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# Non-Lethal Weapons Research in the US: Genetically Engineered Anti-Material Weapons

This paper is the second in a series of three reports on United States government research on chemical and biological non-lethal weapons. Shaken by experiences including its disastrous mission in Somalia, the US has concluded that it lacks appropriate weapons for peacekeeping and other "military operations other than war". To address this problem, the US has embarked on a program to develop new non-lethal weapons to control both armed enemies and civilians. Militaries and domestic law enforcement agencies in the United States and elsewhere are closely following this research and, in some instances, are participating. The non-lethal weapons research detailed here raises questions about protection of civil liberties, particularly freedoms of thought and expression, and US compliance with arms control agreements including the Chemical Weapons Convention and Biological and Toxin Weapons Convention. The first report, on calmatives and malodorants (Backgrounder #8), was published in July 2001. The third report will be published later in 2002 and will address new crowd control technologies.

## Introduction

The use of genetic engineering to manipulate natural processes of microbial degradation is opening up new possibilities for the development of offensive biological weapons that destroy materials. Practically every natural or manufactured material in the world is potentially vulnerable. The development of this technology raises serious arms control concerns for the Biological and Toxin Weapons Convention (BTWC) and, because of the environmental dangers such organisms pose, for the Cartagena Biosafety Protocol, the principal international agreement on movement of genetically modified organisms.

The United States is the world leader in the development of genetically engineered anti-material organisms and a federal law prohibits their military use. The enforcement of this law is weak and under threat. A number of military projects are researching anti-material technology (generally for self-described "protective purposes"), and different elements of the US armed forces and their advisors are in open disagreement about the desirability of developing anti-material biological weapons. Development – including research by the US Army, Navy, and Marine Corps – is proceeding virtually unchecked and, in some cases, in secret.

If governments fail to check the threat, US research threatens to carve an enormous exemption in the global prohibition on biological weapons. The Biological and Toxin Weapons Convention must act to restate that its Article I contains no exemptions, and that anti-material weapons are prohibited.

Naturally occurring biodegradative microorganisms pose virtually no military threat. It is only though the use of genetic engineering that they can become viable weapons. Thus, the development of genetically engineered anti-material microbes underscores the tight relationship between the prohibition of biological weapons and the precautionary approach to regulation of biotechnology. The Convention on Biological Diversity, through its Biosafety Protocol, should develop approaches to control these ecologically unsound weapons and move to more tightly coordinate its work with the Biological and Toxin Weapons Convention (BTWC).

Discussion of military abuse of genetic engineering typically concerns genetic "upgrading" of classic biowarfare agents, such as the creation of antibiotic resistant disease, 'invisible' anthrax, or new poxviruses. Genetically engineered anti-material agents ("GAMAs") are part of a second tier of biotechnological products that may be abused in warfare: new types of weapons that have been previously impossible due to technological restraints. A danger exists that these new technical possibilities will raise new interest in certain biological weapons and may thereby undermine governments' conviction to uphold and strengthen the BTWC.

**Biodegradation and Bioremediation Science**

Throughout the world a very large number or microorganisms exist with the ability to degrade materials. Many of these cause or contribute to familiar processes such as deterioration of food, wood, and the conversion of organic waste into soil. These microorganisms can be destructive; but are also used for beneficial purposes such as environmental cleanup. Less well known are microbes that contribute to the degradation of more permanent and seemingly impervious items even, for example, stone. Limestone ruins in Mexico and marble monuments in Italy (among others) are under 'attack' by naturally occurring microorganisms.[1]

Modern products and infrastructure are not immune to microbial degradation and, in fact, attacks termed biodeterioration, biodegradation, biocorrosion, and biofouling are major problems in infrastructure worldwide. Examples include: Hydrocarbon-loving bacteria that bore holes in asphalt, leading to the deterioration of road and runway surfaces.[2] Oil-degrading microbes are of particular interest to industry, and hundreds of kinds of hydrocarbon-eating bacteria and fungi have been identified.[3] Concrete is also susceptible, for example in the sewer systems of Houston, Texas, where destructive microbes are a significant problem.[4] Microorganisms can also damage most metals, including pipes used in industrial and public water systems, and members.[5] ***Thiobacillus ferrooxidans*** and other microorganisms are used to leech metals in "biomining".[6] Microbe induced degradation causes trouble in high-tech, inhospitable environments, for example in fuel systems[7] and composite materials of military aircraft,[8] as well as lubricants.[9]

These natural phenomena are an expensive and destructive nuisance, hindering the use or causing the loss of property and requiring expensive treatment and/or replacement to restore the full and safe functioning of industrial systems. For this reason, civilian and military research is done to combat the effects of microbial degradation through resistant materials and biocide treatments.

Typically, in the human-built environment, including military applications, biodegradative microbes are more of a problem than a tool. Using them as weapons appears difficult, if possible at all. Although some materials are degraded relatively quickly by naturally occurring organisms (weeks or months), including hydrocarbons, plastics, and, in some cases, metals, the Mayan ruins of Mexico stand firm after centuries of microbiological assault.

Degrading microorganisms can also be put to constructive uses, and there is significant scientific interest in the use of naturally occurring microbes to remove pollutants. Called bioremediation, this process works by recruiting microbes to metabolize waste or contaminants that are otherwise difficult to remove, for example, by introducing them into soils or water contaminated by an oil spill.

In their natural state, bioremediation microbes are generally slow acting; but genetic engineering will increasingly be able to make them more efficient. Such microbes have cleanup potential; but also pose environmental dangers and open the avenue to microbial weapons to destroy materials.

In the United States (and other countries), heavily polluted sites are a common legacy of military and industrial operations. To address environmental problems including radiation, hydrocarbon, and chemical contamination, a number of US military projects seek to develop microbes to remove pollutants. For example, the explosive TNT (2,4,6-Trinitrotoluene) is both a pollutant and a component of many weapons. Bioremediation studies have identified several microbes that degrade TNT[10] and, reportedly, TNT inoculated with one of these loses 50% of its explosive charge every seven days,[11] a rate that would quickly render infected stores useless.

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[1] See, for example, Videla H et al, *Biodeterioration of Mayan archaeological sites in the Yucatan Peninsula, Mexico,* International Biodeterioration and Biodegradation (Intl. B&B) 46 (2000), 335-341.
[2] Campbell J, *Defense Against Biodegradation of Military Materiel*, Non-Lethal Defense III Conference, Feb. 1998, p. 1.
[3] Juhaz A and Naidu R, *Bioremediation of high molecular weight polycyclic aromatic hydrocarbons: a review of the microbial degradation of benzo[a]pyrene*, Intl. B&B 45 (2000) p. 57-88.
[4] Nica D et al, *Isolation and characterization of microorganisms involved in the biodeterioration of concrete in sewers*, Intl. B&B 46 (2000) p. 61-68
[5] Lavoie D and Little B, *Fungal Contamination of H-53 Aircraft*, Report for the Naval Research Laboratory, 1996, p. 5-6.
[6] See, for example, http://www.mines.edu/fs_home/jhoran/ch126/microbia.htm.
[7] Thomas A & Hill E, *Aspergillus fumigatus and Supersonic Aviation, 4 Biocidal Control*, Intl. B&B 48 (2001) p. 245-251.
[8] Mitchell R, *A Study of Microbial Deterioration of Fiber Reinforced Composites and Protective Coatings*, Final Report to the Air Force Office of Scientific Research, October 1998.
[9] Little B et al, *Fungal influenced corrosion of post-tensioned cables*, Intl. B&B 47 (2001) p. 71-77.
[10] See, for example, http://umbbd.ahc.umn.edu/tnt/tnt_map.html
[11] Alexander J, Future War: Non-Lethal Weapons in Twenty-First-Century Warfare, St. Martin's Press, 1999, p. 121.

But such efficiency is exceptional. More often, the major difficulty encountered in bioremediation research is that naturally occurring organisms are inefficient, unpredictable, slow, or require very specific conditions. Even highly selected strains often fail to reach specifications required for bioremediation purposes. Because of these problems, some bioremediation scientists – including US military researchers – are turning to genetic engineering. The goal of this research is to develop specifically targeted, faster-acting, more predictable microbes. Research results to date reveal a field with potential to develop commercial genetically engineered products, but one which will take several years to mature and which is fraught with serious biosafety concerns.

### GMO Microbes: Biotech Bioremediation and GAMAs

***It is quite possible that microbial derived or based esterases might be used to strip signature control coatings from aircraft, thus facilitating detection and destruction of the aircraft.***

- Dr. James R. Campbell, US Naval Research Laboratory(1998)

Thirty years ago, at the dawn of genetic engineering, the first patent ever granted on a living organism was for a genetically engineered microbe that degrades oil; but since then development has been slow. Through the 1990s there was limited development of genetically engineered anti-material agents for use in bioremediation. Only one field trial has been performed, and there is a lack of serious commercial interest in the technology outside the military. For cleanup applications, this has partly to do with (cost) competition with other technical solutions and the thin profit margins for bioremediation industry.[12]

Most bioremediation projects concentrate on selecting and enriching natural occurring bacteria. Genetic engineering approaches have only recently emerged. A major focus is on cleaning up radioactive waste. Two years ago, scientists at the US Uniformed Services University in Maryland genetically engineered radioactivity resistant bacteria to detoxify mercury. Among the few such non-military projects are a Stanford University effort to make a single microbe to remediate both carbon tetrachloride and heavy metals, and Michigan State University research on a genetically engineered microbe to degrade polychlorinated biphenyls (PCB).[13]

The development of genetically modified organisms (GMOs) for bioremediation raises the concrete possibility that microbes that have been heretofore militarily useless might be transformed into serious anti-material biological weapons. The same characteristics that would make many GMOs more useful in bioremediation and other industrial applications (e.g. fermentation to produce certain enzymes) might also convey a weapon potential.

In most research on organisms that can be used as weapons, scientific discoveries and facilities can be ***dual-purpose***, that is, the difference between a peaceful and hostile use is largely a question of intent. For example, the same facilities that produce vaccines can usually be used to produce weapons. This general rule holds true in the area of genetically engineered anti-material agents, where the relationship is aptly captured by the commonly used adage, "***one man's trash is another man's treasure***". In other words, the definition of waste relates to a material's use for its owner and not its physical nature. Biodegrading microbes don't necessarily have to be used on what is unwanted, they can be used on items before they are relegated to the "trash": an engine before it goes to the junkyard, a computer before it's replaced by the next year's model, pavement before it degrades from use.

In the early 1990s, the US government's Los Alamos National Laboratory in New Mexico began to investigate non-lethal weapons.[14] Among the first areas of work was an assessment GAMAs. According to its director, the military-funded science group at Los Alamos "***was amazed at the range of vulnerable targets… we came to understand that there was almost nothing in the world that some organism will not consume***."[15]

In 1998, the US Naval Research Laboratory identified a number of offensive uses of genetically engineered anti-material weapons. These include microbes that damage or destroy hydrocarbons, plastics, natural and synthetic rubber, metals, composite materials. Also included are microorganisms that produce small inclusion bodies of salts, metals, or plastic-like granules ("polyhydroxyalkanates") that can cause failure of machinery. These properties could be used to damage or destroy:[16]

- Highways and runways, both cement and asphalt
- Metal parts, coatings, and lubricants of weapons
- Vehicles (including aircraft) and support equipment
- Fuels, supplies, and replacement parts
- High efficiency filters (through clogging)

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[12] Sayler G, *Field applications of genetically engineered microorganisms for bioremediation processes*, Current Opinion in Biotechnology 11:286–289, 2000.
[13] See Zwillich T, *A tentative comeback for bioremediation*, Science 289:2266, 2000.
[14] As used by the US armed forces, the term 'non-lethal' is misleading. The US definition of 'non-lethal' permits weapons that cause death and serious injury, just at a lower rate than arms specifically designed to kill or maim.
[15] Alexander J, p. 119.
[16] Campbell J, p.1.

•Composites, paints and protective coatings, including "stealth" anti-radar coatings
•Plastics, including body armor

Military researchers have cited these possibilities of offensive use of GAMAs as a rationale for 'biodefense' studies and even, in the case of the US Joint Non-Lethal Weapons Program, to propose development of offensive weapons. Other military-linked research for bioremediation purposes is of a type that yields data and creates facilities that could be diverted into weaponsmaking. No weaponized GAMAs are known to exist. Ongoing US research, however, is rapidly developing more practical GAMAs, including ways to facilitate their field release.

**Profiles of US Military Research**

Confronted with major pollution problems, and an interest in investigating the weapons potential of genetically engineered microbes, the US federal research system is developing a number of facilities capable of pursuing GAMA offensive research and weapons production. These include a significant testing and bioreactor (fermenter) capacity, as well as biodefense experiments genetically-engineering microbes and preparing them for field release.

**Oak Ridge National Laboratory** in Tennessee is a major center of research for the bioremediation of nuclear waste, and world leader in genetically engineered anti-material research. Oak Ridge (with the Center for Environmental Biotechnology of the University of Tennessee), has conducted the first field test of a genetically engineered bioremediation bacteria. For GMO microbe tests, Oak Ridge has constructed unique high-security field lysimetry facility (pictured), a series of twenty enclosed containers with a total capacity of over 250 square meters of soil.[17]

The Environmental Microbial Biotechnology Facility at **Lawrence Livermore National Laboratory** near San Francisco, California features a high-tech industrial-sized production system for biodegradative microbes and enzymes. Livermore's big fermenter (1,500 liters, pictured) has mass-produced ***Methylosinus trichosporium,*** an organism that degrades trichloroethylene, an industrial solvent. Smaller fermenters at Livermore have been used to produce hydrocarbon-degrading enzymes and genetically engineered bacteria for biomedical experiments.

The US Department of Energy's **Microbial Genome Program** focuses on genomics of classical bioweapons and material-degrading organisms. One of the program's goals is to create "***super bugs***" to "***uncover applications relevant to DOE missions.***" DOE's missions include bioremediation and industrial processing, as well as weapons design. The Program has sequenced more than 20 microbes that degrade metals, hydrocarbons, cellulose, and industrial chemicals.[18]

The US military is also researching anti-material microbes, and it is this work that is of the highest concern. The **Naval Research Laboratory** (NRL) in Washington, DC, has a program "***focused on identifying and characterizing the degradative potential of products from naturally-occurring microoganisms***". NRL then takes natural microbes and creates genetically engineered organisms with "***focused degradative capabilities***". These include microbes designed to destroy plastics, particularly polyurethane, which is used in many products, including coatings used on aircraft.[19] Such genetically engineered microorganisms might be applied themselves, or enzymes they produce can be formulated to be applied on a target. One NRL microbe can "***cause hundreds of blisters on mil***[itary] ***spec***[ification] ***polyurethane paints in 72 hours***."[20] The NRL principal investigator has described military applications for such weapons: "***It is quite possible that microbial derived or based esterases might be used to strip signature control coatings from aircraft, thus facilitating detection and destruction of the aircraft***."[21]

At the same time, a separate NRL group (working on bioremediation) is developing delivery techniques that could be used with such agents, including microencapsulation of bacteria.[22] Also according to NRL, "***The potential for***

[17] For an online description of the facility, URL: http://www.esd.ornl.gov/nabirfrc/lysimeters.html.
[18] US Department of Energy Website. URL: http://www.ornl.gov/microbialgenomes/
[19] Campbell J, p. 1.
[20] Dr. Joanne Jones-Meehan, an NRL microbiologist. URL: http://pony.nrl.navy.mil/meehan.html.
[21] Campbell J, p. 2.
[22] Spargo B, *Encapsulated Bacteria for in situ PAH bioremediation*, SERDP Project Cleanup CU 23. This idea also interests JNLWP, which is funding microcapsule technology that *"will release and spread a variety of chemical payloads upon pressure, contact with water, or at a specific temperature."* URL: http://www.jnlwd.usmc.mil/programs/tech_invest.htm

***clandestine employment of these non-lethal weapon systems, particularly since their effects I many cases may closely mimic natural processes, gives an adversary an added advantage of deniability***."[23]

NRL has pushed the anti-material microbial weapon envelope far beyond any other known research; but it claims that its activities are defensive. Without articulating any specific threat, the Navy says that because others ***might*** attempt to create these weapons, it must do so, to provide "***novel defense measures***" for US troops. Equally disturbing is the interpretation of the BTWC that the Laboratory has invented to justify the research. According to the Lab, "***The genetic engineering techniques employed are standard laboratory practices… and this materials science research is not restricted in any way by the*** [BTWC]".[24] Defining away genetic engineering research that creates new weapons agents in such a way does not stand up to reason. Nor could it be expected that the US would sit idle if another country used similar reasoning, for example, by defining military work genetically enhancing diseases of grains as "food science".

The Navy is not just interested in laboratory experiments. Military researchers are incorporating suicide genes (popularly known as "terminator technology") into the microorganisms in order to facilitate their release. According to the Navy, terminator technology would "***prevent their persistence in the environment beyond pre-determined limits of space and time***",[25] although biosafety experts debate such reasoning. Such technology would be very useful for offensive GAMAs, because it would prevent organism spread to unintended targets, impede use by an enemy, facilitate cleanup, and help prevent a 'boomerang effect' of the organism inadvertently impacting friendly forces by surviving beyond its intended mission. It would also provide a questionable, but arguable pretext to defend against allegations that such weapons are indiscriminate and illegal under international law.[26]

> The US Army's patent 6,287,844, issued on September 11th, 2001, claims:
>
> "***new killing genes and improved strategies to control their expression***" for the purpose of "***controlling genetically engineered organisms in the open environment, and in particular, the containment of microorganisms that degrade..."***

It comes as little surprise then, that US Army researchers are working on suicide gene systems specifically tailored for use in biodegradative microbes, including anti-material ***Pseudomonas*** species engineered by the Navy. The Army's suicide systems have been developed by Boston University scientists working with a biotechnology research unit at Natick Laboratories (near Boston, Massachusetts), a division of the US Army Soldier & Biological Chemical Command (SBCCOM).

Natick's terminator system uses a lethal gene from the bacteria ***Streptomyces avidinii*** transferred into other organisms. A September 11, 2001 patent owned by the US Army claims, "***new killing genes and improved strategies to control their expression***" for the purpose of "***controlling genetically engineered organisms in the open environment, and in particular, the containment of microorganisms that degrade…"*** The system is adaptable and, according to the Army ***"a variety of bacterial and non-bacterial recombinant organisms can be controlled in this manner.***" Through a series of genetic manipulations, the Army terminator is designed to commit suicide when its target substance - which could be practically anything - is no longer in the organism's immediate environment.[27]

## Secret US Research

A major unknown in US military research on GAMA are the activities of the US Marine Corps-directed Joint Non-Lethal Weapons Program (JNLWP). JNLWP develops weapons for military use overseas and cites US missions such as those in Somalia, Haiti, and Bosnia as justifying its work. JNLWP has, at least once, sought the approval of the Navy Judge Advocate General for research on offensive uses of anti-material biological weapons. While this request was denied because the Judge Advocate General believed such weapons would violate the Biological and Toxin Weapons Convention, subsequent statements by JNLWP and its affiliates continue to endorse the idea of weakening treaties to permit US development of GAMA.

JNLWP is assessing and developing a wide range of 'non-lethal' weapons, including electromagnetic and acoustic weapons, foams, and other anti-material and anti-personnel technologies. JNLWP attempts to shield most of its activities from public view, particularly those pertaining to biological or chemical weapons. In March 2001, the Sunshine Project (in collaboration with the ETC Group, a US-Canadian non-profit) filed US Freedom of Information Act requests for information on JNLWP biological and chemical activity. The Marine Corps replied with a list of hundreds of research titles, including several that suggest consideration of GAMA.[28]

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[23] Campbell J, p. 3.
[24] ibid, p. 2.
[25] ibid, p. 1.
[26] That is, in addition to being biological weapons, use of uncontrollable microbial weapons might also be considered and indiscriminate and, hence, illegal weapon.
[27] US Patent 6,287,844, 11 September 2001.
[28] Partial response to the Sunshine Project by the Marine Corps Systems Command, FOIA Case #084F-01.

## The Joint Non-Lethal Weapons Program

A selection of JNLWP research titles possibly related to GAMA:

| Title | Study site / Produced by: |
|---|---|
| Anti-Material Biocatalysts | Brooks Air Force Base, Texas |
| Anti-Material Chemical Agents | Naval Air Warfare Center Weapons Division, China Lake, California |
| Biofouling and Biocorrosion | National Security Programs, Idaho National Engineering Laboratory |
| Catalytic Depolymerization of Rubber | Los Alamos National Laboratory, New Mexico |
| Demonstration of Chemical Immobilizers | US Army Aberdeen Proving Ground, Maryland |
| Depolymerization | Los Alamos National Laboratory, New Mexico |
| Direct Viscosification Agents | Los Alamos National Laboratory, New Mexico |
| Enhanced Degradation of Military Material | Naval Research Laboratory, Washington DC |
| Lubricant & Grease Additives to Immobilize | Sandia National Laboratory, New Mexico |
| Lubricants for Ground Transport Denial | Sandia National Laboratory, New Mexico |
| Metabolic Engineering | National Security Programs, Idaho National Engineering Laboratory |
| Non-Lethal Disablement of Equipment | Lawrence Livermore National Laboratory, California |

(Source: Index of JNLWP Non-Lethal Weapons Database, additional open sources.)

Although US law theoretically mandates a response within 20 days, after one year, JNLWP has failed to release a single research document. Results of these requests will be reported in future publications.

### Policy Considerations I: Anti-Material Biological Weapons and the BTWC

The Biological and Toxin Weapons Convention (BTWC) is a landmark in international law in large part because of its Article I, which bans an entire class of arms by prohibiting the development, acquisition, and stockpiling of all biological weapons. The BTWC was intended and designed to prohibit all biological weaponry, contains no exemptions for any class of biological warfare, and has been broadly understood as such since its beginning.

Recent years have seen a disturbing trend, particularly in the United States, towards narrower interpretations of Article I. This includes an ever-more permissive US definition of acceptable biodefense activities, including the well-publicized production of anthrax spores, genetic engineering of anthrax, and testing of biological bombs. Another well-known case are US claims that forcible eradication of narcotic crops – a form of agricultural biological warfare - would not violate the BTWC.

The US generation of ambiguity surrounding the BTWC extends to the poorly defined area of so-called 'non-lethal' biological weapons. These potentially include a number of weapons, such as anti-material agents, riot control agents, and even human disease. A high level US endorsement of this view was made at United Nations in October 2001, where US Assistant Secretary of State Avis Bohlen articulated a new interpretation of Article I by suggesting biological weapons are "***biological agents used with lethal intent***". Avis' distinction implies that so-called 'non-lethal' biological weapons, including anti-material agents, may be acceptable to the US.[29]

If such an interpretation of BTWC Article I were to be widely accepted, it would amount to a major reduction of the scope of the BTWC, potentially relaxing controls on all biological weapons except those used with the specific goal of killing humans (as opposed to sickening them, or harming animals, plants, or materials). Some US supporters of anti-material biological weapons have called on the US to simply ignore a "***doomed***" BTWC.[30]

The BTWC needs to address a lack of foresight in language used in its Final Declaration at the BTWC Third and Fourth Review Conferences. At those meeting, in decisions on Article I, the Conference stated: "***The Conference reaffirms that the Convention prohibits the development, production, stockpiling, other acquisition or retention of microbial or other biological agents or toxins harmful to plants and animals, as well as humans***…"[31] Without a specific reference to use against materials, a specious argument can be made that GAMAs are not prohibited.

BTWC Parties should reject such an argument. Article I bans all agents for non-peaceful purposes and has zero exemptions, much less a huge gap for anti-material agents that would subject the entire human-built environment to legal biological attack. In this sense, the Review Conferences adopted text that poorly re-articulates the treaty's prohibition with respect to materials. By the same token, BTWC States Parties cannot reasonably be asked to predict the future, and the decisions of Review Conferences predate any serious technological possibility of effective GAMAs, which have only recently become feasible due to genetic engineering. Nevertheless, the potential ambiguity in the Review Conference decisions should be cleared up without delay.

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[29] Statement by Avis Bohlen, US Asst. Secretary for Arms Control, in the First Committee, General Assembly, 10 Oct 2001.
[30] Edwards R, *War without tears*, New Scientist, 16 December 2000. p. 4.
[31] Final Declaration of the BTWC 4th Review Conference, December 1996.

**Policy Considerations II: The US Split on Anti-Material Weapons**

The US leads the world in research on genetically modified microorganisms. Its law to implement the BTWC prohibits biological weapons that deteriorate "***equipment, supplies, or material of any kind***".[32] The law is very clear, yet it is under assault by both military research programs and policy advisors. Political maneuvers go on to change arms control agreements to legitimize GAMA and other illegal 'non-lethal' weapons.

An early high-level suggestion that the BTWC's total prohibition on biological warfare might be changed to permit biotechnological arms came in 1995, when a blue ribbon panel of the Council on Foreign Relations (an influential US think tank) reviewed US military options for non-lethal weapons. Among the panel's conclusions was a suggestion that the BTWC requires "***periodic updating***" to accommodate biotechnological developments.[33] The influential panel's membership included Richard Perle (now Chair of the US Defense Policy Board and a leader of the war on terrorism), Kenneth Adelman, (former head of the US Arms Control and Disarmament Agency), a former military advisor to Vice President Richard Cheney, and the ex-Chiefs of Staff of the Army and Air Force.

In the specific area of GAMAs, however, the reasoning suggested by the Council on Foreign Relations panel was not supported - in at least one instance - by the legal division of the US Navy. Judicial review is required of all new weapons systems developed by the US and, in 1997, the US Navy Judge Advocate General (JAG) was prompted to consider GAMA by research proposals from the Pentagon's Joint Non-Lethal Weapons Program. The Navy JAG disallowed work on GAMAs, determining that development of such weapons would violate the BTWC.[34]

But instead of acquiescing to binding treaty commitments, some US military officers and advisors are engaged in a campaign to convince the US government as a whole to seek changes to the BTWC that would permit GAMA and other biological 'non-lethal' weapons. In addition, the Marines Corps, Army, and Navy are conducting research on anti-materiel GMO microbes, classifying the activities as biodefense or bioremediation. The leader of one US Navy project is avoiding treaty concerns by claiming his biotechnology laboratory's genetic engineering of anti-material microorganisms is "materials science", as if his laboratory's stable of material munching microbes are magically transformed into something else by playing with words.[35]

A 1998 lead article in the (US) Navy Law Review briefed commanders on the deployment of non-lethals weapons. It cited the possibility of using genetically engineered anti-material weapons, and did not mention the JAG ruling against them.[36] Since the mid-1990s, US military schools such as the US Army War College and Naval War College have focused dozens of officers on non-lethal weapons. Many of these officer's thesis papers mention the offensive use of biological anti-material weapons. Less often do they seriously discuss these weapons vis-à-vis US law and the Biological and Toxin Weapons Convention and, if they do, they sometimes suggest changing the convention to allow certain biological weapons.[37] Such studies suggest that many US officers are not taught that the BTWC prohibits all biological weapons, and that a disturbing culture of acceptance of certain forms of biological warfare may be developing in advanced training programs.

The Joint Non-Lethal Weapons Program (JNLWP) has spoken out in favor of GAMAs. In late 2000, the JNLWP's top officer, Marine Corps Colonel George Fenton, told ***New Scientist*** that he was interested in researching weapons that would require review and modification of the Biological and Chemical Weapons Conventions.[38] JNLWP's position is unusually aggressive - and inappropriate - because the Navy own legal unit has already denied one request to pursue such weapons.[39] Yet JNLWP marches on. To promote its viewpoint, JNLWP has assembled a group of public relations and lobbying experts. The JNLWP "Public Acceptability Advisory Team" includes the Director of the US Air Force's Public Affairs Office, a least four other military publicity specialists, a Marine Corps lobbyist, military lawyers, and sympathetic scientists who work in weapons development.[40]

In addition, JNLWP works with the Rand Corporation, the preeminent member of a group of policy advisors outside the US military who advocate weakening arms control agreements in order to develop certain chemical or biological weapons. Russell Glenn, head of the Rand Corporation's Urban Operations Team, recently called for

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[32] US Code, Title 18, Part I, Ch. 10, Sec. 178, Para 1(b).
[33] Council on Foreign Relations, 1995. Non Lethal Technologies, Military Options and Implications. URL: http://www.hackvan.com/pub/stig/news/BAD--non-lethal-weapons-tech.htm
[34] US Navy, Deputy Assistant Judge Advocate General, *Legal Review of Proposed Chemical Based Nonlethal Weapons*, 1997. Cited in Coppernoll M, *The Non-Lethal Weapons Debate*, 1998, URL: http://www.aquafoam.com/papers/Coppernoll.html.
[35] Campbell J, p. 2.
[36] Duncan J, *A Primer on the Employment of Non-Lethal Weapons*, 45 Naval Law Rev., 1998, pp. 1-56.
[37] See, for example, Garland K (Maj), *Non-Lethal Weapons: Impact and Utility Concerns for Operational Commanders in Future Conflicts*, thesis, Navy War College, 1998, Lamb J (LtC), *Emerging Nonlethal Weapons Technology and Strategic Policy Implications for 21st Century Warfare*, thesis, Army War College, 1998, or Rice C (LtC), *An Analysis of the Strategic Application of Non-Lethal Weapons to Provide Force Protection*, thesis, Army War College, 2001.
[38] Edwards R, p. 4.
[39] Administratively, the US Marine Corps is part of the US Navy. The Navy JAG has also made controversial rulings in JNLWP's favor, for example, approving research on calmative agents for crowd control.
[40] A list indicating membership of the JNLWP "NLW Public Acceptability Advisory Team" was released to the Sunshine Project by the Marine Corps System Command, FOIA Case #064F-01.

an "updating" of chemical and biological weapons controls.[41] In the midst of severe unrest, in February 2002, JNLWP sponsored the Rand group's annual conference in Haifa, Israel.[42]

Among the most vocal US proponents of GAMAs is retired US Army Colonel John Alexander, who has declared chemical and biological weapons controls "***doomed***". Instead of making him ***persona non grata***, Alexander's advocacy for GAMAs and other biological and chemical weapons has won him influence in US military and policy circles, including kudos from Gen. Anthony Zinni, commander of the 1995 US mission in Somalia, and now US Special Envoy to the Middle East. Alexander has organized US National Defense Industrial Association Conferences on non-lethal weapons and represented the US government at NATO conferences. In the wake of September 11th, Alexander appeared on CNN to promote use of non-lethal weapons in the war on terrorism.[43]

In the absence of a clear implementation of its law against anti-material biological weapons, their promotion by influential US military thinkers is cause for very serious concern, especially in light of the State Department's disturbing suggestion of "lethal intent" as a new qualification to BTWC Article I. The only strong US military voice against GAMAs, the Navy Judge Advocate General, is fading into irrelevance. Should acceptance of GAMAs become dogma of the Pentagon itself, the BTWC will be presented with an even more severe challenge than is presently posed by US development of this technology.

**Conclusion**

Genetically engineered anti-material weapons raise serious concerns for the Biological and Toxin Weapons Convention and, because of the biosafety dangers such organisms pose, for the Cartagena Biosafety Protocol. GAMAs are one of the first of a "second tier" of biological weapons enabled by genetic engineering. These are not genetic derivatives of classical BW agents; but are entirely new weapons made possible by biotechnological advances. A danger exists that these new technologies will raise new interest in certain biological weapons and thereby undermine governments' conviction to uphold and strengthen the BTWC.

Continued BTWC inaction on anti-material weapons will encourage more GAMA research. If governments fail to act, an enormous exemption could be carved in the global prohibition on biological weapons. BTWC Parties need to restate that Article I contains no exemptions and that anti-material weapons are prohibited.

The 144 States Parties to the BTWC should quickly move to prevent any misinterpretation of the Convention by clarifying, at the reconvened 5th Review Conference in November 2002, that biological weapons that destroy materials are equally prohibited as those that attack humans, animals, and plants. This should be done in the Review Conference's Final Declaration statement on Article I.

It is only through genetic engineering that biodegradative microbes become viable weapons. Thus, the development of GAMAs underscores the critical relationship between the prohibition of biological weapons and the precautionary approach to regulation of biotechnology. It is time for diplomats both in the BTWC and the Convention on Biological Diversity to stop talking and start building concrete links between the processes, for example, in capacity-building and in monitoring transboundary movement of GAMAs.

As a first, minimal, step toward strong cooperation, the Intergovernmental Committee for the Cartagena Protocol on Biosafety should request observer status for the Protocol at meetings of the Biological and Toxin Weapons Convention. This decision can be taken at the Biosafety meeting in The Hague in April 2002. The BTWC can accept the request at its November meeting, thereby beginning the process of information exchange and seeking synergies between these instruments. Any future organization to support the BTWC should apply for observer status with the Biosafety Protocol. This concrete link will create opportunities for biosafety law to contribute to biological weapons control, an idea endorsed at the BTWC by nearly every country, including the United States.

In addition, governments may also take the approach of the African Union in implementation of the Cartagena Biosafety Protocol. The African Union's Model Law on Safety in Biotechnology criminalizes hostile use of genetically engineered organisms, including those that degrade materials.

Finally, the US bears particular responsibility for the unchecked military development GAMAs and for attempts to muddy the waters of BTWC Article I. In particular, the Joint Non-Lethal Weapons Program must halt political and scientific adventurism in offensive GAMAs, accept that all biological weapons are illegal, and obey the law instead of undermining it. The Pentagon must also ensure that officers introduced to non-lethal weapons issues are fully aware that any development, acquisition, or stockpiling of biological weapons, including those that target materials, is a violation of US and international law.

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[41] Edwards R, p. 4.

[42] JNLWP's sponsorship of the event in the midst of the Palestinian-Israeli conflict speaks volumes about JNLWP's vision of its "future war". JNLWP and Rand took a bus tour of Israeli Defense Forces (IDF) operations in Palestinian areas and met with commanders who explained IDF tactics. See: http://www.rand.org/natsec_area/products/urbanops.israel.html.

[43] See CNN's website. URL: http://www.cnn.com/2001/COMMUNITY/10/03/alexander.cnna/