundation, accessed 6 December 2010, http://www.jamestown.org/single/?no_cache=1&tx_ttnews[tt_news]=330.

10 Jonathan B. Tucker, "The Future of Chemical Weapons," *The New Atlantis*, 26 (Fall 2009/Winter 2010), accessed 7 December 2010, http://www.thenewatlantis.com/docLib/20100316_TNA26Tucker.pdf, 24.

The Kurdistan Workers' Party (PKK) in Turkey has allegedly expressed an interest in such weapons as well; an ex-member claimed that he had been ordered to build a sarin bomb[11] and that the group had tried to produce potassium cyanide and mustard gas.[12]

One analyst argues that this new interest in NBC weapons comes as a result of the rise of millenarian ideologies among terrorists: "Many of this so-called "new breed" of terrorists have an almost mystical fascination with chemical and biological agents because of the ability of toxic weapons to instill a pervasive sense of dread and their similarity to biblical plagues."[13] Others have suggested that because "conventional methods of assassination and bombing [have] become routine and accepted," because of a global population desensitized to violence, because of the increased number and accessibility of targets, and because of the diffusion of chemical, biological, nuclear, and radiological weapons-related technologies and production information, terrorists may be more likely to turn to NBC weapons.[14]

These changes to the global security environment, coupled with the developments of the scientific and information revolutions, pose serious challenges to the nonproliferation regime.

---

11 Senate Committee on Governmental Affairs, Testimony by Jonathan B. Tucker, "The Proliferation of Chemical and Biological Weapons Materials and Technologies to State and Sub-State Actors."

12 Alex P. Schmid, "The Ulitimate [sic] Threat: Terrorism and Weapons of Mass Destruction," *Global Dialogue* 2(4): Autumn 2000, accessed 7 December 2010, http://worlddialogue.org/content.php?id=112.

13 Senate Committee on Governmental Affairs, Testimony by Jonathan B. Tucker, "The Proliferation of Chemical and Biological Weapons Materials and Technologies to State and Sub-State Actors."

14 James K. Campbell, "On Not Understanding the Problem," in Brad Roberts, ed., *Hype or Reality? The "New Terrorism" and Mass Casualty Attacks* (Alexandria, VA: Chemical and Biological Arms Control Institute, 2000), 27-29.

MATERIALS AND EQUIPMENT: DIFFUSION OF CAPABILITIES

According to the National Research Council, "one can imagine a future where, as biotechnology continues to change radically, rather than becoming big and centralized, the life sciences and related applications may become increasingly domesticated and accessible," and "just as computer technology was transformed over the course of a few decades to a point where computers were small enough and cheap enough to be used in homes...and then to a point where computer games and toys became a dominant feature of children's lives, biotechnology may similarly be transformed."[15] The NRC understates the case, however – this has already begun to happen, and not just in relation to the life sciences or biotechnology industries. Materials and equipment once possessed only by university research programs dependent on government funding are now sold over the internet to individuals who want to set up laboratories in their garages. The technologies necessary to create an NBC weapon are now ubiquitous.

BIOTECHNOLOGY AND BIOSECURITY

This problem is perhaps most evident in considering biotechnology and the materials necessary to develop a biological weapon. As mentioned above, the discipline of microbiology and the advances it made in genetic engineering and manipulation were posing a challenge to the BWC almost as soon as the treaty negotiations were complete; advancements in genetics, molecular biology, and other relevant fields have proceeded at such a rapid pace since then that they almost seem to have taken on a life of their own. In the last seven or eight years, the sub-discipline of synthetic biology, which focuses on developing engineering solutions to life sciences, has emerged as a major force, as scientists advance in their ability to manipulate genes.

15 Institute of Medicine, *Globalization, Biosecurity, and the Future of the Life Sciences* (National Academies Press, Washington, DC, 2006), 27.

The combination of these fields with the practical elements of biotechnology has led to incredibly rapid advances. The accessibility of equipment has skyrocketed while its cost has proportionately declined. Some have referred to this phenomenon as the biological equivalent of Moore's Law, the claim that computing power doubles every two years.[16] In particular, the technologies of gene sequencing and gene synthesis have spread incredibly rapidly; these technologies allow scientists to adapt pathogens, a useful ability for developing medical advances that can cure diseases – or for creating biological weapons.

Microbiologist David Relman sums up this problem succinctly:

> Even our traditional concept of "weaponization" is misleading: nature provides mechanisms for packaging and preserving many infectious agents that can be manipulated through biologic and genetic engineering — for example, by enhancing the virulence of naturally sporulating organisms. Materials science and nanoscale science— advances in encapsulation technology, for instance — will provide new ways to package such agents...Tomorrow's science and technology will present a new landscape with features that are both worrisome and reassuring: the methods and reagents used for reverse-engineering a novel virus, for instance, can also be used to engineer a vaccine against it.[17]

In other words, the advancements made in gene sequencing could potentially lead to far more lethal weapons. Lynn Klotz and Edward Sylvester point out that while Relman's predictions are still a ways off in the future, work to that effect has already begun: "Luckily, there is still a distance from [DNA synthesis] to a potential bioweapon: it would be difficult and require a sophisticated molecular virology lab to enable such a 'handmade' smallpox genome to generate a live, infectious virus. Yet even that feat has already been accomplished with the much smaller

---

16 "IPF 2010: DNA sequencing: Faster, faster, ever Moore," *Physics Today*, 29 October 2010, accessed 28 January 2011, http://blogs.physicstoday.org/singularities/2010/10/ipf-2010-dna-sequencing-faster-faster-ever-moore.html.

17 David Relman, "Bioterrorism – Preparing to Fight the Next War," *New England Journal of Medicine* 354 (2006): 114.

poliovirus, so the gap likely will be closed." They also point out that scientists could use these technologies to "create a panoply of 'new and improved' toxins" as well as viruses.[18]

These advances do not require significant physical infrastructure. Relman writes, "[L]arge-scale industrial processes are not necessary for the development of potent biologic weapons. Increasingly, the means for propagating biologic agents under controlled conditions are being made accessible to anyone."[19] Yet much of the policymaking on biological weapons use and even bioterrorism has been based on the assumption that potential proliferators needed to rely on "large-scale industrial processes." Advancements in science and technology have meant that this is no longer so; as Relman says, the consequence is that traditional biological agents may become even more dangerous, while we may also face a threat from new agents that have not yet been invented.

Why has this shift taken place? As mentioned above, the main reason is the coupling of genetic engineering and biotechnology. Scientific fields focusing on DNA manipulation took off; the commercial sector fed these fields with technologies to enable these advances. Consequently, equipment and technology are now more readily available than ever before. As commercial companies create ever-more sophisticated equipment and tools, laboratories sell off their old instruments, ensuring that these technologies find their way into wide distribution – some equipment is readily available on eBay. Hobbyists also have the option of making their own equipment: the parts for a DNA synthesizer, which enables scientists to engage in gene sequencing and gene synthesis, could be purchased in 2004 for as little as $10,000, and many of these parts are simple plumbing elements and off-the-shelf electronics. According to biotechnologist Rob Carlson, the effort required to assemble such equipment is "similar to that

18 Lynn C. Klotz and Edward J. Sylvester, *Breeding Bio Insecurity: How U.S. Biodefense Is Exploiting Fear, Globalizing Risk, and Making Us All Less Secure* (Chicago, IL: University of Chicago Press, 2009), 22.

expended by many car and computer hobbyists," and interested individuals can find design information to help them assemble it online.[20] Of course, the fact that an individual has the equipment and capability to synthesize genetic material does not necessarily mean that that individual can manufacture a new organism, but it does mean that these abilities are within reach.

Moreover, a number of companies now offer to synthesize DNA on behalf of their paying customers – they provide synthetic DNA via mail to people who submit sequences over the internet, and not all of these companies check to see whether the sequences they have received are the sequences of pathogens or toxins.[21] This option is available because of the incredible decreases in cost to sequence DNA – the original human genome project cost around $3 billion, and in 2007, James Watson's DNA was sequenced for a cost of $2 million. In 2009 the cost of sequencing a genome was between $100,000 and $200,000; in September 2010, the National Human Genome Research Institute reported that the cost was less than $40,000, although it hopes to cut that cost to $1000 or less.[22] Carlson told a conference that the cost of sequencing a

---

19 Relman, "Bioterrorism – Preparing to Fight the Next War," 114.

20 Rob Carlson, "The Pace and Proliferation of Biological Technologies," *Biosecurity and bioterrorism: biodefense strategy, practice, and science* 1, no. 3 (2003): 208.

21 In a rare example of industry self-regulation, several European and American gene-synthesis companies have formed consortia to improve and update gene-sequence and customer screening procedures. However, the best practices adopted by these consortia do not apply to all companies: while the top five gene-synthesis companies, which have helped to develop such standards, represent 80% of the industry, smaller companies that do not participate in such regulation may nevertheless receive thousands of orders for genes and millions of orders for short DNA fragments each day. While it is laudable that the industry has recognized a potential security risk and has attempted to address it, the risk exists as long as these standards remain voluntary. Moreover, while the U.S. government has also attempted to introduce voluntary screening guidelines, these have generally been much weaker than those adopted independently by the consortia. Thus mandatory industry-wide regulation may remain a challenge for some time. For more, see Amy Smithson, "Pathogens and Arms Control: Can Bioscience Police Itself?" *Survival* 52, no. 5 (29 September 2010): 121-124, doi: 10.1080/00396338.2010.522100.

22 "IPF 2010: DNA sequencing: Faster, faster, ever Moore," *Physics Today*, 29 October 2010, accessed 28 January 2011, http://blogs.physicstoday.org/singularities/2010/10/ipf-2010-dna-sequencing-faster-faster-ever-moore.html.

single base of DNA has dropped from around $50,000 in 1995 to less than one tenth of a cent now.[23]

Complicated synthesizing equipment is not the only technology available on the open market. Biotech producers have begun to manufacture disposable components and systems, including bioreactors, in an effort to get around the problems posed by cleaning and resterilization procedures for traditional reusable hardware;[24] the manufacturer's advertisement for one such single-use reactor describes it as "Easy to buy (various options available), install and use – provides simplicity, less labour intensive and enables fast set up times."[25] Such small, disposable, self-contained reactors can easily be used to propagate viruses and microorganisms. Also available are pre-packaged kits to isolate DNA or add foreign DNA to bacteria; these kits are so ubiquitous and simple to use that they are literally being marketed to high-school biology teachers for use in their classrooms.[26] While these kits may not actually contain equipment that could be used to manufacture or develop a biological weapon, their availability suggests that biotechnology companies have recognized a market for easy-to-use technology and have sought to make it as widely accessible as possible. This serves to lower the barrier for biological weapons production.

Some analysts argue that the media has overstated the security threat posed by these life sciences and biotechnology advancements. One writes that "the capability to disseminate BW agents as an aerosol requires profound knowledge not only in microbiology, but also in aerosol

---

23 Richard Burge, "Is science going faster than policy?" Wilton Park, 14 January 2011, accessed 28 January 2011, http://blogs.fco.gov.uk/roller/wiltonpark/tags/wmd.

24 "Disposable Bioreactors Gaining Favor," *Genetic Engineering and Biotechnology News* 26, no. 12 (15 June 2006); Feliza Mirasol, "Disposable bioreactor use grows in commercial production," ICIS News, 4 March 2008, accessed 28 January 2011, http://www.icis.com/Articles/2008/03/10/9105767/disposable-bioreactor-use-grows-in-commercial-production.html.

25 "CellMaker PLUS," Cellexus, accessed 28 January 2011, http://www.cellexusinc.com/pages/content/index.asp?PageID=118.

techniques. This limits the threat of BW agents because only state-run programs or groups supported by states seem to be capable of mastering these technical challenges up to now. Not even Saddam Hussein's regime in Iraq shared its knowledge in this field with terror groups."[27] Klotz and Sylvester reiterate this point: in their book *Breeding Bio Insecurity: How U.S. Biodefense Is Exporting Fear, Globalizing Risk, and Making Us All Less Secure*, they criticize the U.S. Government for pouring so much money into defense against a bioterrorism act and argue that "Whatever large-scale threat we face from bioweapons, it is a threat from nations...Implicit in U.S. biodefense strategy is the presumption that terrorists living in caves or third-world slums are at this moment conceiving and producing biological weapons and delivery systems so sophisticated that our biodefense scientists must work to build them first – *in order to develop countermeasures against them*."[28] The heart of Klotz and Sylvester's argument is that bacteria and viruses are difficult to weaponize as aerosols, the most lethal form of attack: "The sophistication to weaponize and deliver bioweapons lies in the well-equipped laboratories of nations, not the dens of terrorists."[29]

It is true that it is difficult to aerosolize biological agents or to develop other delivery systems, but the biotechnology industry has been at work on technologies that could solve this problem – for example, many companies are working to improve inhalation technologies that will facilitate the diagnosis and treatment of respiratory diseases. It is possible that the advances made in this field could contribute to the development of technology that facilitates the aerosolization of viruses, and this technology could soon be readily available on the open market.

---

26 Patrick Guilfoile, "Biotechnology Topics in the Biology Classroom," ActionBioscience.org, August 2002, accessed 28 January 2011, http://www.actionbioscience.org/education/guilfoile.html.

27 Walter Biederbick, "Terrorism and potential biological warfare agents," in Magnus Ranstorp and Magnus Normark, *Unconventional Weapons and International Terrorism: Challenges and new approaches* (New York, NY: Routledge, 2009), 119.

28 Klotz and Sylvester, *Breeding Bio Insecurity*, 80; emphasis in original.

Thus what Klotz and Sylvester overlook is that the equipment formerly possessed by the "laboratories of nations" is easily acquired by non-state actors and could make its way into terrorists' "dens." Much of the biotechnology of concern is not covered by the AG's export controls, and the industry has grown with such rapid speed that there seems to be little in the way of private-sector regulation or engagement with governments to ensure that national and international security is being preserved.[30]

The cumulative impact of these developments is a new and multifaceted security risk. Would-be proliferators can pay companies to synthesize DNA for them, or can acquire disposable equipment or pre-packaged kits. The assumption that such malevolent actors require traditional large-scale physical infrastructure to create biological weapons therefore no longer holds; at the same time, as a result of the advances in the life sciences, these actors could potentially create far more contagious and/or lethal agents than ever before. While some question whether the most recent advances would make it easier immediately for terrorists to manufacture a biological weapon, these advances, combined with the rapid pace of technological change, mean that we should be concerned about this possibility and aware of the potential proliferation risk.

CHEMICAL EQUIPMENT AND TECHNOLOGY

In some ways, it is difficult today to tell the difference between new biotechnologies and chemical technologies, since the two fields overlap so frequently. Moreover, the changes in the

---

29 Ibid., 73.

30 This is not necessarily for lack of trying – in December 2005, the International Council for the Life Sciences, a membership-based organization, was launched to "[provide] a forum for the sustained engagement of the life sciences community and governments on a global basis" – but the council seems to have struggled to get much attention from the biotechnology industry. See "About Us," International Council for the Life Sciences, accessed 29 January 2011, http://www.iclscharter.org/eng/about_us.asp; Terence Taylor, "Safeguarding advances in the life sciences," EMBO Reports 7 (July 2006), S61-S64, doi: 10.1038/sj.embor.7400725.

life sciences field have been so dramatic that any advances in the chemical industry seem to have been quite overshadowed. Thus some might argue that there are few developments in chemistry that might pose a security risk, or that these developments should be simply wrapped up under the heading of "biochemistry" rather than treated as a separate category. Yet recent years have seen a number of advances that could have serious consequences for proliferation, a number of which focus specifically on the potential for chemical weapon development.

Given that the most successful terrorist attack using NBC weapons relied on sarin gas, those concerned about the potential for such attack should pay particular attention to the chemical field. Chemical weapons analyst Amy Smithson points to a number of reasons why terrorists might find chemical warfare agents attractive: such agents harm quickly, can be tailored to inflict maximum damage or delay the effects, and require equipment and materials that are relatively easy to acquire, such as reactors, piping, and storage vessels that can easily be purchased new or used. According to Smithson, estimates for setting up a full-scale plant to manufacture chemical weapons range from $5 million to $20 million, but a terrorist organization could make a much smaller investment and manufacture a smaller amount of agent that could still cause great damage.[31] She writes, "When accessibility of equipment, materials and know-how is taken into consideration, chemical agents appear to be the low-hanging fruit of unconventional arms."[32]

One technological advance making the acquisition of such arms even easier is the new development of microreactors. Traditionally, chemical weapons programs were believed to require large fermenters, tanks, and other enormous pieces of equipment. Dr. Matthew Meselson,

31 Amy E. Smithson, "Indicators of chemical terrorism," in Magnus Ranstorp and Magnus Normark, *Unconventional Weapons and International Terrorism: Challenges and new approaches* (New York, NY: Routledge, 2009), 68-69.

32 Ibid., 69.

a professor of natural sciences at Harvard, told one media outlet, "People who say that you can make these weapons in your kitchen just don't understand what's involved," arguing that the U.S. chemical weapons program developed during World War II demanded huge facilities at sites like Pine Bluff, Fort Detrick, and Dugway, and that Saddam Hussein had "something like 14 facilities they knew were connected with the program, the biggest of which was Al Hakam, with enormous equipment – fermenters and the like. So as far as we know, he didn't even get all the way there. Maybe some genius has a way of doing it in his garage, but that's not the way anybody's ever tried to do it--including Saddam."[33] Yet Meselson overlooks the fact that the rise of microreactors could, in fact, mean that "some genius" could develop a chemical weapon in his garage.

Microtechnology has been in development since the 1970s, but only began to flourish in the late 1990s. The most shocking feature about a microreactor is its compactness: its dimensions can range from the size of a credit card to the size of a notebook.[34] They are advantageous for the chemical industry for a number of reasons, ensuring that new chemical processes that would previously have been difficult or even impossible are now technically feasible, and some have wondered whether they can be used on an industrial scale or could even replace traditional chemical plants.[35] The growth of the microtechnology industry is manifest, with over 1000 studies describing possible uses of the technology.[36] In 2003, according to CPC's chief executive officer, Thomas Schwalbe, the microreactor market was "in the mid- to low-double-digit

---

33 Gerry O'Sullivan, "Media contagion: botching the science behind the bioterror headlines," 21stC Metanews 3, no. 2 (no date given), accessed 28 January 2011, http://www.columbia.edu/cu/21stC/issue-3.2/osullbio.html.

34 Tuan H. Nguyen, "Microchallenges of Chemical Weapons Proliferation," *Science* 309 (12 August 2005): 1021.

35 It is important to note that because of their small size, microreactors have to be designed for specific reactions. One cannot purchase a single microreactor and use it to carry out different types of reactions. Thus the company providing the microreactor would presumably need some details regarding its intended use. It is unclear how specific these details would need to be or whether companies would be able to infer an actor's malevolent purposes from these details.

36 Nguyen, "Microchallenges of Chemical Weapons Proliferation," 1021.

millions of dollars,"[37] while the Mainz Institute of Microtechnology (IMM) had increased its sales of microdevices by about 300% per year for three years in a row.[38] The cost of the most-purchased reactors ranges between $70,000 and $200,000, making them relatively accessible.[39] Moreover, these reactors are not currently on the AG list of export control items – meaning that no one is monitoring their purchase.

The many advantages of microreactors, as well as their recent prominence in the news, have made many aware of this emerging technology – and its potential to do harm. Despite the fact that the technology of microreactors is still in development and has not yet been fully integrated into industry, the devices nonetheless have already been used to synthesize deadly chemicals such as hydrogen cyanide and methyl isocyanate.[40] Evidently, microreactors can be used to make chemical substances that can be weaponized but that have not been used by terrorists or militaries in the past due to the inherent risks. They could also be used in the preparation of binary weapons, in which two less-toxic compounds are combined at the point of use to create lethal nerve gases such as soman or VX. Micromixers could reduce the time of this process to a few milliseconds and increase the output to several liters per hour.[41] The same principle applies to the "just in time" production of chemicals, which allows proliferators to

---

37 Marc Reisch, "Microreactors For the Chemical Masses," *Chemical & Engineering News*, 1 December 2004, accessed 29 January 2011, http://pubs.acs.org/cen/news/8248/8248earlybus.html.

38 Michael Freemantle, "'Numbering Up' Small Reactors," *Chemical & Engineering News* 81 (16 June 2003): 36-37.

39 Smithson, "Indicators of chemical terrorism," 81.

40 Nguyen, "Microchallenges of Chemical Weapons Proliferation," 1021. Methyl isocyanate is an unstable and highly toxic substance which demonstrated its potential as a chemical weapon in an industrial accident in Bhopal, India, in 1984. Because of its volatility, the transport of this chemical is dangerous, and consequently a group would be unlikely to take the risk of stealing it from a production plant. However, it is possible to manufacture it in a chemical reactor.

41 Holger Löwe, Volker Hessel, and Andreas Mueller, "Microreactors. Prospects already achieved and possible misuse," *Pure Applied Chemistry* 74 (2002): 2274.

"ramp up production" of chemical weapons at certain times[42] without storing large quantities of unstable or corrosive chemicals. Using microreactors could facilitate this process greatly, reducing the risk of discovery of an infrastructure designed to create weapons on demand. The faster reaction time of microreactors might also mean that new types of toxic chemicals could be developed and produced more quickly.[43]

Microreactors would also naturally attract those who hope to conceal their chemical weapons programs. The reactors are inherently small, easily hidden, and require little space. In addition to synthesis of the chemicals themselves, microreactors could also be used for creation of chemical weapons precursors such as thionyl chloride or methylphosphonyl difluoride (DF).[44] Because of the export controls of the AG and the CWC, it can be difficult for proliferators to obtain these chemicals from suppliers, and "back integration," the method of producing chemical weapon precursors from more basic chemicals, requires "substantial effort."[45] Attempts to synthesize or obtain these precursors are traditional signatures for chemical weapons proliferation; in fact, the Iraqi chemical weapons program of the 1990s was discovered in part because scientists attempted to buy thiodiglycol, a chemical precursor, on the international market.[46] However, microreactors might make the method of back integration easier and faster, thereby aiding proliferators in their attempts to make large volumes of chemical gases. Other detection methods might become obsolete as well: because microreactors are easily run on automation and pose less of a hazard to workers than traditional plants, the industrial

42 Charles Krauthammer, "'Just in time' WMD," Townhall.com, 10 October 2003, accessed 29 January 2011, http://www.townhall.com/columnists/CharlesKrauthammer/2003/10/10/just_in_time_wmd.
43 International Union of Pure and Applied Chemistry, *Impact of Scientific Developments on the Chemical Weapons Convention*, Draft Report Revision 1, 13 May 2007.
44 "Export Control List: Chemical Weapons Precursors," The Australia Group, November 2004, accessed 28 January 2011, http://www.australiagroup.net/en/control_list/precursors.htm.
45 US Congress, Senate, Committee on Governmental Affairs, Subcommittee on International Security, Proliferation and Federal Services, Hearing on Current and Future Weapons of Mass Destruction (WMD) Proliferation Threats, 107th Congress, 1st Session, 7 November 2001.

technologies associated with the manufacture of highly-toxic chemicals – such as high stacks or heavy-duty ventilation and scrubbing equipment – might not be necessary in a production line using microtechnology.[47] Consequently, the customary signatures of a chemical weapons program could become irrelevant, resulting in such a program becoming virtually undetectable.

The growing overlap between chemistry and biology could have implications for chemical proliferation as well. The automation of DNA synthesis and screening of chemical compounds have enabled laboratories to assess new chemical structures and have given scientists a better understanding of how chemicals behave. While these advances have many positive benefits, they could also mean that scientists can discover or design new chemical structures that may have utility as chemical warfare agents, thereby leading to an increase in the number of chemical agents.[48] Smithson points out that a "lone wolf" actor with mental problems or grievances to settle might be particularly keen to use next-generation warfare agents, including *novichok* chemicals or next-generation nerve agents, "in order to demonstrate above-average technical prowess and to create extra alarm and fear."[49] The increase in the number of such agents thus poses a serious risk.

The combination of these technical advances means that there are many more agents that now pose a potential threat; the time and effort needed to develop and manufacture these agents

---

46 Ian Hoffman, "Scientist: Terrorists could use microreactors," *Oakland Tribune*, 12 August 2005.

47 International Union of Pure and Applied Chemistry, *Impact of Scientific Developments on the Chemical Weapons Convention.*

48 Ralf Trapp, "Advances in Science and Technology and the Chemical Weapons Convention," *Arms Control Today*, March 2008, accessed 29 January 2011, http://www.armscontrol.org/act/2008_03/Trapp.

49 Smithson, "Indicators of chemical terrorism," 79. *Novichok* agents are a group of binary warfare agents which are manufactured by combining two or more chemical components just prior to use. Dr. Vil Mirzayanov, a former Soviet chemist, reported in 1991 that the Soviet Union had been researching and producing these agents; according to him, these agents are far more lethal than VX or soman. Czech scientists have also been experimenting with next-generation nerve agents that combine the characteristics of VX and sarin, but are more lethal because they can be absorbed via the skin or via inhalation.

have diminished; and the signatures that would suggest such development are now obsolete, making detection far more difficult.

NUCLEAR TECHNOLOGIES

Some may argue that the concern about technological diffusion's effect on proliferation does not apply to nuclear weapons, and it is true that there are obstacles to nuclear proliferation that do not exist for CBW. To make a nuclear weapon, one needs fissile material; highly enriched uranium and plutonium cannot be manufactured in a garage – at least not yet. Nevertheless, a number of technological advances over the past decade have increased the risk of nuclear proliferation.

Terrorists and other non-state actors probably will be unable to manufacture highly enriched uranium or plutonium on their own. However, as numerous scholars have pointed out, they could steal or purchase the relevant materials.[50] Joseph Cirincione writes, "If terrorists could buy or steal 25 kilograms of highly enriched uranium, a well-organized group could probably also obtain the necessary technical expertise to fashion a gun-assembly type bomb, similar to the Hiroshima bomb. In 1987, a group of U.S. nuclear weapons designers was commissioned to determine if this assumption was true. They concluded that such a task was achievable for 'terrorists having sufficient resources to recruit a team of three or four technically qualified specialists.'"[51] Today, there is a substantial risk that terrorists will attempt to steal from the civilian nuclear stockpiles in more than forty countries around the world, many of which do not have adequate protection measures in place.[52]

---

50 See, for example, Cirincione, *Bomb Scare*, 90; Charles D. Ferguson and William C. Potter, *The Four Faces of Nuclear Terrorism* (New York, NY: Routledge, 2005).
51 Cirincione, *Bomb Scare*, 90.
52 Ibid., 95.

Of course, the fact that this threat was of concern in 1987 suggests that it is not new. In the meantime, however, the world has seen a so-called "nuclear renaissance," in which states around the world have sought to develop civilian nuclear energy sources and pursue nuclear power as a result of concerns about climate change, increased energy use, and dependence on overseas supplies of fossil fuels. The result has been the global spread of nuclear materials and technologies. Today, there are 60 reactors currently under construction, 150 or more planned to come online in the next ten years, and over two hundred in development. Twenty-seven countries without nuclear power are planning to construct reactors.[53] While this growth will provide commercial opportunities and jobs in these countries, most of which are outside the OECD, there are serious concerns as to whether these states will have the same safety standards, physical protections, and nonproliferation concerns of current nuclear states, thus creating more possibilities for thefts by non-state actors. Experts are also concerned about the clandestine production of nuclear material at undeclared facilities, as well as the possibility that a state may acquire capabilities for "peaceful" purposes that it may then divert to weapons after withdrawing from the NPT.[54] In addition, some worry that illicit supplier networks, building on the A.Q. Khan experience, may be able to subvert export controls on nuclear-related technologies. Of particular concern are smaller companies who supply sensitive technology, such as components for gas centrifuges used to enrich uranium.[55]

Yet the nuclear renaissance is not the only major change that poses a nonproliferation challenge. Nanotechnology has begun to crop up in discussions of nuclear security as well as

53 "The Nuclear Renaissance," World Nuclear Association, December 2010, accessed 29 January 2011, http://www.world-nuclear.org/info/inf104.html.

54 "Challenges to the Non-Proliferation Regime," in *Non-Proliferation and the Nuclear "Renaissance": The Contribution and Responsibilities of the Nuclear Industry*, Energy Security Initiative at the Brookings Institution, Policy Brief 10-01, May 2010.

55 Ibid., 8.

chemical technologies. Once the stuff of science fiction, nanotechnology – which is, at its most basic, the science of manipulating matter on a molecular level – today has a wide range of applications for engineering, physics, chemistry, and biology. Indeed, the microreactors discussed above are one accomplishment of the science. Nanotechnology in fact has its origins in nuclear weapons laboratories, although it was then known as "micromechanical engineering" or "microelectromechanical systems" (MEMS).[56] A key design technique of nuclear weapons systems is to make the arming and triggering mechanisms as small as possible so that they can withstand the extreme acceleration at detonation. Thus the detonators and locking mechanisms were the earliest MEMS, and nuclear laboratories such as Sandia National Laboratories were the pioneers in this field.[57]

A related impetus was the desire to miniaturize nuclear weapons and develop low-yield nuclear explosives that could be used to create nuclear energy through controlled micro-explosions. Analysts have been particularly concerned about the applications of nanotechnology to new biological or chemical weapons, as it could be used to deliver such weapons in new ways, to develop new weapons by, perhaps, transporting molecules across otherwise impermeable cell membranes or the blood-brain barrier, or to evade medical countermeasures.[58] Yet it is possible that at some point in the future, this technology could also be used to create new, "fourth-generation" nuclear weapons, in which a superlaser or antimatter would trigger a relatively small thermonuclear explosion of a deuterium-tritium mixture in a device whose weight and size are

---

56 André Gsponer, "From the Lab to the Battlefield? Nanotechnology and Fourth-Generation Nuclear Weapons," *Disarmament Diplomacy* 67 (October/November 2002), accessed 29 January 2011, http://www.acronym.org.uk/dd/dd67/67op1.htm.
57 Ibid.
58 For more, see Margaret Kosal, "The security implications of nanotechnology," *Bulletin of the Atomic Scientists* 66, no. 4 (July/August 2010): 58-69, doi: 10.2968/066004006

not much larger than a few kilograms and liters.[59] This type of nuclear weapon would require little or no fissionable material. As a result, states and non-state actors who are currently attempting to buy or steal such material would find a major obstacle in their pursuit of nuclear weapons removed.

It is important to note that this is still only a theoretical possibility. The cost, both financial and in terms of energy, of such a development would be astronomical; while one analyst suggests that laboratories may be able to perfect this science in ten to fifteen years,[60] this estimate seems extraordinarily optimistic – others estimate that it could take a century or more. As well, such advancements would have positive implications for climate change and energy, as well as its potential negative effects for proliferation, and thus a world in which such weapons were possible might look entirely different. Nevertheless, a number of scientists and analysts have suggested that nanotechnology could have major implications for the nuclear nonproliferation regime and have argued for preemptive controls.[61]

It is also important to acknowledge that there is an ongoing debate about how easy it would be for a terrorist organization to acquire and use nuclear weapons, and that this debate has persisted since the Aum Shinrikyo case first drew policymakers' attention to the nexus of NBC weapons and terrorism. Scholars point out that building a nuclear weapon is extremely difficult; that built-in safeguards and self-destruct mechanisms would make it difficult for terrorists to use a weapon that they had stolen from state sources; and that the organization of terrorist groups

---

59 Gsponer, "From the Lab to the Battlefield?"

60 Ibid.

61 Ibid.; see also Angelo Baracca, "Threats to the non-proliferation regime: 'Fourth Generation' nuclear weapons," Europe for Peace, accessed 30 January 2011, http://www.europeforpeace.eu/en/103_threats-to-the-non-proliferation-regime-fourth-generation-nuclear-weapons; André Gsponer and Jean-Pierre Hurni, *Fourth Generation Nuclear Weapons*, INESAP (International Network of Engineers and Scientists Against Proliferation), Darmstadt, Technical Report No. 1, Seventh Edition, September 2000; Sean Howard, "Nanotechnology and Mass Destruction: The Need for an Inner Space Treaty," *Disarmament Diplomacy* 65 (July/August 2002), accessed 30 January 2011, http://www.acronym.org.uk/dd/dd65/65op1.htm.

poses as great an obstacle to nuclear weapons use as do the technical challenges. Some argue that terrorists are more likely to turn to biological or chemical weapons than nuclear technologies.[62] Yet even these doubting scholars admit that, while it is unlikely, a terrorist attack using nuclear weapons is possible and many groups may desire to obtain the necessary capabilities. Therefore, it is important to devote attention to the scientific and technological advances that may make it easier for them to do so.

GLOBAL AVAILABILITY OF SCIENTIFIC EXPERTISE: DIFFUSION OF KNOWLEDGE

The other side of the coin in terms of diffusion of proliferation risk is the global availability of scientific expertise. Gone are the days when the knowledge associated with making NBC weapons was the sole province of scientists and other experts employed by laboratories receiving government funding. This scientific knowledge has become globally available, thanks in part to the scientific revolution and in part to the rise of the internet.

GEOGRAPHICAL DIFFUSION

In recent years, more international players have become scientifically productive. China has rapidly emerged as a science superpower: it is spending approximately 1.5 percent of its GDP on scientific research and development, making it the third-largest spender on R&D in the world (behind the United States and Japan), and experts estimate that it may reach the U.S. figure of approximately 2.5% by 2020. It has also quickly become the world's second largest producer of scientific knowledge, surpassed only by the United States, as measured by the

62 See, for example, Karl-Heinz Kamp, Joseph F. Pilat, Jessica Stern, and Richard A. Falkenrath, “WMD

number of research publications.[63] Quantity means little if it is not backed up by quality; however, China's scientific collaborations with other countries better known for expertise in science are growing in number as well: nearly 9 percent of papers originating from Chinese institutions have a U.S.-based co-author, while collaborations with Japanese and British scientists are increasing as well. Collaboration with South Korea and Singapore almost tripled between 2004 and 2008, and Chinese scientists have also increased their work with their Australian counterparts, which some have suggested might point to an emerging Asia-Pacific regional network.[64] While the impact of these changes is most visible in China, many other countries have also been affected by the globalization of science. The Indian biotechnology industry grew threefold in just five years to report revenues of US$3 billion in 2009-10, and it hopes to increase this to $5 billion in the 2010-2011 fiscal year.[65] In 1999, South Korea launched its "Long-term Vision for Science and Technology Development Toward 2025," a plan consisting of 23 projects aimed, over a 10-year period, at significantly developing technologies that hold commercial potential, including nanotechnology, space technology and biotechnology. Each of these projects received at least US$1 billion in funding.[66] The volume of scientific publications is now increasing faster in China, India, and South Korea than in any Western

---

Terrorism: An Exchange," *Survival* 40, no. 4 (Winter 1998-99): 168-83.

63 Dirk Jan Van den Berg, "EU Must Act Fast and Share Knowledge with China," *Wall Street Journal*, 8 October 2010, http://online.wsj.com/article/SB10001424052748704696304575538072642688764.html?KEYWORDS=delft.

64 Jonathan Adams, "Science heads east," *New Scientist* 205, no. 2742 (6 January 2010): 24-25, doi: 10.1016/S0262-4079(10)60039-5.

65 "Indian Biotechnology Sector – Overview," European Business and Technology Centre, June 2010, last accessed 31 January 2011, http://www.ebtc.eu/pdf/Indian_Biotechnology_Sector-Overview_VO1.pdf, 2.

66 Graham Tearse, "Why Science is Golden for South Korea," *CNRS International Magazine* 10 (April 2008), accessed 31 January 2011, http://www2.cnrs.fr/en/1171.htm.

nation.[67] Research output in other developing countries has increased 194% in the past five years.[68]

A number of analysts have pointed out that in order to make these advances, many of these states continue to rely on assistance from the United States and other Western nations in one form or another. Many firms or universities in these countries partner with their Western counterparts in research cooperation agreements. As well, the number of students from other countries who receive science and engineering degrees in the United States has increased, as has the percentage of those students who return to their own countries after completing their education. Temporary residents earned approximately 13,700 science and engineering doctorates in 2007, as compared to 8,700 in 1995. As well, they earn considerable shares of the doctoral degrees granted in science and engineering fields: in 2007, foreign students on temporary visas earned half or more of doctoral degrees awarded in engineering, physics, mathematics, computer sciences, and economics, although only 30 percent of degrees granted in biological sciences were earned by international students.[69] Many of these students choose to return home after they complete their degrees: between 2004 and 2007, the percentage of U.S. degree recipients from China, India, South Korea, Taiwan, and Canada who reported definite plans to stay in the United States declined. Some suggest that they are being induced to go back by government incentives: "Successful Chinese, Korean, and Indian scientists are being successfully lured back to their home countries to new labs in new research centers stocked with the most advanced equipment.

---

67 Ibid.

68 "Research Output in Developing Countries Up 194% in Five Years," International Federation of Dental Educators and Associations, 2 July 2009, accessed 31 January 2011, http://www.ifdea.org/news/Pages/ResearchOutputinDevelopingCountries.aspx.

69 "Higher Education in Science and Engineering," in *Science and Engineering Indicators: 2010*, National Science Foundation, January 2010.

The Shanghai and Beijing municipal governments offer returning technology entrepreneurs tax breaks, subsidized office space and access to government-investment funds."[70]

What all this means is that the number of regions of the world where people can be found with the requisite ability to exploit knowledge that can do harm has grown significantly. For entirely legitimate reasons, scientific and technological knowledge is now dispersed among a much greater number of actors across a much greater area than ever before. As a result, the burden of potential risk has increased.

THE TRICKLE DOWN EFFECT: BIOHACKERS AND SCIENTIFIC JOURNALS

The geographical distribution of scientific experts is not the only factor that has changed over the past decade, however. Scientific knowledge has now "trickled down" such that a much larger number of individuals now have at least some scientific expertise. In part, this is due to the incredible advancements made in science and engineering – these rapid developments meant that scientific concepts that not long ago were the province of PhD candidates are now taught in high-school classes. While this has always been the case, this "trickle down" process is occurring at a faster pace than ever before. The kits mentioned above that enable high-school students to manipulate DNA are a case in point.

In 2004, biotechnologist Rob Carlson wrote, "The advent of the home molecular biology laboratory is not far off."[71] Only six years later, an article appeared in the Homeland Security Newswire which asserted that "do-it-yourself biology clubs have sprung up where part-timers

70 David Kang and Adam Segal, "The Siren Song of Technonationalism," *Far Eastern Economic Review*, March 2006, accessed 31 January 2011, http://www.feer.com/articles1/2006/0603/free/p005.html.
71 Carlson, "The Pace and Proliferation of Biological Technologies," 203.

share tips on how to build high-speed centrifuges, isolate genetic material, and the like."[72] These amateur enthusiasts, sometimes referred to as "biohackers" or "garage biologists," compare protocols and results from experiments they performed at home. One article disparagingly comments on the media coverage that has suggested that these amateurs could pose a threat, remarking on the "breathless warnings that a bioterrorist is busy crafting the next plague in a garage, safe from the watchful eye of the authorities...As for that imagined bioterrorist, US experts at the FBI's Weapons of Mass Destruction Directorate have investigated and found no sign of a biohacker who intends harm."[73] Yet the fact that there are individuals performing such experiments outside the confines of laboratories speaks to the remarkable availability and mass consumption of scientific knowledge.

One area about which analysts have been particularly concerned is the ready availability of information on scientific research with potential implications for proliferation. In 2001, while attempting to create a contraceptive vaccine, an Australian research team accidentally created a highly lethal mousepox.[74] Policy analysts, scientists, and journalists immediately panicked, calling it a "killer virus" and a "disaster in the making."[75] Yet concern seemed to center as much on the publication of the research in a peer-reviewed journal as on the ramifications of the research itself. According to two news articles, one biodefense scholar said, "I can't for the life of me figure out how we are going to deal with this," referring to "what are effectively blueprints

---

72 "Garage-lab bugs: spread of bioscience increases bioterrorism risks," Homeland Security Newswire, 13 August 2010, accessed 27 January 2011, http://homelandsecuritynewswire.com/garage-lab-bugs-spread-bioscience-increases-bioterrorism-risks.

73 "Garage biology," *Nature* 467 (7 October 2010): 634, doi:10.1038/467634a.

74 Ronald Jackson et al., "Expression of Mouse Interleukin-4 by a Recombinant Ectromelia Virus Suppresses Cytolytic Lymphocyte Responses and Overcomes Genetic Resistance to Mousepox," *Journal of Virology* 75, no. 3 (February 2001): 205–10; for more, see Smithson, "Pathogens and Arms Control: Can Bioscience Police Itself?," 117.

75 Rachel Nowak, "Killer Virus," *New Scientis*t, 10 January 2001, accessed 31 January 2011, http://www.newscientist.com/article/dn311-killer-virus.html; Rachel Nowak, "Disaster in the Making: An

for making microorganisms more harmful regularly appear in unclassified journals."[76] As a result, on 10 January 2003, editors from 32 leading life-sciences journals adopted a joint policy endorsing a security and safety review of potentially sensitive articles prior to publication and guidelines to request authors to revise papers deemed to have security implications. Few journals managed to institutionalize screenings for security concerns in submitted manuscripts, however.[77]

The debate reemerged in 2005 when two publications caused many to question whether the life sciences industry was doing enough to protect national security interests. In June 2005, an article appeared in the *Proceedings of the National Academy of Sciences* that modeled a bioterrorist attack on the milk supply of the United States. In October 2005, *Science* published the reconstructed genome of the 1918 pandemic human influenza virus.[78] Nevertheless, scientists resisted any restraints on open dissemination of such research, arguing that the risk of an NBC terrorist attack was outweighed by the benefit of future scientific work that could build upon the developments exposed in openly disseminated publications.[79] Donald Kennedy, editor of *Science* magazine, told a regional conference, "I think that almost everybody I know who is in the business of evaluating, peer reviewing and publishing scientific work realizes that they have some kind of a responsibility to reassure the public that they are conscious of this problem and watchful for it."[80]

Engineered Mouse Virus Leaves Us One Step Away From the Ultimate Bioweapon," *New Scientist*, 13 January 2001, 4–5.

76 Nowak, "Killer Virus"; Nowak, "Disaster in the Making."

77 Smithson, "Pathogens and Arms Control," 118.

78 "Biosecurity and Dual-Use Research in the Life Sciences," in *Science and Security in a Post 9/11 World: A Report Based on Regional Discussions Between the Science and Security Communities*, National Research Council (US) Committee on a New Government-University Partnership for Science and Security (Washington, DC: National Academies Press, 2007).

79 Ibid.

80 Ibid.

Most recommendations regarding publication of sensitive research have focused on the responsibility and education of individual scientists, as well as peer review processes. For example, the National Research Council published a study in 2004 entitled *Biotechnology Research in an Age of Terrorism* in which it recommended that professional societies create programs to educate scientists about the nature of the dual use dilemma and that "experiments of concern" be subject to a process of peer review by committee.[81] The U.S. National Science Advisory Board for Biosecurity has recommended similar steps. Critics point out a number of problems of this self-governance approach. In a 2007 survey of American life sciences researchers, only 28 percent felt that the knowledge or techniques from dual-use research might facilitate a bioterrorism attack;[82] many scientists therefore may not even be willing to consider self-governance of dual-use research, since they may not feel that it poses a security threat. As well, one analyst points out, "scientists hesitate to place any restrictions on each other's work and regard oversight mechanisms largely as a bureaucratic burden."[83] Even though some progress has been made in identifying voluntary guidelines, there is no evidence to suggest that publications will actually reject contributions as a result of security concerns. Finally, even if such regulations are successfully implemented and followed in the United States, this may not be the case in other countries. A survey of 28 international life-sciences journals, including three Chinese- and five Russian-language publications, found that most lacked policies and procedures to screen submitted manuscripts for information that might raise security concerns.[84]

---

81 National Research Council, *Biotechnology Research in an Age of Terrorism* (Washington DC: National Academies Press, 2004), 5-6.

82 National Research Council and American Association for the Advancement of Science, *A Survey of Attitudes and Actions on Dual Use Research in the Life Sciences: A Collaborative Effort of the National Research Council and the American Association for the Advancement of Science* (Washington DC: National Academies Press, 2009), 116.

83 Jan van Aken, "When Risk Outweighs Benefit," EMBO Reports, vol. 7, SI (2006), S13.

84 Smithson, *Pathogens and Arms Control*, 118; see also Jan van Aken and Iris Hunger, "Biosecurity Policies at International Life Science Journals," *Biosecurity and Bioterrorism* 7, no. 1 (20 April 2009), 61–72.

Concerns about information in the public domain are not unique to this era: just three days after the bombing of Nagasaki, on August 12, 1945, General Leslie Groves released the so-called Smyth Report, whose full title was *A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government, 1940-1945*. This report, essentially a history of the Manhattan Project, was intended to give citizens and policymakers an understanding about what the bomb was and how it was made, and to disseminate basic technical information about nuclear weapons to better enable decision-making about the bomb's future. Yet the Soviets bought numerous copies of this report – "as many as they could find," according to one author.[85] Although the release of the Smyth Report was authorized by President Truman, many were highly critical of this decision, saying that it made the United States a "laughingstock" and that it "made [the] chore of shaping [the] security system a really hard one."[86] Yet information has only become more widely disseminated since the days of the Smyth Report; rather than having to resort to espionage and purchasing as many copies of an article as possible, terrorists and others who want to use the research contained therein can just pull up the journal's website.

"POISONERS' HANDBOOKS" ON THE INTERNET

Terrorists might be better served by relying on scientific journals' websites than on their own. The internet is extremely important to jihadist groups and other terrorists today, as it provides these groups with ideological cohesion within a geographically scattered movement. However, in terms of providing information to would-be attackers, many of the websites

85 Richard Lee Miller, *Under the cloud: the decades of nuclear testing* (The Woodlands, TX: Two Sixty Press, 1991), 63.

86 "Senate Committee on Atomic Energy," *Bulletin of the Atomic Scientists* 3, no. 2 (February 1947).

redistribute and circulate the same material.[87] A case in point is the chemical and biological "recipes" and discussions on jihadist websites. Numerous policymakers, from the Department of Justice to the Senate Committee on Intelligence, have pointed out that al Qaeda has a number of "training manuals" online; these contain a number of formulas that supposedly can be used to create deadly chemical gases or toxins (particularly ricin). Many of these formulas come from publications written by survivalists and right-wing extremists in the 1980s, such as *The Poor Man's James Bond* and *The Poisoner's Handbook*, which are still in circulation. They have been debunked by scientists and analysts for decades, yet al Qaeda persists in using these same formulas in its manuals; one article writes, "Careful examination of the electronic document shows that it is crammed with errors, seemingly the work of someone with little discernible sense, profoundly ignorant of the nature of simple compounds and incompetent in even minor procedures that would be conducted in a high school chemistry lab. What precious little information is actually factual can be found in any good general chemistry book."[88] One analyst who has done extensive research into the chemical and biological recipes on al Qaeda's sites notes that "forum members who engage in CBW discussions do not appear to be highly trained or professional scientists. Rather, they seem to draw their knowledge from media and the internet...It is not surprising, therefore, that the most popular online recipes are those that are quick and easy and do not require advanced laboratory equipment."[89]

---

87 For more on terrorists' use of the internet, see Hanna Rogan, *Jihadism Online – A Study of How al-Qaida and Radical Islamist Groups Use the Internet for Terrorist Purposes,* Forsvarets Forskningsinstitutt (FFI), Norwegian Defense Research Establishment: Kjeller, Norway, 2006; Tim Stevens and Peter R. Neumann, *Countering Online Radicalisation: A Strategy for Action,* Policy Report published by The International Centre for the Study of Radicalisation and Political Violence (ICSR), King's College, London, UK: 2009; Timothy L. Thomas, "Al Qaeda and the Internet: The Danger of 'Cyberplanning,'" *Parameters (*Spring, 2003): 112-123.

88 National Security Notes, "The Recipe for Ricin, Part II: The legend flourishes from the Dept. of Justice to the Senate Intelligence Committee," GlobalSecurity.org, 4 March 2004, accessed 31 January 2011, http://www.globalsecurity.org/org/nsn/nsn-040304.htm.

89 Anne Stenerson, "Chem-bio cyber class: Assessing jihadist chemical and biological manuals," *Jane's Intelligence Review*, September 2007, 11.

Yet although evidence suggests that little of the information available on jihadist websites is new or efficacious, it does seem to be abundant. Moreover, the fact that jihadists appear to be publishing the same information on multiple sites is somewhat concerning: If terrorists were to acquire some of the information available in open-source research about which analysts have been concerned and publish it on their websites, this information could become available to a large number of terrorist operatives relatively quickly.

EXPLICIT VERSUS TACIT KNOWLEDGE

Kathleen Vogel and Sonia Ouagrham-Gormley distinguish between two different types of knowledge: tacit and explicit. As they explain:

> Explicit knowledge can be reduced to a written form (e.g., equations, laboratory protocols) and can be stored, copied, and transferred through impersonal means such as lab notebooks, e-mail messages, or computer files. In contrast, tacit knowledge is more personally held or unarticulated (e.g., skills, tricks of the trade, sense of visual and tactile cues) and sometimes unrecognized: an individual does not realize that he or she is doing things a certain way and that it is important for the success of an experiment. These characteristics make it especially difficult, or in some cases impossible, to reduce tacit knowledge to a written form. Research in the [science and technology] field has also shown that the absence of tacit knowledge can prevent the use of explicit information and make it difficult to repeat previously successful experiments even by experienced individuals. Scientists and other technical experts often develop that knowledge working either individually in a trial and error manner or by watching and replicating another scientist's work. S&TS scholars have argued that the acquisition and transfer of tacit knowledge from one person to another is a process that requires direct, often prolonged, interaction between scientists or other technical experts who often transmit their skills through master-apprentice relationships.[90]

They use the example of the U.S. and Soviet nuclear programs to demonstrate that explicit knowledge of physics and the possession of fissile material were not sufficient to create a nuclear weapon because of unique scientific and technical challenges that were specific to the context of

90 Ouagrham-Gormley and Vogel, "The Social Context Shaping Bioweapons (Non)Proliferation," 13.

each program. These challenges meant that development and inculcation of tacit knowledge was essential for these programs to succeed. What this suggests is that experiments appearing in open literature such as those described by Smithson and others are not necessarily easily replicable. Without the assistance of scientists who have performed such experiments previously, it would be very difficult for a terrorist, even one with expertise in synthetic biology or biochemistry, to replicate the results from the material appearing in scientific journals. Thus Vogel and Ouagrham-Gormley suggest that extended personal contact and hands-on instruction are necessary for proliferation, particularly with relation to nuclear weapons, but for bioweapons and chemical weapons development as well.

Yet as Vogel points out in an earlier article, such findings could have little application for a low-tech attack, where crude materials and basic scientific knowledge suffice.[91] Terrorists may seek to use NBC weapons for reasons other than obtaining the highest number of casualties; indeed, NBC weapons are not necessarily the most efficacious way to kill or injure a lot of people. If terrorists choose to use such weapons in a sustained campaign, rather than a single incident à la September 11, they may not be as concerned with attaining the maximum number of casualties. Thus acquiring tacit knowledge may be relatively unimportant and nonessential.

Moreover, Vogel and Ouagrham-Gormley may overstate the importance of such tacit knowledge in developing an NBC weapon. In 1998, the Defense Threat Reduction Agency (DTRA) planned a new initiative, known as Project Bacchus, to see whether it could set up a working germ factory and simulate the manufacture of large quantities of anthrax without anyone detecting its mission. With $1.6 million in funding, the project team was able to acquire everything it needed from commercial sources – including pipes, filters, a fermenter, and a

91 Bioweapons Proliferation : Where Science Studies and Public Policy Collide," *Social Studies of Science* 36, no. 5 (October 2006): 659-690, doi: 10.1177/0306312706059460

milling machine – and was able to turn out two pounds of anthrax simulants in just over a year.[92] While this project's goal was to demonstrate that a state or a well-funded non-state actor could develop biological agents without being detected, it also suggests that such actors could manufacture weapons without the input of tacit knowledge from former bioweaponeers. Furthermore, advances in biotechnology since Project Bacchus took place more than a decade ago may make it even easier for a small organization to engage in weapons research without being detected. Possibly Ouagrham-Gormley and Vogel's argument holds up for nuclear weapons – indeed, their example of the Soviet and U.S. projects seems to suggest that it does – but it does not seem to hold true for chemical or biological weapons.

BRAIN DRAIN

Finally, Ouagrham-Gormley and Vogel themselves admit that their argument may be challenged by the concept of "brain drain" - the idea that proliferators may hire foreign experts to work directly on their weapon programs, to advise their own personnel, or to train their own experts. There is no evidence to determine whether such tacit knowledge deteriorates over time, so Soviet bioweaponeers, for example, may still be able to sell their expertise to those who hope to proliferate.

Potential proliferators may hire foreign experts to work directly on their weapon programs, to advise their own personnel, or to train their own experts.[93] Many states have tried to deal with this issue by enacting legislation – for example, through secrecy laws that make it illegal for those with classified knowledge to transfer the information, such as the U.S. Atomic Energy Act, which prohibits U.S. nationals from sharing nuclear technology with others. The

92 Miller et al., *Germs*, 297-298.
93 Forsberg et al., *Nonproliferation Primer*, 77-78.

alternative solution is to reward scientists who do not sell their expertise by providing them with alternative employment, as the CTR program aimed to do.[94] Other programs, such as the Nuclear Cities Initiative and Initiatives for Proliferation Prevention, have also sought to provide scientists with expertise in NBC weapons with job and research opportunities.

While such initiatives are laudable and may well stop some scientists from selling their expertise for financial gain, they can do little about scientists who may be motivated by ideology. Some individuals may resent being supported by Western nations and may therefore look for sources of funding outside the brain-drain prevention programs, which might lead them to illicit activity. Others may empathize with non-state actors and desire to assist them. Thus CTR and the other brain-drain programs may have little effect if they are not coupled with efforts to enhance personnel security and reliability in laboratories in the former Soviet Union and elsewhere.

Nor can such programs deal with individuals who take advantage both of the brain-drain employment and the opportunity to earn extra money through providing expertise. Several analysts are concerned about the phenomenon of "moonlighting by modem," in which scientists can perform legitimate research as a day job and support foreign weapons programs by night, usually through email communications.[95] Ouagrham-Gormley and Vogel would argue that such email information exchanges would not be sufficient for a potential proliferator to develop an NBC weapons program, because any such information would be explicit rather than tacit, but so far the evidence has not supported this theory. Analysts have also suggested that rather than physically leaving Russia or their other home states to work abroad, weapons scientists may be enlisted to work on proliferation projects within their countries' own borders. One scholar writes,

94 Ibid.

95 See Jonathan Tucker, "Bioweapons from Russia: stemming the flow," *Issues in Science and Technology*, 15, no. 3 (Spring 1999); Sharon Weiner, "Controlling the Proliferation of Nuclear Knowledge from the Former Soviet

"Former BW scientists living in Russia have been approached by foreign agents seeking information, technology, and designs, often under the cover of legitimate business practices to avoid attracting attention."[96] The existing brain-drain programs can provide legitimate employment and relieve the most immediate financial pressure on former weaponeers, but they cannot solve the problem of differing ideologies or of greed.

CONCLUSIONS

A number of factors have changed the proliferation environment, probably permanently, over the past decade. The empowerment of non-state actors has meant that there are more players in this environment than ever before and that they wield greater power today than at any point in the past. The globalization of science and technology education has meant that actors with the requisite knowledge to manufacture NBC weapons are more geographically dispersed than they have been in the past. The rapid developments in synthetic biology and biotechnology have led to increased availability of scientific equipment and the ability of non-scientists to perform scientific feats that would have been difficult for PhD. candidates to accomplish just a few decades ago. New technologies have made the former signatures of proliferation programs virtually obsolete. The internet has made "recipes" and instructions for developing weapons far more readily available to the lay population.

Taken alone, any one of these factors might not pose a major challenge to the nonproliferation regime. Treaties can be amended or adapted; export control lists can be expanded; states can be encouraged to enact domestic-level legislation. Yet the combination of

---

Union," MIT Security Studies Program Wednesday Seminars, 26 April 2006, accessed 1 February 2011, http://web.mit.edu/ssp/seminars/wed_archives06spring/Weiner.htm.

these factors means that we now face a new type of proliferation threat – one based on how much people know and whether they plan to use that knowledge for malevolent purposes, rather than on what those people can acquire. The existing regime is ill-equipped to deal with this type of threat; its fundamental assumptions are now outdated.

96 Tucker, "Bioweapons from Russia: stemming the flow."

CHAPTER 3

WHAT DO WE DO NOW? A NEW CONCEPTUALIZATION OF NONPROLIFERATION

Some readers may believe that the changes in the global security environment described in the preceding chapters are relatively unimportant. They may argue, for example, that the new ubiquity of materials and equipment is irrelevant with regard to the threat of a terrorist NBC attack, because terrorists are more likely to steal weapons than to make them, or to jury-rig available agents rather than researching and developing new ones.[1] They may contend that the amount of open-source research available or the global diffusion of scientific knowledge are inconsequential, because even detailed explanations of how to perform such procedures are useless without face-to-face interaction to impart tacit knowledge.[2] They may even argue that terrorists are unlikely to turn to NBC attacks because of the risks involved and because of the havoc they can wreak using conventional means.[3] Yet what these arguments overlook is that the global environment is not the only thing that has become more complicated over the past decade. The proliferation threat itself is now complex and multifaceted, stemming from a number of different sources. No longer can we concern ourselves solely with the Soviet Union, or only with al Qaeda. Today, possible proliferators include state actors with the funding to embark on sophisticated scientific research; terrorist organizations with global reach and the ability to

---

1 See, for example, Klotz and Sylvester, *Breeding Bio Insecurity*.

2 See Ouagrham-Gormley and Vogel, "The Social Context Shaping Bioweapons (Non)Proliferation"; Vogel, "Bioweapons Proliferation : Where Science Studies and Public Policy Collide."

3 See John Parachini, "Putting WMD Terrorism into Perspective," *The Washington Quarterly* 26, no. 4 (Autumn 2003): 37-50; Peter Bergen, "Commentary: WMD terrorism fears are overblown," CNN, 5 December 2008, accessed 1 February 2011, http://articles.cnn.com/2008-12-05/politics/bergen.wmd_1_nuclear-weapons-chemical-weapons-mass-destruction?_s=PM:POLITICS.

communicate instantaneously with each member; lone wolf actors who can remain small-scale enough to avoid detection; insurgency movements who may be able to obtain support from states; and a host of others. An NBC capability does not necessarily mean that an actor will immediately try to use this capability to kill or injure as many people as possible: this actor could use this capability in a low-intensity attack, or in a sustained campaign, or could maintain a latent capability and wait to strike until the moment is right. Arguments like those cited above continue to overlook this growing complexity, uncertainty, and change. We cannot ignore significant scientific developments because they may or may not be irrelevant to the actors that we believe pose a threat at this point in time. Rather, we must acknowledge that these developments pose a problem for the regime that has evolved to deal with such threats, and recognize that this could have devastating consequences in the future.

INTENTS AND CAPABILITIES

If, as this paper has argued, NBC capabilities are coming within the grasp of a wider range of actors at an ever-accelerating pace, then the issue of intent becomes of crucial importance. Traditionally, analysts have assumed that "intent drives capability" – that would-be proliferators first make a decision that possessing NBC weapons will suit their strategic goals, and then settle on a method of acquiring them. Today, some have suggested that we face a new framework in which "capability shapes intent," where the primary driver of offensive capabilities is not a particular adversary but rather the ongoing advance of technology and scientific research.[4] In other words, actors may carry out scientific research out of pure curiosity and may

4 Institute of Medicine, *Globalization, Biosecurity, and the Future of the Life Sciences*, 59; see also Robert E. Armstrong and Mark D. Drapeau, "Life Sciences," in Neyla Arnas, ed., *Fighting Chance: Global Trends and Shocks in the National Security Environment* (Dulles, VA: Potomac Books, 2009), 141; Michael Moodie, "Conflict Trends in the 21st Century," *Joint Forces Quarterly* 53 (2009): 19-27.

decide to use this research for malevolent purposes later; alternatively, for groups that already aim to cause harm, scientific advances might lead a group to explore what it might be able to accomplish if it acquired such a capability. Obviously, the decision to *use* these weapons will still be affected by whether these actors believe that such actions will enable them to achieve their strategic goals.

As a result, one possible method of combating this new type of proliferation might be to try to influence intents. As we have seen, actors can acquire NBC capabilities more easily than ever before if they desire to do so; therefore it makes sense to focus on their desire to obtain NBC capabilities and use them, and convince them that such a decision is not in their best interest.

DETERRENCE AND SHAPING CHOICES

The idea of shaping choices and attempting to influence malevolent actors' intent is not a novel concept; on the contrary, it has its roots in deterrence theory. The National Strategy for Combating Terrorism suggests that we need not only to deter attacks through the prospect of an overwhelming response, but also to dissuade attacks by improving our ability to mitigate them.[5] In other words, deterrence can operate either by instilling fear of the consequences in potential actors, or by denying them operational success. Yet deterrence is ultimately a negative policy: it is a stick, not a carrot. Analysts point out that deterrence "is but one of many tools of influence and not always the most promising one."[6] If we focus on shaping choices rather than on "deterring" certain behaviors, however, we are presented with more alternatives for action and more opportunities to influence their behavior. While deterrence and coercion may be useful in

5 *National Strategy for Combating Terrorism*, September 2006, accessed 2 February 2011, http://www.cbsnews.com/htdocs/pdf/NSCT0906.pdf, 14.

targeting some terrorists in certain groups with particular ideologies, such as Osama bin Laden, different strategies may prove to be more successful when dealing with other actors. One study argues, "It is a mistake to think of influencing al Qaeda as though it were a single entity; rather, the targets of U.S. influence are the many elements of the al Qaeda *system*...A particular leader may not be easily deterrable, but other elements of the system (e.g., state supporters or wealthy financiers living the good life while supporting al Qaeda in the shadows) may be. What is needed is a multifaceted strategy that tailors influences to targets within the system."[7]

Thus what we are talking about when we talk about shaping choices is the idea of developing various methods of influence, including coercive methods and positive incentives, and determining which such method is likely to prevent a would-be proliferator from acquiring or using NBC weapons. Some research on this topic has already been performed, focusing largely on al Qaeda and other jihadist groups,[8] but further investigation is needed. For example, analysts could consider the following questions:

- How can we adapt our tools of influence to deal with different types of potential proliferators – for example, lone-wolf actors, state-level programs, or domestic extremists – in addition to jihadist terrorists?
- How might methods of influence differ for the disparate elements of a terrorist organization? For example, would positive incentives work better for a group's foot soldiers than for its leaders?

---

6 Brad Roberts, "Deterrence and WMD Terrorism: Calibrating Its Potential Contribution to Risk Reduction," IDA Paper P-4231, Institute for Defense Analyses, June 2007, 1.

7 Paul K. Davis and Brian Michael Jenkins, "Deterrence and influence in counterterrorism: a component in the war on al Qaeda," Santa Monica, CA: RAND, 2002: xi-xii.

8 See Roberts, "Deterrence and WMD Terrorism;" Lewis A. Dunn, "Next Generation Weapons of Mass Destruction and Weapons of Mass Effect Terrorism," ASCO Final Report, Defense Threat Reduction Agency, 31 January 2008.

- What other decision points are there for potential proliferators beyond the decision to acquire weapons and the decision to use them? How can we influence these decisions? For example, can we influence the choice of weapon, how it is acquired, or the target? How might focusing on these different decision points work to our advantage?
- How can we use the broader community – for example, in the case of jihadist terrorists, the Muslim community – to assist us in developing deterrence strategies and positive incentives?

In viewing proliferation of NBC weapons as a series of choices rather than a single decision that must be deterred, a wide range of policy options opens up to us. It is essential that we shift our thinking to move beyond deterrence of an attack and prevention of acquisition. While these strategies are of supreme importance, we also must think about how to develop positive incentives for nonproliferation and more generally about how to shape choices relating to proliferation.

NORMS AND TREATIES

The treaties described in the first chapter do not merely impose rules and regulations on their signatories. They also serve as the embodiment of the norm against NBC weapons. Julian Perry Robinson of the Harvard Sussex Program on Chemical and Biological Weapons draws our attention to "the existence of a uniquely wide array of societal constraints on CBW armament…Only nuclear weapons share this feature..."[9] With regard to chemical and biological weapons, Robinson suggests that this is caused by

9 Julian Perry Robinson, "Near-Term Development of the Governance Regime for Biological and Chemical Weapons," SPRU – Science & Technology Policy Research, University of Sussex, 4 November 2006, accessed 7 December 2010, http://www.sussex.ac.uk/Units/spru/nonstateactors/uploads/GovernanceRegimePaper.pdf, 5-6.

> an ancient cross-cultural taboo, evident in different literatures over the millennia, against weapons that exploit disease…Weapons of any type are designed to harm, and there is no obvious reason for regarding one type of weaponized harm as more (or less) reprehensible than another. Is it worse to be the victim of unnatural disease than, say, to be shattered by shell fragments? One may ask this and then be surprised that so strong an obloquy should nevertheless have attached to disease weapons and not to other weapons. There is an irrationality here whose very strength and depth is characteristic of taboo.[10]

Other analysts have argued that this taboo extends to the use of nuclear weapons, although not necessarily to their acquisition.[11] These arguments suggest that the norm against these weapons already exists, and that it can shape leaders' predisposition to acquiring these weapons. Consequently, it is essential that the NPT, BWC, and CWC remain in effect, and that world leaders and policymakers continue to amend them and enforce them in order to strengthen them. They are the foundation of consensus about the norm against the use and acquisition of these weapons.

One method of influencing actors' choices regarding proliferation is to strengthen these norms. In order to do so, we must continue to update and reinforce the treaties. This means strengthening the capabilities of the IAEA and OPCW and continuing the efforts of the BWC Work Programme while looking for a sustainable solution to the problem of verification. It also means refusing to allow partisan politics to get in the way of important arms control and disarmament work, as such initiatives demonstrate the United States' commitment to the norm of nonproliferation.

We must also acknowledge that the treaties and their corresponding export control organizations can no longer fully meet the proliferation threat. This does not mean that the

---

10 Ibid.

11 See, for example, Nina Tannenwald, *The Nuclear Taboo: The United States and the Non-Use of Nuclear Weapons Since 1945* (Cambridge, UK: Cambridge University Press, 2008); Thomas Doyle, "Taboos and Sanctions: Preventing the Acquisition of Nuclear Weapons," Paper presented at the annual meeting of the International Studies Association 48th Annual Convention, Hilton Chicago, Chicago, IL, 28 February 2007.

Australia Group's control lists, for example, should be jettisoned – that would be a mistake, as such initiatives only make it more difficult for would-be proliferators to acquire what they need. But it does mean recognizing that these methods are no longer sufficient. The NSG, the AG, and the treaty organizations have done their best to meet the challenge of the new proliferation, enacting new ITT requirements and adding new materials to their lists of controlled items. Such efforts are laudable, but they cannot disguise the fact that this regime was set up under assumptions that have not stood the test of time.

Therefore, analysts and policymakers need to consider the following questions:

- How can we adapt the export control lists such that they allow actors to continue using materials and technology for legitimate purposes, while also recognizing the risk posed by these technologies with regard to proliferation?
- Can the treaties be adapted to encourage international cooperation in preventing the exploitation of scientific knowledge?
- How can we continue to bolster the norm against acquisition as well as use of NBC weapons? To what extent will disarmament strengthen this norm? Can we leverage the momentum of the Global Zero movement to reinforce this norm?

MANAGING THE NEW ACTORS

It is not only the number of malevolent actors with access to technology that has increased over the past decade. Today, there are more actors than ever before who have a stake in preventing proliferation – and the ability to do something about it. Law enforcement agents and health professionals are now trained to deal with potential mass-casualty attacks using NBC weapons; scientists are repeatedly told that their work may have implications for national security; the biotechnology industry has sought to self-regulate to avoid selling its equipment to wrongdoers. Efforts have been made to integrate these communities and get them to work together with regard to nonproliferation through role-playing exercises and simulations at the local and regional level, but by and large these communities do not have opportunities to engage with each other and develop the relationships that will allow them to cooperate to this end.

A number of questions thus present themselves:

- What opportunities for interaction among these various actors already exist, and how can these opportunities be leveraged?
- To what extent should we focus on the nonproliferation options available to each such group and its responsibilities, as opposed to opportunities for collaboration? For example, should initiatives such as the International Council for the Life Sciences continue to focus on targeting one specific group of actors and encouraging that group to engage with government on proliferation-related issues? Or should such initiatives broaden their focus to encourage further collaboration between, for example, scientists and law enforcement?
- What incentives can be offered to encourage the life sciences, chemistry, and nuclear industries to continue to self-regulate? How can we encourage these industries to develop

and standardize security measures, such as personnel reliability programs or best practices for publication of security-sensitive articles?

KNOWLEDGE AS A COMMODITY

In essence, this paper argues for viewing knowledge as the primary driver behind the decision to engage in proliferation, rather than materials and equipment, which have traditionally been thought of as the determining factor. In other words, what people know of the basic science behind NBC weapons will lead them to decide whether or not to develop those weapons. This differs from the model of the Cold War, in which actors would make a decision to pursue these weapons before attempting to develop their capabilities, and their decision was influenced in part by whether they believed they could acquire the materials and equipment that would enable them to do so. This means that scientific knowledge is of critical concern. Perhaps, therefore, it makes sense to think of scientific knowledge as a commodity that can be traded, bought, or sold, as can materials and technologies. This raises a number of questions for analysts to consider:

- How can we build on the existing CTR and brain-drain programs to prevent the export of knowledge to potentially malevolent actors? Is offering them gainful employment on challenging projects sufficient?
- What lessons can be learned from the Russian decision to withdraw from the International Science and Technology Center? How can such programs strike an appropriate balance between providing assistance and allowing countries to develop their repository of scientific expertise independently?

- How can these programs deal with the emerging issue of "moonlighting by modem" in which scientists sell their expertise via the internet? Is a strategy of deterrence, of incentives, or some combination of the two the most successful approach to this issue?
- How else is knowledge being trafficked? What methods do we have to deal with this issue?
- To what extent is tacit knowledge necessary for proliferation? Can this be leveraged in prevention strategies, and if so, how?

CONCLUSIONS

It is frightening to think that the nonproliferation regime, in which many states and individuals have placed a great deal of faith over the past fifty years, may be underpinned by fundamentally wrong assumptions. But regimes are useless if they do not evolve and change to take new developments into account. We cannot ignore the fact that today's proliferation risks and threats are not the same as those of the 1960s, and we must encourage existing institutions to adapt and develop new initiatives to deal with the new challenges.

Obviously, there are no simple answers to any of the above questions. Some may argue that the risk of an attack using NBC weapons, whether by a state or a non-state actor, is low, and that we therefore should not invest energy in considering these issues. But the potential consequences would be so devastating as to be unimaginable. We must, therefore, challenge our thinking and attempt to answer these questions to the best of our ability.

BIBLIOGRAPHY

"The Baruch Plan, Presented to the United Nations Atomic Energy Commission." atomicarchive.com, accessed January 11, 2011, http://www.atomicarchive.com/Docs/Deterrence/BaruchPlan.shtml.

"About Us." International Council for the Life Sciences, accessed January 29, 2011, http://www.iclscharter.org/eng/about_us.asp.

"Atoms for Peace." IAEA, accessed January 12, 2011, http://www.iaea.org/About/history_speech.html.

"Biosecurity and Dual-use Research in the Life Sciences." In *Science and Security in a Post 9/11 World: A Report Based on Regional Discussions between the Science and Security Communities*, National Research Council (US) Committee on a New Government-University Partnership for Science and Security. Washington, DC: National Academies Press, 2007.

"Bioweapons Proliferation: Where Science Studies and Public Policy Collide." *Social Studies of Science* 36, no. 5 (October 2006): 659-690.

"CellMaker PLUS." Cellexus, accessed January 28, 2011, http://www.cellexusinc.com/pages/content/index.asp?PageID=118.

"Challenges to the Non-Proliferation Regime." In *Non-Proliferation and the Nuclear "Renaissance": The Contribution and Responsibilities of the Nuclear Industry*. Policy Brief 10-01: Energy Security Initiative, Brookings Institution, 2010.

"Cooperative Threat Reduction." Federation of American Scientists, accessed January 25, 2011, http://www.fas.org/nuke/control/ctr/index.html.

"Cooperative Threat Reduction." U.S. Department of Defense, accessed January 25, 2011, http://www.dod.gov/execsec/adr95/ctr_.html.

Declaration on the use of Projectiles the Object of which is the Diffusion of Asphyxiating Or Deleterious Gases, (1899). Avalon Project, accessed January 25, 2011, http://avalon.law.yale.edu/19th_century/dec99-02.asp.

"Disposable Bioreactors Gaining Favor." *Genetic Engineering and Biotechnology News* 26, no. 12 (June 15, 2006).

"Export Control List: Chemical Weapons Precursors." The Australia Group, accessed January 28, 2011, http://www.australiagroup.net/en/control_list/precursors.htm.

"Garage Biology." *Nature* 467 (October 7, 2010): 634.

"Garage-Lab Bugs: Spread of Bioscience Increases Bioterrorism Risks." Homeland Security Newswire, accessed January 27, 2011, http://homelandsecuritynewswire.com/garage-lab-bugs-spread-bioscience-increases-bioterrorism-risks.

"History of the NSG." Nuclear Suppliers Group, accessed January 18, 2011, http://www.nuclearsuppliersgroup.org/Leng/01-history.htm.

"Indian Biotechnology Sector – Overview." European Business and Technology Centre, accessed January 31, 2011, http://www.ebtc.eu/pdf/Indian_Biotechnology_Sector-Overview_VO1.pdf.

"IPF 2010: DNA Sequencing: Faster, Faster, Ever Moore." *Physics Today*, accessed January 28, 2011, http://blogs.physicstoday.org/singularities/2010/10/ipf-2010-dna-sequencing-faster-faster-ever-moore.html.

"Joint Statement by U.S. President George Bush and Russian Federation President V.V. Putin Announcing the Global Initiative to Combat Nuclear Terrorism." Office of the White House Press Secretary, accessed January 25, 2011, http://www.whitehouse.gov/news/releases/2006/07/20060715-2.html.

"Main Page." Australia Group, accessed May 6, 2010, http://www.australiagroup.net/en/index.html.

"*National Strategy for Combating Terrorism,*" accessed February 1, 2011, http://www.cbsnews.com/htdocs/pdf/NSCT0906.pdf.

National Strategy to Combat Weapons of Mass Destruction, 2002.

"The Nuclear Renaissance." World Nuclear Association, accessed January 29, 2011, http://www.world-nuclear.org/info/inf104.html.

"Nuclear Suppliers Group." Federation of American Scientists, accessed January 18, 2011, http://www.fas.org/nuke/control/nsg/index.html.

"The Nuclear Suppliers Group (NSG) at a Glance." Arms Control Association, accessed January 18, 2011, http://www.armscontrol.org/factsheets/NSG.

"Nunn-Lugar Global Cooperative Initiative." Defense Threat Reduction Agency, accessed January 25, 2011, http://www.dtra.mil/missions/NunLugar/NunLugarHome.aspx.

"Office of Cooperative Threat Reduction (ISN/CTR)." U.S. Department of State, accessed January 26, 2011, http://www.state.gov/t/isn/58381.htm.

"The Origins of the Australia Group." Australia Group, accessed May 6, 2010, http://www.australiagroup.net/en/origins.html.

"Proliferation Security Initiative." U.S. Department of State, accessed January 24, 2011, http://www.state.gov/t/isn/c10390.htm.

"The Proliferation Security Initiative (PSI) at a Glance." Arms Control Association, accessed January 24, 2011, http://www.armscontrol.org/factsheets/PSI.

"Research Output in Developing Countries Up 194% in Five Years." International Federation of Dental Educators and Associations, accessed January 31, 2011, http://www.ifdea.org/news/Pages/ResearchOutputinDevelopingCountries.aspx.

"Ricin Fever: Abu Musab Al-Zarqawi in the Pankisi Gorge." Jamestown Foundation, accessed December 6, 2010, http://www.jamestown.org/single/?no_cache=1&tx_ttnews[tt_news]=330.

"UN Security Council Resolution 1540." U.S. Department of State, accessed January 24, 2011, http://www.state.gov/t/isn/c18943.htm.

"Senate Committee on Atomic Energy." *Bulletin of the Atomic Scientists* 3, no. 2 (February 1947).

Treaty on the Non-Proliferation of Nuclear Weapons, (1968). United Nations, accessed January 11, 2001, http://www.un.org/Depts/dda/WMD/treaty/.

"The Zangger Committee." Federation of American Scientists, accessed January 18, 2011, http://www.fas.org/nuke/control/zangger/index.html.

Aas, Pål, Monica Endregaard, Hans Christian Gran, and Bjørn Arne Johnsen. *Improved Countermeasures Against Chemical Weapons are Needed*: Norwegian Defence Research Establishment (FFI), 2007.

Adams, Jonathan. "Science Heads East." *New Scientist* 205, no. 2742 (January 6, 2010): 24-25.

Anthony, Ian, Christer Ahlström, and Vitaly Fedchenko. *Reforming Nuclear Export Controls: The Future of the Nuclear Suppliers Group*. Oxford, UK: Oxford University Press, 2007.

Argonne National Laboratory. "Export Control Helps Prevent WMD Proliferation." *ScienceDaily* (February 10, 2005).

Armstrong, Robert E. and Mark D. Drapeau. "Life Sciences." In *Fighting Chance: Global Trends and Shocks in the National Security Environment*, edited by Neyla Arnas. Dulles, VA: Potomac Books, 2009.

Arnold, Aaron. "UN Security Council Resolution 1540, PART I: Resolution 1810: Progress since 1540." *WMD Insights* (August, 2008).

Baracca, Angelo. "Threats to the Non-Proliferation Regime: 'Fourth Generation' Nuclear Weapons." Europe for Peace, accessed January 30, 2011, http://www.europeforpeace.eu/en/103_threats-to-the-non-proliferation-regime-fourth-generation-nuclear-weapons.

Bergen, Peter. "Commentary: WMD Terrorism Fears are Overblown." CNN, accessed February 1, 2011, http://articles.cnn.com/2008-12-05/politics/bergen.wmd_1_nuclear-weapons-chemical-weapons-mass-destruction?_s=PM:POLITICS.

Bergenäs, Johan. "Beyond UNSCR 1540: The Forging of a WMD Terrorism Treaty." James Martin Center for Nonproliferation Studies, accessed January 24, 2011, http://cns.miis.edu/stories/081022_beyond_1540.htm.

Biederbick, Walter. "Terrorism and Potential Biological Warfare Agents." In *Unconventional Weapons and International Terrorism: Challenges and New Approaches*, edited by Magnus Ranstorp and Magnus Normark, 109-121. New York, NY: Routledge, 2009.

Bolton, John R. "Remarks to the Chicago Council on Foreign Relations." (October 19, 2004).

Bosch, Olivia and Peter van Ham, eds. *Global Non-Proliferation and Counter-Terrorism: The Impact of UNSCR 1540*. Washington, DC: Brookings Institution Press, 2007.

Bristol, Joseph C., Ryan Close, Crystal L. Frierson, Adam Keith, Amber Mahone, Victor L. Marsh II, Douglas Mercado, Bi Vuong, Victoria Whitford, and Matthew M. Zais. *A New Urgency for Nonproliferation: Implementing United Nations Security Council Resolution 1540*. Princeton, NJ: Princeton University: Woodrow Wilson School, 2007.

Brugger, Seth. "Australia Group Concludes New Bio-Chem Measures." *Arms Control Today* 2010, no. May 6 (July/August 2002).

Bunn, George and John B. Rhinelander. "Looking Back: The Nuclear Nonproliferation Treaty then and Now." *Arms Control Today* (July/August 2008).

Campbell, James K. "On Not Understanding the Problem." In *Hype Or Reality: The "New Terrorism" and Mass Casualty Attacks*, edited by Brad Roberts, 17-45. Alexandria, VA: Chemical and Biological Arms Control Institute, 2000.

Carlson, Rob. "The Pace and Proliferation of Biological Technologies." *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* 1, no. 3 (2003): 203-214.

Cirincione, Joseph. *Bomb Scare*. New York, NY: Columbia University Press, 2007.

Croddy, Eric, Clarissa Perez-Armendariz, and John Hart. *Chemical and Biological Warfare: A Comprehensive Survey for the Concerned Citizen*. New York, NY: Copernicus Books, 2006.

Cupitt, Richard T., Suzette Grillot, and Yuzo Murayama. "The Determinants of Nonproliferation Export Controls: A Membership-Fee Explanation." *Nonproliferation Review* 8, no. 2 (Summer, 2001): 69-80.

Datan, Merav. "Security Council Resolution 1540: WMD and Non-State Trafficking." *Disarmament Diplomacy* 79, (April/May 2005).

Davis, Paul K. and Brian Michael Jenkins. *Deterrence and Influence in Counterterrorism: A Component in the War on Al Qaeda*. Santa Monica, CA: RAND, 2002.

Doyle, Thomas. *Taboos and Sanctions: Preventing the Acquisition of Nuclear Weapons*. Chicago, IL: Paper presented at the annual meeting of the International Studies Association 48th Annual Convention, 2007.

Dunn, Lewis A. *Next Generation Weapons of Mass Destruction and Weapons of Mass Effect Terrorism*: Defense Threat Reduction Agency, 2008.

Ferguson, Charles D. and William C. Potter. *The Four Faces of Nuclear Terrorism*. New York, NY: Routledge, 2005.

Forsberg, Randall, William Driscoll, Gregory Webb, and Jonathan Dean. *Nonproliferation Primer*. Cambridge, MA: MIT Press, No date given.

Freemantle, Michael. "Numbering Up' Small Reactors." *Chemical & Engineering News* 81 (June 16, 2003): 36-37.

Gold, Hal. *Unit 731 – Testimony*. Singapore: Yenbooks, 1996.

Gsponer, André. "From the Lab to the Battlefield? Nanotechnology and Fourth-Generation Nuclear Weapons." *Disarmament Diplomacy* 67 (October/November 2002).

Gsponer, André and Jean-Pierre Humi. *Fourth Generation Nuclear Weapons*. Darmstadt, Germany: INESAP (International Network of Engineers and Scientists Against Proliferation), 2000.

Guilfoile, Patrick. "Biotechnology Topics in the Biology Classroom." ActionBioscience.org, accessed January 28, 2011, http://www.actionbioscience.org/education/guilfoile.html.

Hanlon, Querine H. "Globalization and the Transformation of Armed Groups." In *Armed Groups: Studies in National Security, Counter-Terrorism, and Counterinsurgency*, edited by Jeffrey Norwitz, 137-147. Newport, RI: Naval War College Press, 2008.

Harris, Elisa D. "Chemical and Biological Weapons: Prospects and Priorities After September 11." Brookings Institution, accessed May 6, 2010, http://www.brookings.edu/articles/2002/summer_defense_harris.aspx.

Heine, Pete. "Export Controls and the Problem of Secondary Proliferation Networks for APEC Economies." Lecture presented at the Effective Elements of Export Control for APEC Economies Conference, Honolulu, HI.

Hoffman, David E. "Where Will Russia's Scientists Go Now?" *The World of Threats* (blog), *Foreign Policy*. http://hoffman.foreignpolicy.com/posts/2010/08/18/russia_pulls_out_of_program_for_post_soviet_scientists (August 18, 2010).

Hoffman, Ian. "Scientist: Terrorists could use Microreactors." *Oakland Tribune,* August 12, 2005.

Holsti, Kalevi J. *The State, War and the State of War*. New York, NY: Cambridge University Press, 1996.

Howard, Sean. "Nanotechnology and Mass Destruction: The Need for an Inner Space Treaty." *Disarmament Diplomacy* 65 (July/August 2002).

Institute of Medicine. *Globalization, Biosecurity, and the Future of the Life Sciences*. Washington, DC: National Academies Press, 2006.

International Union of Pure Applied Chemistry. *Impact of Scientific Developments on the Chemical Weapons Convention*, 2007.

Inventory of International Nonproliferation Organizations and Regimes. "Australia Group (AG)." James Martin Center for Nonproliferation Studies, accessed May 6, 2010, http://cns.miis.edu/inventory/pdfs/ag.pdf.

Jackson, Ronald, Alistair J. Ramsay, Carina D. Christensen, Sandra Beaton, Diana F. Hall, and Ian A. Ramshaw. "Expression of Mouse Interleukin-4 by a Recombinant Ectromelia Virus Suppresses Cytolytic Lymphocyte Responses and Overcomes Genetic Resistance to Mousepox." *Journal of Virology* 75, no. 3 (February, 2001): 205-210.

House of Representatives Committee on International Relations. *Statement.* June 4, 2003.

Joyner, Daniel H. *International Law and the Proliferation of Weapons of Mass Destruction* . Oxford, UK: Oxford University Press, 2009.

Kamp, Karl-Heinz, Joseph F. Pilat, Jessica Stern, and Richard A. Falkenrath. “WMD Terrorism: An Exchange.” *Survival* 40, no. 4 (Winter 1998-99): 168-83.

Kang, David and Adam Segal. "The Siren Song of Technonationalism." *Far Eastern Economic Review* (March 2006).

Kaplan, David E. and Andrew Marshall. *The Cult at the End of the World*. London, UK: Random House, 1997.

Kaplan, Eben. "The Proliferation Security Initiative." *Backgrounder* (October 19, 2006).

Kimball, Daryl. "The Australia Group at a Glance." Arms Control Association, accessed May 6, 2010, http://www.armscontrol.org/taxonomy/term/46.

Klotz, Lynn C. and Edward J. Sylvester. *Breeding Bio Insecurity: How U.S. Biodefense is Exploiting Fear, Globalizing Risk, and Making Us All Less Secure*. Chicago, IL: University of Chicago Press, 2009.

Kosal, Margaret. "The Security Implications of Nanotechnology." *Bulletin of the Atomic Scientists* 66, no. 4 (July/August 2010): 58-69.

Krauthammer, Charles. "'Just in Time' WMD." Townhall.com, accessed January 29, 2011.

Littlewood, Jez. "Export Control and the Nonproliferation of Materials: National Boundaries in International Science?" In *A Web of Prevention: Biological Weapons, Life Sciences and the Governance of Research*, edited by Brian Rappert and Caitríona McLeish, 143-162. London, UK: Earthscan, 2007.

Löwe, Holger, Volker Hessel, and Andreas Mueller. "Microreactors. Prospects Already Achieved and Possible Misuse." *Pure Applied Chemistry* 74 (2002): 2274.

Mackinlay, John. "Globalization and Insurgency." *Adelphi Papers* 352 (November, 2002): 1-27.

Mashhadi, Hassan. "Biological Warfare and Disarmament Problems, Perspectives, and Possible Solutions: Complementary Measures Inside and Outside the Framework of the BWC." *Politics and the Life Sciences* 18 (March 1999): 98-102.

Mathews, Robert J. "Chemical and Biological Weapons Export Controls and the 'Web of Prevention': A Practitioner's Perspective." In *A Web of Prevention: Biological Weapons, Life Sciences and the Governance of Research*, edited by Brian Rappert and Caitríona McLeish, 163-175. London, UK: Earthscan, 2007.

Miller, Judith, Stephen Engelberg, and William Broad. *Germs: Biological Weapons and America's Secret War*. New York, NY: Simon & Schuster, 2001.

Miller, Richard Lee. *Under the Cloud: The Decades of Nuclear Testing*. The Woodlands, TX: Two Sixty Press, 1991.

Mirasol, Feliza. "Disposable Bioreactor Use Grows in Commercial Production." *ICIS News,* March 4, 2008, 2008.

Moodie, Amanda and Michael Moodie. "Alternative Narratives for Arms Control: Bringing Together Old and New." *Nonproliferation Review* 17 (July 2010): 301-321, doi: 10.1080/10736700.2010.485430.

Moodie, Michael. "Conflict Trends in the 21st Century." *Joint Forces Quarterly* 53, (2009): 19-27.

Müller, Harald. "Reform of the System of Nuclear Export Controls." In *Nuclear Export Controls and Supply Side Restraints: Options for Reform*, edited by Harald Müller and Lewis A. Dunn. Vol. Study Number 4: Programme for Promoting Nuclear Non-Proliferation, 1993.

National Institute for Public Policy. *The Proliferation Security Initiative: A Model for Future International Collaboration*: National Institute Press, 2009.

National Research Council and American Association for the Advancement of Science. *A Survey of Attitudes and Actions on Dual Use Research in the Life Sciences: A Collaborative Effort of the National Research Council and the American Association for the Advancement of Science*. Washington DC: National Academies Press, 2009.

National Research Council. *Biotechnology Research in an Age of Terrorism.* Washington DC: National Academies Press, 2004.

National Science Foundation. "Higher Education in Science and Engineering." In *Science and Engineering Indicators: 2010*. Washington, DC: National Science Foundation, 2010.

National Security Notes. "The Recipe for Ricin, Part II: The Legend Flourishes from the Dept. of Justice to the Senate Intelligence Committee." GlobalSecurity.org, accessed January 31, 2011, http://www.globalsecurity.org/org/nsn/nsn-040304.htm.

Nayan, Rajiv. "Australia Group." *CBW Magazine* 1 (July 2008).

Nguyen, Tuan H. "Microchallenges of Chemical Weapons Proliferation." *Science* 309 (August 12, 2005): 1021.

Nowak, Rachel. "Disaster in the Making: An Engineered Mouse Virus Leaves Us One Step Away from the Ultimate Bioweapon." *New Scientist* (January 13, 2001): 4-5.

———. "Killer Virus." *New Scientist* (January 10, 2001).

NTI Databases: UN Resolution 1540. "United Nations Security Council Resolution 1540." Nuclear Threat Initiative, accessed January 24, 2011, http://www.nti.org/db/1540/.

Office of Research. "What is Export Control?" University of Tennessee, accessed 17 January, 2011, https://my.tennessee.edu/portal/page?_pageid=43,618777&_dad=portal&_schema=PORTAL.

Ogilvie-White, Tanya. "Facilitating Implementation of Resolution 1540 in South-East Asia and the South Pacific." In *Implementing Resolution 1540: The Role of Regional Organizations*, edited by Lawrence Scheinman. Geneva: UNIDIR, 2008.

O'Sullivan, Gerry. "Media Contagion: Botching the Science Behind the Bioterror Headlines." *21stC Metanews ,*No date given.

Conference on Disarmament. *Statement made on Behalf of the Australia Group by the Representative of Australia.* CD/1164 Cong., 629th Plenary Meeting sess., 1992.

Ouagrham-Gormley, Sonia Ben and Kathleen Vogel. "The Social Context Shaping Bioweapons (Non)Proliferation." *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* 8, no. 1 (March 2010): 9-24.

Parachini, John. "Putting WMD Terrorism into Perspective." *The Washington Quarterly* 26, no. 4 (August 2003): 37-50.

Perkovich, George. "Bush's Nuclear Revolution: A Regime Change in Nonproliferation." *Foreign Affairs* 82, no. 2 (March/April 2003): 2-8.

Reisch, Marc. "Microreactors for the Chemical Masses." *Chemical & Engineering News* (December 1, 2004).

Relman, David. "Bioterrorism – Preparing to Fight the Next War." *New England Journal of Medicine* 354, (2006): 113-115.

Roberts, Brad*. Deterrence and WMD Terrorism: Calibrating its Potential Contribution to Risk Reduction*. Alexandria, VA: Institute for Defense Analyses, 2007.

Robinson, Julian Perry. "Chemical & Biological Weapons." In *Combating Weapons of Mass Destruction: The Future of International Nonproliferation Policy*, edited by Nathan E. Busch and Daniel H. Joyner, 74-94. Athens, GA: University of Georgia Press, 2009.

———. *Near-Term Development of the Governance Regime for Biological and Chemical Weapons*, edited by SPRU – Science & Technology Policy Research University of Sussex, 2006.

Rogan, Hanna. *Jihadism Online – A Study of how Al-Qaida and Radical Islamist Groups use the Internet for Terrorist Purposes*. Kjeller, Norway: Forsvarets Forskningsinstitutt (FFI), Norwegian Defense Research Establishment, 2006.

Schmid, Alex P. "The Ulitimate [sic] Threat: Terrorism and Weapons of Mass Destruction." *Global Dialogue* 2, no. 4 (Autumn, 2000).

Schmidt, Fritz W. "The Zangger Committee: Its History and Future Role." *Nonproliferation Review* 2, no. 1 (Fall, 1994): 38-44.

Seevaratnam, James I. "The Australia Group: Origins, Accomplishments, and Challenges." *Nonproliferation Review* 13, no. 2 (July, 2006): 401-415.

United States Senate Committee on Governmental Affairs. *Nuclear Non-Proliferation Concerns and Export Controls in Russia.* 6 June, 2002.

———. *Current and Future Weapons of Mass Destruction Threats.* November 7, 2001.

United States Senate Subcommittee on International Affairs and Monetary Policy. Export Controls and Non-Proliferation Regimes in the Post-Cold War World. February 24, 1994.

Smith, Rupert. *The Utility of Force*. New York, NY: Penguin, 2006.

Smithson, Amy E. "The Biological Weapons Threat and Nonproliferation Options: A Survey of U.S. Decision Makers and Policy Shapers." *CSIS Report* (November, 2006): i-43.

———. "Indicators of Chemical Terrorism." In *Unconventional Weapons and International Terrorism: Challenges and New Approaches*, edited by Magnus Ranstorp and Magnus Normark, 67-94. New York, NY: Routledge, 2009.

———. "Pathogens and Arms Control: Can Bioscience Police itself?" *Survival* 52, no. 5 (September 29, 2010): 117-134.

Smithson, Amy E. and Leslie-Anne Levy. *Ataxia: The Chemical and Biological Terrorism Threat and the US Response*. Washington, DC: Henry L. Stimson Center, 2000.

Sokolski, Henry. "What does the History of the NPT Tell Us about its Future?." In *Reviewing the Nuclear Nonproliferation Treaty*, edited by Henry Sokolski, 27-64. Carlisle, PA: U.S. Army War College, Strategic Studies Institute, 2010.

Stenerson, Anne. "Chem-Bio Cyber Class: Assessing Jihadist Chemical and Biological Manuals." *Jane's Intelligence Review* (August 31, 2007).

Stern, Jessica Eve. "Lethal Compounds: The New Chemical Weapons Ban." *Brookings Review* 12, no. 3 (Summer 1994): 32-35.

Stevens, Tim and Peter R. Neumann. *Countering Online Radicalisation: A Strategy for Action*. London, UK: International Centre for the Study of Radicalisation and Political Violence (ICSR), 2009.

Tannenwald, Nina. *The Nuclear Taboo: The United States and the Non-use of Nuclear Weapons since 1945*. Cambridge, UK: Cambridge University Press, 2008.

Taylor, Terence. "Safeguarding Advances in the Life Sciences." *EMBO Reports* 7 (July 2006): S61-S64.

Tearse, Graham. "Why Science is Golden for South Korea." *CNRS International Magazine* 10 (April 2008).

Thakur, Ramesh and Ere Haru. *The Chemical Weapons Convention*. Tokyo: United Nations University Press, 2006.

The Australia Group. "2005 Australia Group Plenary", accessed May 10, 2010, 2005.

———. "2007 Australia Group Plenary", accessed May 10, 2010, http://www.australiagroup.net/en/agm_june2007.html.

———. "New Measures to Fight the Spread of Chemical and Biological Weapons." In *2002 Australia Group Meeting Summary*. Paris, 2002.

The Zangger Committee. "History", accessed 18 January, 2011, http://www.zanggercommittee.org/History/Seiten/default.aspx.

Thomas, Timothy L. "Al Qaeda and the Internet: The Danger of 'Cyberplanning'." *Parameters* (Spring, 2003): 112-123.

Trapp, Ralf. "Advances in Science and Technology and the Chemical Weapons Convention." *Arms Control Today* (March 2008).

Tucker, Jonathan. "Preventing Terrorist Access to Dangerous Pathogens: The Need for International Biosecurity Standards." *Disarmament Diplomacy* (September 2002).

———. "Strengthening the CWC Regime for Transfers of Dual-use Chemicals." *Pugwash Meeting* 324 (March 17-18, 2007).

———. "Bioweapons from Russia: Stemming the Flow." *Issues in Science and Technology* 15, no. 3 (Spring 1999).

———. "The Future of Chemical Weapons." *The New Atlantis* 26, (Fall 2009/Winter 2010, 2009/2010): 3-29.

U.S. Government Accountability Office. *Weapons of Mass Destruction: Nonproliferation Programs Need Better Integration*. Washington, DC: U.S. Government Accountability Office, 2005.

Van Aken, Jan. "When Risk Outweighs Benefit." *EMBO Reports* 7 (2006).

Van Aken, Jan, and Iris Hunger. "Biosecurity Policies at International Life Science Journals." *Biosecurity and Bioterrorism* 7, no. 1 (20 April 2009): 61–72.

Van den Berg, Dirk Jan. "EU must Act Fast and Share Knowledge with China." *Wall Street Journal,* October 8, 2010.

Weiner, Sharon. "Controlling the Proliferation of Nuclear Knowledge from the Former Soviet Union." Lecture Series.

Weitz, Richard. "Global Initiative to Combat Nuclear Terrorism: Steady, but Slow Progress." *WMD Insights* (August, 2008).

Wittner, Lawrence S. "The Nuclear Non-Proliferation Treaty, Past and Present." History News Network, accessed January 12, 2011, http://hnn.us/articles/125933.html.