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Biological Weapons and Modern Warfare

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ABSTRACT

Biological warfare, or the intentional use of living organisms or their toxic products in a destructive manner, has always been a subject of considerable discussion. This paper reviews the history of the development and use of biological agents and their toxins, with specific reference to the U.S. biological warfare program. This effort began in 1941 and evolved into a military-driven research and acquisition program, shrouded in controversy and secrecy. With the Presidential decision in 1969 to halt offensive biological weapons production, and the agreement in 1972 at the international Biological Weapons Convention to never develop, produce, stockpile, or retain biological agents or toxins, the program was modified into a defensive program. However, the scientific breakthroughs in biotechnology during the 1970s and 1980s that permitted the genetic sequencing and synthesis of toxins, and the continuing effort by the Soviet Union and several other nations to develop and stockpile such weapons made the future of biological warfare unclear. This paper discusses the requirements, advantages, and disadvantages of biological agents in modern warfare; the strategic, tactical, resource, and human implications of such warfare; the current threat facing the U.S.; the technological advances that have impacted on offensive and defensive programs; and the ethical issues surrounding use of such weapons. The military importance of continuing a well-defined research effort is emphasized.

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ABSTRACT

Biological warfare, or the intentional use of living organisms or their toxic products in a destructive manner, has always been a subject of considerable discussion. This paper reviews the history of the development and use of biological agents and their toxins, with specific reference to the U.S. biological warfare program. This effort began in 1941 and evolved into a military-driven research and acquisition program, shrouded in controversy and secrecy. With the Presidential decision in 1969 to halt offensive biological weapons production, and the agreement in 1972 at the international Biological Weapons Convention to never develop, produce, stockpile, or retain biological agents or toxins, the program was modified into a defensive program. However, the scientific breakthroughs in biotechnology during the 1970s and 1980s that permitted the genetic sequencing and synthesis of toxins, and the continuing effort by the Soviet Union and several other nations to develop and stockpile such weapons made the future of biological warfare unclear. This paper discusses the requirements, advantages, and disadvantages of biological agents in modern warfare; the strategic, tactical, resource, and human implications of such warfare; the current threat facing the U.S.; the technological advances that have impacted on offensive and defensive programs; and the ethical issues surrounding use of such weapons. The military importance of continuing a well-defined research effort is emphasized.

"The value of biological warfare will be a debatable question until it has been clearly proven or disproven by experience. Such experience may be forthcoming. The wise assumption is that any method which appears to offer advantages to a nation at war will be vigorously employed by that nation. There is but one logical course to pursue, namely to study the possibilities of such warfare from every angle, make every preparation for reducing its effectiveness and thereby reduce the likelihood of its use. In order to plan such preparation, it is advantageous to take the point of view of the aggressor and to give careful attention to the characteristics which a biologic offensive might have."

**-1942 National Academy of Sciences report on the
feasibility of conducting research on biological weapons**

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I. INTRODUCTION

Biological warfare (BW) has been officially defined as "the intentional use of living organisms or their toxic products to cause death, disability, or damage in man, animals, or plants." [1] BW agents include invasive bacterial, viral, rickettsial, and fungal organisms, or toxins produced by such organisms, that can cause physical harm. But agents also include other highly poisonous substances, such as toxins, produced by certain invertebrates, vertebrates, and plants. Hence, a distinction is made between pathogenic organisms and their toxins. Biological agents differ from "chemical agents," which are not a direct product of living organisms. Both biological and chemical warfare agents, however, share the capability of inflicting considerable disruptive damage on a military force, rendering a unit incapable of accomplishing its desired missions. Biological weaponry has been referred to as "the poor man's atomic bomb," because of its ready availability and devastating potential [2].

An individual who is ill with a highly communicable pathogen may: infect others through direct personal contact, airborne spread, or sharing of personal items; infect, debilitate or kill those holding critical positions; contaminate the air, ground, or immediate surroundings; contaminate supplies, equipment, foodstuffs, or water; and utilize medical resources for intensive care.

Since symptoms of a BW agent may often be similar to those of endemic infections in a geographical area, a weapon may be capable of overcoming a military force before its presence is even suspected. By the time one member falls victim, others may be incubating disease or showing early signs of illness. Foreign-stationed troops may be at greater risk of contracting exotic infections, since these troops may lack natural immunity. Also, the psychological impact of a lethal infection or toxin cannot be underestimated.

It has been stated that a biological weapon of high virulence is capable of mass destruction in a susceptible population with a mortality rate that may parallel that of an atomic weapon [3,4]. This is plausible when one considers the one and one-half million people in Europe who died of plague during just one epidemic of the Black Death in 1346-1361 [5]. Many biological weapons have the advantage over nuclear and chemical weapons, by silently self-replicating and spreading to unsuspecting victims in epidemic fashion. Many biological agents are also easy and inexpensive to produce and can be aerosolized, ingested, or even delivered through arthropod vectors. These factors make biological agents particularly attractive to warring nations with limited resources.

Some agents, such as the microorganisms causing anthrax, coccidioidomycosis (valley fever), and certain exotic viral hemorrhagic fevers, can remain viable for prolonged periods, only to be aerosolized with blowing dust and inhaled at some later time; most chemical agents will not persist as long in the environment. Crops and animal herds can be destroyed by BW agents, rendering food supplies scarce and crippling the economy of a country.

It is no wonder why military forces of the past recognized certain infectious organisms, such as plague, as crude but effective weapons that could sway the tide of a battle, provided attack rates could be maximized and the forces using the weapon protected from its effects. In today's climate, BW agents are also attractive weapons for terrorists or saboteurs, who could deliver the weapon behind enemy lines and slip away undetected and wait for the ultimate outcome.

So what role do biological weapons play in modern day conflicts? What are the limitations or considerations for use of such weapons, and what defenses can realistically be provided? What has history taught us about biological

warfare, and what are the applications for the future? This paper addresses such issues by reviewing the historical events that have influenced today's BW defense program, and current efforts in building a strong defense against a myriad of agents. Information of a classified nature is not included, for obvious reasons. The implications of new technology are discussed, as well as the political and ethical concerns surrounding BW weaponry.

II. HISTORY OF BIOLOGICAL WARFARE

A. Early Use of Biological Weapons:

It is appropriate that a discussion of early use of biological agents begin with the accomplishment of the great Carthaginian leader Hannibal, who in preparation for a naval battle against King Eumenes of Pergamum in 184 B.C., ordered earthen pots to be filled with "serpents of every kind." During the heat of battle, Hannibal hurled the earthen pots on the decks of the puzzled Pergamene warriors, who remained amused only until they saw their ships crawling with serpents. The battle was won by Hannibal's forces, as the Pergamene soldiers battled two enemies [2].

Recognition of the devastating impact that infectious diseases could have on an army resulted in the often crude but ingenious use of disease organisms and poor sanitation to weaken the enemy. The use of corpses of men and animals to pollute wells and other sources of water of the opposing forces was a common strategy. The fouling of water supplies continued to be used through the many European wars, the American Civil War, and into the twentieth century [2,6]. In his Memoirs, General W. T. Sherman expressed discontent with Confederate troops, who were deliberately shooting farm animals in ponds so that their "stinking carcasses" would compromise the water supplies of the Union

forces [2]. Not only did such actions have a demoralizing impact on the enemy, but the consumption of contaminated water probably accounted for many undocumented epidemics of gastrointestinal disease.

Ancient military leaders recognized that victims of infections could become weapons in themselves. In a discussion of the events leading up to the Black Plague that killed twenty-five million Europeans in the 1300-1400s, Derbes describes how bodies of dead soldiers and "2000 carloads of excrement" were hurled into the ranks of the enemy at Carolstein in 1422 [7]. Derbes also relates the observations of Gabriel de Mussis, who saw the Mongol attack of Caffa in 1346, in which plague-weakened Tartar forces attacking the well-fortified Genoese-controlled seaport of Caffa in Crimea catapulted victims of plague into the town [8]. An epidemic of plague resulted, forcing a retreat of the plague-stricken Genoese forces back to Italy. The exported disease continued to spread in Europe [7,9]. A similar strategy was used in 1710, when Russian troops battling Swedish forces in Reval resorted to the throwing of plague victims over the city walls [6].

In 1763, Captain Ecuyer of the Royal Americans, out of concern of a possible Indian attack in the near future and under the pretense of friendship, deliberately distributed two variola virus-contaminated blankets and a handkerchief from a smallpox hospital to enemy Indian forces [5,8,9]. This was followed several months later by large outbreaks of smallpox among various Indian tribes in the Ohio region. A similar strategy was used during the Revolutionary War by smallpox-immune Americans who had been mandatorily vaccinated against smallpox by General Washington [6,10].

B. World War I and the Post-War Period:

Biological warfare became more sophisticated during the 1900s and involved both man and animals. During World War I, reports circulated of attempts by

the Germans to ship horses and cattle inoculated with disease producing bacteria, such as Bacillus anthracis (bacterium causing anthrax) and Pseudomonas pseudomallei (bacterium causing glanders in livestock) to the U.S. and elsewhere [6]. This accusation was difficult to substantiate, since glanders was widespread in Europe at the time. However, a German saboteur, who supposedly infected 4,500 mules with glanders, was arrested in Mesopotamia in 1917 [6,9]. Other allegations of attempts by Germany to spread cholera in Italy and plague in St. Petersburg in 1915 followed, and the dropping of contaminated fruit, chocolate, and children's toys into Romanian cities, such as Bucharest, by German planes was also alleged. Germany denied all allegations, including the accusation that biological bombs were being dropped over British positions. In 1924, a subcommittee of the Temporary Mixed Commission of the League of Nations, in support of Germany, stated that in contradistinction to the chemical arm, there was no hard evidence that the bacteriological arm had been employed in war [6].

C. The 1925 Geneva Protocol:

On 17 June 1925, the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases and of Bacteriological Methods of Warfare was signed. This represented the first multilateral agreement that extended prohibition of chemical agents to biological agents [6,9]. Since viruses were not differentiated from bacteria at the time, they were not specifically mentioned in the protocol. However, subsequent interpretations of the agreement considered "bacteriological" to be inclusive of viruses, rickettsiae, and fungi, and synonymous with the term "biological." A total of 108 nations, to include the five permanent members of the UN Security Council, signed the agreement.

Nations currently implicated with chemical and biological weapons, i.e., Iraq and Libya, also signed the protocol, raising questions about the agreement's true effectiveness. Verification of compliance was not addressed.

D. World War II:

Events during and following World War II were clouded by charges and counter-accusations of BW experimentation [6,9]. The Japanese were accused of using biological agents against the Soviet Union and Mongolia in 1939, against Chinese civilians from 1940 to 1944, and against Chinese troops in 1942 [6,9]. In October 1940, a Japanese plane supposedly scattered contaminated rice and dead fleas over the city of Chuhsien in Chekiang province. This event was soon followed by an outbreak of bubonic plague, a disease never recorded previously in Chuhsien. Several other mysterious flights of Japanese aircraft over at least eleven Chinese cities with the dropping of grain (wheat, rice, sorghum, or corn), strange granules containing gram-negative bacilli, and other materials suspected of being contaminated with the plague organism, took place through August 1942. It has been estimated that thousands were hospitalized and 700 became victims of artificially spread plague bacilli [9]. However, despite compelling evidence, testimony, and documents, failure to associate directly the isolation of plague bacilli in the laboratory with actual materials dropped by the planes made prosecution difficult. It is worth noting that a Japanese document entitled "Defense and Security Intelligence Report No. 8: Chinese Employment of Chemical and Bacteriological Warfare Against the Japanese" revealed a paranoia about secret Chinese initiatives:

There is evidence that during the China Incident the enemy has skillfully and secretly carried out chemical and bacteriological warfare activities against personnel, animals, natural resources water and food supplies. It may be presumed that the enemy will become increasingly active in such methods. Therefore, security and defense measures must be thorough during advances and halts.¹

It was alleged that at least three thousand prisoners of war (to include Chinese, Koreans, Mongolians, Soviets, Americans, British, and Australlians) were used by Japan's Imperial Unit No. 731 as guinea pigs [6,11]. Conservatively, more than a thousand died in experiments with agents causing anthrax, botulism, brucellosis, cholera, dysentery, gas gangrene, meningococcal infection, and plague ². Experiments with tetrodotoxin (highly poisonous fugu toxin) were also conducted. These experiments were later considered to be "most regretable from the view point of humanity" by the Japanese government [6].

In December 1949, twelve Japanese prisoners of war, including the Commander-in-Chief of the Japanese Kwantung Army, were tried by a Soviet military tribunal for preparing and using biological weapons, including agents causing plague, typhoid, paratyphoid, and typhus [11]. The Japanese, in turn, accused the Soviets of experimentation with BW agents, citing, as an example, recovered glass bottles and ampules containing Shigella (bacillary dysentery), B. anthracis, and V. cholerae (cholera) organisms recovered from Russian spies [6].

Although German medical researchers during World War II experimentally infected prisoners with disease-producing organisms such as Rickettsia prowazeki, R. mooseri, hepatitis A virus, and malaria, no charges were addressed at the conclusion of the war. The only significant incidents possibly involving the use of biological agents was the fecal pollution of a large reservoir in northwestern Bohemia in May 1945, resulting in an outbreak of dysentery, and the dropping of Colorado beetles on potato crops on southern England's Isle of Wight [6]. A biological warfare program by Nazi Germany could never be documented, although there was interest in developing an adequate defense against biological agents.

An interesting side note to events during World War II was a charge made by Dr. Josef Goebbels, German Minister of Propaganda, who accused the British of attempting to introduce yellow fever into India by transporting infected mosquitoes from West Africa [6]. This was believable to many, for, in 1941-1942, the British were indeed experimenting with at least one biological agent. British trials were held on Gruinard Island off the coast of Scotland with Bacillus anthracis. The small bomb experiments resulted in heavy contamination with persistent anthrax spores still contaminating parts of the island today [8]. Supposedly, Winston Churchill had seriously considered the use of anthrax if Nazi Germany used biological agents [9].

In the fall of 1941, in response to a growing atmosphere of BW development, U.S. Secretary of War Henry L. Stimson directed that a study be made into the feasibility of a biological warfare attack against the U.S. [12,13] A National Academy of Sciences committee saw BW as a distinct possibility, and the War Reserve Service was formed in August 1942 to begin a biological warfare program. This program will be discussed in more detail later in Section III.

E. Post-World War II to Vietnam:

During the years immediately following World War II, newspapers were filled with articles of disease outbreaks supposedly caused by foreign agents with biological weapons [6]. Outbreaks of cholera in Egypt in 1947 were reportedly due to by Zionist infiltrators. In 1951, a Soviet Navy newspaper reported that the U.S. had tested biological weapons against Canadian Eskimos, leading to an epidemic of plague in 1949. In 1950, East Germany accused the U.S. of spreading Colorado beetles over parts of Germany.

During the Korean conflict, the Soviet Union, China, and North Korea accused the United States of using biological warfare against North Korea and China [6,14]. In 1952, a group of international scientists formed as a result of North Korean complaints, concluded that bacteriological weapons, in the form of tests, were being used against North Korea and China. Supposedly, experiments included mosquitoes carrying yellow fever virus and other means of disseminating infectious agents. The U.S. admitted that it had the capability to produce biological agents but denied conducting germ warfare. They requested a United Nations team to investigate, but the request was vetoed by the Chinese and the Koreans [8]. So like so many other incidents, the issue remained unsettled.

Other events included: accusations by the Eastern European press of Britain using biological agents in Oman in 1957; deliberate infection of Indian tribes by Brazilian landowners in 1970, to remove them from parts of the Amazon; Chinese accusations of the U.S. of starting a cholera epidemic in Hong Kong in 1961; use of biological agents against the peasants of Colombia and Bolivia; and accusations by Iraq that the "imperialist aggressors" were using BW agents in the Middle East [6].

In 1970, South Korea maintained that the North Korea was planning to launch a BW attack, based on a large order from a North Korean facility for anthrax, cholera, and plague bacteria from a Japanese trading firm. Although the situation was peacefully resolved, biological warfare merely provided one more item on which to find disagreement and be distrustful of each other.

In 1967, the Secretary-General of the United Nations issued the following statement in attempt to reduce the tension over biological agents being used in war:

Since the Second World War, bacteriological (biological) weapons have also become an increasing possibility. But because there is no clear evidence that these agents have ever been used as modern military weapons, discussions of their characteristics and potential threat have to draw heavily upon experimental field and laboratory data...rather than on direct battlefield experience. There is no military experience on the use of bacteriological (biological) agents as weapons of war, and the feasibility of using them as such has often been questioned...[9]

In 1969, the UN Secretary-General further clarified this statement:

"...increased potency as weapons has resulted from a process of selection rather than from the production of entirely new agents..." [9]. This attitude was to change in the 1970s with the advances in molecular biology and genetic engineering, when it became apparent that synthesis of "new" or altered organisms was possible. The impact of high technology on BW strategies will be discussed later in Section VI.

During the Indo-China/Vietnam conflict in the 1960s, many considered the use of fecally-contaminated spear traps ("pungi sticks") to be the Viet Cong's adaptation of BW. Emphasis was largely on conventional warfare and special operations in the jungles of Southeast Asia, although concern continued over endemic and artificially introduced infectious agents. "Yellow rain" was to become an issue later, along with controversies surrounding use of the chemical herbicide orange.

In November 1969, the World Health Organization of the United Nations issued a report on chemical and biological weapons. This report (and an earlier report by the Eighteen-Nation Committee on Disarmament) described the unpredictability of BW weapons, and the risks and lack of control with use of such weapons. In July 1969, Great Britain submitted a recommended statement to the Conference of the Committee on Disarmament prohibiting the "development production, and stockpiling of bacteriological (biologic)

and toxin weapons" [12]. In September 1969, the Soviet Union unexpectedly recommended a disarmament convention to the UN General Assembly.

F. The 1969 National Security Decision:

Also, in 1969, President Richard M. Nixon requested an extensive review by the National Security Council, the Departments of State and Defense, the Office of Science and Technology Policy, the Arms Control and Disarmament Agency, and the Central Intelligence Agency, on the issue of the Geneva Protocol and the use of biological weapons by the U.S. In the fall, he was presented with the options, and reviewed the alternatives with his trusted advisors, including his National Security Advisor, Henry Kissinger.

On 25 November 1969, in a National Security Decision Memorandum (No. 35), President Richard M. Nixon renounced the U.S. offensive biological weapons program, without any prior negotiations with the Soviets. His statement included the following words:

Mankind already carries in its own hand too many of the seeds of its own destruction...The U.S. shall renounce the use of biological agents and weapons, and all other methods of biological warfare [16].

In a public statement, President Nixon explained:

Biological warfare, which is commonly called germ warfare, has massive, unpredictable, and potentially uncontrollable consequences. It may produce global epidemics and profoundly affect the health of future generations. Therefore, I have decided that the United States of America will renounce the use of any form of deadly biological weapons that either kill or incapacitate. I have ordered the Defense Department to make recommendations about the disposal of the existing stocks of bacteriological weapons [16].

This unilateral action was driven by the changing international sentiment against BW weapons and followed an earlier decision by Congress to ban open-air testing of chemical and biological weapons. This was to be

followed on 14 November 1970 by an announcement to dismantle offensive preparation for the use of biological toxins. The Department of Defense was in support of this position, feeling that biological weapons were marginal and problematic anyway, and not superior to nuclear or chemical weapons [16]. Existing agent and weapon stockpiles were subsequently destroyed. All U.S. research facilities involved with biological warfare research redirected their programs to defensive programs.

In a carefully worded precautionary statement, President Nixon also warned:

Neither our association with the convention nor the limiting of our program to defensive research will leave us vulnerable to surprise by an enemy who does not observe these rational restraints. Our intelligence community will continue to watch carefully the nature and extent of biological programs of others [17].

This decision on the part of President Nixon greatly facilitated the 1972 Biological Weapons Convention, which the Soviet Union finally supported.

G. The 1972 Biological Weapons Convention:

As a follow-on to the 1925 Geneva Protocol, the 1972 Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, commonly known as the "Biological Weapons Convention," was convened [6,9].

Agreement was eventually reached among the 103 co-signing nations to:

...never to develop, produce, stockpile, or otherwise acquire or retain "microbial or other biological agents or toxins, whatever their origin or method of production, of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes; and weapons, equipment or means of delivery designed to use such agents or toxins for hostile purposes or in armed conflict."

The agreement went into effect in March 1975 and reduced the concerns that some nations had over the development and use of biological agents.

However, problems with verification and the interpretation of "defensive" research continued.

Every year, signatories of the agreement are requested to submit to the United Nations information on facilities where biological defense research in their respective countries is being conducted; scientific conferences held at specified laboratory facilities; information on exchanges of scientists or information; and information on disease outbreaks. The Security Council, of which the U.S. and the Soviet Union are members, reserves the right to veto any request for an investigation, should any allegations of infractions be lodged to the United Nations.

H. The Sverdlovsk Incident:

On April 3, 1979, a mysterious explosion at the Soviet Institute of Microbiology and Virology in Sverdlovsk, long suspected of being a biological weapons research facility, raised questions about the effectiveness of any weapons control agreements [9,18]. It had been estimated that at least a hundred persons had been killed (including several with inhalation anthrax), and perhaps thousands had been infected with Bacillus anthracis.⁴

The Soviets initially refused to disclose any details of the event and did not allow outside investigative teams to visit the site. Many months later, it was reported by Soviet scientists that ninety-six persons had been infected, seventy-nine with gastrointestinal infections and seventeen with skin lesions; sixty-four had died [19,20]. The incident resulted in a mass immunization program of area residents and workers. The Soviets, maintaining that an outbreak of gastrointestinal anthrax had occurred as a result of ingestion of contaminated meat [19], refused to discuss other possibilities, but simply stated that the epidemic occurred in a province

with at least two hundred known sites of natural contamination with anthrax spores. It seems unlikely that inhalation anthrax associated with high mortality would have resulted from ingestion alone, but the Soviets have steadfastly maintained that there were no cases of inhalation anthrax. The Soviet Union was accused of not providing all of the facts on the incident and not operating within the spirit and intent of the Biological Weapons Convention agreement. However, little could be done to enforce the Biological Weapons Convention. As anticipated earlier, compliance (and verification) would be a major deficiency of the treaty.

The incident was not forgotten and the U.S. government continued to maintain that the Soviet Union was actively involved in producing offensive biological weapons. No further outbreaks or accidents have been reported, but anthrax remains high on the list of potential biological agents that could be easily weaponized.

I. Yellow Rain:

The specter of biological warfare took on new meaning in 1981, when the U.S. charged that the Soviet Union and other socialist states were using trichothecene mycotoxins ("yellow rain"), potent toxins from the mold Fusarium, in Southeast Asia and Afghanistan⁵ [9,16]. Use of trichothecenes was also suspected during the Yemen civil war [21], based on similar symptoms in the affected population. In November 1981, following an earlier announcement in September by Secretary of State Alexander Haig, Richard Burt, Director of the Bureau of Political-Military Affairs in the State Department, described the clouds of yellow, orange, red, and other tints that fell upon villages and rice paddies in Laos and Kampuchea. According to Burt, the victims experienced symptoms of itching vomiting, dizziness, and distorted vision, followed by the vomiting of

blood and the development of shock a short time later (the rapid progression from vague symptoms to hemorrhaging is characteristic of trichothecene poisoning) [8]. The accusation by the U.S. was largely based on long-held suspicions by the U.S. government of continuing Soviet research efforts with highly potent biotoxins, and the increasing number of anecdotal reports of human illnesses in Southeast Asia (and later Afghanistan).

Soviet scientists had published numerous articles on trichothecenes, and, according to intelligence experts, they had conducted most of their research at the Institute of Microbiology and Virology at Kiev [21]. It was no secret to Soviet or Western scientists that trichothecenes could be easily produced on millet grain in large doses, but some of the specific toxins could be synthesized chemically. The toxins were known to be very stable and could be stored for years at room temperature. They could also be easily dispersed as an aerosol with a surfactant (lauryl sulfonate), that bonded the toxins. Lauryl sulfonate, which does not occur naturally, was found on the leaves of the most remote sections of Laos at sites where the use of yellow rain had been suspected [21].

Samples of materials from the environment and victims were collected by investigative teams, but only a few showed "high" levels of trichothecene toxins. Laboratories differed in their analyses, and discrepancies were blamed on the instability of mycotoxins over time. Several independent scientific investigations were largely inconclusive, with some scientists even suggesting the possibility of bee excrement as an explanation for the "yellow rain [21,22,23]." British and Canadian investigators also had no evidence of biotoxins being used in Southeast Asia. The number of suspected incidents decreased over time, with critics

saying that there never was a problem in the first place, since other biological agents are more effective. Supporters of the claims maintained that the publicity had forced the Soviets to stop experimenting with mycotoxins in Southeast Asia and Afghanistan. The issue still remains unresolved.

J. The Smallpox Issue:

Smallpox, a naturally occurring viral illness associated with a case-fatality rate of 15-40% among unvaccinated persons, has been long been considered to be possible BW agent. The infection is transmitted through airborne droplets, direct contact with open sores, or indirect contact with contaminated articles. In 1958, the Soviets proposed to the World Health Assembly that a global eradication of smallpox be instituted [24]. The World Health Organization initiated a successful campaign in 1967. Although smallpox is a disease that has been considered by the World Health Organization to be eliminated with the last confirmed indigenous case occurring in October 1977, the possibility that certain powers may still possess undisclosed quantities of variola virus in their laboratories that could be used as a biological weapon has resulted in a continuation of smallpox vaccination programs by the military of some nations, including the U.S. and the Soviet Union.

Variola virus is highly communicable, especially when delivered in nebulized airborne droplets, but the attack rates are highly variable. The long incubation period (seven to seventeen days) is also variable, and the fact that smallpox has been eradicated from the world makes its detection as a biological warfare agent highly likely, once it is used. When considered in relationship to other potential agents, variola virus is a less than ideal choice for a biological warfare agent. However, the

virus is able to persist in the environment for prolonged periods, especially under dry conditions, and it can be easily replicated in the most primitive laboratories. Hence, variola remains on the list of potential biological agents.

Recognizing the devastating effect that smallpox could have on a military unit, General George Washington instituted a mandatory vaccination program during the Revolutionary War, using the method of variolation. During the War of 1812, a safer Jennerian vaccination procedure was adopted [10]. As mentioned earlier, smallpox was used by the British as a biological weapon against the Indians, but the threat to the military at that time was based on endemic disease.

Smallpox can have a demoralizing psychological effect on a military unit, and the impact as a terrorist weapon against unprotected civilian populations could be devastating. Since the world ceased routinely vaccinating its population in the 1970s, many civilians are at risk of contracting infection, should they be exposed to the variola virus.

It has been proposed by many that since smallpox is no longer around, routine vaccination of the military should cease, due to the unnecessary risks of a serious adverse reaction from vaccination [25]. The Department of Defense continues to maintain a smallpox vaccination program for its recruits and other selected personnel who may be at increased risk. Laboratory workers who handle the variola virus are also vaccinated. The program requires maintenance of sufficient quantities of smallpox immune globulin to treat any serious adverse reactions to vaccination. Negotiations with the Soviet Union to stop vaccinating military personnel routinely have been unsuccessful thus far. This may in part be due to continuing concern that all variola organisms have not been destroyed.

III. THE U.S. BIOLOGICAL WARFARE PROGRAM

The biological warfare program of the U.S. began in the fall of 1941 under military auspices and was characterized during its early years with a high degree of secrecy and controversial testing programs. The U.S. policy toward biological warfare between 1941 and 1969 was to deter the use of biological agents against the U.S. and its forces, and to retaliate, if deterrence was unsuccessful. The program was characterized by an aggressive offensive and defensive research and development effort, that would be modified in 1969 to one based on maintaining a strong "defense" against biological agents.

A. The Early Years (1940s-1960s):

In the fall of 1941, Secretary of War Henry L. Stimson recommended to President Franklin D. Roosevelt the creation of a civilian agency that would coordinate the governmental and privately owned institutions in a biological warfare effort [12,13]. This idea was controversial, since little was known about the predictable effectiveness of BW agents as wartime weapons. Confronted with BW research initiatives of the Axis powers, the plan met with presidential approval in 1942. The War Reserve Service, headed by George W. Merck, was established and attached to the Federal Security Agency. This agency received consultative advice from national scientific committees and organizations, including the National Academy of Sciences and the National Research Council. Several locations were selected for biological research, with the main headquarters at Camp Detrick, Maryland (later to be designated Fort Detrick in 1956). Information was exchanged with Great Britain and Canada, two other nations

concerned about the BW threat, but the general public was unaware of a U.S. biological warfare program until four months after the war was over.

In the spring of 1942, President Roosevelt and Prime Minister Winston Churchill announced policies limiting the use of biological weapons for retaliation only, policies closely paralleling previous decisions on the limited use of chemical weapons. But this did not prevent the U.S. and Great Britain to begin to amass arsenals of offensive BW agents [8]. At the end of World War II, the effort on BW development was largely limited to research only. Although the highly classified program was initially a defensive program closely tied with the chemical weapons program, research continued on developing an independent retaliatory capability against various infectious agents.

In 1946, the Research and Development Board (now under the Secretary of Defense), which had been given the responsibility to supervise the governmental research program, requested an evaluation of biological agents as weapons of sabotage. A Committee on Biological Warfare was formed, and the Baldwin Report⁹ prepared by the committee stated that the U.S. was particularly vulnerable to covert attack with biological agents; it also mentioned that the current research and development program was "not authorized to meet the requirements necessary to prepare the defensive measures against special BW operations" [8]. The Baldwin committee recommended: the development of means to detect BW agents; the development of methods in decontamination and protection; and the assessment of methods for dissemination of biological agents. Specifically recommended were research programs, such as the testing of ventilation systems, subway systems, and public water supplies with "innocuous organisms".

This guidance influenced several subsequent administrations over the next twenty years, and the program included an incredible sequence of highly classified scientific tests on unknowing populations throughout the U.S., with agents and materials believed to be non-pathogenic. In fact, it was not until early 1977 when the extent of the military biological weapons testing program was publicly disclosed before Congress [8,13].

The biological warfare research program over the next several years involved anti-personnel, anti-crop, and, for a brief period, anti-animal studies [10]. Open air vulnerability testing and contamination of public water systems with live organisms, such as Serratia marcescens. Covert programs were conducted with the Central Intelligence Agency. Pathogenic organisms were also tested in Florida and the Bahamas in the 1940s. Chemical anti-crop studies evaluated defoliation and crop destruction. Explosive munition tests with pathogens were begun in 1949. In 1950, the first open air tests with biological simulants were conducted in various locales, such as off the coast of Norfolk, Virginia. This would be followed by limited zinc cadmium sulfide ⁷ dispersal tests in Minneapolis, Minnesota and St. Louis, Missouri, in 1953 and Bacillus subtilis (variant niger) in the New York City Subway system in 1966 [8]. The Special Operations Division at Camp Detrick conducted much of the research on possible methods of covert attack and sabotage, and many environmental studies were often conducted without informing local or state governmental agencies or the general population.

Between 1948 and 1950, several reviews were conducted by the Research Review Board of the biological warfare, chemical warfare, and radiological warfare programs. Recommendations included the creation of a specific BW production facility, continued field tests with BW agents and munitions,

and expansion of the overall program. The Korean conflict added justification for program continuation, with the possible entry of the Soviet Union. Concerns over the Soviet Union were justified, for the Soviet Union would pronounce later in 1956 that chemical and biological weapons would indeed be used for mass destruction in future wars [9]. In October 1950, the Secretary of Defense approved continuation of the BW program, based largely on the Soviet threat, and a belief that the North Korean and Chinese communists would use biological weapons [15]. The BW research facilities at Camp Detrick were expanded, and a BW production facility was created at Pine Bluff Arsenal, Arkansas, in 1951.

In September 1950, the first large-scale aerial vulnerability test was conducted in San Francisco Bay, using two bacteria (Bacillus globigii and Serratia marcescens) and fluorescent particles. Various Bacillus species were used in many experiments because of their spore-forming capability and similarity to the organism causing anthrax. Serratia was used because of its red pigment that made it readily identifiable. What was unexpected was an increase in number of cases of Serratia infections over the next few years in communities that had been doused earlier with the organisms [8]. The military considered the situation coincidental, but many civilian physicians were of the opinion that the situations were directly related. Other limited scale field tests were conducted with pathogenic organisms at Dugway Proving Ground, Utah. Anti-animal studies were also conducted at Eglin Air Force Base, Florida.

In 1951, the retaliatory first anti-crop bombs were produced by the U.S. Air Force, in conjunction with the Department of Agriculture. This represented the first peacetime biological weapons production by the U.S. [14]. The Pine Bluff laboratory eventually produced Brucella suis

(causative agent for undulant fever) and Pasteurella tularensis (tularemia) by 1954. By 1955, the accelerated program was producing stocks of Brucella and Tularemia germs. It should be noted that although many of the investigations involved military researchers, the Public Health Service, other Federal departmental agencies, and civilian scientific institutions were involved in much of the research efforts.

The general public was uninformed of these ongoing studies, especially the environmental and open air experiments that were being conducted. An example of an environmental test was in 1951, when Army researchers deliberately exposed a disproportionate number of black citizens to the fungus Aspergillus fumigatus, to see if blacks were more susceptible to such infection in a manner already recognized with coccidioidomycosis; it was felt that such knowledge would assist in preparing defenses against a more virulent form of this fungus. Similarly, in 1951, unsuspecting workers at the Norfolk Supply Center in Virginia were exposed to crates contaminated with Aspergillus spores.

Needless to say, there was a public outcry several years later when much of this information was released, and the BW research program would be forever identified with what L.A. Cole described as operating within the "clouds of secrecy" [8]." The first lawsuit against the U.S. government was filed by family members of an individual who had died supposedly as a result of the San Francisco experiments in 1950.⁸ The court decided that the U.S. government could not be sued (under the Federal Tort Claims Act), since the decision to spray Serratia was a part of national planning. This decision was upheld in the U.S. Court of Appeals.

Several of the organisms (such as Serratia marcescens and Aspergillus fumigatus) considered at one time to be innocuous are now recognized to cause infections in humans, on occasion; immunocompromised or debilitated persons appear to be at greatest risk. Early experiments conducted with such organisms involving subjects or populations who were unaware of the ongoing experiments may have posed a small risk to highly susceptible persons.

During the two decades following the second World War, laboratories for biological and chemical warfare research continued to increase in size, and programs were expanded with a multimillion dollar budget. The Fort Detrick research program was complemented by contractual civilian institutions, such as Ohio State University, which was tasked with making vaccines. Human volunteers were used in many of the studies. Vaccines against diseases, such as Q fever and tularemia, were developed.

The BW program was now accumulating invaluable data on personal protection, decontamination, immunization, and the potential for mosquitoes to be used as biological vectors. Preventive approaches toward infections of all kinds were funded under the auspices of biological warfare. As concern increased over the BW threat during the Cold War, so did the budget for the program. The budget increased to \$38 million by FY 66. A new Department of Defense Biological and Chemical Defense Planning Board was created in 1960 to establish program priorities and objectives.

The U.S. Army Chemical Corps was given the responsibility to conduct BW research for all of the services [13]. In 1962, testing of promising BW agents was given to a separate Testing and Evaluation Command. Depending on the particular program, different test centers were used, such as the Desert Test Center at Fort Douglas, Utah, headquarters

for the new biological and chemical warfare testing organization. In response to increasing concerns over public safety and the environment, the Testing and Development Command implemented a complex system of approval of its research programs, that included the Army Chief-of-Staff, the Joint Chiefs-of-Staff, the Secretary of Defense, and the President of the U.S.

In the 1960s, a philosophical change was evident with attention now being directed at biological agents that could "incapacitate" but not kill. In 1964, research programs involved staphylococcal enterotoxins capable of causing food poisoning. Research initiatives also included new therapy and prophylaxis. Pathogens studied included the agents causing anthrax, glanders, brucellosis, melioidosis, plague, psittacosis, Venezuelan equine encephalitis, Q fever, coccidioidomycosis, and a variety of plant and animal/fowl pathogens [6,15].

Of particular note was the attention directed at chemical and biological detectors during the 1960s. The first devices were primitive field alarms to detect chemicals, but the development of sensitive BW agent detectors was at a standstill. Nonetheless, two systems were investigated, the first being a monitor that detected increases in the number of one to five-micron sized particles, based on the assumption that a biological agent would include airborne particles of this size. The second system involved the selective staining of particles collected from the air. Both systems lacked enough specificity and sensitivity to be of any practical use [11]. But in 1966, a research effort directed at detecting the presence of adenosine triphosphate (a chemical found only in living organisms) was begun. By using a fluorescent material found in fireflies, preliminary studies indicated that it was possible to detect

the presence of a biological agent in the atmosphere. The effort to find a satisfactory detection system continues today, to include the use of animal sentinels that could also detect chemical agents.

The Army also experimented with and developed highly effective barrier protective measures against both chemical and biological agents. Special impervious tents and personal protective equipment were developed, to include individual gas masks even for military dogs (it should be noted that dogs can be trained to detect minute concentrations of certain chemicals and may serve a useful role on the chemical/biological battlefield).

During the late 1960s, funding for the biological warfare program decreased temporarily, to make up for the accelerating costs of the Vietnam conflict. The FY 69 budget was \$31 million, decreasing to \$11.8 million by FY 73. But the offensive and defensive programs continued to be defended. John S. Foster, Director of Defense Research and Engineering, responded to a query by Congressman Richard D. McCarthy:

It is the policy of the U.S. to develop and maintain a defensive chemical-biological capability so that our military forces could operate for some period of time in a toxic environment, if necessary; to develop and maintain a limited offensive capability in order to deter all use of chemical and biological weapons by the threat of retaliation in kind [26].

When President Nixon stopped U.S. production of biological weapons in 1969, much of the program was redirected. The large biological warfare facility under construction at Fort Detrick was finally completed in 1971 but became known as the U.S. Army Medical Research Institute for Infectious Diseases (USAMRIID). Many other facilities underwent mission changes. The emphasis shifted away from offensive weapons to personal protection, immunizations, chemoprophylaxis, and rapid detection systems.

Although chemical defoliants, such as herbicide orange (containing phenoxyacetic acids) were also developed under the auspices of the chemical and biological warfare research program, they will not be discussed in this paper, since such defoliants are not of biological origin. Such herbicides were tested in 1944-1945 with biological agents, however, and were eventually used in Vietnam in 1962, the first time that aerosolized herbicides were used in modern warfare.

B. The Later Years (1970s-1990):

In response to President Nixon's decision in 1969, all anti-personnel BW stocks were destroyed between 10 May 1971 and 1 May 1972, and the laboratory at Pine Bluff Arsenal was converted to a toxicological research laboratory. Biological anti-crop agents were destroyed by February 1973. BW demilitarization continued through the 1970s, with continuing input provided by the U.S. Departments of Health, Education, and Welfare, Interior, and Agriculture, and the Environmental Protection Agency. Fort Detrick and other installations involved in the BW program took on new identities and modified missions, but a biosafety level-4 containment capability⁹ continued to be maintained at the USAMRIID.

In 1984, the Department of Defense requested funds for the construction of another biological aerosol test facility in Utah. The proposal submitted by the U.S. Army called for a biosafety level-4 containment, although the Army maintained that the level-4 inclusion was based on a possible need in the future and not on a current research effort. The proposal was not well-received in Utah, with many citizens and government officials still recalling the secretive projects of the military, the areas on Dugway Proving Ground still contaminated with anthrax spores, and the well-publicized accidental chemical poisoning of a

herd of sheep in Skull Valley in March 1968 [15]. Questions arose over the safety for the employees and the surrounding communities, and a suggestion was even made to shift all biological defense research to a civilian agency, such as the National Institutes of Health. The plan for a new facility was revised to utilize a level-3 facility, but not before Congress had instituted more surveillance, reporting, and control measures on the Army to insure compliance with the Biological Weapons Convention agreement.

Currently, the BW research effort (known as the Biological Defense Research Program) is concentrated at the USAMRIID at Fort Detrick. Some research continues at Edgewood Arsenal, Maryland, and Dugway Proving Ground, Utah. BW research programs are now directed at early diagnosis, prevention, and treatment:

...the Biological Defense Research Program of the U.S. Army has a large medical component that develops strategies, products, information, procedures, and training for medical defense against biological warfare agents. The products include diagnostic reagents and procedures, drugs, vaccines, toxoids, and antitoxins. Emphasis is placed on protection of personnel before exposure to the biological agent [27].

Rapid diagnostic tests, vaccine development, and drug prophylaxis constitute a large part of the current research effort. Since BW agents are often etiologic agents for naturally occurring diseases, the military research effort provides substantive benefits for civilian populations also. Vaccines against tularemia, Q fever, Rift Valley fever, Venezuelan equine encephalitis, Eastern and Western equine encephalitis, chikungunya, Argentine hemorrhagic fever, and anthrax are examples of products produced through a military research effort [27,28]. Similarly, antitoxins against diseases such as botulism have been produced. Human immune globulin preparations (passive antibody protection) against various bacteria and viruses are being developed. Antiviral drugs are being tested against

multiple viral agents. Some vaccines also have applicability for animal herds (Rift Valley fever and Venezuelan equine encephalitis). Vaccines are provided to persons who may be occupationally exposed to such agents, such as laboratory workers, entomologists, and veterinary personnel.

USAMRIID also provides diagnostic and epidemiological support to Federal, state, and local agencies and foreign governments. Examples of how the Army Research and Development Command has assisted civilian health efforts are: the massive immunization program instituted during the Venezuelan equine encephalitis outbreak in the Americas in 1971; the laboratory support provided to the U.S. Public Health Service during the outbreak of Legionnaires' disease in Philadelphia in 1976; the management of patients suspected of having African viral hemorrhagic fever in the 1980s; international support for the outbreak of Rift Valley Fever in Mauritania in 1989; and assistance with the outbreak of Ebola infections among imported monkeys in Reston, VA in 1990.

The current research effort combines new technological advances, such as genetic engineering, and applying such biotechnology toward prevention and treatment of infectious diseases or exposures to toxins of military significance. The program is conducted in full compliance with requirements set forth by the Food and Drug Administration, the U.S. Public Health Service, the Nuclear Regulatory Commission, the U.S. Department of Agriculture, and the Occupational Safety and Health Administration, and the agreements of the Biological Weapons Convention [27].

While some of the military's biological defense programs continue to be classified today based on worldwide threats and uncertainties, the military facilities and resources continue to be an invaluable resource

for the nation. The overall biological defense research effort was reviewed by the civilian-operated Army Science Board in July 1987 and found to be in full compliance with existing safety guidelines and with no indications suggesting an offensive research effort.

Despite such reviews, the Biological Defense Research Program has continued to be criticized as being conducted without proper safeguards or clear direction [29]. Concern has been raised over the Department of Defense's research initiatives using genetically altered organisms, and the possibility of uncontrolled research contributing to a biological arms race [30]. In all likelihood, the scientifically credible program will continue to be controversial, despite all efforts at openness.

IV. DEPLOYMENT AND USE OF BIOLOGICAL WEAPONS

A. Requirements for an Ideal BW Agent:

BW agents can be described as anti-personnel weapons, for it is the vulnerable human element that is specifically targeted. One must, therefore, consider the ideal BW agent in terms of susceptibility of individuals. The following characteristics have been commonly used to characterize an ideal weapon that can inflict a significant number of casualties [2,31,32,33]:

a. It must be lethal or incapacitating. Examples of infections associated with high morbidity and mortality are anthrax (in particular, pulmonary anthrax, which almost always results in death); viral hemorrhagic fevers, such as Ebola, Marburg, or Congo-Crimean hemorrhagic fever viruses; brucellosis (undulant fever); and plague (in particular, the pneumonic form, which is associated with high mortality and aerosolized

communicability). Viral agents are particularly attractive, since most agents do not have specific therapies. Also, many viruses are able to undergo substantial antigenic changes, as seen with the antigenic shifts with influenza, which make previous immunization programs ineffective.

b. It must be able to be produced economically and in sufficient quantities. Many live agents can be propagated relatively easily, but production of large amounts of toxins may require more sophistication.

c. It must be relatively stable and maintain its viability or virulence and infectivity during production, storage, transportation, and delivery. Agents susceptible to effects of temperature or dryness will not be effective agents unless they are provided a protective medium and environment that preserves viability and pathogenicity. Low persistence in the environment after delivery is desirable.

d. It must be capable of being easily disseminated. Dispersal may include delivery through air, water, food, vectors, or contact with infected persons. An individual ill with a highly communicable pathogen may infect others through direct personal contact, airborne spread, or sharing of personal items. In general, aerosolization is considered to be the favored route of dispersion, because of the relative ease of spreading an agent over a large area in a short time, the susceptibility of the respiratory tract, and the associated debilitating pulmonary effects of many agents. Also, many dispersal methods already developed for chemical weapons could be used for delivering biological agents. Environmental factors, such as prevailing winds and rain, may reduce the effectiveness of such weapons, however.

e. It must be in a form that can enter the body efficiently to cause its desired effect. With respiratory agents, particulate size is very

critical, for particles one to five microns in size will be capable of reaching the alveolar bed of the lungs; particles greater than five microns will be filtered out by the upper respiratory tract, and particles less than one micron in size will be easily exhaled [4]. Anthrax, Q-fever, glanders, brucellosis, tularemia, and plague are examples of potent respiratory pathogens.

f. The intended victim(s) must be susceptible. If they are selectively immunized or provided with effective external personal protection or prophylactic drugs, susceptibility is reduced. The ideal weapon is one for which there is no prophylaxis adopted by the enemy.

g. The agent should require a low infective dose to cause death or disease. Few infective organisms per individual would increase the predictability of damage to the enemy. A short incubation period would create a greater explosive epidemic situation.

These characteristics must be assessed from the standpoint of specific enemy capabilities and strategies. As will be discussed later, these factors must be considered in terms of an evolving world, where advances in modern technology and weapons delivery systems, such as long-range cruise missiles with multiple warheads, have overcome some of the earlier physical limitations. A BW agent need no longer be highly lethal to be effective, for incapacitation and confusion may be all the disruption necessary to change the course of a battle.

Since initial symptoms resulting from a BW agent may often be similar to those produced by infections endemic to an area, a weapon may be capable of overcoming a military force before its presence is even suspected. When one member of a unit falls victim, others may still be incubating disease. Troops deployed to foreign lands may be at greater

risk for exotic agents, since they may even lack natural immunity. Also, the psychological and demoralizing impact of a sinister lethal infection or toxin cannot be underestimated.

B. Advantages of Biological Warfare:

The advantages of biological weapons over conventional weapons include: (1) their potentially deadly or incapacitating effect on a susceptible population; (2) the self-replicating capacity of many biological agents to continue proliferating in the affected individual and the population or his surrounds; (3) the relatively low cost of producing many biological weapons; (4) the insidious symptoms that may mimic endemic diseases; (5) the inability for the enemy to detect the immediate use of a biological agent, due to a prolonged incubation period preceding onset of illness or the slow onset of symptoms; (6) the sparing impact on property and physical surrounds, as compared to conventional or nuclear weapons; and the current limitations in fielding a multi-agent sensor system on the battlefield. By the time the first casualty is recognized, the agent may have already been ingested, inhaled, or absorbed by others.

Biological weapons can be more sinister than conventional, chemical, or nuclear weapons, where effects are more immediate. Minute particles can silently pass through filtration systems of ships, vehicles, command headquarters, sleeping quarters, and even hospitals.

C. Disadvantages of Biological Warfare:

The major disadvantages include: (1) the danger of biological agents also affecting the health of both friendly and enemy forces; (2) the high level of dependence that many agents have on prevailing winds and other weather conditions influencing dispersion; (3) the effect of temperature, sunlight, and desiccation on the survivability of some infectious

organisms; (4) the persistence of some agents, such as spore-forming anthrax bacteria, on the environment, making an area uninhabitable for long periods; (5) the unpredictability of morbidity secondary to a biological attack, since casualties (to include civilian casualties) will be related to quantity and manner of exposure; (6) the relatively long incubation period for many agents, a factor that may limit their tactical usefulness; and (7) the public aversion to use of biological agents.

Many of these points have been presented in Congressional testimonies and public documents [13,31,34], but it should be noted that, unlike chemical agents, BW organisms or toxins have never been used thus far in modern warfare. Therefore, there is no practical experience.

D. Psychological Impact:

Biological agents, by virtue of their silent dissipation, may be more psychologically disruptive than conventional weapons to an unprepared military unit. The prospects of dying from an incurable, painful, and highly communicable disease can create a panic among unprotected soldiers trained to fight against conventional weapons only. Most militaries of the world have little experience in dealing with BW casualties, and facing an unknown threat can give rise to considerable anxiety and fear.

E. Personal Protection:

Decontamination procedures must be directed at biological agents and chemical agents, since one is never sure initially after an attack if both have been used. Therefore, a 5-10% hypochlorite solution is probably effective against most agents. Masks present a different problem, however, for chemical masks equipped with special canisters for absorbing specific toxic substances may not provide protection against minute infectious particles or toxins. If filters have too small a pore size,

breathing will be significantly impaired. No self-injectable antidotes, as seen with atropine autoinjectors, are available for BW agents. Therefore, respiratory protection against biological agents may be more difficult than for chemical agents.

It is currently impossible to immunize personnel against every BW agent. Also, immunizations may not be effective against overwhelming exposure, as seen following typhoid and cholera immunizations. Although immunizations against highly likely agents will probably provide some protection, such an effort may also decrease the likelihood that a particular agent would be used by the enemy. Drug chemoprophylaxis may provide some added protection when used prior to, during, or immediately following exposure.

F. Medical Care:

Medical care for the casualties of a biological war is a serious concern. The medical resources that will need to be directed to care for an individual infected with a highly communicable disease, and the infection control procedures that would need to be instituted, will force a difficult prioritization of medical care. It is impractical to commit a large number of medical resources to care for a few BW casualties, when other injuries must also be addressed. Field hospitals are not equipped with segregated laboratories to handle highly infectious specimens, and such patients cannot be quarantined or evacuated very easily or safely from the field. The risk of transmission to medical personnel and other patients and soldiers must be evaluated; this decision is made more difficult when the specific pathogen(s) is unknown.

The impact that such casualties could have on the medical care system has been already vividly realized with the difficult care of a few

patients with contagious viral hemorrhagic fever (level-4 organisms: Marburg, Ebola, and Congo-Crimean viruses) from Central Africa [35]. Such patients have required air-tight transportable isoletes, separate medical staff, and strict infection control procedures.

Broad-spectrum antibiotics, antiviral drugs, and antitoxins to suspected agents must be in adequate supply, with the recognition that biological agents may exhibit multiple drug resistance. However, it should be recognized that many viral infections may not be responsive to drug therapy.

G. Strategic and Tactical Concerns:

Knowledge and understanding of enemy strategy, tactics, and doctrine are essential parts of waging a successful military campaign. The Chinese strategist Sun Tzu appropriately stated:

...know the enemy and know yourself...If ignorant both of your enemy and of yourself, you are certain in every battle to perish.¹⁰

This understanding includes an appreciation of whether the enemy possesses biological weapons and in what quantity, what compels him to use them, and in what manner he will employ them. It is also stated in Army doctrine that enemies can be expected to use "large and effective quantities of weapons systems," and, on occasion, these weapons systems may equal or exceed our own [20]. Biological weapons, like chemical weapons, have the potential of inflicting heavy casualties in selected areas, contaminating personnel and equipment, causing disruption of troop movement and maneuvers, impacting on resources in forward and rear areas, and restricting or denying the use of terrain by friendly and enemy forces.

Biological weapons, when compared to nuclear or chemical weapons, have a less likely potential of causing widespread devastation; it is unlikely

that they would be used in this manner in modern warfare. A more likely scenario is their application on a limited scale to cause disruption, rather than annihilation. As a force is demoralized and reduced by disease and strange illnesses, attrition becomes a more significant factor. Therefore, a proper defense against biological weapons requires an understanding of the enemy, and the adoption of effective personal protective measures to minimize their impact. But one should also heed the wisdom of Sun Tsu when he advised: "attack when he [the enemy] is unprepared."

BW agents, by themselves, are not ideal tactical weapons, due to their unpredictability and delayed effects. They are also viewed as inhumane by many, and their "first use" would predictably generate world criticism. The tactical importance may increase, however, as more is learned about the predictability of damage from specific biological agents. But the U.S. military must be prepared to defend against biological attack at all levels of conflict. Their use with other weapons systems must also be anticipated. With the development of new missile delivery systems, even intercontinental delivery of biological bombs is possible, although low-flying cruise missiles provide the best opportunity to generate a dense toxic cloud close to the ground [3]. It has been estimated that under suitable conditions, a cruise missile could deliver anthrax spores over an area of the same magnitude as the lethal fallout from a ground-burst nuclear warhead [3].

To simply maintain a defensive posture against attack is not adequate, however, for the military must be able to sustain an offensive campaign in a biologically-contaminated environment. Otherwise, it will only invite further use of such weapons by the enemy. The impact of infectious

diseases on military units has been well-documented through the years, but the fielding of highly lethal agents makes personal hygiene, individual protective measures, and command-driven discipline even more important.

Field Manual 100-5 (Operations) describes the AirLand Battle and the offensive and defensive scenarios for the Army [36]. While more accurate weapons systems make collateral damage less likely, multiple warheads may make the extent of chemical or biological contamination greater.

Biological weapons are most effective when used for "saturation effect" and preservation of enemy materiel, and current NATO strategy emphasizes rapid advances with ground-winning initiatives; the doctrine presupposes the use of captured weapons and infrastructure, as opposed to mass destruction, thereby making biological weapons more well-suited than nuclear weapons to accomplish this purpose [9,37].

H. Deterrence:

The renunciation of the offensive use of biological weapons by the U.S. and many other nations has reduced by not totally eliminated biological agents from being used offensively in the world. The rationale for biological warfare as a deterrent is poor for several reasons. First, the international outcry against the inhumane spread of disease and suffering would be overwhelming. Second, a defeated nation plagued with man-generated illnesses throughout the land still leaves the victor with the problem of curing and controlling disease and disability, if he intends on claiming the territory. Stated another way, the victorious nation will find itself confronting its own weaponry. Third, since other deterrent measures, such as chemical and nuclear retaliation, still exist, biological warfare with highly lethal agents or toxins serves little

purpose. The elimination of a biological warfighting capability places greater reliance on other more reliable weapons systems. Therefore, the U.S. decision to renounce biological weapons is clearly justified in today's world, and strategists must accept the fact that wars will need to be won in other ways.

Many maintain that biological weapons pose less of a danger of escalation than conventional and nuclear weapons, and are not convinced that signers of the 1972 Biological Weapons Convention agreement are not secretly preparing weapons. Since biological weapons can be prepared more quietly than nuclear weapons, and verification is extremely difficult, assurance of a deterrence may be near impossible anyway.

I. Terrorism:

The availability of less sophisticated biological weaponry has been mentioned before. Biological weapons can be employed effectively as a means of terrorism or sabotage, especially in rear echelon areas, port or staging sites, and industrial and storage areas. Biological weapons can also be used on civilian populations, creating situations of panic. The possibilities of contamination of logistical supplies has been recognized for many years, and security in all areas of the battlefield is of great importance when dealing with an enemy with such capabilities. From a strategic perspective, biological agents may still be an effective means to the end.

J. Surveillance, Monitoring, and Detection:

A satisfactory defense requires a sensitive monitoring and surveillance system to be employed, one that can detect the presence of toxic biological materials in the environment in a similar manner to chemical detectors [9]. Detectors must be reliable and sensitive, and

must be able to determine when an area previously contaminated is safe. Less sophisticated detector systems may employ live animals.

A medical surveillance system that closely monitors unusual illnesses or outbreaks of disease is equally important. A field medical laboratory capable of identifying agents or toxins quickly and accurately is a necessity if use of biological weapons is predicted. Viral agents and toxins present the most difficult diagnostic problem, however, for current diagnostic tests based on monoclonal antibody, radioimmunoassays, or enzyme-linked immunosorbent assays rely on specific antigens. Laboratory capabilities must be coordinated closely with intelligence information on enemy capabilities and information on endemic diseases and outbreaks.

K. Combined Exercises:

Combined exercises with allies present additional problems, especially when offensive and defensive doctrines differ, national security is in question, or separate intelligence analyses of the biological threat may lead to different conclusions. This may prove to be one of the most difficult issues to resolve in the future, since forces of other nations may not be as prepared to deal with biological warfare threats as the U.S. Personal protective measures, such as sophisticated vaccines, may be available through the U.S. only, a potential logistical problem in the future if combined exercises and deployments become more frequent.

V. THE BIOLOGICAL WARFARE THREAT

A. The Soviet Threat:

The biological warfare research program of the Soviet Union has been known for decades, and it is no secret that the Soviets continue to

evaluate and test potential biological agents. More recently, biotechnological advances have been incorporated into their research programs, to improve the tactical usefulness of such agents on the battlefield [18]. The Defense Intelligence Agency believes that the Soviets have developed anthrax, tularemia, plague, cholera, botulinum toxin, staphylococcal enterotoxin, and various mycotoxins as BW agents. The Chemical Troops of the Ministry of Defense supervises the development, testing, evaluation, acquisition, and storage of chemical and biological weapons. Soviet vaccines are available for anthrax, tularemia, plague, and botulism, as well as other dangerous endemic infections in the Soviet Union, such as Russian spring-summer encephalitis.

B. Continuing Proliferation:

One must assume that all nations with biological warfare capability will use such weaponry to attain victory. The recent advances in biotechnology has broadened tremendously the opportunities for new highly virulent agents to be synthesized, but as will be discussed later, many of these new toxins may not be covered by the Biological and Toxin Weapons Convention of 1972. According to a 1988 article in The Wall Street Journal, ten nations are now believed to be developing some type or types of biological weapons.¹¹ This is in addition to approximately twenty other nations that the U.S. Defense Intelligence Agency now believes to possess chemical weapons, in addition to the U.S., Great Britain, and France [3]. Biological weapons are cost-effective, which makes them particularly attractive for Third-World nations. It has been estimated that biological weapons cost \$1 per square kilometer, compared to \$600 per square kilometer with nerve gas, \$800 per square kilometer with nuclear weapons, and \$2000 per square kilometer with conventional weapons [38].

All of these factors indicate that, despite the Biological Weapons Treaty, proliferation of biological weapons is continuing.

C. Third World Nations:

Less controversial is the stark reality that several Third World nations can develop and may already possess arsenals of biological weapons. Even when used in a primitive manner, the impact of such weapons can be significant. When combined with attitudes of fanaticism and desperation, biological agents employed by a nation or a radical group can be extremely disruptive and dangerous. The threat of biological agents being used has resulted in some nations adopting defensive immunization programs against specific agents. Often these agents may also be causes of endemic diseases, and from that standpoint, the preventive measures protect against both a natural and a man-made threat.

During the Persian Gulf crisis of 1990-1991, the biological capabilities of Iraq once described by Central Intelligence Agency Director William H. Webster as "a sizeable stockpile,"¹¹ resulted in the procurement and use of immense quantities of special BW vaccines (anthrax and botulinum vaccines), for military personnel belonging to the coalition forces [39]. The BW capability of Iraq has also threatened civilian communities in adjoining nations. The ability for short, intermediate and long-range missiles to deliver biological agents provides another dimension for defenses on the present-day and future battlefields.

D. Non-Human Targets of Attack:

It is worth noting that the initial research in 1943 on biological agents included a \$405,000 confidential research request from the Department of Agriculture to conduct investigations on insect infestations and plant diseases [12]. This was based on the early recognition of the

devastating impact a biological agent directed against crops could have. From a BW perspective, destruction extends beyond locust infestations and plant blights. New advances in technology have now made it theoretically possible to target destruction to specific economic crops, poultry, or livestock, and history is replete with naturally occurring infections that have destroyed such industries. Many highly communicable infections, such as Newcastle's disease attacking poultry or rinderpest affecting cattle herds, determines the dismal fate of the entire flock or herd. One should not forget also that many infections may be zoonotic, i.e., transmissible under natural conditions from vertebrate animals to man.

Plants and crops lack an immune system, so they are far more susceptible to biological agents than animals [4]. Monocultivation, where the cultivars p'anted in an area are identical genetically, makes crops very susceptible to attack with plant pathogens. The planting of resistant crops will take time, because enough seeds could not be produced in a short time. Crop destruction can cripple the economy of a nation and lead to famine and starvation.

VI. NEW TECHNOLOGY

Rapid advances in biotechnology over the past ten years, in particular, have dramatically changed the outlook of biological warfare. Although many pathogenic organisms can still be produced in large numbers relatively easily, sophistication in gene sequencing, genetic manipulation, and toxin production has made biological warfare achieve new and more worrisome significance in modern day warfare. A noticeable shift in scientific interest to dangerous viral agents and highly lethal toxins

has been apparent, along with a continuing interest in highly lethal bacterial agents, such as Bacillus anthracis. Many toxins are far more deadly and incapacitating than chemical agents, and are difficult to identify in a rapid manner. Tetrodotoxin, aflatoxins, and trichothecenes, as examples, are among the most toxic substances known to man. The list of possible biological agents and toxins is extensive, but based on the ideal requirements for a biological agent, certain candidates appear to be more attractive. Tables I and II lists those agents that appear to be receiving the most attention, and it is likely that over time, more agents with increased virulence and pathogenicity will be developed. This justifies an aggressive research program of defense, that incorporates detection systems, protective measures, and therapeutic options.

The recognition of the importance of biotechnology has actually been recognized for over twenty years, as evidenced by a highly sophisticated research effort by the Soviets. Physician Jane M. Orient [3] reported in her 1989 article on chemical and biological warfare that during a Warsaw Pact scientific conference in East Germany in 1971, the following statement was made:

...the rapid development of biological engineering will make it possible in just a few years to produce synthetic or partially synthetic toxins on a large scale. Such toxins agents represent a combination of the hitherto chemical and biological weapons... Neurotropic toxins are toxic proteins which are primarily byproducts of the life cycles of microorganisms. The neurotropic toxins are the most toxic chemical substances...Under combat conditions, they can be used as an aerosol or in solid or liquid state in mixed elements of ammunition; they can also be used for sabotage purposes.¹²

The reality of biotechnology extending weapons proliferation beyond the scope of the Biological Weapons Convention has led many to criticize the ultimate goals of the Department of Defense's biological defense

program. After all, is a synthetic toxin a chemical or a biological agent? And how do you prevent the advancement of science, when gene sequencing has so many potentially beneficial rewards?

Assertions that the overall policy on defense is vague or non-existent, and the chemical and biological warfare research program involving many civilian subcontractors supported by a budget of over \$80 million per year for biological defense alone is difficult to oversee, has created confusion in the minds of many as to what are the long-range objectives [30,39]. The separation between offensive and defensive research initiatives has become increasingly more vague, as development of defenses require a characterization of the agent(s) involved.

A. Gene Sequencing:

An enormous diversity of dangerous biological weapons is now possible through recombinant DNA research and other biotechnologies. Sequencing of the actual genetic structure of organisms and their toxins is now possible, allowing for artificial synthesis of the genetic components in a cell. The artificial replication of nucleic acids permits multiplication outside of the human host, and numerous quantities of a potential BW agent can be theoretically produced by methods, such as monoclonal antibody techniques. Symptoms resulting from infection by pathogenic organisms are usually the result of the process by which an organism invades and multiplies in a host, or of the direct action of a toxin produced by the organism. Toxin-coding genes contribute to pathogenicity and virulence, and through gene manipulation, it is theoretically possible to alter these characteristics in the development of a better biological weapon. But building a defense against a particular agent requires knowledge of its antigenic components, only possible through gene sequencing.

Although much is still unknown about how viruses, for example, alter their virulence, accumulating knowledge on how such viruses enter the body and invade tissues and cells has resulted in interest in examining ways to strengthen (or to weaken) natural host defenses. By changing the arrangement or composition of specific genes, the cell and tissue affinity (attraction of infectious agents to target tissues or organs) can be affected, thereby allowing for infection to occur more easily. Genes affect protein synthesis, the immunological response of the host, and actions of other invasive organisms. Ironically, anti-viral antibodies produced in response to one infection could also lead to enhanced pathogenicity of other viruses, but if antibodies are broad in scope, the result might be broad protection across a group of viruses.

B. Molecular Vectors for Agents:

Viruses can also act as molecular vectors for toxin-encoding genes or virulence factors. Vaccinia virus strains, for example, have been modified with the insertion of genes coding for several antigens, thereby allowing for vaccination against a variety of antigens at once with a modified vaccinia vaccine. The modification of the genetic structure of an invasive virus, however, also permits multiplicity of different pathogenic factors with one organism, thereby increasing the overall virulence and pathogenicity. Genes coding for certain toxins can also be inserted into viruses and bacteria, increasing invasiveness and multiplication. The non-virulent strain of Bacillus anthracis, for example, produces toxin but no capsules that would protect the organism by attack by the host defense mechanisms, but the presence of a capsule made of d-glutamyl polypeptide protects the bacteria from attack [9]. Other organisms that possess a protective capsule include meningococcal and

pneumococcal organisms, infectious agents that invade through the respiratory tract.

C. Resistance Coding:

Gene manipulation also makes possible the insertion of drug resistance into an organism; the resistance may be multiple, rendering commonly used antibiotics ineffective in treatment. This is especially true with bacteria, where chromosomally mediated drug resistance (resistance incorporated into the genome of the cell) will confer long-lasting resistance; this is preferable to plasmid-mediated resistance (resistance conferred by unincorporated plasmids), which can be more easily reversed. Resistance to ultraviolet radiation is also theoretically possible, making an agent more stable in the environment.

The developments in biotechnology also mean that highly specific vaccines can be developed against specific agents. The availability of a specific vaccine by a BW aggressor nation may encourage use of the agent offensively, since the aggressor forces will be protected. Hence, one must assume that nations with an offensive biological warfare capability will very possibly have a defensive program also.

D. Delivery Systems:

Micro-encapsulation allows for increased penetration of a substance through cell membranes. Liposomes, such as microscopic vesicles containing phospholipids, have been used to deliver nucleic acids, drugs, and toxins into living cells [9]. Such vesicles loaded with numerous quantities of infectious agents could pass through cell membranes and be released. Natural barriers, such as mucosal linings of the respiratory or gastrointestinal tract, could be easily overcome with such enhancements, making biological agents even more lethal.

But improvements in delivery systems also apply to more efficient ways of aerosolizing agents (such as lyophilization of agents in a medium that preserves the integrity of the agent in a powder form), delivering agents through vectors such as mosquitoes or fleas, or maximizing rapid skin absorption. When combined use with chemical weapons, such as blister agents, more rapid absorption could be easily achieved.

E. New BW Agents:

Groups of BW viral agents that have been studied include poxviruses, alphaviruses, flaviruses, bunyaviruses, Hantaan viruses, filoviruses, picornaviruses, arenaviruses, and various bacteria, to include Bacillus anthracis [9]. The list of organisms include agents that have long been considered to be potential threats, as well as naturally occurring exotic viruses that are highly communicable and associated with high morbidity and mortality (see Table 1). Many of these "newer" agents occur in geographically isolated parts of the world, thereby making it more unlikely for prior immunity to be present in the target population. Organisms, such as Marburg virus, Lassa fever virus, Legionella pneumophila (cause of Legionnaire's disease), Ebola fever virus, and human T-lymphotrophic viruses (cause of AIDS and AIDS-like diseases) are pathogens that have been only recognized since the 1960s, making it highly likely that other unrecognized pathogens exist in the wild or will be subject to virulent mutations in the future.

F. Toxins:

Toxins have usually been defined as proteinaceous or non-proteinaceous poisonous substances produced by living organisms. The ability to chemically synthesize many toxins through gene sequencing has made this definition less clear, however, for toxins are sometimes classified as

chemical agents. The availability and toxicity of many naturally-produced toxins, such as staphylococcal enterotoxins, ricin, botulinum toxins, and mycotoxins, has generated military interest in such agents as weapons, which could be used against U.S. forces and its allies. Genetic engineering and immune techniques now permit synthesis of large quantities of toxins (and antitoxins).

Mycotoxins are low-molecular weight non-proteinaceous compounds produced by molds, that can produce severe illness when ingested, inhaled, or touched. They are heat resistant and are difficult to detect, destroy, and treat [9]. Mycotoxins include four major types of aflatoxins, produced by Aspergillus flavus and A. parasiticus, and trichothecenes, produced by various species of Fusarium and other molds. Over fifty different kinds of trichothecenes alone have been identified, thus far. Trichothecenes and yellow rain has been discussed previously.

Toxins that have been partially or entirely sequenced include anthrax toxin, botulinum toxin A-E, cholera toxin, diphtheria toxin, Escherichia coli enterotoxins, staphylococcal enterotoxin, Shigella dysenteriae toxin, tetanus toxin, snake venom, and ricin. Monoclonal antibodies (the homogeneous production of antibodies reacting to a single determinant) have been developed against several of these toxins [9].

Toxins are often classified according to their pathological effects. Neurotoxins affect the nervous system primarily; cardiotoxins are especially toxic to the heart; hepatoxins have the liver as their main target organ; and dermatoxins affect the skin primarily. The major toxins of military importance by pathological effect are listed in Table II. Toxins may be used independently, in combination with other toxins to achieve a synergistic effect, or in combination with chemical agents.

G. New Agents and the Biological Weapons Convention Agreement:

The ability to alter various organisms genetically led to worry among many of the signers of the Biological Weapons Convention agreement of 1972. Concerns were voiced in several areas: (1) the possibility that agents, which could be modified and tailored to suit specific needs, would make biological warfare more attractive to the military; (2) new methods and products, to include live organisms and toxins, would not be applicable to the agreement; and (3) verification of peaceful intent in research programs and separation of offensive from defensive programs would be difficult to determine. Since many organisms and toxins considered to be potential BW agents were naturally occurring, and preventive and therapeutic measures against such dangers were within the scope of peaceful medical research, how could secret offensive intentions be separated? How could new vaccines and antitoxins, specific antidotes, and diagnostic tests be produced without knowledge of the antigen or combined antigens? How could medical research be halted when it was known that certain toxins, such as trichothecenes, were promising candidates for chemotherapeutic drugs against certain malignancies? It was apparent that any BW research program could be easily justified along defensive lines, since "development" and "production" were often necessary.

It was generally agreed that any agent that is able to multiply and be used as an offensive weapon, would fall within the scope of the earlier agreement (the earlier agreement prohibited "development, production, and stockpiling). This was also within the framework of the earlier 1925 Geneva Protocol, which prohibited "use" of such weapons.

Agreement on toxins continues to be controversial, however. Since the term "toxin" was never specifically defined at the Biological Weapons

Convention of 1972, artificial toxins are considered by many to be "synthetic poisons" not covered by the agreement. Such interpretation does weaken the intent of the agreement, but allows for the development of a strong defense program by the U.S. against specific agents of military significance. This is certainly an area where future efforts must be directed to reach international consensus.

H. New Defense Initiatives:

Vaccines will continue to be a means by which the military protects its personnel, but it is physically impossible to create a vaccine against every potential BW agent. Hence, research has been directed at looking at alternative approaches that would apply to a variety of different agents. This generic approach has led to research on immunomodulators, immunopotentiators, and broad-spectrum antiviral drugs. Vector vaccines, where antigenic subunits of various agents can be incorporated into a single vaccine, have been pursued, the best example being the vaccinia virus recombinants; several antigenic determinants to other infectious agents are combined into one vaccine. A military force must have some way to defend itself against its own weapons; this is especially important with biological weapons. Agents that would naturally degrade would need to be used, if territorial occupation is within the military plan. Hence, the development of new agents must be accompanied by preventive strategies, such as specific vaccines, in order not to increase its own vulnerability.

Many vaccines have been produced through the U.S. biological warfare program. Vaccines have been developed, for example, against anthrax, chikungunya virus, Eastern equine encephalitis, Venezuelan equine encephalitis, Western equine encephalitis, Rift Valley fever, Q fever,

anthrax, plague, and tularemia, and many of these have been stockpiled for various contingencies; these infections are not commonly encountered, but have the potential of compromising a military mission. Antitoxins have also been developed against BW agents, such as the botulinum toxins and staphylococcal enterotoxin B, and research continues in developing protection against the other potential agents listed in Tables I and II. All of these products are tested in full compliance with Food and Drug Administration requirements and guidelines, but because many of these products may still be unlicensed, they fall in a category of "limited use vaccines and products" for specific contingencies or emergencies [28].

Stockpiling and war reserves, however, have not been adequately addressed in relationship to the limited vaccine industrial base of the nation, and whether the pharmaceutical industries would be able to respond to short-notice increases in vaccine or antitoxin production is uncertain.

VII. ETHICAL CONCERNS

A. The Humaneness of Weapons.

A frequent contrast is made between the ethics of using conventional versus non-conventional (nuclear, chemical, and biological) weapons. The public perception is that the later is associated with more suffering, devastation, and cruelty. If war can be considered to be moral, adoption and use of biological agents will probably be guided more by cultural attitudes, expectations, and experiences. It should come as no surprise, therefore, that we will find ourselves confronted by a foreign enemy who does not share our common values and beliefs on right and wrong. If

victory is of foremost importance, it must be presumed that a country with biological warfare capability will use such weaponry that it has spent time and effort developing, when it appears to be advantageous. But is there a place in modern warfare for biological weapons? Will use of such weapons be more harmful or beneficial?

During his acceptance speech at the Republican National Convention on August 18, 1988, George Bush stated: "Ban chemical and biological weapons from the face of the earth. That will be a priority for me." He followed this speech with support for the Chemical Weapons Convention, but defining a specific course of action for biological weapons was much more difficult.

The recent Iraqi invasion of Kuwait has made it obvious that the U.S. must maintain a strong defensive posture against biological weapons. The continuing research program of the Soviets and the interest by many Third World nations in biological weapons have made it unlikely that any new steps towards non-proliferation that are agreed upon internationally will occur anytime soon. The fact that the U.S. and 102 other nations signed the non-verifiable Biological Weapons Convention agreement in 1972 should not infer a sense of security that there is international agreement on the limits of war, for several of the signees are now believed to be developing such weapons secretly. As stated earlier, biological weapons are effective and cheap.

Richard J. Krikus in his discussion of morality of chemical and biological war points out the conflict in war doctrine:

...modern just war doctrines share the fate of their predecessors in becoming scarcely distinguishable from mere ideologies the purpose of which is to provide a spurious justification for any use of force [40].

As seen in the continued nuclear proliferation, the reality is that nations will use whatever force necessary to achieve their goals.

B. Equality In Counterforce and Strategy:

Many envision some thread of humanity necessary for the conduct of war, while the militarist may see victory to be of paramount importance, with resulting annihilation of the enemy. This is not to imply that the militarist is not sensitive to human suffering, but he may actually see biological weapons as being useful in a war or in a long conflict with a concealed enemy. By possessing biological weapons, he, therefore, has another weapon that he can use when the tactical situation indicates to disrupt enemy forces. He would probably not use a biological weapon in territory that he intends to occupy, unless he can be sure that the agent will dissipate or degrade by the time he enters the area, or his troops are appropriately protected. Since U.S. forces are prohibited from using biological weapons of any kind, to include incapacitating weapons, they may be at a distinct disadvantage against such an enemy.

President Franklin D. Roosevelt stated in 1943 at the commencement of the research program his reservations about biological weapons:

I have been loath to believe that any nation, even our present enemies, would or would be willing to loose upon mankind such terrible and inhumane weapons...Use of such weapons had been ruled out by the general opinion of mankind [41].

Yet, despite his personal feelings, Roosevelt made the decision to proceed ahead with the development and production of offensive biological weapons, primarily as a deterrent, and not as a first strike option. Biological weapons were never used, but there was at least one occasion when it was seriously considered by President Roosevelt (use of bacteriological warfare against Japanese rice crops in 1944); when asked about the idea,

Admiral William D. Leahy responded that "this would violate every Christian ethic...It would be an attack on the noncombatant population of the enemy."¹³

The "no first-strike policy" was reiterated almost thirty-five years later by Deputy Defense Secretary of Defense Cyrus R. Vance when he testified before a Senate disarmament subcommittee in 1967:

We think we must have a retaliatory capability and a defensive capability [in chemical and biological warfare] and those are the ends to which we are devoting both our research and development and our procurement. It is clearly our policy not to initiate the use of lethal chemicals or lethal biologicals [41].

What we appear to have learned through the years in our dealings with other great powers is that possession of offensive biological weapons provide no great advantage strategically. Possession is unpopular in the international community, and an aggressive program that promotes disease and injury in a sinister fashion is counterproductive toward creation of a peaceful world. This realization led to the Nixon decision to stop offensive biological weapons research and production, and the movement to a defensive program is consistent with the principles of this nation.

C. The Non-Lethal Weapon:

The injury and suffering by the innocent is an unfortunate outcome of war, but the high level of modern day weaponry now makes non-conventional weapons ironically more destructive than some biological weapons. The specter of promoting incurable diseases and plagues are not within the Christian ethic and the principles of humanity. But if one considers the adoption of BW agents that are temporarily debilitating but not lethal, is this not more humane than the permanent injuries and death resulting from conventional warfare? Tear gas, for example, is a non-lethal chemical weapon that we readily adopt in our riot control efforts, but few envision

the use of tear gas as chemical warfare; its acceptance has been due, in part, to a recognition of its temporary effects. Some would argue that all biological weapons are inhumane in principle, and it is impossible to separate some less destructive ones from others. The refinement of weapons and the evolution of the concept of incapacitating agents may lead to a redefining of a "biological weapon," in terms of morbidity and mortality.

D. The Environmental Impact.

Putting aside the issue of human death and suffering for a moment, the reality of a contaminated environment for generations to come is also not desirable. Nor is the mass destruction of crops, foliage, or livestock, that would cripple a defeated nation and forecast economic ruin and famine. Biological weapons provide a mechanism for such devastation, especially when uncontrolled. Such weapons are considered by many to be inherently immoral, since they may only set the stage for greater destruction.

Biotechnology has also brought forth the unsubstantiated concern for agents with built in resistance traits transferring their characteristics to other organisms. The transfer of drug resistance between bacteria has been well-documented, and multiple drug resistance complicates therapy. Although highly speculative, such concern justifies well-defined environmental safety and monitoring programs.

VIII. THE FUTURE OF BIOLOGICAL WEAPONS

So what does this all mean from a military perspective? Several observations and recommendations are appropriate at this point:

First, as abhorrent as the prospects of biological warfare may seem to many, the reality that biological warfare capabilities are increasingly more widespread and may provide certain advantages to aggressor forces must be recognized. A strong and viable biological defense program is, therefore, of critical importance. Although the U.S. has no intent to use biological weapons in an offensive capacity, the defense against biological agents must be viewed in an atmosphere of changing threats to the national security and a steady proliferation of both chemical and biological weapons in the world contributing to world instability.

Second, total reliance on the Biological Weapons Convention agreement of 1972, an agreement that has no requirements for verification, increases the vulnerability of the U.S. Although appropriate for the time, the Biological Weapons Convention agreement has already required modification on several occasions, with the discovery of viruses and toxins and the reality that artificial synthesis of agents through bioengineering is now possible. Recent crises in the Middle East involving co-signers of the agreement have also raised questions over its true value and the problems associated with enforcement of such agreements. Therefore, while supporting the principles of the convention, it is appropriate that the U.S. continue with a strong defensive program.

Third, despite the world becomes increasingly more interdependent from an economic and defense perspective, threats will still be perceived differently. The biological threat will become a potential area of disagreement, especially when a commitment of resources will be required. Reliance on coalition forces to "carry their share" of the defense may not necessarily extend to protection against biological agents. In an uncertain world, sharing of defense information may also carry security

risks and endanger readiness. The U.S. must, therefore, be prepared to carry the bulk of the biological defense effort, especially in the area of biological research, but the program must continue to be directed at defensive or peaceful applications.

Fourth, the diversity of potential biological agents will require a revised strategy of defense that stresses more broad-based personal protective measures. Improvements in personal protective clothing and respiratory masks that are effective against both chemical and biological agents are required. Broad-coverage immunizations against a multitude of infections would clearly be preferable to single-coverage vaccinations. The research effort must promote this approach.

Fifth, biological agents of the future may not necessarily kill, but may provide greatest benefit through subtle or slow changes affecting performance of personnel on the battlefield or during other crisis periods. Dealing with agents that incapacitate rather than kill adds a new dimension to biological defense. Personnel must be aware of agents that are not necessarily lethal but can detrimentally affect overall performance.

Sixth, the decision to use biological agents by the enemy will be influenced by the effectiveness of other offensive weapons systems. BW agents still have an element of unpredictability that make them less suitable as a first-line weapon, but infectious agents and toxins are still capable of weakening a military force. Increased automation on the battlefield may increase the attractiveness of biological agents, since their use could be targeted to specific command-and-control centers. Vulnerability in the rear echelon areas and the possibility of sabotage will be an increasing concern and will require heightened awareness.

Seventh, the use of biological weapons require increased emphasis to be placed on the development of highly sensitive detection systems capable of detecting both biological and chemical agents. Such systems must be hardened to meet the rigors of the field, fool-proof, portable, and adaptable for specific situations or threats.

Eighth, biological agents, by their inherent nature, may become more popular weapons of terrorists and other radical elements of society. Crops, livestock, and other living sources of food will remain vulnerable to attack, and epidemics and blights could very likely be the result. The impact could be significant for nations highly dependent on agriculture or having a marginal economy.

Finally, progress in bioengineering will continue to influence strongly the pace of the biological defense program, but with each breakthrough will come controversy. New breakthroughs will find peaceful applications by promoting health, for example, but the applications to improve the effectiveness of biological weaponry or its delivery systems will shadow the peaceful applications. It will, therefore, be increasingly necessary to establish international organizations to monitor the peaceful applications of genetic research and biotechnology and the development of "new" organisms. The defense issues can no longer be divorced from the purely scientific applications. The U.S. must continue in its world leadership role in this arena, if it wishes to direct scientific progress to a peaceful end. This can be accomplished through a scientific research effort and international participation that includes elements of the U.S. biological defense program.

e TABLE I: Bacterial, Viral, Rickettsial, and Fungal Agents Recently Evaluated as Biological Warfare Agents Against Man

Etiologic Agent	Disease Produced Based on Likely Mode of Transmission
BACTERIA:	
<u>Bacillus anthracis</u>	Pulmonary Anthrax
<u>Chlamydia psittaci</u>	Psittacosis (Pneumonic)
<u>Francisella tularensis</u>	Tularia (Pneumonic)
<u>Brucella melitensis, B. suis</u>	Brucellosis (Pneumonic)
<u>Shigella dysenteriae</u>	Shigellosis
<u>Yersinia pestis</u>	Plague (Pneumonic)
<u>Salmonella typhi</u>	Typhoid
<u>Salmonella paratyphi</u>	Paratyphoid Fever
<u>Vibrio cholerae</u>	Cholera
<u>Corynebacterium diphtheriae</u>	Diphtheria
<u>Actinobacillus mallei</u>	Glanders
<u>Pseudomonas pseudomallei</u>	Meloidosis
<u>Mycobacterium tuberculosis</u>	Tuberculosis
<u>Clostridium tetani</u>	Tetanus
VIRUSES:	
Poxvirus:	
<u>Variola major</u>	Smallpox
Alphaviruses:	
Chikungunya virus	Chikungunya Fever
Eastern Encephalitis virus	Viral Encephalitis
Venezuelan Equine Encephalitis	Viral Encephalitis
Western Equine Encephalitis	Viral Encephalitis
Flaviruses:	
Dengue virus	Dengue
Yellow fever virus	Yellow Fever
Russian Spring/Summer Encephalitis virus	Russian Spring/Summer Encephalitis
Japanese Encephalitis virus	Japanese Encephalitis
St. Louis Encephalitis virus	St. Louis Encephalitis
Arenaviruses:	
Junin virus	Argentine Hemorrhagic Fever
Lassa fever virus	Lassa fever
Lymphotropic choriomeningitis virus	Lymphotropic Choriomeningitis
Machupo virus	Bolivian Hemorrhagic Fever
Filoviruses:	
Ebola virus	Ebola fever
Marburg virus	Marburg fever
Bunyaviruses:	
Crimean-Congo Hemorrhagic Fever virus	Crimean-Congo Hemorrhagic Fever
Hantaan virus	Korean Hemorrhagic Fever
Rift Valley fever virus	Rift Valley Fever

Orthomyxovirus:

Influenza

Influenza A & B

Picornavirus:

Hepatitis A virus

Hepatitis A

RICKETTSIAE:

Rickettsia rickettsi

**Rocky Mountain Spotted Fever;
Tickborne Typhus Fever**

Rickettsia tsutsugamushi:

Scrub Typhus

Rickettsia prowazeki

Epidemic Typhus

Coxiella burnetti

Q Fever

FUNGI:

Coccidioides immitis

Coccidioidomycosis (Valley Fever)

TABLE II: Major Toxins and Sites of Action

Type of Toxin	Name of Toxin	Producer/Source of Toxin
Cardiotoxin	Sea wasp toxin	(box jellyfish <u>Chironex fleckeri</u>)
Dermatotoxin	Diacetoxyscipenol Fusarenon-X Nivalenol T ₂ toxin	(fungus <u>Fusarium roseum</u>) (" " ") (" " ") (" " ")
Hepatotoxin	Aflatoxin B ₁ ,G ₁	(fungus <u>Aspergillus flavus</u> , <u>Aspergillus parasiticus</u>)
Neurotoxin	Batrachotoxin Botulinum A,B,C,D,E Alpha-Bungarotoxin Conotoxins Microcystin & other cynobacterial toxins Palytoxin Red tide toxin Saxitoxin <u>Shigella dysenteriae</u> Tetanus toxins Tetrodotoxin	(Colombian frog <u>Phyllobates aurotaenia</u>) (bacteria <u>Clostridium botulinum</u>) (Formosan snake <u>Bungarus multicinctus</u>) (cone shell <u>Conus geographus</u> , <u>Conus magus</u>) (bacteria <u>Microcystis cyanea</u>) (soft coral <u>Palythoa</u>) (protozoa <u>Gymnodinium brevis</u>) (shellfish <u>Gonyaulax catanella</u>) (bacteria <u>S. dysenteriae</u>) (bacteria <u>Clostridium tetani</u>) (pufferfish <u>Arothron hispidus</u> , <u>Arothron meleagris</u>)
Inhibitor of Nucleic Acid Synthesis	Cobrotoxin Aflatoxins	(Chinese cobra <u>Naja naja atra</u>) (fungus <u>Aspergillus flavus</u> , <u>Aspergillus parasiticus</u>)
Inhibitor of Protein Synthesis	Abrin Diphtheria toxin Modeccin <u>Pseudomonas aeruginosa</u> exotoxin A Ricin Shigella dysenteriae Trichothecenes	(plant <u>Abrus precatorius</u>) (bacteria <u>Corynebacterium</u> <u>diphtheriae</u>) (plant <u>Adenia digitata</u>) (bacteria <u>P. aeruginosa</u>) (castor bean <u>Ricinus</u>) (bacteria <u>S. dysenteriae</u>) (fungus <u>Fusarium spp.</u>)
Interference with Regulation	Anthrax toxin Cholera toxin <u>Escherichia coli</u> enterotoxins LT,ST	(bacteria <u>Bacillus anthraci</u>) (bacteria <u>Vibrio cholerae</u>) (bacteria <u>E. coli</u>)
Membrane- Damaging	Staphylococcal enterotoxins A, B Staphylococcal haemolytic toxins	(bacteria <u>S. aureus</u>) (" " ")

FOOTNOTES

¹ See Stockholm International Peace Research Institute (SIPRI). The Problem of Chemical and Biological Warfare, Vol. I: The Rise of CB Weapons. New York: Humanities Press Inc., 1971, p. 221.

² A detailed description of the alleged Japanese biological weapons program is described in Appendix 2 (pp. 342-347) of Stockholm International Peace Research Institute (SIPRI): The Problem of Chemical and Biological Warfare, Vol. I: The Rise of CB Weapons.

³ A full description of the 1972 Biological Weapons Agreement may be found in Biological and Toxin Weapons Today, E. Geissler (ed.), Stockholm International Peace Research Institute, Oxford University Press, 1986, p. 135-137.

⁴ The Sverdlovsk incident is discussed in the Defense Intelligence Agency report entitled "Soviet Biological Warfare Threat," DST-1610F-057-86, 1986, pp. 4-7.

⁵ The controversy over yellow rain is discussed in detail in Sterling Seagrave's Yellow Rain, M. Evans & Co., Inc., 1981, and in "Yellow Rain," by T. D. Seeley, J. W. Nowicke, M. Meselson, J. Guillemin, and P. Akrantanrakul, Scientific American, 28(3): 128-137, Sept. 1985.

⁶ I. L. Baldwin, Chairman, Committee on Biological Warfare, "Report on Special BW Operations, Memorandum for the Research and Development Board of the National Military Establishment, Washington, DC, October 5, 1948.

⁷ Zinc cadmium sulfide is a dry fluorescent powder that was used to study dispersal patterns of aerosolized materials. This chemical, especially the cadmium component, has subsequently been determined to be

toxic to humans (L. Cole, Clouds of Secrecy, Rowman & Littlefield, Totowa, NJ, 1988).

⁸ A detailed description of the Edward J. Nevin vs. the U.S. Government trial may be found in L. A. Cole's A Cloud of Secrecy.

⁹ Biosafety level-4 is the highest level of biosafety for microbiological and biomedical laboratories; level-4 agents include Congo-Crimean hemorrhagic fever, Marburg, Ebola, Lassa, Machupo, and Russian spring-summer encephalitis viruses (Biosafety in Microbiological and Biomedical Laboratories, DHHS Pub. No. CDC 84-8395, U.S. Government Printing Office, Washington, DC, March 1984).

¹⁰ Sun Tzu. The Art of War, Oxford Univ. Press, New York, 1963, p. 84.

¹¹ Article by M. Moore entitled "Iraq Said to Have Supply of Biological Weapons" appeared in The Washington Post, (p. A-1, 24), on Sept. 29, 1990.

¹² J. M. Orient's article appearing in the Journal of the American Medical Assn. (262:644-648, 1989) refers to a publication by E. Chene: Chemical and Biological Warfare - Threat of the Future (Toronto, Canada, MacKenzie Institute, 1989), from which quotation is drawn.

¹³ Admiral W. D. Leahy's comments are mentioned in S. Hersh's Chemical and Biological Warfare: America's Hidden Arsenal (Indianapolis, IN: Bobbs-Merrill Co., Inc., 1968) on p. 26.

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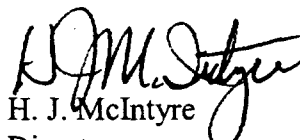
Mr. Gregory Koblentz
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Massachusetts Institute of Technology
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Cambridge, MA 02139

Dear Mr. Koblentz:

This responds to your November 6, 2001, Freedom of Information Act (FOIA) request to the Defense Technical Information Center (DTIC) requesting a document from that organization (DTIC FOIA # 2002-15). Your request, along with one document located by DTIC, was received on January 16, 2002, and assigned the above reference numbers for administrative control.

Document AD-B166001, Biological Weapons and Modern Warfare, has been cleared by the Department of Defense and is enclosed. There are no assessable fees for this response.

Sincerely,


H. J. McIntyre
Director

Enclosures:
As stated

Cc:
Defense Technical Information Center
ATTN: Kelly Akers
8725 John J. Kingman Road
Fort Belvoir, VA 22060-6218

