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U. S. Army Nuclear and CWMD Agency

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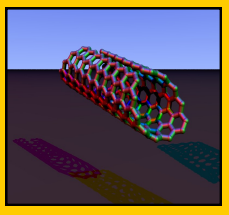

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Observant? Find the cloud, it's been hiding in plain sight!

CWMD Integration

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Since the publication of the National Military Strategy to Combat Weapons of Mass Destruction (CWMD), much has been done to develop, coordinate, operationalize, and institutionalize functions and capabilities to achieve the CWMD strategy. Through integration efforts, including key activities in planning, doctrine, and survivability, we are beginning to see the realization of our efforts.

Participation in the development of a joint doctrine for CWMD will result in the necessary foundation from which continued integration and development of CWMD capabilities may occur. The Joint Publication for Combating Weapons of Mass Destruction (JP 3-40, revision first draft, 23 April 2008), was recently staffed for Joint Planning and Execution Community (JPEC) review. Organized around tenets of joint operations, this revision offers a translation of CWMD guidance toward operational consideration across the full range of military operations (e.g., emphasizing Phase 0 operations, full spectrum operations [FSO], and the imperative of interagency coordination). The comprehensive review of this keystone document demonstrates both the evolutionary nature of the CWMD enterprise and the high degree of joint group of people engagement.

The Army continues to better integrate CWMD strategy and policy supporting its role in national security. U.S. Army Central Command (USARCENT) was the first to operationalize DOD strategy to CWMD. In July 2008, the U.S. 3rd Army/USARCENT completed its operational plan to CWMD. Key to success was iterative and persistent planning between USARCENT, various agencies (e.g. Defense Threat Reduction Agency [DTRA], Defense Intelligence Agency [DIA], and the Defense Logistics Agency [DLA]), the Army Staff, and USANCA. The approval of USARCENT's CWMD plan will provide the necessary guidance for the Army to prepare, plan and execute CWMD activities in the U.S. Central Command (USCENTCOM) area of responsibility. Additionally, lessons learned, especially those in the form of requirements, are paramount in determining and solving Army capability needs.

U.S. Strategic Command (USSTRATCOM) and U.S. Special Operations Command (USSOCOM) are leading and are heavily engaged in global aspects of combating weapons of mass destruction and identifying complementary efforts from the respective Command's operational focus. Aggressive planning synchronization efforts have a unifying effect that is tied to a commitment to strong, interagency outreach across the U.S. Government. CWMD/CBRN personnel assigned to supporting Army Commands, Components, and staffs play a crucial role in coordinating across the CWMD community to ensure awareness of and attention to identified Army requirements and desired capability development.

Continued integration of CWMD strategy is crucial to better enable Army forces to operate effectively and to prevent the alienation of the field in the all-to-often seen stovepipe. Secretary Geren and General Casey in the 2008 Army Posture Statement articulated aspects of the environment in which our Army will engage - “As we look to the future, we believe the coming decades are likely to be ones of persistent conflict—protracted confrontation among state, non-state, and individual actors who use violence to achieve their political and ideological ends.” An integrated strategy, and not one that stands alone, will best serve our nation.

As we rely to an even greater degree upon electronic systems and communications, we can be sure our adversaries are working on ways to attack those capabilities. Potential vulnerabilities are not limited to a high altitude electromagnetic pulse (HEMP) event. A future enemy could use directed energy or radiating devices in an asymmetric attack, which could affect our networked force in ways we have not anticipated. The Army now includes electromagnetic effects as an emerging technology of concern, to be evaluated during the Unified Quest 2009 exercise next spring. The event promises to increase awareness of EM threats; it could also identify critical nodes for further analysis. USANCA is coordinating technical input to provide realism in the exercise scenarios.

The Army must continue efforts to ensure the integration of Army-related CBRN materiel survivability capabilities throughout the Defense Acquisition, Technology, & Logistics Life Cycle Management Framework. A key aspect is review of Army and DOD weapon system programs' capability documents to ensure compliance with Army and DOD survivability standards. In particular, the Future Combat System must include the tools needed to field a future Army that is poised to deal with the growing threat of WMD on the battlefield. Paramount to these activities is effective Army implementation of the new DOD Instruction (DODI) 3150.09, The CBRN Survivability Policy. This is both a challenge and an opportunity. It is a challenge because the instruction mandates significant reporting requirements and sets standards that will take time and money to meet. It is an opportunity because the DODI will focus attention on CBRN survivability and help set a common standard for the Joint Force.

In cooperation with our Allies, the Army continues efforts on two products aimed at improving the U.S. ability to influence and shape the way NATO approaches CWMD and CBRN defense. The first is a Program of Action and Milestones (POAM) that is guiding USANCA-led U.S. delegations to the NATO Joint Capability Group on CBRN (JCGCBRN) defense and the NATO CBRN Operations Working Group (CBRNWG). The JCGCBRN & CBRNWG POAM establishes program objectives based upon both U.S. and NATO strategic guidance and objectives for CWMD. This program management tool fosters attainment of delegation objectives (shaping and improvement) and fulfillment of U.S. obligations to the JCGCBRN and CBRNWG. The recently published US-NATO CBRN Delegate Handbook complements the POAM by providing delegates a tool kit of essential information and tips needed to participate effectively as a member of the U.S. team to the JCGCBRN and CBRNWG.

Additional benefit emerges as we synchronize the Defense Security Cooperation Agency (DSCA) and CWMD strategies and activities. Numerous Allied and Partner nation combined exercises, training, and capacity developing efforts result in increase the depth and scope of capability. This effort begins within each respective staff by CWMD/CBRN personnel coordination with DSCA personnel. Situational awareness and staff heads-up actions truly result in optimizing activities and preserving resources. Building partner capacity in consequence management operations and preventing proliferation through interdiction operations are two examples of the convergence of CWMD and security cooperation strategies and operations.

Integration of CWMD will continue to advance as we develop, coordinate, operationalize, and institutionalize functions and capabilities to achieve the national, DOD, and Army strategies. And just as important, integration relies upon continued coordination horizontally within staffs and vertically from the strategic to operational domains. Through integration efforts, including key activities in planning, doctrine, and survivability, we will continue to increase the effectiveness of our force and better the protection of our personnel.

3rd Annual Combating Weapons of Mass Destruction Conference

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USANCA conducted the 3rd Annual Army Combating WMD Conference on 9 and 10 September 2008 in Arlington, VA.

The focus of this year's conference was the integration and synchronization of Army CWMD efforts with regard to policy, and strategy to include activities with security cooperation, contingency planning, and informing the capabilities requirements to solutions" process.

Mr. Michael Evenson, Associate Director Operations Enterprise of the Defense Threat Reduction Agency (DTRA) provided the keynote address informing about the directions and scope of numerous DTRA efforts, military integration of U.S. Government activities, Counter Threat Reduction (CTR), Counterproliferation (CP) Weapons of Mass Destruction (WMD) Planning, and Global CTR concepts.

Representatives from Army Commands (ACOMs), Army Service Component Commands (ASCCs), and invited Services Staffs identified actions to increase integration of CWMD strategy and optimize effects for geographic implementation of activities to CWMD and invited members of the Army Council for Combating WMD (ACCWMD).

The ACCWMD provide forums that address crosscutting Army CWWMD issues and concerns. The ACCWMD provides: integration and synchronization of CWMD issues across DOTMLPF; a mechanism that identifies Army CWMD capability requirements; and a means for moving key issues forward to the Army leadership for resolution and/or decision. It also serves as a conduit to CWMD organizations within the Office of the Secretary of Defense (OSD), the Joint Staff, Army Service Component Commands (ASCCs), and Army Commands (ACOMS). These key organizations enable the Army to identify, define, focus and increase the effectiveness of Army CWMD Non Proliferation (NP), Counter Proliferation (CP) and Consequence Management (CM) activities.

Actions for near and mid-term engagement include: increasing both internal staff visibility across functions as well as between commands; codifying support for specialized CBRN training; developing tracking mechanism for ASCC efforts in CWMD exercises (particularly those involving building partner nation capacity); developing process to infuse CWMD objectives in training (particularly unit level through joint force); and identifying and monitor gaps in CWMD capability.

On behalf of Chief of Plans COL Steve Mitchell and USARCENT staff, a plaque was presented to Mr. Mark Fishback for his diligence and expertise to complete the Army's first Combating Weapons of Mass Destruction Component Plan. A key lesson learned during this effort was the requirement for an upfront, tailored CWMD planning vignette to the component Staff. USANCA's Combating WMD Planning Assistance Team (CPAT), as outlined in AR 10-16, was validated during this major planning effort and the planning assistance was favorably endorsed by the USARCENT G-3 and Chief of Plans.

A big thanks to the conference planner and coordinator Ms. Elizabeth Calhoun and her staff from (CSC), G-35-D for ensuring that the conference went smoothly.

The conclusion of the conference established initial goals for Army CWMD efforts for FY09.

Detection Systems for Biological Warfare Agents, Present and Future

LTC Mitchell L. Wise, USAR

Jon J. Calomiris, Ph.D.
U.S. Army Nuclear and CWMD Agency

On 9 December 1979 the World Health Organization (WHO) declared the world free of smallpox. The last known naturally-occurring case was identified in Somalia in 1977 (in 1978 a laboratory technician working with smallpox died of the disease in England). All known stocks of the virus were destroyed except those held by the Centers for Disease Control and Health Promotion (CDC) in the United States and the State Research Center of Virology and Biotechnology (VECTOR) in Koltsovo, Russia. An international debate ensued concerning destruction of these remaining stocks until 2002, when WHO determined it best to retain, for research purposes, this vestige of a by-gone scourge. While the debate took place, the Soviet Union secretly weaponized smallpox virus and packaged tons in missile warheads.[1] Smallpox, an extremely contagious disease with a mortality rate as high as 50 percent for some strains, remains a biological weapon threat to this day.

Biological warfare is nearly as old as organized war itself. As early as the 6th century BCE the Assyrians used ergot (a fungus) to poison the drinking water of their adversaries. Hannibal is reputed to have used clay pots filled with poisonous snakes against his enemies in a naval battle with the Emperor of Pergamene in 184 BCE, and the Mongol's use of human carcasses catapulted over castle walls at the siege of Kaffa (Theodosia, Ukraine) is believed to be one source for the spread of Black Plague or "Black Death" in Europe during the 14th century. During the French-Indian war the British attempted to infect the Delaware Indians besieging Fort Pitt by giving them blankets contaminated with smallpox virus; the efficacy of this tactic is subject to debate.

In modern times germ warfare has seen limited use. During WW I, the Germans attempted to infect allied horses with *Burkholderia mallei*, the bacterial species that causes Glanders. The effort was spearheaded by Dr. Anton Dilger, an American expatriot serving in the German army, while he was living in Baltimore prior to official U.S. involvement in the conflict. Although generally thought to be ineffective, these efforts marked the beginning of agricultural biowarfare.[2]

In the lead-up to the siege of Stalingrad thousands of German and Soviet soldiers developed pneumonic tularemia (which is caused by the bacterium *Francisella tularensis*). Dr. Ken Alibek [1] later speculated that the Soviets had utilized the bacterial pathogen for activities leading to the siege of Stalingrad. As the implied consequence, thousands of German and Soviet soldiers succumbed to pneumonic tularemia

Probably the most widespread employment of biological warfare in World War II was promulgated by Japan's infamous Unit 731 commanded by General Shiro Ishii. Allegations still exist that the Japanese deliberately infected thousands of Chinese with *Yersinia pestis,*[2] the bacterium that causes the plague. As in nearly all allegations of biological warfare, the actual employment is shrouded in secrecy and the effects typically obfuscated by the possibility of a natural-disease outbreak. Nevertheless, it is well known that Unit 731 engaged in human experimentation with biowarfare agents and could count its victims in the thousands.

Since WW II, there are no confirmed large-scale employments of biological weapons. However, the Soviets are suspected of using fungal mycotoxins (trichothecenes) against Hmong tribesmen in Southeast Asia during the Vietnam War. Although plausible, there is insufficient evidence to substantiate this activity. In recent years the threat and practice of biological attacks has come largely from non-state sponsored terrorists. In September 1984, for instance, the Rajneesh religious cult attempted to sway local elections in The Dalles, Oregon, by poisoning the salad bars in several popular local restaurants with *Salmonella typhimurium*. The hope was that with a significant portion of the local population ill, the Ranjeeshes could capture key political positions in an up-coming election. Although there were no fatali-

ties, 751 individuals were infected and 45 required hospitalization. Only after two years and serious in-fighting among the membership of the Raanjeesh organization, which resulted in law suits, was the etiological basis for these food poisoning outbreaks determined.

The Aum Shinrikyo sect, notorious for the Tokyo subway nerve agent attacks, attempted biological attacks on several occasions during the 1990s using botulinum toxin (a highly potent neurotoxin) and *Bacillus anthracis* spores (the causative agent of anthrax). In October 2001, shortly after the 9/11 terrorist attack, probably the most widely publicized act of bioterrorism in history was perpetrated through the U.S. Postal Service with mailings of *Bacillus anthracis* spores to various media outlets and the U.S. Senate offices of Patrick Leahy and Thomas Daschle. The spores were carefully prepared in a fashion that allowed them to disseminate profusely through the air when the envelopes were opened. In addition, the particles were a size that allowed them to efficiently enter the lungs, which was the primary site of infection. Consequently, these attacks killed five people and infected at least 22 in addition to causing widespread panic. Less well publicized was a second bioterror attack in 2004 in which ricin, a plant toxin, was mailed to Senator Bill Frist. Although no one was injured, Senate offices were closed for several days. For the "anthrax letters" case after almost seven years of investigation, one suspect was identified and subsequently committed suicide. These events illustrate the dire consequences we can face when microbial pathogens are employed for nefarious activities.

From this brief history it should be clear that the threat of biological attack is of grave concern. A glance at world news should convince anyone that the terrorist threat, especially that from Islamic jihadist, has no bounds; they will take any measure to inflict suffering on their perceived enemies.

At some point, terrorists or adversary states could use biological pathogens to attack U.S. forces or civilians. Consequently, there is a dire need for defense capability that would avert or remediate such an attack. Central to biological defense is technology for detection or identification of biological agents released to critical sites of the battlefield or civilian populations. To be reliable, detection of biological threats must be effective for agents that could be released in a variety of sites, including air spaces, surfaces, water supplies, and food. Ideally, detection systems should provide results in time to prevent infection (detect-to-warn) or, lacking that, the capability to control spread of the biological agent (detect-to-treat). A key factor for reliable detection is its accuracy with respect to a "signal" being generated only when a biological threat is present. Conversely, the system should have no "signal" when the biological threat is not present. This article will describe the fundamental technologies currently available for bioagent detection and the prospects for future improvements.

Sample Collection and Recovery of Biological Material for Detection

The first task for bioagent detection is to recover target microorganisms from samples collected from the attack site or site of concern. In a scenario such as the "anthrax letters" this is a relatively easy task since there would likely be a sufficient amount of material and a major component of the material would be *Bacillus anthracis* spores. However, with respect to all the possible avenues for a biological attack, sample collection is usually a formidable task. To devise an effective sampling strategy, allowing reliable detection, a variety of factors must be addressed. For example, the concentration of the target biological agent in a sample is critical to the ability to detect the agent. Because any given detection system requires a certain number of organisms to generate a detection signal (i.e. detection sensitivity), a sample with a low density of target organisms requires a larger sample to be collected. With air samples, it may be possible simply to sample the air for a longer period to collect a larger volume, hence a larger number of organisms. In contrast, with complex samples such as blood, muddy water, or food, recovery and concentration of target microorganisms can require complex, cumbersome, and time-consuming procedures. Even then, other components may interfere with the detection process. In particular, many materials which are commonly present in clinical specimens (heme of red blood cells), environment samples (clay, tannins, humic acids, and metals), and foods (lipids) are reported to inhibit Deoxynucleic Acid (DNA) based detection.

A variety of sampling systems have been developed to recover microorganisms from air, water, solid surfaces, and clinical specimens. Some systems are highly complex, especially those with automated sample preparation. Because aerosol delivery represents one of the likely scenarios for biological attack, this article will describe basic systems employed to sample air. As for any type of sampling, aerosol sampling strategies must address design and operational considerations to meet military requirements. For example, air sampling devices must operate over an array of environmental conditions including extreme temperatures, extreme levels of humidity, dust and fog. For most detection systems, transfer of the biological agent to a liquid phase is necessary. Hence, collection of sub-freezing air must be accomplished without freezing the liquid phase. The power requirements for aerosol collection can be impressive.

Aerosol collectors can be classified into two general types: cyclone and impactor (Figure 1). The cyclone design involves a cylindrical chamber, usually with a cone shaped bottom. The inlet is on the side and the outlet is formed by an interior tube with its opening near the bottom of the chamber. Thus, incoming air is forced into a vortex, creating a centrifugal force on any entrained particles; the heavier ones being forced to the outer walls of the chamber. In some applications the walls of the cyclone chamber are "wetted" with a solvent or aqueous solution to facilitate an

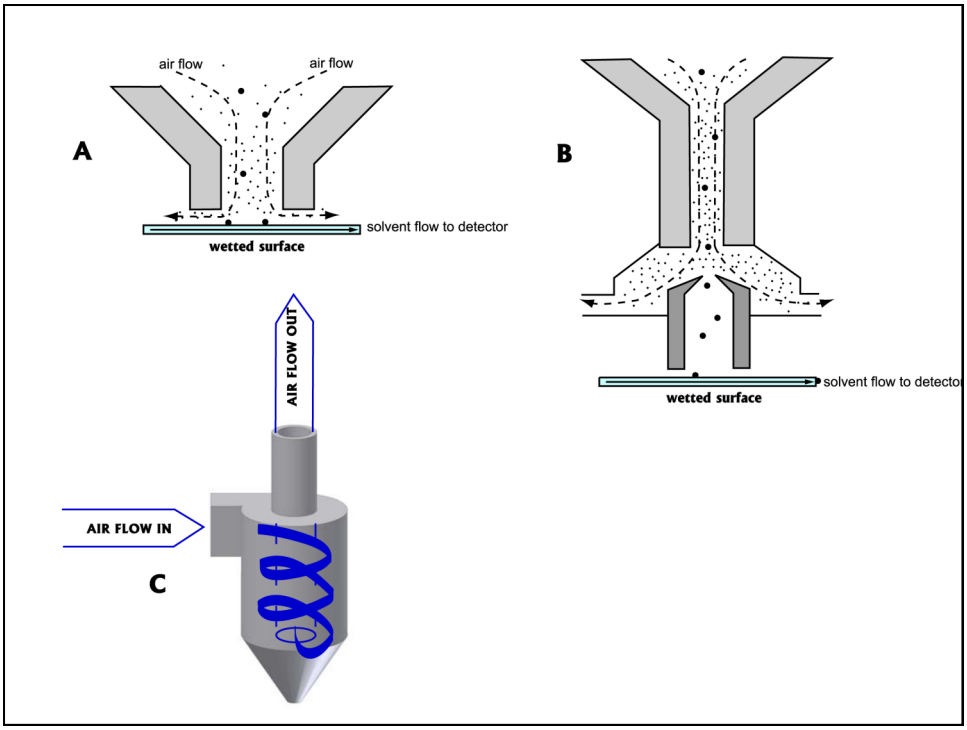

Figure 1. Bioaerosol Collectors. (A) Impact collector (B) Virtual impact collector (C) Cyclone type collector.

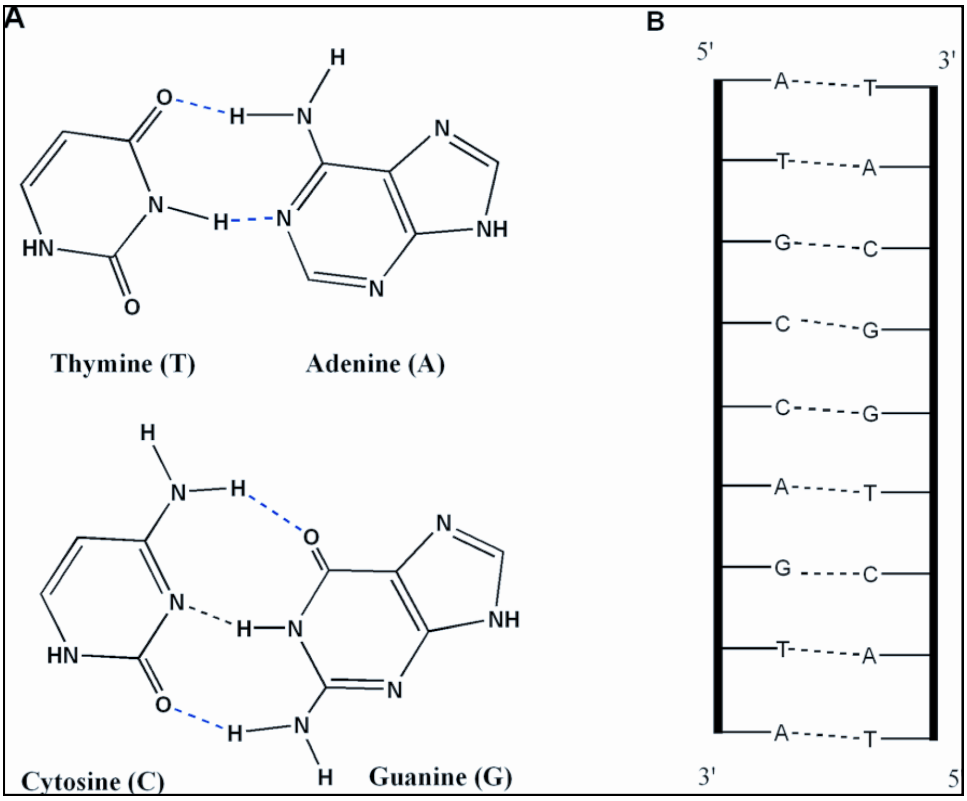

Figure 2. (DNA). (A) Chemical structures of the four bases responsible for complementary binding in DNA. Dashed lines represent hydrogen bonding between the base pairs. (B) Two anti-parallel strands of DNA showing the specific A:T and C:G complementation.

aerosol-to-hydrosol transfer stage (AHTS).

Impactor collectors work on a somewhat different principle analogous to the way that heavy, wet snow impacts on the windshield of a moving automobile while lighter snowflakes are diverted into the main airflow around the windshield. Impactors rely on the momentum of heavier, denser particles to maintain their trajectory onto a collecting surface while lighter particles are swept away into the effluent airstream. Virtual impactors are an adaptation where the impact surface is replaced by another collecting tube in which air flow is highly restricted. Thus the heavier particles are swept into a collecting tube for transport to an AHTS. There are practical limitations to each of these technologies. The cyclone collectors generally have a larger dynamic range for particle size but, especially for use in sub-freezing environments, can have excessive power requirements to avoid the problem of freezing. Because of the lower air flow rates at the AHTS, virtual impactors do not suffer this liability and relatively low power input can effectively prevent freezing. But the orifice sizes necessary to capture smaller diameter particles may restrict their ability to capture larger particles without becoming clogged. Limiting the size range of particles collected can facilitate collection efficiency. Particles from 1 to 10 μm are considered most important due to enhanced deposition in lung tissue.

Aerosol samplers are available that are capable of collecting in excess of 1,000 liters of air per minute and concentrating the particulate matter to a relatively small volume (approximately 1 milliliter).

Detection Technologies

One of the hallmarks of bioweapons is the extremely small amount of agent required to produce casualties. This, coupled with the complex chemical makeup of biological agents, precludes many of the technologies used for detection of chemical agents. The principle chemical components of biological particles are, in terms of physicochemical properties, rather uniform. These components consist of nucleic acid polymers (DNA and RNA), amino acid polymers (proteins) and lipids (molecules soluble in non-polar sol-

vent and largely composed of hydrocarbons with specific functional groups). On a gross level these classes of molecules are quite similar and cannot be used to differentiate pathogenic and non-pathogenic organisms. But, as will be addressed below, they can be exploited, at a molecular level, to provide quite specific identification of essentially any microorganism.

There are four basic detection technologies currently available. These are based on: (1) nucleic acid sequence, (2) molecular structure, (3) chemical property and (4) function.[3] In this section the rationale of each of these is examined and their relative merits and weaknesses are explored.

Nucleic Acid Sequence

In all living organisms the genetic code is inscribed by the sequence of bases in the nucleic acid polymers, deoxynucleic acid (DNA) (some viruses employ the chemically less stable ribonucleic acid (RNA)). DNA contains four distinct heterocyclic bases: adenine (A), cytosine (C), guanine (G), and thymine (T). It is the particular sequence of these bases as they are arranged in genetic material that dictates all the characteristics of any living organism. These four bases are linked into a linear polymer by sugar and phosphate molecules to form a long single strand of DNA. DNA, then, consists of two single-stranded polymers joined together side-by-side in a spiral staircase fashion, commonly referred to as a "double helix." The two single strands are held together by hydrogen bonds between complementary bases, with A's and T's always bonding with each other and C's and G's always bonding with each other (see Figure 2 page 6). Thus, each linear polymer will always bind to a complementary polymer to form double-stranded DNA. Moreover, these hydrogen bonds are weak and can be disrupted by relatively mild temperatures, increases in salt concentrations, pH changes or combinations of these parameters. The fidelity of DNA sequence complementation can be exploited in numerous ways to identify specific DNA sequences and thus the organism from which they originate.

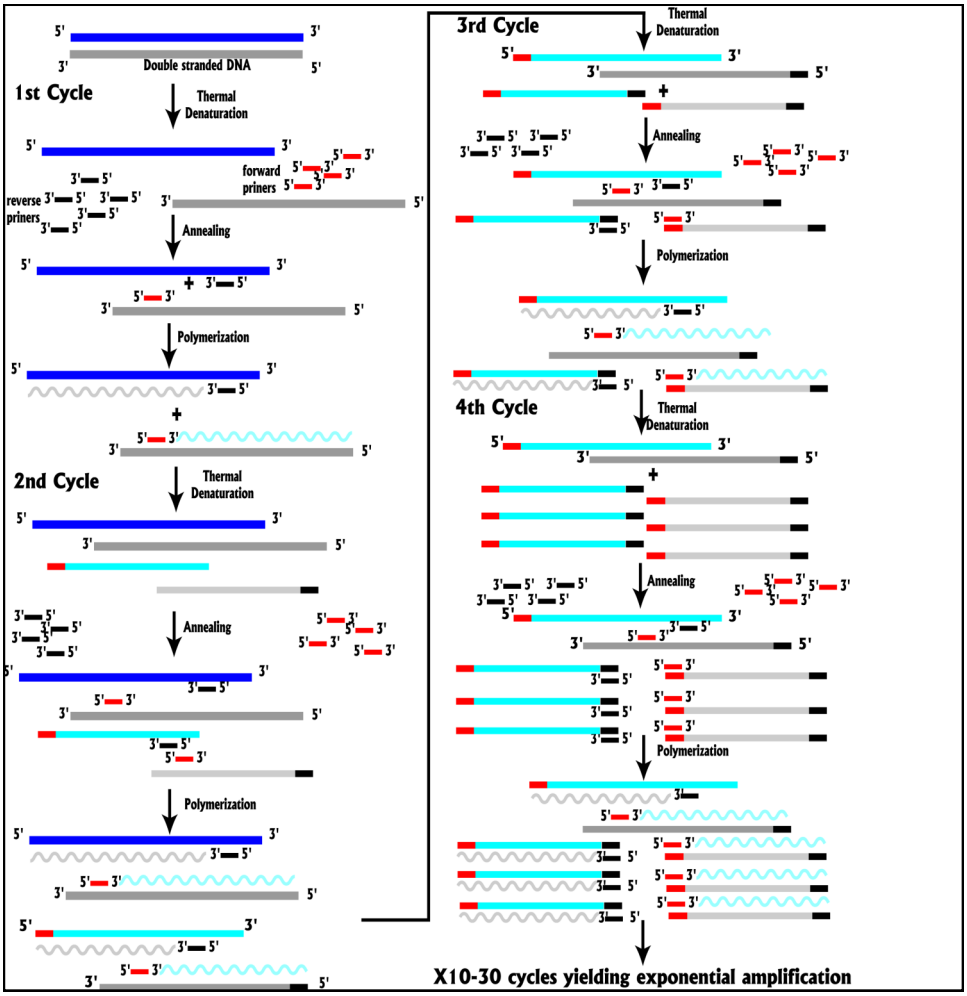

Figure 3. Polymerase Chain Reaction (PCR). A sample of DNA serves as template for amplification of a target segment. Short nucleic acid oligomers with target specific sequence serve as primers. The reaction mixture also contains a thermally-stable DNA polymerase and a supply of individual nucleotides. The original template DNA (solid blue and gray) is only depicted in cycle 1 and 2.

One tool to employ DNA sequence for detection is the polymerase chain reaction (PCR), arguably the most significant development in biochemical technology in the twentieth century. This technique relies on the thermal lability of DNA complementation as well as the discovery of certain DNA polymerases that withstand the temperature regimes necessary to denature the double-stranded DNA. DNA polymerases are enzymes (proteins) that biosynthesize linear strands of DNA from the individual nucleic acids, given a complementary strand and a short segment (10 to 25 nucleotides) of double-stranded DNA (Figure 3 above). By combining pairs of short DNA oligomers ("primers") which complement a segment of DNA on opposite strands and distal to one another, with a template of target DNA, along with thermally-stable DNA polymerase in a solution of individual nucleotides in a thermocycler (a device to alternatively heat and cool the solution to prescribed temperatures for specific time periods) it is possible to amplify the target DNA exponentially.

If a sequence of DNA in an organism is known it is quite simple and inexpensive to synthesize short DNA primers of a prescribed sequence. Complete gene sequences for an ever expanding library of organisms are being determined and literally millions of partial sequences are now known and readily available from public databases on the internet. By

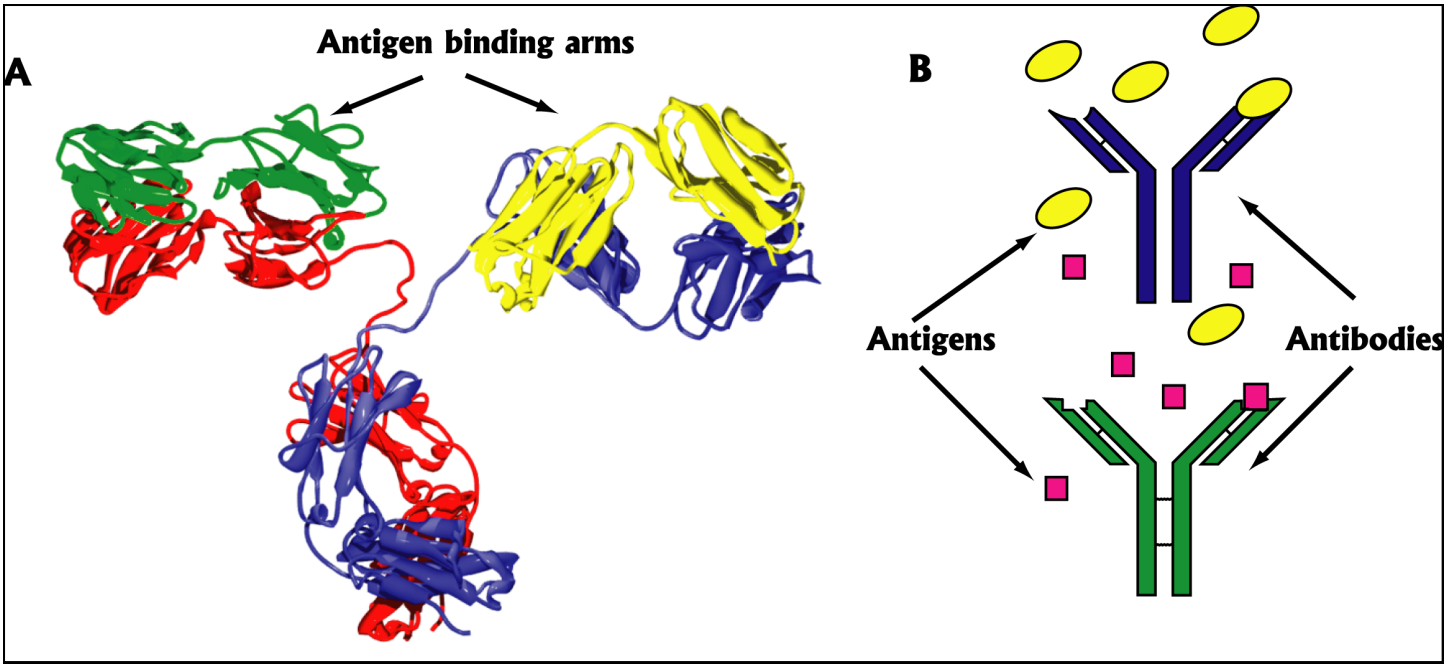

Figure 4. Antibody Molecules. (A) A ribbon structure depicting the protein molecules composing an antibody. (B) Stylistic representation of antibody molecules.

alternately raising the solution temperature to the point that the double-stranded DNA denatures into two complementary single strands, then lowering the reaction temperature to a point that allows complementary DNA strands to re-anneal, some of the primers will spontaneously bind to their complementary segments on the single-stranded DNA. These short segments of double-stranded DNA serve to initiate polymerization, through the action of DNA polymerase, which fill out the complementary strand until the reaction vessel is re-heated and again denatures the double strands into single strands. Because DNA strands have directionality (the ends are termed 5' and 3') and DNA polymerase only works by extending the DNA polymer in the 5' to 3' direction, and because the primers are designed to complement the double-stranded DNA on opposite strands, only the intervening sequence is amplified during a single thermal cycle. As the reaction vessel is subjected to repeated cycles of high and low temperatures the intervening sequence is doubled with each round. Hence, with *X* thermocycles 2^X copies of the original sequence are generated. Thermocyclers are now available that can complete 3 to 4 cycles per minute. In addition, clever use of fluorescent labels for the generated amplicons (amplified segments of DNA) has substantially improved detection levels. Other nucleic acid hybridization techniques are also being exploited for the identification of biowarfare agents.[4]

Currently, detection methods based on DNA hybridization are generally considered the most specific. Unfortunately, while the hybridization of specific DNA sequences to target DNA can and does occur in a milieu of competing DNA sequences, interference by other substances or DNA polymerase inhibitors, such as those found in crude extracts of environmental samples, can be severely limiting. Preventing "carry-over" of target DNA from one analysis to another, resulting in false-positive signals, must also be avoided. Employment of fluorescent-labeled hybridization probes for the nascent amplified sequences can substantially lower the amount of PCR product required for detection. Although fairly rapid thermal cycling instruments have been developed, even the best PCR detectors require tens of minutes to amplify detectable levels of target sequence.

Molecular Structure-Based Techniques

Immunization is a concept familiar to most people. One of the cornerstones of the immune response is the generation of antibodies. Antibodies are proteins expressed on the surface of and secreted into the blood stream by white blood cells (leukocytes) termed B-cells. These proteins form, in essence, a Y-shaped structure with the tips of the Y convoluted into a three-dimensional configuration with pockets shaped to accommodate the three-dimensional shape of surface molecules on the invading organism (termed antigens) like a hand fits into a glove. In addition to the complementation of the antigen-antibody three-dimensional configuration, chemical and electrostatic interactions between the bound antigen and the antibody are also possible (Figure 4). Recent advances in biotechnology have allowed the production of clones of individual B-cells, i.e. a collection of cells from a single parent, expressing a specific antibody, in artificial culture. Indeed, it is now even possible to generate specific antibodies in genetically engineered yeast cells. Mammals may be able to produce antibodies to more than a billion unique antigens. In addition there are well developed methods to chemically

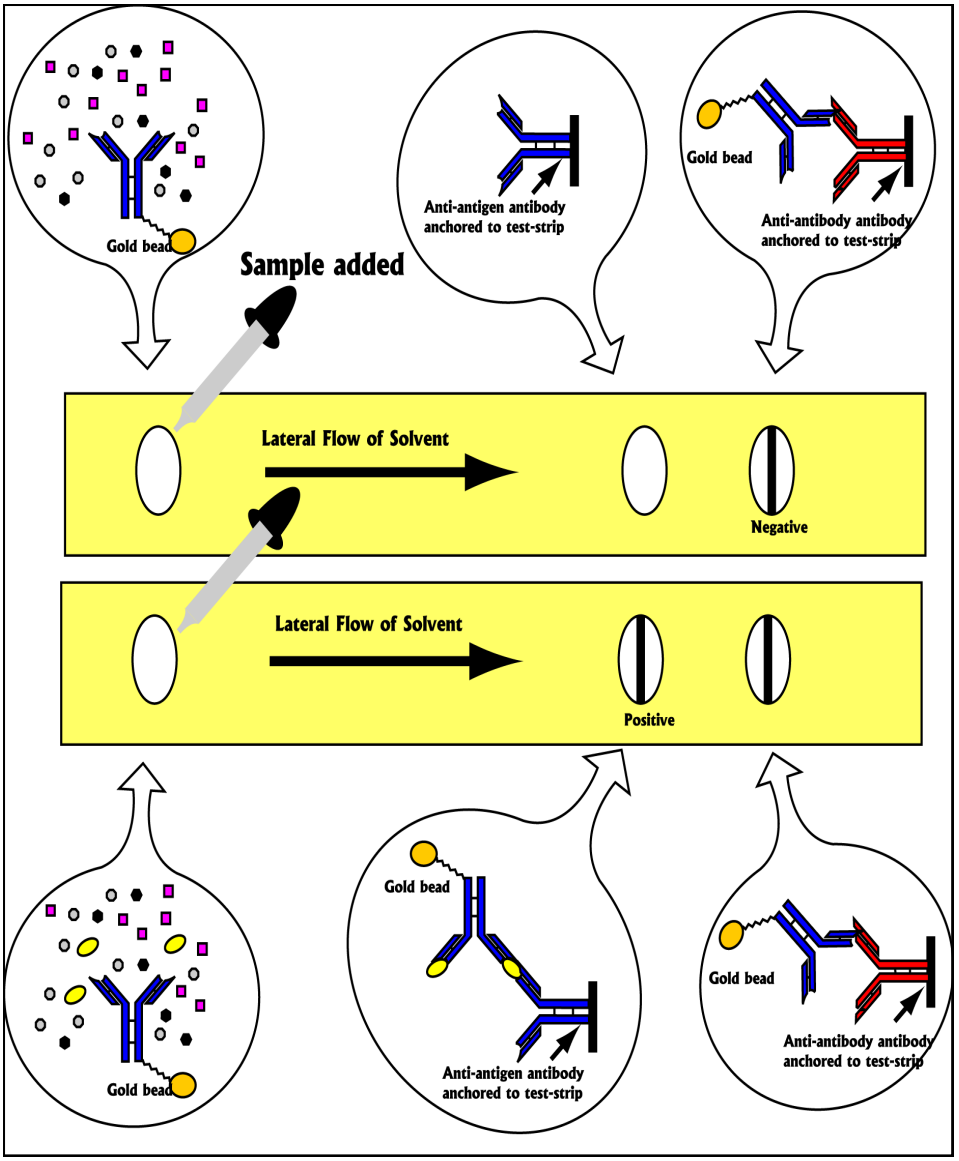

Figure 5. Lateral Flow Immunoassay. A sample solution is loaded into the well containing free, labeled antigen-specific antibodies. The antibodies, bound and/or unbound to antigen, are wicked up the chamber where they encounter a line of antigen specific antibodies and a line of anti-antibody antibodies. A similar technology is employed with the Smart Ticket® and the JPBDS.

modify antibody molecules, allowing them to be attached to other molecules such as fluorescent dyes or to other surfaces like polymeric beads.

Exploitation of the high specificity of the antibody-antigen interaction for identification of biological molecules has led to numerous bioassay techniques. [5] One familiar example is the over-the-counter pregnancy test. Similar "enzyme linked immunosorbant assays" (ELISA) are now available for biowarfare agent detection. The Hand-Held Immunochromatographic Assays (HHA) and SMART® tickets are examples of immunoassay-based detectors (Figure 5). Immunochemistry-based detection systems can be quite rapid (seconds to minutes) and fairly specific but, because there is no inherent amplification of the target molecules, they cannot rival PCR-based detection for sensitivity. There are, however, numerous mechanisms for signal transfer from antibody-based detectors that portend their utility, especially in detect-to-warn systems where response time is a critical consideration.

One approach, for example, is a system developed by Luminex Corporation that uses styrene beads coated with bioagent-specific antibodies. The beads are impregnated with a fluorescent dye that can be illuminated by a laser. The agent specific beads are thus "color coded" to indicate the particular bioagent detected. Analysis by flow cytometry, i.e. passing the fluorescent-antibody-labeled cells or beads through a narrow tube allowing only one bead at a time and illuminated by a laser coupled with a light detector to measure the fluorescence, allows identification of a biohazard. This device is incorporated into the Autonomous Pathogen Detection System (APDS), developed by Lawrence Livermore National Laboratory and currently used by the Department of Homeland Security.

Chemical and Physical Methods

As indicated earlier, biological agents are composed of certain classes of chemicals. In general terms these are encompassed by: proteins (polymers of the 20 common amino acids), carbohydrates (sugar molecules), nucleic acids, lipids (metabolites soluble in non-polar solvents, typically variations of hydrocarbons with associated functional groups) and relatively low molecular weight metabolites. Although the bulk properties of these classes of compounds are indistinguishable between organisms, certain aspects of their occurrence can be exploited to identify individual agents. We have already seen how nucleic acid sequence information can be used. Proteins, likewise, have specific sequences. Indeed the central dogma of biology describes the relationship between the DNA sequence and the amino acid sequence of proteins. Unfortunately, the hybridization approach used for DNA sequencing is not possible to determine protein sequences. Nevertheless, methods are available to allow protein sequence determination. One of these is through mass spectrometry.

The principal of mass spectrometry is really quite simple. A particle moving through a force field will, due to inertia, be more or less affected as a consequence of its mass. Early models of mass spectrometers em-

ployed large magnetic sectors to influence the path of charged molecules and had substantial space requirements. In the past few decades far more compact mass selectors have been designed. Based on the use of radiofrequency alternating voltage as well as direct current electric fields to manipulate the trajectory of ions, these instruments are configured as either quadrupole mass filters or ion-traps. Quadrupole mass spectrometers are small and physically robust, permitting use in mobile laboratories such as the M93A1 FOX chemical reconnaissance vehicle. Early designs for the E31 Biological Integrated Detection System (BIDS) included a mass spectrometer but they are not included in the currently fielded version.

Typically the quadrupole or ion-trap is interfaced with a gas or liquid chromatography system that allows separation of complex solutions into individual components. As the individual analytes elute from the chromatographic column they are ionized (electrically charged). In the case of liquid chromatography the process is called electrospray ionization (ESI). The charged particles can then be subjected to mass spectral analysis. Another format for mass spectral analysis particularly useful for analysis of biological material is termed Matrix Associated Laser Desorption-Time of Flight (MALDI-TOF). This approach uses a light absorbing chemical matrix to embed the analyte of interest, which is then subjected to a pulse of high intensity laser light. The solid matrix volatilizes almost instantly and at the same time imparts an electrical charge on the analyte. The charged analyte is subjected to a voltage potential in a vacuum where it is accelerated to a detector. The lower molecular weight analytes are accelerated more rapidly than the heavier ones; thus molecular weights can be determined by "time-of-flight". Using sophisticated computer algorithms it is now possible to determine protein sequences from mass spectral data obtained by either ESI-quadrupole mass spectrometry or MALDI-TOF. While the sizes of the quadrupole-type mass spectrometers are comparable to a large coffee cup (TOF instruments are somewhat larger), they both require high vacuums, usually supplied through a rotary vane rough pump and a diffusion or turbomolecular pump. These hardware requirements substantially increase the size, weight, and power requirements of the system. Mass spectrometry is also useful for identification of lipids, carbohydrates, and small metabolites.

Another common analysis system is gas chromatography. This instrument is limited to analysis of volatile compounds such as lipids (molecules soluble in non-polar organic solvents) or chemically derivatized lipids. The typical laboratory gas chromatograph is about the size of a large microwave oven and requires external gas tanks to provide a "carrier" gas to carry the volatilized analytes through a long, narrow tubular column. By heating the column as the mixture of particles passes through, advantage can be taken of the differing affinities of the sample admixture for the material coating the wall of the column as well as their different volatilities. Various components can be separated and, with a detector to determine retention time, an indication of the analyte's identification is obtained. Additional information is afforded depending on the detection method used. Quadrupole mass spectrometers are commonly employed; thus the chromatographic characteristic as well as a mass spectrum is obtained providing substantial evidence for identification of a chemical component. Microorganisms often produce unique chemical signatures allowing presumptive identification. For the purposes of bioagent detection the inlet to the GC can be interfaced with a pyrolysis chamber. A system that utilizes aerosol pyrolysis (thermal decomposition without oxygen) with gas chromatography and ion-mobility spectrometry is currently under development at the U.S. Army Edgewood Chemical Biological Center (ECBC). [6] Ion-mobility is analogous to a TOF-MS; however, the charged particle traverses an air filled chamber (rather than through a vacuum) and the time of transition under defined voltage conditions provides some indication of the analyte's identity. Although not nearly as definitive as mass spectrometry, this methodology is considerably less expensive and far more compatible to field application. The currently fielded M41 chemical agent alarm uses this technology.

Surface Active Sensors

Optical and acoustic waveguide technology is being employed for bioagent detection. Waveguides are simply structures that propagate electromagnetic (e.g. light) or acoustic waves along a specific path. Fiber optics is a familiar application of waveguide technology. Waveguide technology is more accurately termed a signal transduction mechanism. Optical and acoustic waveguides are typically linked to one of four biological recognition elements: enzymatic, immunochemical, nucleic acid, or whole-cell sensors.[7] The advantages of waveguide signal transduction are the rapidity with which the signal is transmitted, the relatively simple design of the detectors and potentially low costs and durability. Signal initiation can be generated by a variety of mechanisms, e.g. enzyme reaction with a substrate to generate an optically active (light absorbing or fluorescent) product that alters the incident light to the detector. For example the system could involve linkage to a bioluminescent reaction catalyzed by luciferease (an enzyme that yields light as a product) or to green fluorescent protein. Alternately, single-stranded DNA molecules might be employed to attract a complementary sequence which in turn binds, through a down-stream DNA sequence, to another complementary sequence covalently linked to an optically active probe.

The basic principle of waveguide transducers involves a core fiber, suitable for transmission of a light or acoustic wave that is surrounded by a cladding with different optical or acoustic properties (e.g. refractive index). Light or sound waves are transmitted by reflectance between the two surfaces with little or no attenuation. Some detector designs incorporate an analyte binding molecule, e.g. an antibody or DNA probe,

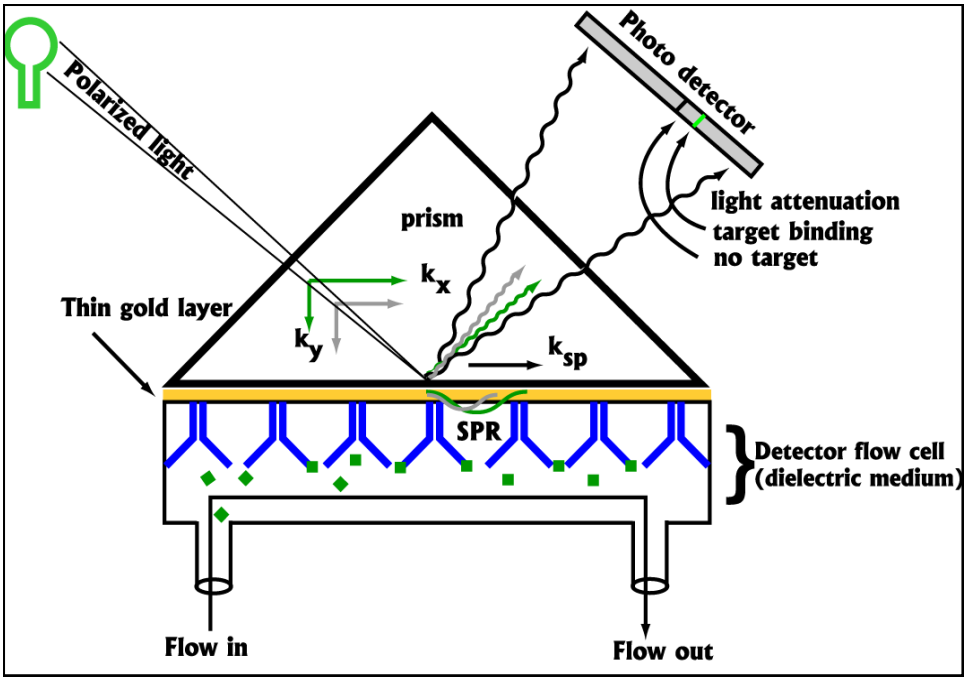

Figure 6. Surface Plasmon Resonance. At the angle where the incident light energy vector (k_y) coincides with the charge density wavelength along the metal – dielectric interface, the adsorbed energy results in a sharp decrease in reflected light.

into the cladding, resulting in an alteration in the optical or acoustic properties of the cladding material upon binding of the target. This, in turn, results in changes in signal transfer efficiency that can be determined electronically.

A similar type of biosensor that uses refractive index to generate a signal is termed surface plasmon resonance (SPR). When plane polarized light of a particular wavelength impinges at a specific angle on a thin (50 to 100 nm) metal film (e.g. gold) interfaced on one side with a dielectric medium, some of the energy can be adsorbed through interaction with the metal lattice electrons in the form of a charge density wave or plasmon. This adsorbed energy results in a reduction of intensity of the reflected light, which can be measured with high precision. The precise incidence angle at which the surface plasmon occurs is a function of several factors, one being the refractive index of the underlying (dielectric) surface. By including a biomolecular recognition element, e.g. an antibody or DNA probe, at or near the surface of the metal, the reflective index will be altered upon binding of the target (Figure 6). The advantage of SPR is that no fluorescent or otherwise labeled molecules are needed for signal elicitation. This technology also lends itself to miniaturization and offers the potential for detect-to-warn bioagent detection.[3,8]

Currently Fielded Systems

The Joint Biological Point Detection System (JBPDS) is the principal biological agent detection system fielded by the DOD. This system employs a Biological Agent Warning Sensor (BAWS) as a triggering device. Developed by the MIT Lincoln Laboratory and manufactured by Intellitec Products LLC, the BAWS constantly draws environmental air and monitors for a surge in biological material. Using a laser beam to stimulate fluorescence of the particles in the air stream, photomultiplier tubes measure the fluorescent and backscattered light at particular wavelengths. An algorithm translates these light signatures and interprets whether they derive from biological material; a sudden increase in particle count triggers the JBPDS cyclone aerosol collector to begin operation. The aerosol is transferred through an AHTS and streamed into a immunochemistry based detector. Aliquots are simultaneously collected and stored for follow-up confirmatory analysis. This system is currently capable of detecting 10 biowarfare agents and provides results in less than 30 minutes. The JBPDS is the detection system employed in the Biological Integrated Detection System (BIDS) used by the U.S. Army, Navy, and Air Force.

A PCR-based detection device called the Joint Biological Agent Identification and Detection System (JBAIDS) is also in the DOD inventory. This instrument evolved from the Ruggedized Advanced Pathogen Identification Device (R.A.P.I.D.® System) developed by Idaho Technology, Inc. The R.A.P.I.D.® System weighs about 50 pounds (23 kg) and measures 19 x 14 x 10 inches (49 x 36 x 27 cm); it is man portable and battery operated. The PCR instrument's detection signal is termed "real-time," meaning it uses fluorescent probes to signal PCR amplification of a target DNA sequence enabling electronic, hence real-time, detection of the amplification. The reagents employed in the JBAIDS are freeze-dried for improved shelf-life and are reported to be stable for 12 months at 28˚C or 2 months at 45˚C. Many of the National Guard Civil Support Teams (CSTs) and other first responders as well as the U.S. Army 1st and 9th Area Medical Laboratories (AMLs) employ the JBAIDS. As the "next generation" R.A.P.I.D.® System, the RAZOR® was recently developed by Idaho Technologies, Inc., for simpler operation using a plastic pouch for easier sample handling.

A similar device, the Hand-Held Advanced Nucleic Acid Analyzer (HANAA), was developed largely at the Lawrence Livermore National Laboratory. Smiths Detection, a United Kingdom-based technology company, has commercially developed this instrument with the trade name Bio-Seeq™. The HANAA marketed by Smiths Detection is a compact (13 x 7 x 4 inches or 34 x 19 x 10 cm), light-weight (approximately 5 pounds or 2.6 kg), battery operated, field-deployable PCR instrument and

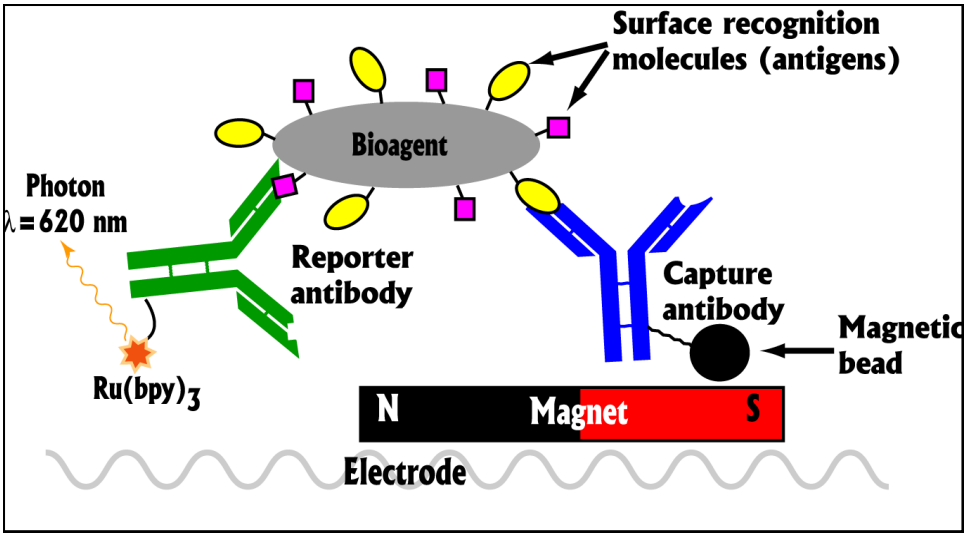

Figure 7. Electrochemiluminescence (ECL). One antibody is bound to a magnetic bead facilitating transport of the complex to the proximity of an electrode. The other antibody is linked to ruthenium tribispyridine ($Ru(byp)_3$) which yields a photon of light upon stimulus through a reduction-oxidation reaction with tripropylamine (TPA) in the presence of a charged anode. This technology is employed with the BioVeris M1M.

costs about $35K. This device can monitor for *Bacillus anthracis, Francisella tularensis, Yersinia pestis* and orthopox virus simultaneously and provide identification in less than 30 minutes. The machine is robust and requires relatively little training. These systems require user sample preparation but little technical expertise. As the "next generation" unit, the Bio-Seeq™ PLUS was developed as a fully field-deployable detector that is more amenable to hand-held operation.

Complementing the JBAIDS on many CSTs and the AMLs is the BioVeris M1M electrochemiluminescence (ECL) detector. ECL allows substantially lower limits of detection than conventional immunoassay techniques. This is accomplished through a light signal generated by the antigen-antibody complex. Basically this instrument employs ELISA technology in which one antigen specific antibody is linked to a magnetic bead and a second antigen specific antibody is bound with ruthenium-tri 2,2'-bipyridine ($Ru(bpy)_3$). When both antibodies bind the target antigen (a bioagent or toxin) a magnet attracts the complex to the proximity of an electrode in a solution of tripropylamine (TPA). Application of an electric potential oxidizes both the TPA and the $Ru(bpy)_3$ complex. These two chemical species interact resulting in the $Ru(bpy)_3$ emitting a photon, which can be detected with a photomultiplier tube and converted to an electric current. By rapid alteration of the electrode potential multiple photons are emitted from each of the bound $Ru(bpy)_3$ labeled antibodies (Figure 7). This advent allows exquisite sensitivity; femtomolar levels (10^{-15} moles per liter) of analyte can be detected.

Future Directions

The "anthrax letter" attacks in the aftermath of 9/11 clearly illustrate our nation's vulnerability to biological terrorism. As safeguards to provide homeland defense against future biological attacks, bioagent detection systems, like those described in this article, are employed to monitor key government buildings, transportation hubs, and special events. Systems are also employed to protect military installations and the warfighter on the battlefield. While these systems provide reliable detection capability, they are costly and require operators with specialized training. In order to field a more comprehensive, responsive detection capability, we need small, inexpensive, autonomous, and highly sensitive bioagent detectors a concept similar to today's "smoke detector". Such devices could be mounted in multiple locations or worn by soldiers, left un-attended or under remote control, and would be relatively inexpensive to maintain.

Nearly all the bio-recognition chemistries described in this article necessarily occur in solution. Transfer of aerosolized bioagents to solution at detectable concentrations is a major technological hurdle. At present there are numerous biodetection systems available. A 2007 survey of systems with utility for homeland security catalogs over 100 bioagent detection devices commercially available.[9] However, they all suffer serious shortcomings, especially in the area of cost, speed of operation, and maintenance requirements. The JBPDS, for example, has a fairly rapid response time and requires little on-site operation, but system size, power requirements and capital as well as operating costs limit its employment. A U.S. Army BIDS company, for example, is a Corps-level asset consisting of 35 mobile units. The APDS, which combines automated sampling with automated immunochemical detection, sample preparation and PCR confirmation, is an impressive system in terms of autonomous operation, but also carries an impressive price tag and it occupies the space of a three-drawer file cabinet.

Nevertheless, tremendous strides are being taken in the field of biodetection. For example, the MicroChem station, in development by Sandia National Laboratory since 1996, was originally designed as a chemical agent and explosives detector. This device employs microfabrication technology to miniaturized chromatography and detection components. Early models intended for chemical agent detection included a gas-chromatography column the size of a nickel (Figure 8 page 13). Recent developments have incorporated a liquid chromatographic capability, with a working volume of picoliters (10^{-12} liter), which allows detection of non-volatile biological material including bacteria, viruses and toxins. Separation of complex mixtures is

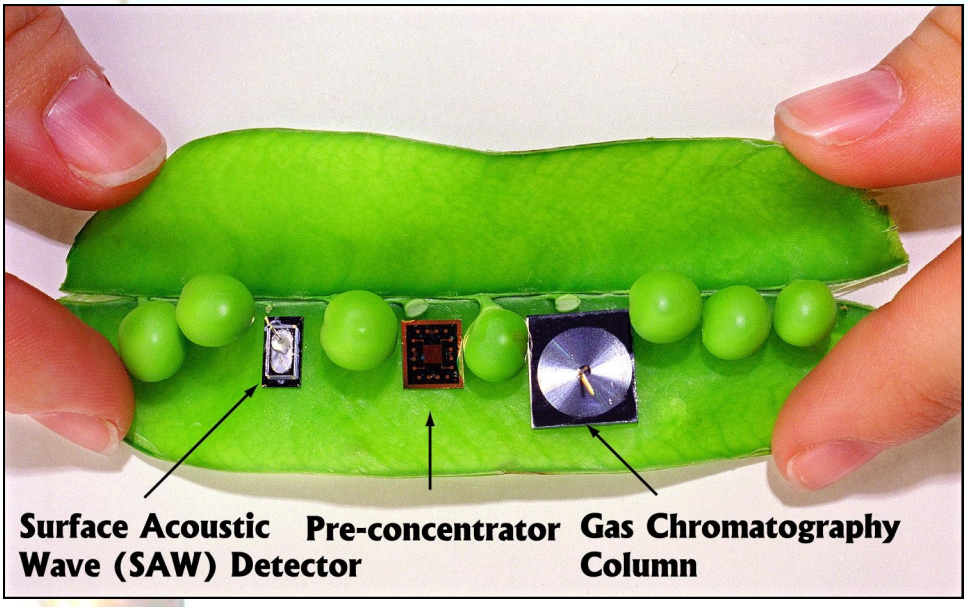

Figure 8. Key components of Sandia's ChemLab compared to "peas in a pod". Advances in micro-fabrication portend rapid development in the field of micro total analysis (or "lab-on-a-chip") instrumentation.

accomplished by electrokinetic mobility of extremely small volumes of ionic solvents through semi-porous media under the influence of a small electric field. Although presently of limited applicability for the detection of biological warfare agents, this system illustrates some of the remarkable advances being made in miniaturization of biosensors, the so-called "lab-on-a-chip" or micro total analysis systems. It has been likened to the "tricorder" used by Bones, the pixilated ship's doctor in the Star Trek television series of the 1960s.

Since 2001 the U.S. Federal Government has provided over $40 billion for biodefense, a significant portion going to research and acquisition of biodetection devices.[10] While there has been legitimate criticism for these expenditures,[11] we need still more investment to counter the emerging bioterrorism threat. Furthermore, like the advances in computer technology and materials science resulting from our national space program, research on bioagent detection technology is also having an impact outside the arena of biodefense, including medicine, forensics, and food safety. The DOD should help guide future investment in the field to expedite improvements in bioagent detection systems. Strategies to advance biodetection capability must address development of systems that not only provide reliable, accurate and sensitive detection (essential features) but also focus on minimal cost, operation speed and simplicity, minimal operator burden, field utility, and effective sample handling.

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References

1. Alibek, K. *Biohazard*; Random House: New York, 1999.
2. Sidell, F. R.; Takafuji, E. T.; Franz, D. R. *Medical Aspects of Chemical and Biological Warfare*; United States Government Printing: Washington D.C., 1997; Vol. 3.
3. Vitko, J. J.; Franz, D. R.; Alper, M.; Biggins, P. D. E.; Brandt, L. D.; Burge, H. A.; Ediger, R.; Hollis, M. A.; Laughlin, L. L.; Mariella, R. P. J.; McFarland, A. R.; Schaudies, R. P. "Sensor systems for biological agent attacks: Protecting buildings and military bases," National Academies of Science, 2005.
4. Ivnitski, D.; O'Neil, D. J.; Gattuso, A.; Schlicht, R.; Calidonna, M.; Fisher, R. *BioTechniques* 2003, *35*, 862-869.
5. Peruski, A. H.; Peruski, L. F. J. *Clinical and Diagnostic Laboratory Immunology* 2003, *10*, 506-513.
6. Snyder, A. P.; Maswadeh, W. M.; Wick, C. H.; Dworzanski, J. P.; Tripathi, A. "Correlation of mass spectrometry identified bacterial biomarkers from a fielded pyrolysis-gas chromatography ion mobility spectrometry biodetector with the microbiological gram stain classification scheme," Edgewood Chemical Biological Center, 2005.
7. Monk, D. J.; Walt, D. R. *Analytical and Bioanalytical Chemistry* 2004, *379*, 931-945.
8. Homola, J. *Chemical Reviews* 2008, *108*, 462-493.
9. Fatah, A. A.; Barrett, J. A.; Arcilesi, R. D. J.; Ewing, K. J.; Lattin, C. H.; Moshier, T. F.; Justice, D. O., Ed., 2001; National Institute of Justice Guide 101-00; pp 41.
10. Franco, C. *Biosecurity and Bioterrorism: Biodefense Strategy, Practice and Science* 2008, *6*, 131-146.
11. Shane, S. In *http://www.nytimes.com/2005/03/0 / politics/01petition.html?_r=1&oref=slogin*; New York Times, 2005.

Undergraduate Perspectives on U.S. Nuclear Policy, A Report on the Proliferation of Weapons and Materials Round Table at the 59th Annual Student Conference on United States Affairs (SCUSA)

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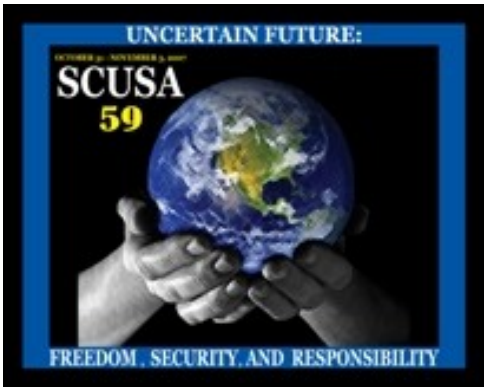
Each autumn, undergraduate[1] students from all over the U.S. and around the world converge on the United States Military Academy (USMA) to meet, discuss, and debate U.S. foreign policy at the Student Conference on United States Affairs (SCUSA). In 2007, SCUSA took place from 31 October to 3 November and was attended by 274 students and cadets from 100 universities and 30 countries. Student delegates from all four service academies were joined by civilian counterparts from universities such as Columbia, Stanford, Michigan, Southern California, and Alaska. International students from Canada, Cameroon, China, India, Japan, Pakistan, Russia, Singapore, and seven European nations also participated. Distinguished guests included former Central Command commander GEN (R) John P. Abizaid and Medal of Honor recipient COL(R) Jack Jacobs.

SCUSA is organized and administered by the faculty and staff of the USMA Department of Social Sciences and 2007 marked the 59th time USMA has hosted SCUSA. USMA "continues to sponsor SCUSA in the belief that it can foster the growth of mutual understanding among potential civilian and military leaders of the country (U.S.) and thus make a significant contribution toward the future security of the United States."[2] The objectives of SCUSA are: to produce an informative examination and discussion of selected aspects of U.S. public policy, primarily foreign relations; to facilitate an increased appreciation for the complex nature of the policy-making process among a group of outstanding college students; and to broaden the student participants' contact with their contemporaries in an academic endeavor.[3] Each SCUSA has a theme around which discussions center. In 2007, the theme was "Uncertain Future: Freedom, Security, and Responsibility." Recognizing the uncertainty inherent in today's security environment, delegates were asked to come to some agreement on the purpose and goals of American power in crafting their foreign policy proposals.



SCUSA 59 logo, Uncertain Future: Freedom, Security, and Responsibility.

SCUSA is organized as a series of "round tables", each one discussing and debating a specific aspect of U.S. foreign policy. Each round table has from twelve to sixteen student delegates and is moderated by two co-chairs. Students choose their round table prior to the conference, giving them the opportunity to prepare in advance by reading an on-line "table paper", prepared by the table co-chairs, outlining the background, key issues, and current events for their chosen topic. Table co-chairs are selected by the SCUSA organizers for their subject-matter expertise. In 2007 there were eighteen SCUSA round tables, ranging from those with a regional focus such as Middle East Gulf States, Sub-Saharan Africa, and Russia and Central Asia, to those with a topical focus such as State Building and Democratization, the Role of Non-State Actors, Globalization, Homeland Security and the Challenges of Insurgency. Over the four days of the conference, the delegates for each table met for four discussion sessions, and produced and presented a policy paper. Outside of the formal sessions, civilian student delegates were exposed to life at

USMA. They stayed in the cadet barracks, ate in the mess hall, viewed static weapons displays and even relaxed and had some fun at a dinner/dance. Both the civilian students and the cadets benefited from the opportunity to exchange views and learn from others' academic and personal experiences.

This year, for the first time, SCUSA included a round table on the Proliferation of Weapons and Materials (PWM). This article by the table co-chairs and the cadet-in-charge chronicles the events of this first-ever PWM round table, and presents the policy recommendations made *by the students*. We hope that the Nuclear and Counterproliferation community finds these perspectives by the student delegates to be fresh, interesting, and thought-provoking.

Delegates and co-chairs for the first SCUSA Proliferation of Weapons and Materials Round Table.

Organizing the Proliferation of Weapons and Materials Round Table

In preparing for the conference, the co-chairs wrote a "read ahead" table paper for the PWM student delegates. To narrow the scope of the discussion, the PWM table paper[4] focused on four main areas of nuclear proliferation: the Nuclear Non-Proliferation Treaty (NPT), Iran's and North Korea's nuclear weapons programs, and nuclear terrorism. USMA faculty in the Department of Social Sciences and the Department of Physics provided invaluable assistance in preparing the table paper.[5] Several weeks prior to the start of the conference, the table paper was made available to the student delegates.

Eight civilian student delegates served on the PWM table. They came from American University, Farleigh Dickinson University (three students), George Washington University, Piedmont College, Wellesley College, and Wilfrid Laurier University (Canada). The PWM table also had four USMA cadet delegates: one international relations major with a nuclear engineering core engineering sequence,[6] two nuclear engineering majors, and one freshman planning to major in international relations.[7] In the weeks leading up to SCUSA, three USMA "table advisors"[8] assisted these cadets in preparing for the conference by discussing key issues with them and directing them towards articles and references of interest on the subject of nuclear proliferation.

The primary role of the table co-chairs was to keep the student discussions focused on the key issues and serve as resident subject matter experts. By design, the PWM co-chairs had expertise in both policy (Ms. Young) and in scientific and technical issues (LTC Musk), and so were able to answer the full range of student questions on the complex topic of nuclear proliferation. The goal of the student delegates was to fully discuss the issues, come to a group consensus, and capture the table policy recommendations in a final five to ten page policy paper. At the conclusion of the conference, all policy papers were published on the SCUSA website so they could be viewed by interested policy makers and others. Delegates display their creativity (and in some cases, humor) by presenting their table recommendations to all SCUSA attendees on the morning of the final day.

Student Discussions, Consensus, and Preparing the Policy Paper

Using the "read ahead" table paper as their starting point, the PWM delegates quickly realized the enormity of their task and spent the first couple of sessions collectively defining the problems of nuclear non-proliferation. The delegates with an understanding of the technical characteristics of nuclear weapons or the intricacies of the Nuclear Non-Proliferation Treaty were complemented by those who had regional expertise in Northeast Asia, the Middle East, or global non-proliferation policy. After much discussion (including, for example, whether total nuclear disarmament was attainable and in the interest of the United States), delegates defined what they saw as a realistic and attainable policy objective: a severely decreased likelihood of nuclear attack, nearly to the point that such an attack would not be possible for those who might seek to perpetrate it. In formulating their policy objective the delegates used four main assumptions: 1. as the number of nuclear weapons states increase, so does the risk of use of nuclear weapons by both state and non-state actors, 2. extensive diplomatic engagement by the U.S. is required due to the global nature of the issue, 3. norms alone will not prevent proliferation; enforcement or

threat of enforcement may be necessary, and finally 4. the U.S. must play a significant role in solving this problem.

Once the delegates had agreed on the objective and the assumptions, they broke up into teams to discuss, formulate, and outline their policy recommendations. Three teams were formed to address the perceived main areas for concern for nuclear non-proliferation U.S. policy: methods and materials, nuclear fuel cycle protections, and counter-proliferation. Each team presented their outline to the group for comment and discussion.

In the discussion of methods and materials, specifically highly enriched uranium and nuclear expertise, delegates identified the tension that existed between the desire to strengthen existing control regimes or to create new ones. They also discussed the balance needed between domestic law enforcement mechanisms and multilateral international regimes such as the Proliferation Security Initiative. In discussing nuclear fuel cycle protections, the delegates discussed the ambiguity in Article III of the NPT and how best to ensure that energy poor states acquire the fuel they need while at the same time ensuring that states do not use this ambiguity to pursue weapons. The final outline on counter-proliferation addressed enforcement. Here, the delegates did an excellent job of considering costs, benefits, and risks of various courses of action. A consistent theme throughout the discussions was the need for the U.S. to show leadership while at the same time stressing the importance of diplomacy and multilateralism in addressing the issue. The discussions and outline formed the basis for the final student policy paper and recommendations summarized in the following section.

Student Policy Paper and Policy Recommendations

The PWM student delegates agreed early on that a multilateral approach is vital to any non-proliferation or counter-proliferation initiative. The students believed that the U.S. would not be effective in preventing nuclear terrorism and stopping the spread of nuclear weapons if it failed to garner international support for its policies. From this basic principle, the students developed three major policy recommendations.

First, the regulation and control of highly-enriched uranium requires domestic revisions for nuclear technology protections as well as the development and expansion of international regimes to regulate the production, transportation, and use of highly-enriched uranium (HEU). To provide the best deterrence against U.S. export violations, Congress should pass the U.S. Department of Commerce-supported Export Enforcement Act, which, after being introduced by Senator Christopher Dodd (D-CT) in August 2007, was effectively killed in committee.[9] At the international level, nuclear non-proliferation regimes should increase the level of control and tracking of non-military nuclear material and technology. Existing efforts to track and secure HEU should continue to expand under the direct purview of the IAEA, as an "independent" body for the promotion of nuclear security. Existing IAEA inspection agreements fail to address security concerns at nuclear facilities, placing sole responsibility for protection in the hands of the individual state. Through the IAEA, states should be able to acquire additional security assistance. As the non-proliferation norm globalizes, these expanded security programs should be mandated and formulated into additional protocols or reforms to the existing NPT.

Some delegates expressed concern about emphasizing international regimes in non-proliferation efforts. The scope of these regimes might increase, but, in the view of some delegates, an expansion would do little to include states such as China, North Korea, and Pakistan, that would be unlikely to participate in any restrictive non-proliferation effort. Most delegates recognized this problem, and also believed that existing international regimes for non-proliferation and nuclear security did little to influence current nuclear-weapons states to ensure the safety of their own nuclear material. In Russia, for example, relaxed security measures due to funding cuts have deteriorated their ability to adequately secure all HEU within the country.[10] An international system for assisting states in nuclear fuel protection would go far in alleviating the many concerns associated with unsecured nuclear materials.

Second, the actions of Iran have shown the danger that comes from states developing their own entirely indigenous nuclear fuel cycles. On a global scale, there are environmental and security-related issues associated with numerous states developing and running their own nuclear fuel cycles. In theory, such problems can be significantly reduced by expanding programs such as the Global Nuclear Energy Partnership to include current non-weapons states that have a need for an expanded energy infrastructure, but lack the capital and technology to safely and securely conduct such a program. Regardless of which multilateral enrichment regimes are supported by the United States, efforts towards nuclear fuel cycle protection must be multilateral.

One area that caused heated disagreement among the table delegates was whether the United States should utilize its broad economic and diplomatic assets to expand and internationalize the Additional Protocol of the NPT.[11] While many thought that full acceptance would serve to change the international norms surrounding nuclear proliferation, others argued that the states most willing to develop nuclear weapons would be unlikely to sign the Additional Protocol anyway. Instead, they argued, the U.S. should place an emphasis on funding programs to prevent the theft of nuclear material and technologies (such as the Nuclear Cities Initiative or the revised Nunn-Lugar agreement).

Third, the delegates agreed that in all counter-proliferation efforts, the United States should use military force only as a last resort and for immediate threats. First and foremost, international diplomatic efforts should

be used to garner support from friendly states to increase the costs of noncompliance to proliferating countries. Because of the technology and material required for nuclear weapons development, non-state actors must either steal nuclear material or enlist the support of a proliferating state. If states understand that even their implicit cooperation with terrorist organizations will be met with severe international punishment in the event of an attack, much of the non-state actor problem is reduced to preventing the theft of nuclear materials.

Although there were minor differences in opinion among PWM delegates, all agreed that the U.S. has been largely unsuccessful in its efforts to prevent the proliferation of nuclear weapons. Many programs, such as the Proliferation Security Initiative, have done great work in this field, but the standard for success is necessarily high. The development of nuclear weapons by North Korea and Iran and the failure of Russia to adequately protect all of its existing HEU stores place the U.S. at a greater risk of nuclear attack in the near future. While experts predict that this attack will most likely be from an Al-Qaeda-affiliated organization, preventing the proliferation of technology to rogue states will also decrease the availability of unprotected nuclear fuel and information.

Lessons Learned

A number of valuable lessons were learned from this first SCUSA roundtable on the proliferation of weapons and materials. Foremost was the value of having both policy-oriented and technically-oriented delegates and co-chairs participate in the proliferation discussions, since in the opinion of the co-chairs, routine interactions between these groups of experts are infrequent and thus limits the types of solutions they offer to decision makers. Having one table co-chair from the policy side and one from the technical side is a model that should be continued for SCUSA in the future.

At a two-day conference, some major proliferation topics, deterrence and U.S. nuclear weapons policy for example, could not be addressed. Deterrence is a concept that was fairly well understood in the Cold War but it is not clear how it applies in today's uncertain security environment with multiple state and non-state actors. The U.S. nuclear weapons policy is to rely on its nuclear stockpile as the "ultimate deterrent", and will likely be so for the foreseeable future, but it is not clear that the current stockpile is sized and shaped to meet the challenges of today, nor that we have a strategy that outlines our ends, ways, and means with regards to nuclear weapons. Country and region-specific issues could also have been addressed more directly. Although countries such as Iran and North Korea were frequent topics of discussion during the conference, the discussions were not systematic. A more robust discussion of the history of the weapons programs in these countries in the "read ahead" table paper may have helped the delegates better tailor deterrence and non-proliferation policies to these particular countries of concern.

Finally, the student delegates felt that they would have liked to have had more time to discuss the economic underpinnings of their policy recommendations. While many readers understand the idealist nature of some of the student recommendations, it should be noted that the delegates did try to support ideas that could be economically feasible. For example the delegates, as part of their analysis, noted that a U.S.-led multilateral fuel cycle would require billions of dollars of start-up capital.

Overall, the table-discussion format was an excellent medium for the student delegates to express their opinions on the issues. Because the co-chairs allowed the debate to flow from the feasible to the idealistic, students were put at ease and could concentrate on logically evaluating the proposed policy recommendations. Breaking up the round table into smaller groups to work on policy recommendations in specific areas proved to be an efficient use of delegates' time. Finally, the "out-of-the-box" imagination and creativity displayed in the final presentation of the student policy paper is a plus. The use of humor and skits in the final presentations was particularly effective at grabbing the audience's attention. This should be emphasized to future delegates, as should the importance of adequately rehearsing their presentations.

Final Thoughts

Participation in SCUSA was a rewarding experience for all involved, co-chairs and delegates alike. In addition to the thought-provoking discussions on key components of U.S. foreign policy, SCUSA gave students from around the country and around the world the opportunity to experience USMA and to interact with cadets and subject-matter experts from academia and the U.S. Government. SCUSA co-chairs had the unique opportunity to educate and inform a wider and more diverse audience than they normally have access to. With the high caliber of student representation, it is possible that some of the delegates from SCUSA today, may be the policy makers of tomorrow.

If you are interested in participating in SCUSA 2008 in early November as a table co-chair, please contact Ms. Joy Pasquazi in the USMA Department of Social Sciences at (845) 938-6401 (Joy.Pasquazi@usma.edu).

LTC Jeffrey H. Musk is the Director of the Nuclear Science and Engineering Research Center, a Defense Threat Reduction Agency field activity located at the United States Military Academy in the Department of Physics. He has served in multiple FA52 assignments including: Nuclear Physicist at the Armed Forces Radiobiology Research Institute; Assistant Professor and Nuclear Engineering Program Director at the United States Military Academy Department of Physics; and a Defense Programs Staff Officer at the National Nuclear Security Administration. His degrees include a BS from the University of

Maine in Engineering Physics, a MS from M.I.T. in Nuclear Engineering, and a Ph.D. in Nuclear Science from Cornell University.

Ms. Lesley Young is a Strategist in the Office of the Deputy Assistant Secretary of Defense (DASD) for Policy Planning, in the Office of the Secretary of Defense (OSD). In this capacity, she is responsible for analysis and policy recommendations related to deterrence, non-proliferation, and future trends in conflict. Prior to this, Ms. Young held several assignments in various OSD offices including: DASD for Strategy, the Assistant Secretary of Defense for Homeland Defense, Office of the Director, Program Analysis and Evaluation, and the DASD for Resources and Plans. Her degrees include a Juris Doctor from Northwestern University School of Law, a MSc in National Security Strategy from the National War College in Washington, D.C. an MA from the London School of Economics in International History, and a BA in modern European History from Brown University.

Second Lieutenant Zachary Furst is a 2008 graduate of the United States Military Academy, where he majored in International Relations with a Nuclear Engineering sequence. As a four-year member of the West Point Model United Nations team, he has discussed non-proliferation issues in crisis simulations at Oxford, Harvard, and Princeton Universities. Second Lieutenant Furst is currently serving in the U.S. Army's Military Intelligence Branch.

ENDNOTES

1. Though SCUSA is primarily attended by undergraduate students, some graduate students also attend. SCUSA 59 was attended by 22 graduate students, all Fulbright scholars.

2. SCUSA 59 Handbook, p. 6.

3. Ibid, p.6.

4. Full text of the Proliferation of Weapons and Materials table paper, and all the other SCUSA table papers can be accessed on-line at http://www.dean.usma.edu/sosh/Conferences/scusa/index.html.

5. Assistance in preparing the table paper was provided by Captain Amanda Gookins, (USAF) from the Department of Social Sciences, MAJ Geoffrey Bull from the Department of Physics, and MAJ Robert Schlicht from the Defense Threat Reduction Agency's Nuclear Science and Engineering Research Center (NSERC).

6. All USMA cadets not majoring in engineering are required to take a three-course core engineering sequence in an engineering discipline of their choice. Cadets in the nuclear engineering core engineering sequence take Nuclear Reactor Analysis, Nuclear Reactor Design, and Nuclear Systems Design (i.e., nuclear weapons and weapons effects).

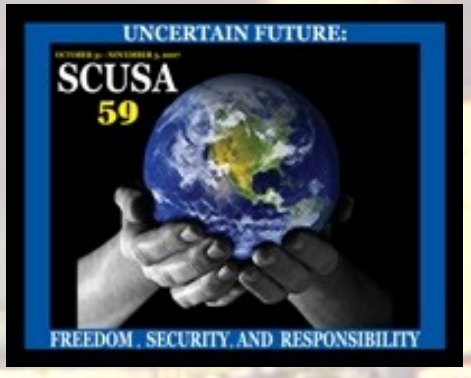
7. USMA cadets serving on the Proliferation of Weapons and Material round table were: CDT Zachary W. Furst, '08 majoring in international relations with a nuclear engineering sequence, CDT Josh A. Caldwell, '08, nuclear engineering major, CDT Brett A Shaffer, '09, nuclear engineering major, and CDT Sahm Cho, '11.

8. The table advisors for the Proliferation of Weapons and Materials round table were Captain Amanda Gookins, (USAF) from the Department of Social Sciences, MAJ Doug Rothenbush from the Department of Physics, and MAJ Robert Schlicht from the Defense Threat Reduction Agency's Nuclear Science and Engineering Research Center (NSERC).

9. Information on the Export Enforcement Act can be found at http://www.bis.doc.gov/adminbillexportcontrol.htm.

10. Matthew Bunn, Securing the Bomb 2007, white paper by the Nuclear Threat Initiative, September 2007, p. 26.

11. "The essence of the Additional Protocol is to reshape the IAEA's safeguards regime from a quantitative system focused on accounting for known quantities of materials and monitoring declared activities to a qualitative system aimed at gathering a comprehensive picture of a state's nuclear and nuclear-related activities, including all nuclear-related imports and exports. The Additional Protocol also substantially expands the IAEA's ability to check for clandestine nuclear facilities by providing the agency with authority to visit any facility-declared or not-to investigate questions about or inconsistencies in a state's nuclear declarations. NPT states-parties are not required to adopt an Additional Protocol, although the IAEA is urging all to do so." Such a model "Additional Protocol" was adopted by the IAEA in 1997, http://www.armscontrol.org/factsheets/IAEAProtocol.asp



Spartans Make Their Home in Texas

Cathy Kropp
20th Support Command PA Staff

They call themselves Spartans. "As the Spartans of the past, we too are trained and ready to respond when our nation calls," said COL Vance P. Visser, commander of the 48th Chemical Brigade.

Marking the first time since World War I that a brigade-level headquarters has been available to command and control chemical forces in support of a war, the 48th Chemical Brigade was activated in September 2007. Headquartered at Ft. Hood, Texas, these modern-day Spartans include close to 2,800 chemical, biological, radiological and nuclear (CBRN) Soldiers in five battalions with 27 operational companies spread across nine military installations.

While fully supporting operations in Iraq and Afghanistan, the brigade is simultaneously training to demonstrate its initial operational capability during an exercise in September 2008. Still, to support the Army's overall modularization and the revolutionary transformation of U.S. Army's Chemical, Biological, Radiological, Nuclear and High Yield Explosives (CBRNE) assets, more growth and reorganization may be in the brigade's future.

As part of the Army's overall modular transformation the 20th Support Command (CBRNE), higher headquarters for the 48th Chemical Brigade, is initiating a comprehensive review of its subordinate chemical and explosive ordnance disposal (EOD) organizations and evaluating strategies that combine both the CBRN and the EOD capabilities within standardized multi-capable expeditionary CBRNE brigades and battalions. This same valuable mix has already been proven effective in

the 48th Chemical Brigade's technical escort battalions.

Of the five battalions in the brigade today, two are technical escort battalions. Technical escort battalion assets are strategically responsive, rapidly deployable and can be tailored to the specific mission. They are designed to rapidly respond to mitigate and eliminate CBRNE hazards both at home and overseas. Each specially trained and equipped CBRNE response team has the capability to sample, detect, and monitor CBRNE hazards. They are able to mitigate initial hazards, package hazardous material for transport, provide technical escort of that package, and decontaminate themselves and their equipment. They also have the capability to render unexploded ordnance safe, or when necessary eliminate or disable CBRNE hazards or production facilities. Their analysis, munitions assessment, and CBRNE advice are invaluable to the decision makers they support.

The remaining three conventional chemical battalions, in both heavy and light configurations, are outfitted with various arrays of specialized reconnaissance, smoke, Biological Integrated Detection Systems (BIDS) or decontamination companies to support the operational force.

The primary mission of these conventional units is to improve the survivability and mobility of ground forces. Using CBRNE vehicles and equipment, such as the Fox and Stryker CBRN reconnaissance vehicles, reconnaissance units are able to detect, identify and mark areas of chemical and radiological contamination. Recon units also collect and transport air, water and ground samples to identify nuclear, biological and chemical contamination and convey real-time detailed hazard information to supported commanders.

Like recon, smoke units are employed to increase warfighter survivability. Their mission is to buy maneuver time for friendly forces and to protect assembly areas and other high-priority targets. Using equipment such as the M56 and M58 smoke generation systems, these units can lay vast amounts of obscurants as camouflage, a decoy or to counter new generation smart weapons.

The BIDS consists of biological detection, identification and sampling equipment. The BIDS units are capable of detecting when a biological attack has occurred and can also provide presumptive identification of biological agents and produce a sample for detailed analysis at a laboratory.

The final possible configuration of a conventional chemical company is as a decontamination unit. The primary mission of a decontamination unit is to return units to the field for future combat operations. Using equipment such as the M12A1 and

48th Chemical Brigade Activation Ceremony at Fort Hood, TX 19 September 2007.

M17 decontamination apparatus the units can rapidly decontaminate a vehicle and return it to the fight. The units are undergoing a significant modernization effort to enable them to conduct hazard response operations.

However, impressive equipment and technology are not the sole indicators of success. As Visser points out, "humans are more important than hardware; quality is better than quantity; CBRNE forces cannot be mass produced; and competent CBRNE forces cannot be created after emergencies occur."

With a full-time focus on countering CBRNE threats at home and abroad, the Spartans of the 48th Chemical Brigade are using the lessons learned in today's operations to transform and evolve to meet the needs of the nation to combat the WMD and CBRNE threats of tomorrow.

"We stand ready with sharp swords and polished shields to deploy on short notice anywhere in the world to provide CBRNE support to protect the nation," said Visser. "Spartans, leading to victory!"

Cathy Kroop is a staff writer for the 20th Support Command PA Office.

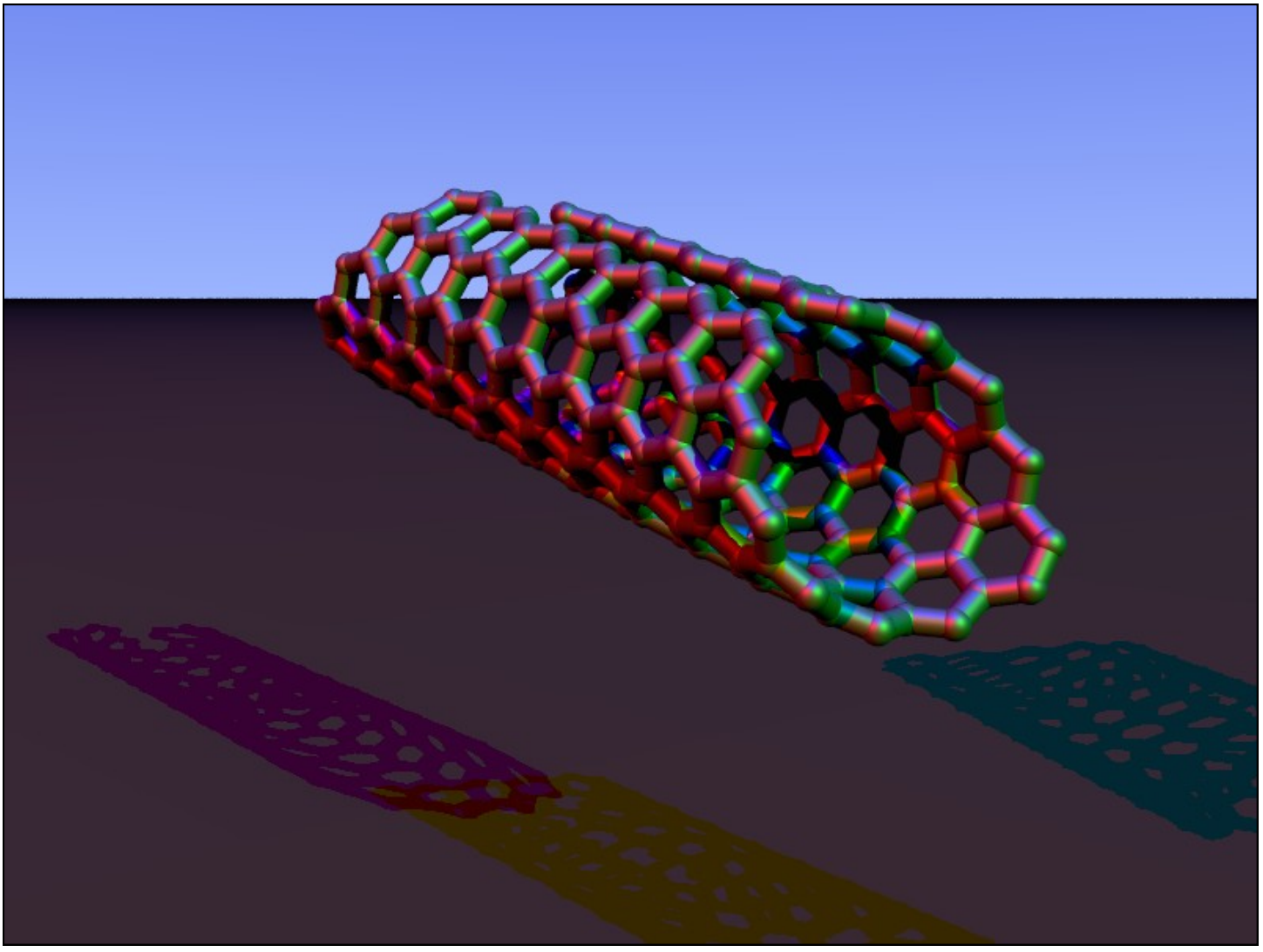
Photo Credit
48th Chemical Brigade website http://www.cbrne.army.mil/subordinates/48th/leadership.html

48th Chemical Brigade
Distinctive Unit Insignia

One Carbon Nanotube Molecule Does An Operable Radio Make?

Robert A. Pfeffer
Physical Scientist, U.S. Army Nuclear and CWMD Agency

Carbon nanotube technology is still in its infancy but it is now starting to flex its muscles in a wide range of applications; some of them, in my opinion, could have enormous military applications.



Artists's concept of a SWCNT chiral wrap [1]

So just what is a carbon nanotube (CNT)? Wikipedia[1] says it is a "carbon allotrope, a pure form of carbon that differs in structure from other carbon forms (e.g., diamond, graphite, amorphous carbon, and fullerene)." A single-walled CNT (SWCNT) happens to be a fullerene, a one-atom thick sheet of graphite (called graphene) rolled into a seamless cylinder having a diameter of the order of a nanometer (10^{-9} meter). A nanometer is about the length of ten atoms side-by-side, so we are talking about a small diameter! This single-layer wrap is called a chiral wrap.

The article says SWCNT had already been made into operational discreet devices and integrated circuits. What Wikipedia doesn't say is that a SWCNT molecule has al-

ready been configured to be an operating radio.

So what about this single-walled carbon nanotube radio? The U.S. Department of Energy Lawrence Berkeley National Laboratory and the University of California at Berkeley first used SWCNT to make "… an exceptionally sensitive force sensor. Nanotubes are like tiny cat whiskers. Small forces, on the order of attonewtons (10^{-18} newton), cause them to deflect a significant amount. By detecting this deflection, you can infer what force was acting on the nanotube. This incredible sensitivity becomes even greater at the nanotube's flexural resonance frequency, which falls within the frequencies of radio broadcasts, cell phones and GPS broadcasting. Because of this high resonance frequency, Alex (Zettl) suggested that nanotubes could be used to make a radio." [2] And that is just what happened. Dr. Zettl oversaw the work of one of his graduate students (Kenneth Jensen), who designed and then constructed the radio.

"Incoming radio waves interact with the nanotube's electrically charged tip, causing the nanotube to vibrate. These vibrations are only significant when the frequency of the incoming wave coincides with the nanotube's flexural resonance frequency, which, like a conventional radio, can be tuned during operation to receive only a preselected segment, or channel, of the electromagnetic spectrum.

Amplification and demodulation properties arise from the needle-point geometry of carbon nanotubes, giving them unique field emission properties. By concentrating the electric field of the DC bias voltage applied across the electrodes, the nanotube radio produces a field-emission current that is sensitive to the nanotube's mechanical vibrations. Since the field-emission current is generated by the external power source, amplification of the radio signal is possible. Furthermore, since field emission is a nonlinear process, it also acts to demodulate an AM or FM radio signal, just like the diode used in traditional radios." [2]

SWCNTs have been made to function as an antenna, a tunable bandpass filter, an amplifier, and a demodulator, so says Dr. Zetti, the leader of the radio nanotube research effort. This means SWCNTs can function almost as an entire radio, the exception being the speaker. For more technical information on the radio and to actually see a SWCNT and then hear the theme music from Star Wars by John Williams (first transmitted to it, and then recorded off it), go to http://www.lbl.gov/Science-Articles/Archive/MSD-nanoradio.html.

Absolutely incredible!

In my opinion, SWCNT radios are just the tip of the nanotube application iceberg. They represent the first of many military and intel applications that can range from weapons systems to sensors to C4I and medical applications. And now that SWCNT has been made into flexible discrete components (i.e., transistors on a thin film substrate) using nanonet technology,[3] their applications could be realized even sooner. Some applications include: SWCNT radio(s) woven into uniforms for short-range communication links powered by solar cells made with quantum dots (another nanotube application); tiny sensors attached to aircraft to detect surface cracks or hidden virtually anywhere to monitor real-time battlefield conditions. Nanotubes, under the proper control, are even small enough to be injected into the bloodstream for medical monitoring or treatment. Finally, SWCNT particles could be used to compromise electronic equipment.

Expect to hear about many more technology breakthroughs once the cost for producing SWCNTs is reduced from the year 2000 cost of $1500 per gram.

Now if only I could find a carbon nanotube speaker….

Further Reading

1. http://en.wikipedia.org/wiki/Carbon_nanotube.html.

2. Yarris, Lynn, Make Way for the Real Nanopod: Berkeley Researchers Create First Fully Functional Nanotube Radio, Research News Berkeley Lab, 30 October 2007.

3. Google SWCNT and nanonet technology.

Chemical Warfare Decontamination of Eurofighter Materials A Case Study of the SX34 System

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Professor of Chemical Engineering, University of Padua, Italy

The European Fighter Aircraft (Eurofighter) Typhoon currently is the most advanced aircraft designed for high performance multirole in aerial maneuvers. This twin-engine fighter aircraft is distinguished for its air agility, canard-delta wing, interface optimized man-machine systems, fusion of sensory data, integrated networks of military data, and equipped with the most modern armament and new technologies. The aircraft was built by a consortium of three partner companies: Alenia Aeronautica, BAE Systems, and EADS[1] working through a holding company formed in 1986. The Eurofighter has entered into service with the U.K. Royal Air Force, the German Luftwaffe, the Italian Air Force, the Spanish Air Force and the Austrian Air Force.[2] The aircraft is still in the beginning phase of expanding the development of its own abilities, as agreed among the participant nations.

Figure 1. Eurofighter Typhoon.

Several construction materials from the Eurofighter have been selected for testing their maximum resistance against penetration of chemical warfare (CW) agents. Concerning aircraft operation in a CW environment, the joint commission of experts from the four partner countries sorted the materials in four lists[3] based on their chemical and physical properties. The material resistance to agent penetration was rated as: 1. Poor, 2. Sufficient, 3. Good, and 4. Excellent. The decontamination experiment was carried out with the purpose of evaluating the efficacy of a new concept of decontamination system, the SX34, which was designed for "thorough decontamination" of "sensitive equipment". The SX34 decontamination system has been developed at the University of Padua, Italy, and sponsored by the Italian Company Cristanini. The evaluation test was carried out at the Centro Tecnico Logistico Interforze NBC (NBC Technical Logistic Interforces Centre), in Civitavecchia, Italy.

"Sensitive equipment" includes all materials that are particularly vulnerable to degradation in a CW-contaminated environment and need to be reused after decontamination. Sensitive equipment and environments include avionics, electronics, optics, aircraft/vehicle interiors and associated cargos.[4] These are generally difficult to decontaminate due to their construction characteristics, component materials, and location on the aircraft. Some of these materials may be damaged by humidity and become corroded with current decontamination products. Weaponized chemical and biological agents are designed to resist decontamination by penetrating the surfaces they touch.[5] For these reasons the SX34

decon system excludes the chemical deactivation of the agent directly on the contaminated surface and the destruction of CW agent is performed in a confined device. In contrast, current decontaminants available on the market are strong enough to deal with such agents, but they are so harsh that they cause damage to the sensitive equipment they are intended to cleanse. Apart from materials damage, the runoff and seepage of the agent/decontaminant into the aircraft gaps normally cause cross-contamination.

The SX34 decontamination system has been developed with the purpose of satisfying the following objectives:

- Ready-for-use system, active for different chemical, biological, and radiological (CBR) agents, as well as any other substance that may contain them
- *No liquid* form in order to avoid spread of contamination
- *No chemical reaction* on the surfaces except removal of agents
- Detoxification/disposal of the decon residue remotely
- Virtually useable on all surface material and shape without causing damage, even after multiple application cycles
- Environmental friendly
- Suitable for military and civil application
- Long life span
- Easy to handle and store
- Simple to use with no need for specific training

EVALUATION TEST

The aim of the test was to assess the SX34 decontamination efficacy on "sensitive materials" that should be reused after the decontamination process. The procedures were conducted according to NATO Document -STANAG 4653-AEP 58 Chapter 3, para 3.5. One goal was to determine the SX34 efficiency and ability to extract Yperite (sulfur mustard gas) from contaminated sensitive materials. The decontamination yield provides the measure of such capability at the n-decontamination cycle. The yield is defined as $\eta_n = [(C_0 - C_{end})/C_0] \times 100$ (where C_0 is the initial concentration of the chemical weapon and C_{end} is the corresponding concentration after the decontamination treatment). The results obtained have been compared with solvent washing using isopropyl alcohol and scrubbing with absorbent paper.

Table 1. Names and descriptions of materials used in the test.

Commercial Name	Description and Applications
Fluorined rubber sheet type 6000	Sheet based on FKM (fluorinated rubber) highly resistant to high temperatures, oils, fuels and ozone. Excellent flame resistance and use at elevated temperatures with chemical. Maximum working temperature 200°C. Good mechanical properties.
Fluorined rubber sheet type Viton® 6000	Sheet based on FKM (fluorinated rubber) highly resistant to high temperatures, oils, fuels and ozone. Excellent flame resistance and use at elevated temperatures with chemical. Maximum working temperature 200°C. Good mechanical properties.
Chloroprene sheet type 3012	Sheet based on CR (polychloroprene rubber) and SBR rubber with good resistance to oils at room temperature and atmospheric agent. Good mechanical properties.
Super Chloroprene sheet type 3015	Sheet based on CR (polychloroprene rubber) with excellent resistance to oils, atmospheric agents and flame. Excellent mechanical properties.
Fuel-resistant sheet type 2026	Sheet based on NBR (nitrile rubber) with good oil and fuel resistance and with good mechanical properties. Maximum working temperature 100°C.
Oil-resistant sheet type 2001	Sheet based on NBR (nitrile rubber) resisting to oils and animal fats. Good mechanical properties. Maximum working temperature 100°C.
Polymethyl metacrylate	Plexiglas sheet, transparent and light material, with high optical and mechanical properties.
PVC	Polyvinyl chloride sheet resisting to alkali, acids and general electrolytes and also quite good resisting to organic solvents; soluble in esters, ketones and chlorinated solvents. Good mechanical properties.
ULTEM® 1668A (29)	Extruded Polyetherimide sheet resisting to a wide range of solvents and chemical cleansing; it's attacked from chlorinated solvents and ketones.

Chemical agents used in the experiments were Yperite HD Mustard Agent (this HD agent is a colorless and odorless liquid with a great blistering power). The threshold amount of mustard vapor required to produce a skin lesion varies greatly depending on a number of factors, including temperature, humidity, moisture on the skin, and exposure site on the body. HD has very low solubility in water (< 1%), but once dissolved, it readily hydrolyzes forming the thiodiglycol. Its low solubility and low vapor pressure (~ 0.11 mmHg at 25°C) contribute to its high persistence. The penetrability of HD depends on the amount used, the temperature and the nature of the contaminated material.[6]

Materials

Ten different materials in group 2, commonly employed in the internal parts of the aircraft, were chosen by the CSV (Centro Sperimentale di Volo – Experimental Flight Centre) of "Pratica di Mare", Italy. The different materials tested in this study are listed in Table 1 (Above).

Contamination procedure

The selected aircraft materials

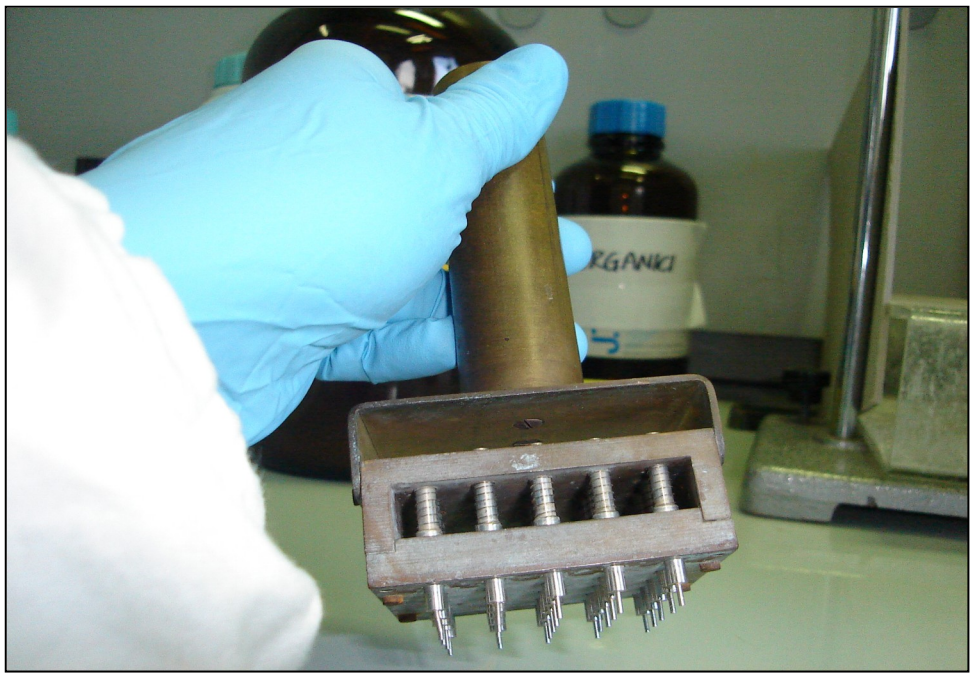

Figure 2. The "mold" with metal pins.

were size 5 × 5 cm (25 cm^2). Each sample was contaminated with 2 g/m^2 (0.2 mg/cm^2) of HD agent corresponding to a chemical weapon release amount of 5 mg (i.e. 3.9 µl; 0.2 mg/cm^2 × 25 cm^2 = 5 mg; 5 mg/d_{HD}=3.9 µl). This is ten times more than that amount given in *NATO Document (STANAG 4653–AEP58, Ed. 1, "Decontamination Triptych", 20 Sept 2005)* as the expected CW contamination (0.2 g/m^2) for interior surfaces of military equipment. The contamination was performed by using a "mold" instrument specifically designed for the test and calibrated to dispense 2 g/m^2 of agent. The mold consists of a metal support with a cylindrical tube fixed on one side, the mold's handle, and 25 metal tips located on the opposite side where each tip is attached to a spring piston (Figure 2).

To perform the contamination, the 25 mould tips were placed in a vessel containing 5 ml of HD corresponding to 6.4 g (such excessive volume is required to ascertain immersion of all metal tips). The agent-soaked tips were placed on the sample and then the mold was slightly swung, making a gentle pressure on the material. The mold with pins-spring system allowed a uniform contamination on the entire material, even if the surface was uneven, and deposited 25 small droplets (0.16 µl each) reaching a total volume of 4 µl per sample (Figure 3).

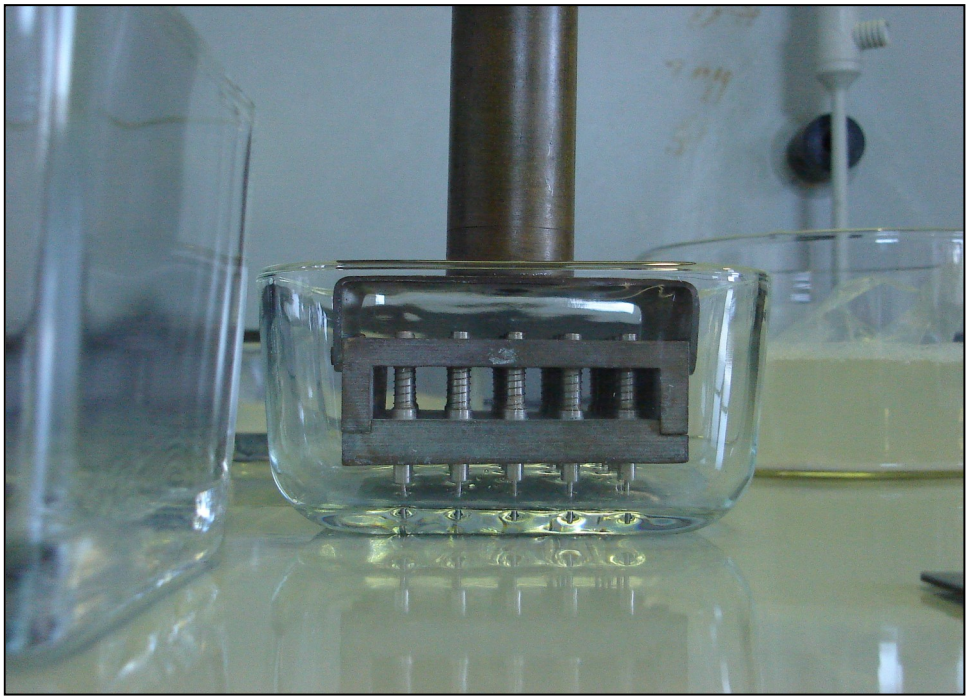

Figure 3. Yperite drawing .

This contamination pattern would have been impossible to achieve using the traditional method (Hamilton pipette) by which only one drop of 1 µl can be dispensed at the most. Using the mold also allowed a much faster contamination on several samples in a short time, thus representing another advantage of performing a simple but not trivial "stamping" pattern over the material (Figure 4).

Decontamination procedure

The SX34 decontaminant product is a multiphase aerosol system contained in a pressurized metal canister (pressure equals 8 to 5 bar with continuity, ready to use (see Figure 5).

The pressurized system was composed of a liquid part (solvent), a solid part (sorbent) and the propellant. The generated aerosol was chemically inert towards the toxic agent and it does not damage the materials on which it was applied, thus making it possible to reuse the material. The aerosolized physical state also made it possible to decon those surfaces hard to reach. SX34 system is equipped with a vacuum device designed to remove the product and it cleaned the surfaces once the decon treatment was completed. The vacuum device contained two filters (HEPA and ULPA) to assure a powder free-air ejection, while contaminated residuals were collected in a small bag placed inside the device that was safely disposable afterwards. It was possible to deactivate the agent by using the BX24[7] decon solution previously placed inside the bag.

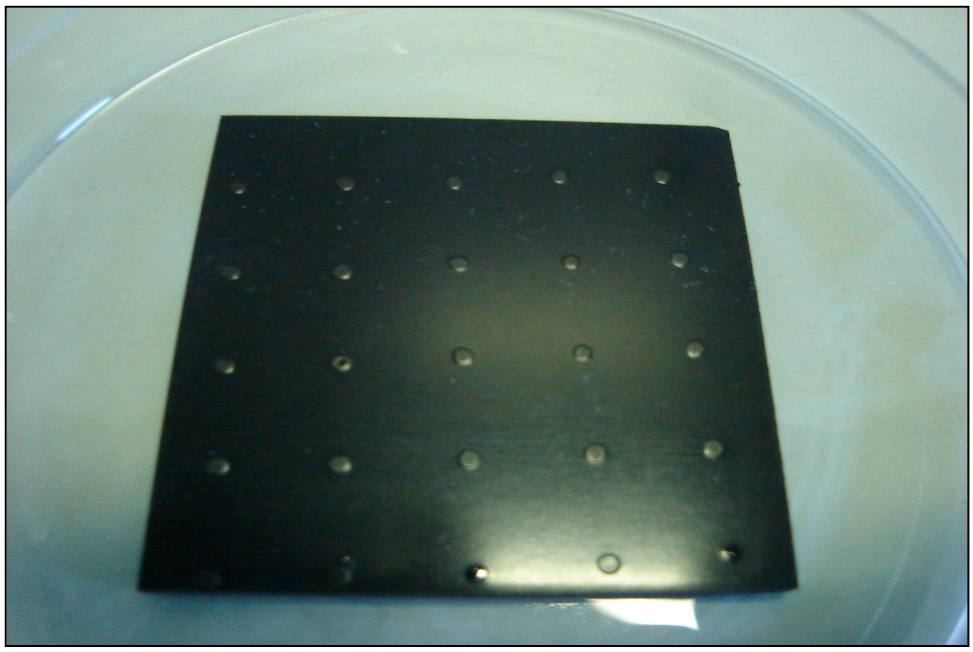

Figure 4. Oil-resistant nitrile rubber (type 2001) one minute after contamination.

Figure 5. SX34 decontaminant canister

The decontamination procedure for SX34 employment in the laboratory was performed by defining one "*decontamination cycle*" composed of three consecutive stages:

1. *Application:* SX34 was sprayed like paint directly on the contaminated surface in order to cover it with a thick layer.

2. *Drying:* once the product was applied, it was necessary to wait for it to dry and turn into a powder; the waiting time can vary slightly depending on the weather conditions and the amount of product used in the treatment (a standard time of 30 min was set for laboratory tests). The dried surface appeared covered with a thick and compact, white layer.

3. *Removal:* after 30 min of contact time the layer was vacuumed. The residue was easily removed with the toxic agent trapped inside; if the decontamination was successful the surface will appeared perfectly clean.

Laboratory procedure

A contamination of five samples was consecutively carried out for each different material available; the five samples were named as follows: sample A (control), sample B (washing), samples 1, 2, 3 (respectively processed with 1, 2 and 3 decontamination cycles). After contamination, sample A was extracted with 100 ml of a solvent mixture; an amount of this solution was collected and analyzed by GC-MS; sample B was washed with isopropyl alcohol, then extracted and analyzed; samples 1, 2 and 3 were extracted and analyzed in this order at the end of the corresponding consecutive decontamination cycle. The decontamination treatment was repeated up to five or six times for the materials less resistant to chemical weapon effect.

Samples A and B were placed in a glass vessel provided with a cover, while samples 1, 2 and 3 were fixed on laboratory bench and then covered by upside-down beakers after being contaminated (Figure 7, page 28).

After 30 min, samples 1, 2 and 3 were treated with SX34 decontaminant spray, sample A was extracted with 100 ml of heptane acetone and sample B was washed with 20 ml of isopropyl alcohol. The washing procedure was performed by raising the sample with steel tweezers and pouring the solvent over it using a Pasteur pipette, and collecting the solvent in the same vessel. The sample was then dried with blotting paper and put in a second clean vessel where it was extracted with 100 ml of extraction mixture. Then extracts A and B were collected and analyzed by ultrasonic vibration (40 min, room temperature ~ 20°C). For samples 1, 2 and 3, the decontamination residues, once dried and turned into a powder (t=30 min), were removed using the vacuum-device (Figure 8 page 28). Sample 1 was extracted with 100 ml of solvent mixture and analyzed. Samples 2 and 3 were treated again with the decontaminant and successively removed once dried. Sample 2 was extracted and analyzed, while sample 3 was subjected to the third decontamination cycle and finally extracted and analyzed.

CHEMICAL ANALYSIS

Instrument specifications

Capillary column gas chromatography-tandem mass spectrometry technique (GC-MS) was applied to the extracted samples of HD for identification and quantification. The ion fragmentation was performed by electron impact (EI) (mass spectrometer running in EI mode) and the mass identification was attained by an ion trap analyzer operated in full scan mode. The GC-MS system employed was a PolarisQ mass spectrometer (Thermo Fischer Scientific) interfaced to a Trace GC gas chromatograph (Thermo Fischer Scientific), both run by Xcalibur software.

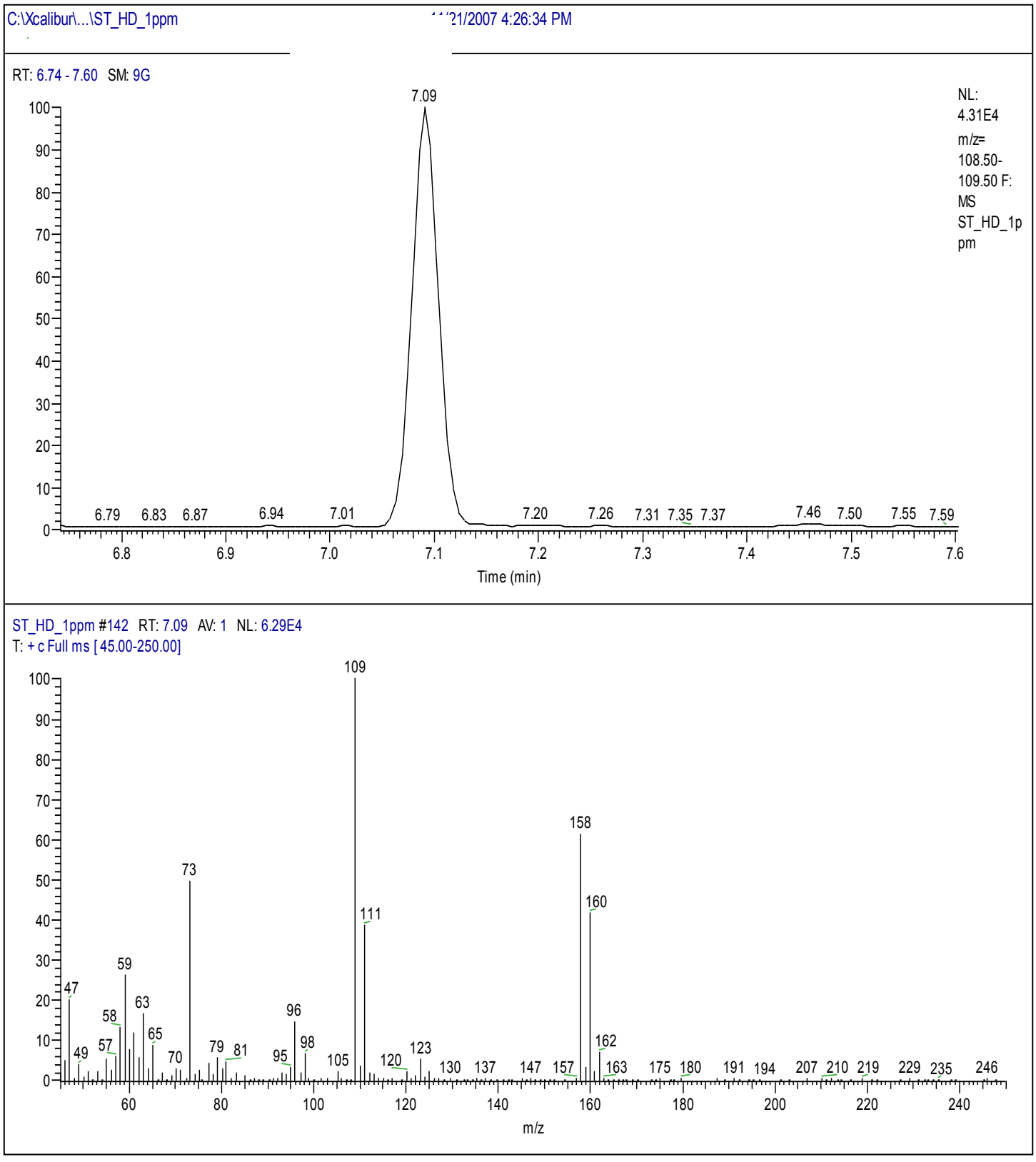

Figure 6. (a) Extracted ion GC-MS chromatogram for m/z 109 of HD standard solution (1ppm); (b) Electron impact mass spectrum of Yperite corresponding to the above chromatogram peak (full spectral scan).

Figure 6 shows a typical chromatogram of HD with its corresponding mass spectrum, showing the characteristic ions provided by fragmentation (111, 109) with the molecular peak (molecular ion 158), which all together allowed the identification of the target compound. Among these, the ion 109 was the one with greatest abundance in the full scan-MS spectrum of HD.

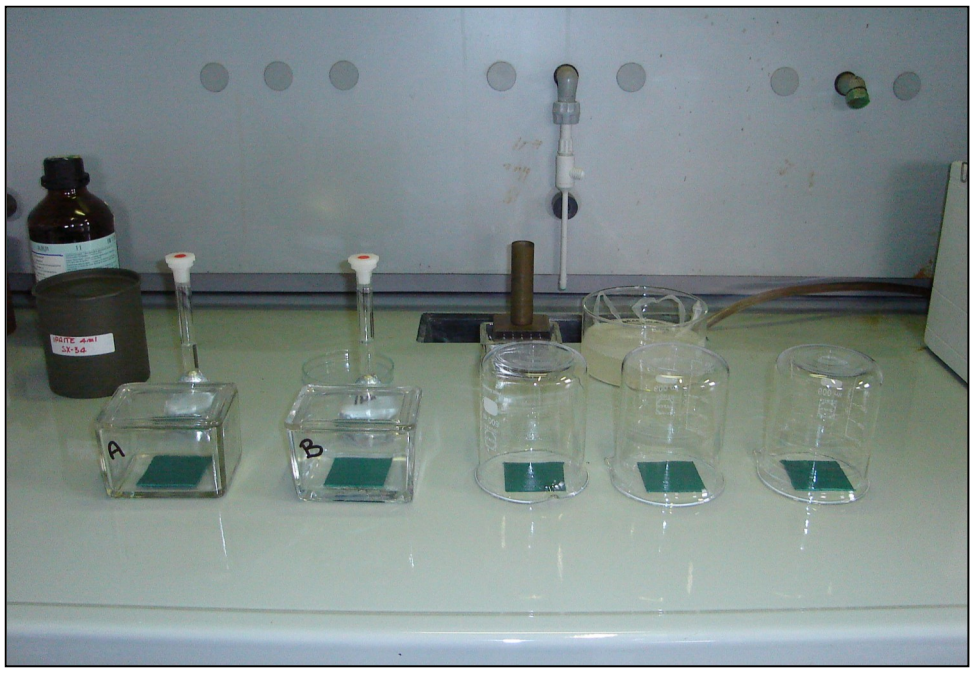

Figure 7. Arrangement of samples A, B, and 1, 2, and 3.

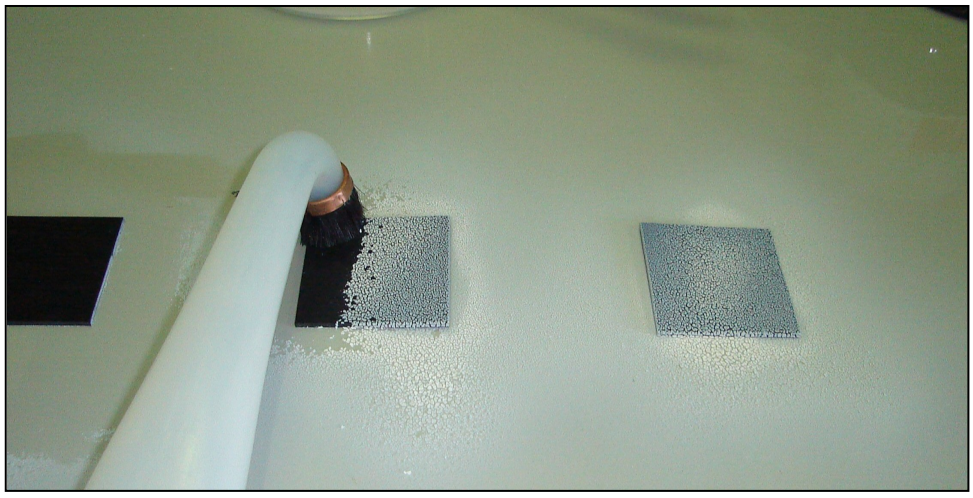

Figure 8. SX34 applied (white powder) on material and removal of residues.

The instrument was operated at the following GC-MS experimental conditions:

- Injection volume: 1 µl
- Injection mode: PTV *splitless*
- Injector temperature program: initial temperature 70°C, +14.5°C/min. up to 250°C, held for 1min
- Split flow: 20 ml/min
- Splitless time: 1 min
- GC Column: 30 m × 0.25 mm × 0.25 µm (max. temp. 250°C); enabled the analytical separation of HD from its degradation and hydrolysis products
- Gas carrier: He, 1 ml/min
- Oven temperature program: initial temp. 50°C (held for 1 min), +20°C/ min up to 235°C, held for 2 min
- Source temperature: 250°C
- Solvent delay: 6.8 min
- Mass range: EI full scanning MS data were acquired over a mass range of 250-45 amu

Calibration

HD sample concentrations were calculated by external standard calibration. Known amounts of HD were weighed and dissolved in heptane-acetone (9/1) to give stock solution having a concentration of ~100 mg l^{-1}; appropriate dilutions of the stock solution where then used as working standards. HD levels were chosen in function with the concentration range investigated during the measurements (0 to 60 ppm), which depended on the amount of chemical agent used in the initial contamination and the dilution volumes employed in the successive extractions (5 mg /100 ml = 50 mg/l). A calibration curve was established plotting the measured quantity (instrumental signal) towards the different levels of HD. The standards analyses were performed by using the same electron impact MS operating conditions employed for samples analyses. Data were acquired in triplicate at each concentration level. The external standard calibration curve was prepared based on the peak area of the quantitation ion at m/z 109 (extracted ion chromatogram) vs. concentrations (range: ~0.5 to ~60 mg/l). A good linearity was observed in the investigated range using the full scan acquisition mode and quantifying only the base peak of HD.

In the course of experiments the instrumental calibration curve was periodically checked by injecting two standard solutions whose concentrations belong to the work range of interest (0 to 50 ppm), and testing the analytical response. The detection limit (LoD) of the chromatographic method was estimated from extracted ion chromatogram for m/z 109 corresponding to HD standard solution at a low level (0.64 ppm) and calculated as the peak having a signal to noise ratio of 3. Experimental LoD was found to be ~ 7 µg·l^{-1} (Figure 9 page 30).

Chemicals

All solvents (heptane, acetone and isopropanol) were High Performance Liquid (HPLC) grade (purity ≥ 99% Chromasolv®, Sigma-Aldrich Corp.).

Table 2. Decontamination yields (η_n)

Material (Commercial Name)	Decontamination Yield (%) *η_n= [(C_0-C_{end})/C_0] x 100						
	η_B	η_1	η_2	η_3	η_4	η_5	η_6
	Solvent Washing	SX34 Treatment					
Polymethyl-metacrylate sheet	99.5	98.3	100				
Fluorinated rubber sheet type Viton® 6000	99.0	93.5	98.7	99.8			
PVC sheet	98.7	99.9	100				
ULTEM® 1668A (29) sheet	98.6	98.6	99.8	99.9			
Fluorinated rubber sheet type 6000	97.9	93.5	99.2	99.5			
Painted metal (CARC paint)	92.2	88.1	98.1	99.4			
Chloroprene sheet type 3012	43.9	66.1	78.5	87.1	89.0	93.2	
Fuel-resistant sheet type 2026	9.3	32.1	58.9	73.8	77.3	86.4	
Super chloroprene sheet type 3015	1.8	44.3	80.7	89.2	90.7	93.2	
Oil-resistant sheet type 2001	1.4	31.8	44.8	63.3	73.0	80.0	83.9

***C_0** = HD initial concentration (mg/l), sample A.
C_{end} = HD concentration (mg/l) at the end of SX34 treatments (from 1 to 6) and after the solvent washing (sample B).
n = number of repeating decontamination cycle. [Average of three acquisitions; LoD (Limit of Detection) ≅7 ppb] (Figure 10).

Test Results

GC-MS results obtained for all extracted samples reported in Table 2 are expressed as decontamination yields (%), calculated for each repeating SX34 treatment and for the isopropanal, 99.5%, and washing (η_B). (see Table 2).

Materials on Table 2 are arranged in order of growing sensitivity to the chemical agent. A greater quantity of agent penetrates into inner surfaces of the more sensitive materials making its complete extraction by simple solvent washing unreachable; therefore such materials show a lower washing yield value (η_B). The observed effects induced by contamination represent an experimental proof of such high sensitivity to the chemical agent: the "liquid" droplets disappear and leave a swollen surface after only a few minutes after placing HD on the sample. This effect is shown on Figure 4 (page 26).

Considerations

The test results obtained show some fundamental aspects of the decon mechanism of SX34, thus helping to understand the effects influencing the efficiency of the decontamination process. For this purpose it is useful to focus on the differences between the SX34 decontamination yields and the solvent-wash ones.

Comparison of Decontamination and Solvent Washing

The SX34 treatment gives a greater decontamination performance for all tested materials when compared with solvent-washing (sample B), with differences in overall yield ranging from 0.05 to 91.4%. Table 3 shows the differences calculated at the end of the third decontamination cycle and at the end of the fifth and sixth decontamination cycles for the less chemically resistant materials. The results show that the greatest differences are related to the more sensitive materials, which are those with less resistance to the HD penetration after 30 min of contact time. A reasonable interpretation of the data is that the HD penetrated into the material is effectively extracted by SX34 decontaminant and proves the high SX34 extraction capability. Moreover, such large differences with the SX34/solvent-wash yields (Δ_3 = 43.2-87.4) suggests that the SX34 employment should be more suitable in these cases than with the chemically inert materials. On the other hand, the SX34 capability to extract the toxic agent from the more resistant materials, in which the chemical aliquot remaining over the surface is the most from the total contamination amount, are partially hidden by solvating process, which is the primary process by which the toxicity is removed.

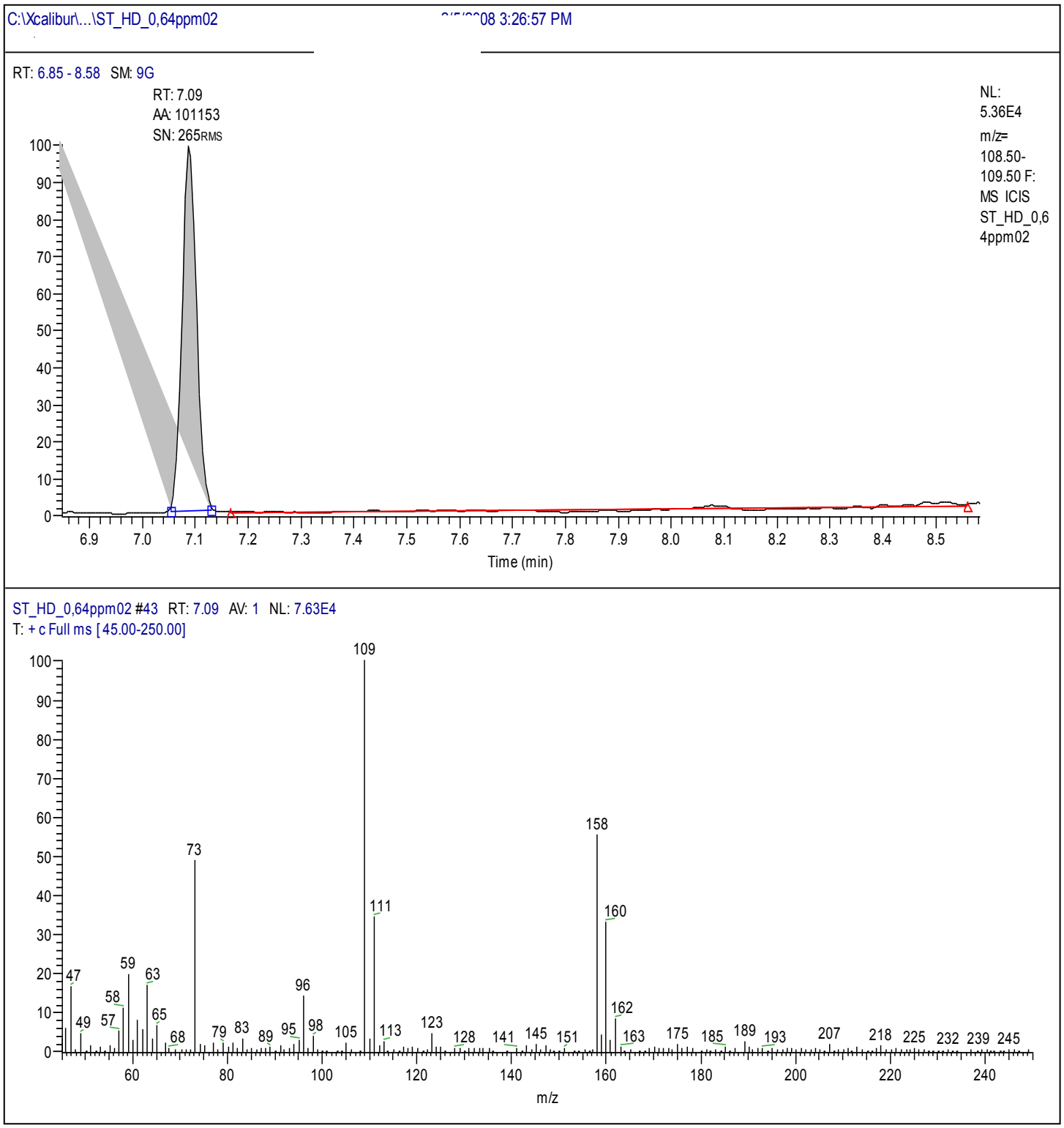

Figure 9. Limit of detection (LoD) calculated from the GC-MS (extracted ion) chromatogram of HD standard solution (0.64 mg•l-1)

Thus, SX34 achieved excellent decontamination yields because of its good solvent power and its concomitant extraction activity that removes the chemical residual traces not eliminated by the solvent action. In two cases (PVC and Polymethyl methacrylate), the 100% of the decontamination yield was gained since the second SX34 treatment.

For the remaining materials (CARC-painted metal, Ultem® 1668A (29), fluorinated rubber 6000, fluorinated rubber Viton® 6000), a high percentage level of decontamination was achieved (99.4 $<\eta_{dec}<99.9$) at the end of the third treatment.

Table 3. Differences between decontamination yields obtained at the end of the third, fifth and sixth SX34 treatments.

Materials	Δ_3	Δ_5	Δ_6
Oil–resistant sheet type 2001	61.9	78.6	82.5
Super chloroprene sheet type 3015	87.4	91.4	
Fuel-resistant sheet type 2026	64.5	77.1	
Chloroprene sheet type 3012	43.2	49.3	
Painted metal (CARC paint)	7.2		
Fluorinated rubber sheet type 6000	1.6		
ULTEM® 1668A(29) sheet	1.3		
PVC sheet	1.3		
Fluorinated rubber sheet type Viton® 6000	0.8		
Polimethyl metacrylate	0.5		

Table 3. Differences between decontamination yields obtained at the end of the third, fifth and sixth SX34 treatments (η_3, η_5, η_6) and the solvent-wash ones (η_B); $\Delta_{3(5,6)}$ are the differences between $\eta_{3(5,6)}$ and η_B.

CONCLUSIONS

Mechanism evidence

This evaluation test has highlighted the two chemical-physical steps by which the multiphase system SX34 works: the liquid phase dissolves the toxic agent and the solution diffuses into the porous solid system where the agent is trapped. This double solvation-absorption action is particularly successful in the removal of the HD penetrated deeply into the material that cannot be removed with just the solvent.

Workability

After testing SX34 decontamination system, its operation effectiveness was evaluated. The experimental activity and test results show that SX34 has considerable capability as a decontaminant based on its dual-phase operating process. A special feature of this system is that it can be easily used by personnel with low-level training. Another peculiarity of its designed operating process emerged during the comparative tests with the solvent.

In fact, the solvent, or possibly the emulsion/micro-emulsions, transports the chemical agent into the subsurface layers not affected by the original contamination in a way that is not easily detectable, thus originating a secondary contamination. This inconvenience can be overcome in a laboratory by completely washing the surface. It is clear that in actual military operational conditions this behavior could have other consequences such as agent penetration into grooves, gaps of sensitive devices, or on rough surfaces, which would inevitably increase the contaminated area. An example of this possibility is in the complex Eurofighter cockpit area.[8]

Conversely, using the SX34 decontaminant it is possible to attain coverage of the entire surface with the drying characteristic of the product as a white powder. This paint-like decontaminant allows specific intervention only in the area where SX34 was sprayed. For odd surfaces that are difficult to decontaminate due to their construction characteristics, the component materials or locations can also be reached by the aerosolized product. Finally, the test showed that SX34 neither damaged nor caused loss in weight of the materials on which it was applied. This is a desirable property for a product designed to decontaminate sensitive equipment that would normally be damaged by the moisture and corrosivity of other decontaminants. The SX34 decontamination kit is a rapid and effective system for the resolution of unexpected situations requiring immediate action.

Dr. Renato Bonora is a professor of Chemical Engineering at the University of Padua, Italy. His broad field of expertise includes remediation of contaminated sites, CBR decontamination, and conventional and nonconventional ammunition demilitarization processes. He has delivered numerous research papers in worldwide conferences on the aspects of CBR decontamination. His email address is: renato.bonora@unipd.it

ENDNOTES

1. European Aeronautic Defence and Space Company EADS N.V. Le Carré · Beechavenue 130-132, 1119 PR Schiphol Rijk, Paesi Bassi EADS Deutschland GmbH, 81663 Monaco di Baviera, Germany. EADS France S.A.S., 37, boulevard de Montmorency, 75781, Paris Cedex 16, France. EADS CASA · Ava. de Aragón, 404, 28022 Madrid, Spain. http://quicklink.all.googlepages.com/eurofighter.htm

2. http://www.eurofighter.com/default.asp - European Aeronautic Defence and Space Company EADS N.V.

Figure 10. SX34 Kit Components.

1. 10 canisters (0.75 liter capacity each) of SX34 decontaminant
2. 1 storage / transportation box, drop shock resistant
3. 1 Deco Vacuum [weight 9.5 kg (20.9 lbs), 220 to 240V, 50 to 60HZ, 1200 W]
4. 1 HEPA and N°1 ULPA filter
5. 5 bags for collection of contaminated materials
6. 6 various accessories for access to those “hard to reach” places
7. 2 brushes
8. 10 nozzles
9. 1 decontamination/detoxification system PSDS1,5 MIL
10. 2 containers for correct dosage of the detoxification / decontamination product BX24
11. 1 bottle (1 kg) of detoxifying /decontaminating product BX 24
12. 1 removable decontamination box for Deco Vacuum hose

3. Aeronautica Militare Italiana, Comando Logistico, Personal Communication.

4. NATO Document - STANAG 4653 – AEP 58 Ed. 1 “Decontamination Triptych”, 20 Sept 2005.

5. Navy Training System Plan For The Joint Service Sensitive Equipment Decontamination System N78-NTSP-A-50-0117, April 2002.

6. Experimental Research on SX34 Decontaminant System, Technical report, Centro Tecnico Logistico Interforze NBC, Civitavecchia, Italy, May 2009.

7. http://www.ncjrs.gov/pdffiles1/nij/189724c.pdf, http://www.cristanini.it/mil/bx_24.htm

8. http://www.eurofighter.ch/1024/it/eurofighter/cockpit/displays.htm

Eurofighter Typhoon picture: http://quicklink.all.googlepages.com/typhoon_002.jpg

A Russian Assessment of Several U.S.S.R. and U.S. HEMP Tests

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Introduction

Immediately after the dissolution of the Soviet Union the United States and Russia began a period of cooperation in several technical areas. One of those areas included the documentation of U.S.S.R. nuclear test results. In the 1990s, several technical exchanges on this subject took place, both in the United States and in Russia. Additionally, a number of Russian scientists were funded to document some of their work. This article provides a short history of Russian openness and looks at two unclassified Russian articles published in international journals,[1,2] one published in 1998 on long line response to high-altitude electromagnetic pulse (HEMP) and the other in 2004 on geomagnetic effects caused by several high-altitude nuclear explosions (HANEs). Their findings are then compared to several other unclassified Russian and United States sources.[3-10]

Figure 1. Dusk or Second Sunrise...

Short History of Russian Openness

There was a period of time after the Soviet era during which the Russians became somewhat open in their willingness to share information pertaining to their nuclear test program. Scientists at the Russian nuclear laboratory – VNIEF in Sarov, Russia – produced reports[11,12] under contract to the Defense Special Weapons Agency (DSWA), one of the forerunners of the current Defense Threat Reduction Agency (DTRA) – that chronicled the history and provided many technical details of their nuclear test program. In 1995, Dr. Lynn Shaeffer, under the auspices of LLNL, invited two scientists from the Central Institute of Physics and Technology (CIPT) in Sergei Posad, Russia, viz., General Major Loborev (head of CIPT) and Lt. Col. Kondratiev, to come to the U.S. to talk about the functional outages that occurred along a telecommunications line during the last three Soviet HANEs over Kazakhstan in October and November of 1962. That invitation was prompted by talks presented by Loborev and Kondratiev on this subject at a conference in Bordeaux, France in 1994.[4] Although very little additional information was revealed by Loborev and Kondratiev, their visit to the U.S. did set the stage for further engagement between U.S. scientists and the Russians on the subject of HEMP.

In 1996, Loborev and several of his colleagues attended the Nuclear Electromagnetic Pulse (NEMP) Conference held in Albuquerque, New Mexico. This is a biennial conference originally organized by Dr. Carl Baum of the former Air Force Weapons Laboratory (AFWL) that has since been subsumed under the Air Force Research Laboratory. At this meeting, several Russian scientists were inducted as fellows in the NEMP honor society. A number of poster papers authored by Russian scientists were presented at this meeting. Subsequent to this time, Dr. William Radasky, who attended the meeting with Loborev and Kondratiev at LLNL, established close working relations with scientists at CIPT. He assisted, through his company called Metatech, the Russians in their attempt to publish a paper.[1] That article reported the telecommunication outages that occurred in Kazakhstan during the last three Soviet HANEs in 1962. Metatech also supported Russian research in HEMP with internal research and development funding.

In addition to these interactions,

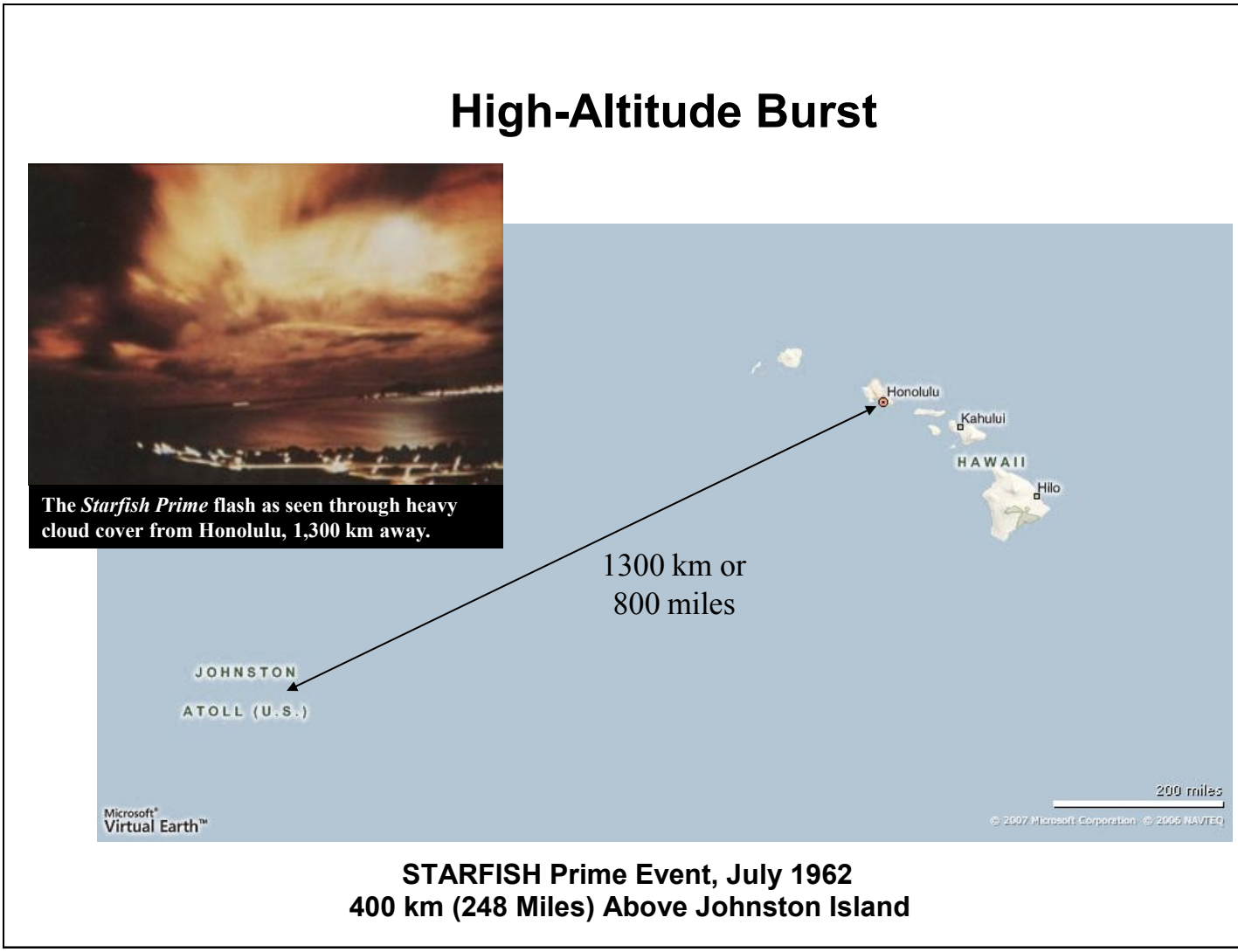

Figure 2. Starfish Prime Event, July 1962.[6]

the Russians have provided input to the US congressionally-appointed EMP Commission. This information has been valuable in helping to understand the effects of HANEs over land. Finally, the Russians, under the auspices of the International Science and Technology Center (ISTC), have performed some work to harness certain HEMP phenomena for industrial applications. ISTC was funded by the U.S. and other countries to assist Former Soviet Union (FSU) nuclear scientists to make the transition to non-nuclear work.

HEMP Effects on National Power Grids

One of the earliest recorded results of a high-altitude (400 km) nuclear detonation possibly affecting commercial electronics and electrical systems occurred during the July 1962 Starfish Prime Event[13,14] over Johnston Island. About 1300 km (800 miles) away in Hawaii, the detonation seemed to trigger a number of electrical problems. Unfortunately, U.S. scientists failed to conduct a rigorous cause and effect assessment until years later, when Charles Vittitoe[5] of Sandia National Laboratory, Albuquerque, NM, concluded HEMP from Starfish did, indeed, trigger problems with commercial electronics.

Prior to the Vittitoe assessment, several US scientists e.g., Randy Barnes of Oak Ridge National Laboratory,[10] predicted HEMP-like environments could bring down the U.S. power grid. These predictions, however, were based upon limited test results and analytical predictions. Real nuclear test results over ground were not available to further validate predictions. The two Russian articles discussed below provided independent non-U.S. assessments that supported the U.S. prediction of potential power grid vulnerability to HEMP.

Vasily N. Greetsai was the principal author of the 1998 article on long line response to HEMP.[1] He and his co-authors, all from the Central Institute of Physics and Technology, reported the analysis of the effects generated by the last three Soviet HANES that occurred in 1962 over Kazakstan in which a HEMP protected 500-kilometer long line was exposed to a significant HEMP signal. Protection device failures were noted and calculations made to determine which part of the HEMP environment (early-, mid-, or late-time) caused the damage. The work was supported by Metatech Corporation under Metatech Project 96-1.

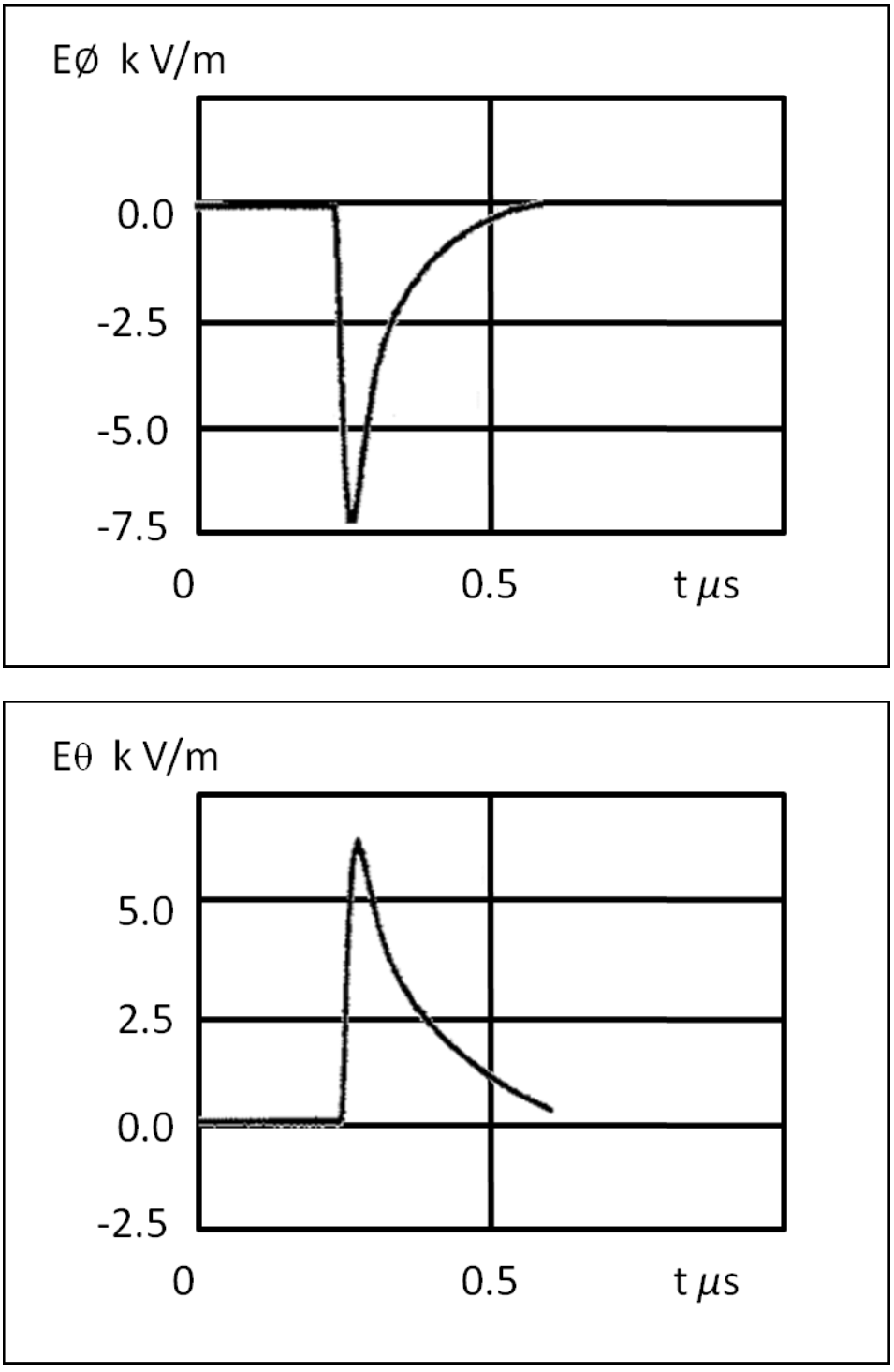

Figure 3. Computed Early-time HEMP Amplitudes from 1962 Kazakstan Event.[1]

Early-time HEMP is the prompt EMP (E1) that occurs in times less than about 1 micro-second (μs) and is caused by photon-generated Compton electrons turning about the geomagnetic field lines. Mid-time HEMP (E2) occurs between about 1 ms and tens of milliseconds (μs) and is caused by multiply-scattered gammas and by neutron-induced gammas from neutron interactions with air and the ground. Late-time HEMP (E3) occurs between tenths of a second and hundreds of seconds and is caused by the HANE-induced magnetic bubble and by upward motion across geomagnetic field lines of heated air that is ionized by ultraviolet and x-ray radiation from the HANE.

Based upon the test data, Greetsai *et al*. computed the early-time HEMP E-field to be between 5 and 7.5 kV/m (Figure 3), which they concluded to be sufficient to cause the observed arrestor damage. In addition, the maximum amplitude late-time E-field was calculated to be no more than 5 V/km, an amplitude capable of causing the observed fuse failures. This 5 V/km amplitude is also similar to the amplitude of geomagnetic field disturbances created by solar flares known to have disturbed numerous power grids in the Northern Hemisphere. Examples include the geomagnetic storm of March 1989[15,16] that caused a blackout in Canada and damaged a transformer, valued at $10,000,000, in New Jersey, and the storm of August 28, 1859 that was the fiercest geomagnetic storm ever recorded.[17]

Yu. I. Zetser (Institute of Geosphere Dynamics (IGD), Russian Academy of Sciences, Moscow) was the principal author of the 2004 article on geomagnetic effects caused by high-altitude nuclear explosions.[2] He and his co-authors (from IGD and the Institute of Experimental Physics, Russian Federal Nuclear Center, Sarov) used the data from eleven U.S. and U.S.S.R. atmospheric explosions that occurred in the late 1950s and early 1960s to assess the primary cause of monitored geomagnetic disturbances. Of particular interest was the correlation of the amplitude and duration of what is now called late-time EMP (E3) to the amplitude and duration of naturally occurring-geomagnetic disturbances (i.e., solar storms).

Table 1 provides specific information on all eleven high-altitude detonations, including coordinates for latitude and longitude, height of burst, and yield. An interesting point is all five (K-1, K-2, K-3, K-4, and K-5) Soviet explosions occurred over land, while all six U.S. explosions occurred over water.

It should be noted it is not a simple matter to correlate all E3 waveshapes from even the six U.S. explosions,

Table 1. Parameters of High-Altitude Nuclear Explosions.

NE	Coordinates of ground zero				Altitude, km	Equivelant, kton	Data
	Geographic		Geomagnetic				
	Latitude	Longitude	Latitude	Longi-tude			
Ground Zero							
Orange	17° n.lat.	192° e.l.	14° n.lat.	257° e.l.	43	2000-4000	1958.08.12
K5	50° n.lat.	70° e.l.	41° n.lat.	141° e.l.	60	300	1962.11.01
Teak	17° n.lat.	192° e.l.	14° n.lat.	257° e.l.	80	2000-4000	1958.08.01
Above layer *B*							
K1	50° n.lat.	70° e.l.	45° n.lat.	138° e.l.	150	1.2	1961.10.27
K4	50° n.lat.	70° e.l.	45° n.lat.	138° e.l.	150	300	1962.10.28
K2	50° n.lat.	70° e.l.	45° n.lat.	138° e.l.	300	1.2	1961.10.27
K3	50° n.lat.	70° e.l.	45° n.lat.	138° e.l.	300	300	1962.10.22
Starfish	17° n.lat.	192° e.l.	14° n.lat.	257° e.l.	450	1400	1962.07.09
Argus 1	38° n.lat.	12° w.l.	36° s.lat.	45° w.l.	480	1-2	1958.08.27
Argus 2	50° s.lat.	8° w.l.	45° s.lat.	45° w.l.	480	1-2	1958.08.30
Argus 3	50° s.lat.	10° w.l.	44° s.lat.	44° w.l.	480	1-2	1958.09.06

Figure 4. From left to right, the ORANGE, TEAK, KINGFISH, CHECKMATE, and STARFISH high-altitude nuclear tests conducted in 1958 and 1962 by the United States near Johnston Island in the mid-Pacific. Burst conditions for each were unique, and each produced strikingly different phenomena and different enhancements of the radiation belts. [18]

since their parameters differ significantly.

Figure 4 illustrates just how different the explosions can look due to such conditions as varying heights of burst and weapon yield. The figure is composed of five U.S. events, three of which (Orange, Starfish, and Teak) are cited in Zetser's Table 1.

Figure 5 is used by Zetser to support the conclusion that geomagnetic field variations caused by nuclear induced explosions are similar to variations caused by natural geomagnetic storms.

One noticeable difference between the two waveshapes in his figure is the front end. The text states the nuclear induced signal has a sharper front end than the geomagnetic storm induced signal; however, this seems to conflict with the above figure. It is possible there is a typographical error or (a) and (b) are reversed.

Long before high-altitude nuclear detonations were identified with long-line problems (as early as August 28, 1859), nations in the upper Northern regions of the globe (e.g., Sweden, Canada) correlated solar flare disturbances with power grid problems. One of the earliest documented events was on March 13, 1893, when there was a total blackout of the Montreal, Quebec power grid for 9 hours. More recent authors calculated the actual amplitude of more recent geomagnetic disturbances. Magnus Wik of the Swedish Institute of Space Physics, Lund, Sweden, determined that a disturbance of the order of 1 V/km caused power grid problems on the Swedish power grid.[7] The similarity of the disturbances from nuclear explosions and geomagnetic storms led scientists to correlate the natural geomagnetic disturbances caused by solar flares and the electromagnetic environment caused by a high-altitude detonation. This comparison was the subject of numerous reports, including the 2004 EMP Commission Report to the House Armed Services Committee.[8] Another is a qualitative assessment reported in an earlier USANCA publication, the NBC Report,[9] which is co-authored by Mr. Robert Pfeffer.

Summary

The two Russian articles cited above[1,2] provide experimental data for HANEs occurring over land to support what the U.S. had already concluded from data obtained for HANEs occurring over water. Qualitatively, the two Russian articles ascribe at least some of the HEMP damage on long lines to coupled E3 (or late-time portion of HEMP). Both articles, however, fail to provide detailed experimental data to support their calculations. This lack of detail makes a rigorous assessment impossible. Nevertheless, their conclusions fall in line with conclusions documented earlier by Loborev and other Russian scientists[3,4] on the same Soviet nuclear explosions, and by Vittitoe[5] on the 1962 Starfish Prime Event, a high-altitude detonation over Johnston Island. All results for nuclear detonations over land or water support the conclusion that HEMP environments can be severe enough to upset or damage even 1960s electronics/electrical systems.

Late-time HEMP has the ability to couple sufficient energy onto long lines and affect attached electrical/electronic hardware, even though the radiated E3 amplitude is low (a few V/km) compared to the early-time HEMP (a few to tens of kV/m). This is because the signal duration can be many seconds and cause significant overheating of critical parts. An electromagnetically similar natural event is solar flares, which on several occasions has caused power grid brown outs and black outs to occur (e.g., power grids in Canada, U.S.A., and Europe).

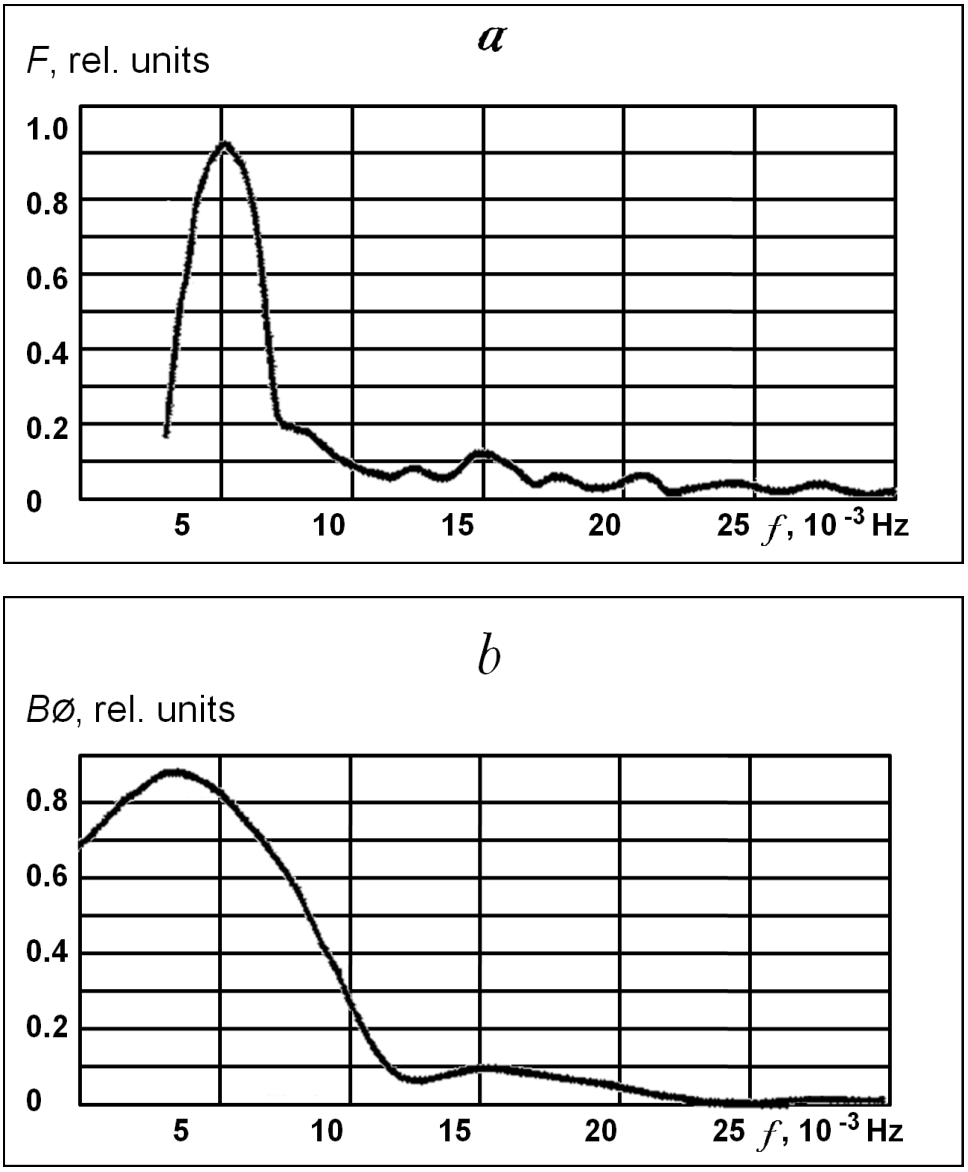

Figure 5. Frequency Spectra of the H-component of the Geomagnetic Disturbance During the Substorm on July 15, 2000 (a) and a Calculated Spectrum of the Signal from an Explosion at an Altitude of 300 km (K-3) (b).[2]

Prologue

The time for close cooperation on this subject between the U.S. and Russia may have passed. Though conditions are not the same as they were in the Cold War, the open dialogue on HEMP effects between the two nations is once again getting cold. These open literature documents provide a unique opportunity to see not only how the U.S.S.R. was organized to handle such research and technology but also to see some of the results of their testing.

Mr. Robert A. Pfeffer is a Physical Scientist at the United States Army Nuclear and CWMD Agency in Springfield, VA, working on nuclear weapons effects. He has a B.S. in Physics from Trinity University and an M.A. in Physics from The Johns Hopkins University. Previous government experience includes Chief of the Harry Diamond Laboratory (HDL) Electromagnetics Laboratory and Chief of the 400-acre Woodbridge Research Facility, both in Woodbridge, VA.

Dr. Shaeffer is a research physicist at Lawrence Livermore National Laboratory in Livermore, California. He has a B.S. in physics from Carnegie Institute of Technology and a Ph.D. in plasma and space physics from the University of Pittsburgh. Dr. Shaeffer has worked for many years in the field of nuclear weapons effects and phenomenology and has published extensively in the open and classified literature.

Further Reading

1. Greetsai, Vasily N., *et al*; Response of Long Lines to Nuclear High-Altitude Electromagnetic Pulse (HEMP); *IEEE Transactions on Electromagnetic Compatibility*, VOL. 40, NO. 4; November 1998.
2. Zetser, Yu. I., *et al*; Geomagnetic Effects from Expanding Plasma Formation of a High-Altitude Nuclear Explosion; *Combustion, Explosion, and Shock Waves*, Vol. 40, No. 6, pp. 638-648; 2004.
3. http://nuclearweaponarchive.org//News/Loborev.text.
4. Loborov, Vladimir M., *et al*; Up to Date State of the NEMP and Topical Research Directions; 1994 EURO EM Conference, Bordeaux, FRA; 30 May – 4 June 1994.
5. Vittitoe, Charles N., Did High-Altitude EMP Cause the Hawaiian Streetlight Incident?, Sandia National Laboratory report SAND88-3341, April 1989.
6. Figure provided by Joint Spectrum Center from their 2008 EMP Training Course.
7. Wik, Magnus, *et al*; Simulation of Geomagnetically Induced Currents: Past, Present and Future Events; Third European Space Weather Week; Brussels, Belgium; November 13-17, 2006.
8. Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Volume 1: Executive Report, 2004.
9. Radasky, William A.; Kappenman, John; Pfeffer, Robert A.; Nuclear and Space Weather Effects on the Electric Power Infrastructure; NBC Report, Fall/Winter 2001.
10. http://www.ornl.gov/ORNLReview/rev26-34/text/tecmain.html.
11. Tchernyshev, A.K., Andryushin, I.A., Zelentsov, S.A., Mikhailov, V.N., and Tsyrkov, G.A., "General Characteristics, Objectives,

Figure 6. Johnston Island shot observed in downtown Honolulu.

Arrangement of USSR Nuclear Testing," Contract DNA 001-95-C-0153 between PTC/VNIEF, Sarov, Russia and Defense Special Weapons Agency, unpublished draft report, 1996.
12. Tchernyshev, A.K. *et al*., "Nuclear Testing in the USSR: Facts,
Technologies and Environment (U), Contract DNA 001-92-C-0179 between PTC/VNIEF, Sarov, Russia and Defense Special Weapons Agency, unpublished draft report, 1995 (CFGI).
13. Glasstone, Samuel, and Dolan, Philip J., The Effects of Nuclear Weapons, Third Edition, prepared and published by the United States Department of Defense and the Energy Research and Development Administration, 1977.
14. Dyal, Palmer, , "Particle and Field Measurements of the Starfish Diamagnetic Cavity," *J. Geophys. Res.*, 111, A12211, doi:10.1029/2006JA011827, 16 December 2006.
15. Kappenman, J. G. and V. D. Albertson, "Cycle 22: Geomagnetic Storm Threats to Power Systems Continue," *IEEE Power Engineering Review*, pp. 3 – 5, September 1991.
16. Robertson, D. F., "Predicting the Storm," *SPACE*, pp. 22 - 26, February–March 1992.
17. Odenwald, Sten F. and Green, James L., "Bracing for a Solar Superstorm," *Scientific American*, August 2008.
18. McCormac, Billy M., Ed., Radiation Trapped in the Earth's Magnetic Field, Gordon and Breach/Science Publishers, New York, 1966.

Army Role in the U.S. Nuclear Capability

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Historical Perspective

The United States and the U.S. Army have been intimately connected in nuclear capabilities throughout our Nation's nuclear history. An Army Engineer led the, "Manhattan Engineer Project" during World War II with the Army Air Forces employing the project's "deliverable" – atomic / nuclear weapons. From the end of World War II in 1945, nuclear weapons became an element of national power. Nuclear research advanced rapidly along with an evolution in both the weapons and their place in national military strategy. Heavy Air Force bombers were required to deliver the massive nuclear weapons in the early days. This air delivery of nuclear bombs provided the initial nuclear military force structure. This new force structure and military needs evolved in parallel. The Services' needs framed eventual production of various nuclear warheads for use on land, in air, and at sea.

Though the doctrinal construct envisioned nuclear capabilities distributed in the Army from tactical levels to higher levels, nuclear weapons deployment and employment authorization consistently required Presidential approval. The Army's organic nuclear capabilities became refined over time. At the end of the Cold War, Army forces planned for nuclear capabilities worldwide.

Army nuclear capability needs were provided by the nuclear weapons complex. Army nuclear doctrine evolved over time and focused on their substantial and tailorable target effects that made nuclear weapons a true force multiplier. Nuclear weapons required a very small logistic "footprint" to tactical forces while providing highly significant potential effects on targets. Army nuclear doctrine described organic, nuclear weapons capabilities at a variety of tactical and higher levels of commands. Over time, nuclear weapons shrank in physical size to a point where even some short range rockets, cannon artillery, and demolitions charges were nuclear capable. Army nuclear employment doctrine provided each of these capabilities a framework for their effective use as weapons of war.

For much of the Cold War, nuclear weapons provided U.S. forces with a "combat multiplier." Once authorized by the President, the use of nuclear weapons allowed commanders to include those at the lower levels, the ability to employ a variety of weapons with different yield configurations.

Smaller yield weapons were designed to give the equivalent of extremely large conventional explosions. Equivalent conventional weapons would require hours-long, continuous, cannon and rocket fires, or repeated bombing runs and still not get the required effects to the target. Nuclear weapon(s) could provide a greater effect in a smaller package, or survivable platform in a relatively short period of time. The employment of nuclear weapons would have significant effects on targets with little or no warning. Nuclear weapons offered land forces the ability to realistically engage massed enemy formations, key installations, and fortified targets at high risk.

Following the fall of the Berlin Wall, U.S. Presidential Nuclear Initiatives in early 1990s resulted in a draw down and elimination of Army nuclear weapons and associated Army nuclear programs. The Army performed a methodical weapons turn in process with the U.S. Department of Energy (DOE). The Army completed its nuclear weapons drawdown by the mid 1990s. During the nuclear drawdown, Army leadership decided to retain a core of Army officers designated for initial and continued development as functional experts in nuclear operations. This group of officers is a subset of the Army officer corps initially assigned with a single basic branch from their initial commissioning and later selected as Functional Area 52 (FA 52 Nuclear and Counterproliferation Officer). Under current career development paths, officers typically are assessed as FA52 by their seventh year of service, attend advanced degree programs in approved specialties, and serve in strategic level assignments at the Army Staff, the Defense Department (DOD), Defense organizations, (DOE), and Combatant Commands. They are also assigned to the Army War College, West Point, Air Force Institute of Technology, and the Defense Nuclear Weapons School.

While the Army no longer pos-

Pershing missile, once a part of the U.S. Army's nuclear arsenal.

sesses an organic nuclear weapons capability, the Army continues to be engaged in DOD and Service development in key military capabilities; of which nuclear capabilities are part. Military nuclear capabilities are vetted at the Joint level and are under consistent oversight of senior DOD, Joint, and Military Department representatives. The Army, as a part of the Joint Services, fully participates in the staffing of current and planned nuclear capabilities as well as nuclear-weapons related issue deliberations. DOD nuclear weapons programs are resident and led by the Navy and Air Force; with day-to-day responsibilities for nuclear planning and employment performed by U.S. Strategic Command (USSTRATCOM). The unification of US nuclear weapons issues and capabilities are performed jointly by DOD and DOE Nuclear Weapons Council (NWC).

The NWC is chaired by the Undersecretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)) with four organizations providing NWC membership. Those members are the Vice Chairman of the Joint Chiefs of Staff (VCJCS), the Undersecretary of Energy, Undersecretary of Defense for Policy (USD (P)), and Commander, US Strategic Command (USSTRATCOM). For the NWC activities, VCJCS obtains Service input on NWC issues of concern and for NWC decision items. Technical details of most issues and program decisions are addressed by the Nuclear Weapons Council Standing and Safety Committee (NWCSSC) who makes recommendations on significant actions to the NWC. Significantly, the Army has an equal voice with the other Services in providing input on Joint actions to the NWC through the VCJCS and directly in the NWCSSC as a Member on nearly all nuclear weapons issues and actions. The NWCSSC's primary mission is to advise and assist the NWC and to provide preliminary approval for many

NWC Activities. The NWCSSC is composed of flag-level representatives or civilian equivalents from the DOE and DOD. In this body, the Army has an equal weighting of input with the Navy and Air Force. Army teaming and dialogue on Nuclear Issues with other Services provides our military with a total force multiplier.

The Army Staff lead for nuclear weapons issues is the Deputy Chief of Staff for Operations, Plans, and Training, G3/5/7. Within the G3/5/7, G3/5 has been delegated daily responsibility for Army both nuclear weapons issuers and Army FA52 Personnel Proponency. G3/5 leads, coordinates, and provides formal Army staffing and input into a variety of DOD and Joint issues, to include nuclear weapons. Nuclear issues span the breadth of nuclear doctrine and policy to future nuclear force structure, plans and programs. NWC and supporting bodies work on issues and perform activities occurring in parallel with having a level of required coordination and approval. At senior levels, formal NWC and NWCSSC meetings occur (nearly) monthly, with action officer level meetings occurring weekly that refine and present the progress of ongoing and planned activities that will be presented to the senior level meetings. The meetings address myriad issues requiring recommending actions and decisions for senior leaders up to and including the President of the United States.

Within the Army Staff, the responsibility for Nuclear issues reside with the Deputy Chief of Staff for Operations, Plans and Training, G-3/5/7. The G3/5/7 has delegated day-to-day nuclear issue leadership and management to the Deputy Director G3/5, Plans and Policy, who is dual hatted as the Director, U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA). The Director of USANCA provides representation of Army interests at both the NWC and NWCSSC meetings and all staff actions. Within the G3/5 resides the core of the Army's expertise in nuclear issues which is supported by FA52s and other branch officers; Army Civilians, and contractors at the Army Staff's G3/5 Nuclear and CWMD Policy Division as well as those assigned to USANCA.

Understanding Operational Nuclear Effects

Operational conditions can be significantly affected by employment of friendly nuclear weapons. As most conflicts are fought on or over land, nuclear employment supporting National objectives will likely occur on or over those same or adjacent land areas where the Army is lead as the Joint Force, Land Component Commander (JFLCC). The Army in particular, therefore, requires resident expertise in understanding potential nuclear weapons effects on the adversary that may also affect friendly forces, allies, and partner nations. The Defense Nuclear Weapons School offers the Theater Nuclear Operations Course (TNOC), that provides instruction on nuclear policy, planning, a comprehensive end of course exercise, and a tour of the Weapons Display Area. Army personnel are awarded an additional skill identifier (ASI) of 5H, Nuclear Target Analyst. Please see the CWMD Resource page under TNOC at the end of the Journal for more specifics.

Army concern on battlefield effects on targets

The overall effects whether intended or unintended are considered as part of consequences of execution. It is the totality of the nuclear strike that must be considered by land forces and the targeting criteria most often seen in consideration of the physical damage caused by the nuclear weapon. As a consequence of execution, nuclear target planning expertise found in FA52 officers remains a singular skill set in our Army.

Political effects on the Campaign

Nuclear weapons remain an element of national power. While the use of nuclear weapons by the military must be a consideration, direct effects of nuclear employment must be balanced against the totality of effects: physical as well as political. It is the full consideration of all physical effects that can better inform policy leaders that address the potential political effects of all issues nuclear: from nuclear force development to nuclear force deployments to nuclear employment itself.

Equipment Hardness and Survivability

An additional effect of nuclear weapons of Army concern is the effects of nuclear detonations on military force equipment. The ability for mission critical military equipment to withstand and continue operations following nuclear detonations or in the presence of radiation is called "nuclear hardness." Critical equipment is often designed and built to standards which withstand environments induced by nuclear detonations that include a variety of electromagnetic, blast, thermal, and radiation effects. Each of these effects may independently as well as collectively pose challenges to equipment. It is known that equipment can be designed to withstand many nuclear effects and incorporate requisite hardening, backed up by testing, to confirm resiliency of the equipment to continue to operate under challenges. It is the testing as well as the knowledge of effects on equipment that forms a vital element of ensuring continued Army mission accomplishment even in the most challenging, potentially nuclear operational environment – regardless of whether the effects are from friendly force or adversary nuclear detonations.

Nuclear Weapons Stockpile

USSTRATCOM is the military command responsible for sustaining the enduring U.S. Government capability for nuclear command, control, and employment. The Navy and Air Force provide and manage their Service nuclear weapons programs as well as the associated delivery platforms. Regular assessments of and reports on the U.S. nuclear weapons capabilities and supporting processes are approved by the NWC in actions that are normally first coordinated through the NWCSSC. Army input into these capability development and supporting processes is regular, informed, and consistent.

The Army, no longer possessing nuclear weapons programs, is in a unique position to provide an objective viewpoint to and be an impartial participant in DOD's nuclear capability discussions. The impartiality must be supported by a keen awareness of the nuclear capabilities possessed by the other Services. The Army ensures continued engagement into how those capabilities are maintained, enhanced, and transitioned into the future as part of our Nation's capabilities and their potential and planned roles in U.S. military operations world-wide as part of its membership in the NWCSSC and input to VCJCS actions in the NWC .

Army View of Other Services and Command Nuclear Roles

The Navy and Air Force are our Nation's Military experts in nuclear weapons and systems; to include their hardness and survivability. The Navy and Air Force are individually responsible for managing their nuclear weapons as well as delivery systems. This is a challenging programmatic responsibility that addresses land and sea based missiles and aircraft based weapons. All aspects of the weapons and delivery systems that provide the DOD and Nation with capabilities fall within the Services for their leadership and management into the future.

Army nuclear expertise facilitates not only being an informed member of the Joint Service team, but also can provide objective input for seeking a balanced force among the Services. FA52 officers are engaged in strategic level nuclear and counterproliferation issues and often find themselves engaged in related issues with the requisite nuclear-focused, professional education and career development. FA 52 officers also find themselves as providing a linkage between operational requirements and policy adherence in nuclear and counterproliferation issues. The Army remains engaged in the Nation's nuclear capabilities and is supported by FA52 officers serving worldwide at Combatant Commands; but are heavily weighted at Army and Joint Staffs, Defense Agencies, and the DOE both in serving those organizations and providing a greater depth of knowledge back to the Army during their careers.

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Tactical Nuclear Weapons in the Cold War Era... A Blast from the Past

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A cannon battery is standing by, ready in a moments notice for a fire mission…

Suddenly the radio crackles to life, "DMV05 this is SMS27 Fire Mission, Number 3 and Number 4, 1 Round Shell AFAP, Lot MD, Charge 7 Fuze PD, Deflection 2870, Quadrant 320"

This fictional artillery Fire Mission request to send an Atomic Field Artillery Projectile (AFAP) down range would have allowed the tactical ground commander a rapid way to change the course of battle to his favor with nuclear rounds, but this is now a distant memory.

The specter of nuclear war was very real during the cold war era as the two predominant super powers were postured for the advent of nuclear exchange. This series will cover tactical and strategic weapons of the cold war. Part 1 covers nuclear weapons typically employed by the U.S. Army. In the interest to keep services together, I will incorporate U.S. Army anti ballistic missile and Air Defense weapons in the last portion of the article to separate tactical from sub strategic weapons. Strategic and sub-strategic nuclear weapons employed by the U.S. Air Force and surface and subsurface nuclear weapons employed by the U.S. Navy will be covered in future articles.

The Army's role during the Cold War

Employment of U.S. Army nuclear delivery systems once authorized by the President offered the tactical ground commander almost an immediate response, and could range the entire area of responsibility (AOR) from very short ranges, as close as several hundred meters to well over hundreds of kilometers.

The U.S. Army Field Artillery (FA) surface-to-surface delivery systems at the time consisted of cannon, free rockets and guided missiles.

The U.S. Army Engineers (EN) primarily employed atomic demolition munitions (ADM). These were used to deter and deny key installations, and land features.

The U.S. Army Air Defense Artillery (ADA) provided the force with protection from air threats.

The U.S. still retains a nuclear inventory for deterrence. However, the U.S. Army is out of the delivery business since turning in their nuclear arsenal in the early 1990's.

Employment Times varied for different platforms, as you can see within the table, the ground com-

Table 1. Employment Times.

Delivery System	Assumed Planning Times after Decision to Fire		Time between Successive Rounds
	Targets of Opportunity	Preplanned Targets	
CANNON Short Range	10 min	5 min	1 round per tube per 10 min
Medium Range	15 min	5 min	1 round per tube per 10 min
Long Range	30 min	10 Min	1 round per tube per 15 min
FREE ROCKET Small	30 min	5 min	1 round per launcher per 15 min
Large	1 hour	10 min	1 round per launcher per 30 min
GUIDED MISSILE Light	30 min	10 min	1 round per launcher per 15 min
Medium Range	1 hour	20 min	1 round per launcher per 30 min
Heavy	3 hour	30 min	1 round per launcher per 2 hours
ATOMIC Demolition Munition	2 hours required to emplace and prepare for firing.		not applicable

mander could apply different systems resulting in an overwhelming attack. (Table 1).

Delivery Systems

Cannon

The capability of cannon to fire nuclear shells capitalized on their great flexibility and high degree of reliability and accuracy. Cannon was exceptionally responsive to the tactical ground commander because of the long established means of command and control inherent in artillery employment, and because of the relative ease with which individual rounds can be fired. Nuclear “shells” delivered by cannon are relatively invulnerable to enemy countermeasures while in flight, because of the speed at which they travel. Although target acquisition and observed fire techniques are adversely affected by poor visibility and bad weather, cannon can deliver nuclear weapons regardless of these conditions.

The cannon systems employed by the U.S. Army during the cold war era were the 280-mm gun commonly referred to “Atomic Annie”, the 8-inch howitzer and the 155-mm howitzer.

M65 280-mm Atomic Cannon

The M65 Atomic Cannon, affectionately called "Atomic Annie" was the Army's largest artillery piece. The M65 was the first and only cannon designed specifically to deliver an atomic projectile; it was also capable of firing conventional warheads. The cannon weighed in at 47 tons alone and with carriage an incredible 83 tons, requiring two tractors to move the artillery piece. It proved to be a highly mobile weapons system despite its size and adaptable to most road conditions with a top road speed of nearly 35 miles per hour. The M65 fired a projectile weighing over 500 pounds and had an approximate range of 20 miles (32 km).

This artillery piece enabled the US. Army to have a tactical nuclear capability for U.S. land forces. One atomic test was conducted at the Nevada Test site in 1953. This heralded a new era for tactical nuclear weapons as the Atomic Cannon test was history's first atomic artillery shell fired from the Army's new 280-mm cannon.

M65 Atomic Cannon “Atomic Annie.”

The first atomic cannon went into service in 1952, and the M65 was retired in 1963. There were twenty atomic cannons produced, stationed in Europe and the Far East. The design of the cannon was based in part on the successful German 280-mm German K5 Railroad gun of WWII.

On a side note, the atomic cannon was part of the inaugural Parade for Gen. Dwight Eisenhower when he became President of the United States in January 1953.

8-inch (203-mm) Howitzer

This was an improvement over the 280-mm cannon, and could fire both conventional and atomic projectiles. It was quite mobile and had a very high degree of accuracy.

155-mm Howitzer

The 155-mm could fire both conventional and atomic projectiles. The 155-mm was the final development in cannon delivered atomic projectiles.

Free Rockets and Guided Missiles

Nuclear delivery provided by the U.S. Army during the cold war derived from two distinct platforms; they were free rockets and guided missiles.

The free rocket was an unguided, rocket propelled missile. It was directed toward the target by establishing initial azimuth and elevation, as with a conventional artillery piece; then launched from a rail or beam. Since the free rocket uses no external guidance, and travels at a high speed, it was relatively immune to known enemy countermeasures at the time. The free rocket has adequate range and flexibility for close support. It was less reliable than tube cannon, but more reliable than longer range Army missiles. It was as responsive to cannon and utilized a larger more efficient warhead.

The U.S. Army arsenal of free rockets were the Honest John, Little John and the Davy Crockett. Many times the system designator, munition nomenclature and model are used interchangeably. As this may lead to some confusion, the munition model designation will be used in this article for clarity.

MGR-1 "Honest John"

The M31 "Honest John" system was the U.S. Army's first nuclear-armed surface-to-surface rocket. The M31 used the MGR-1, an unguided 762-mm artillery rocket, powered by a solid-fuel rocket engine, and spin-stabilized in flight by two spin motors.

The Honest John was a rocket 27 feet long and 2.5 feet in diameter and launched from a simple monorail mounted on a 5 ton truck. The Honest John had a range between 3 and 15 miles (5 and 24 km).

MGR-1 Honest John in firing configuration.

Honest John Test flight demonstrating the Spin Motor Stabilization.

MGR-3 "Little John"

The M51 "Little John" system was the smallest nuclear capable rocket in the U.S. Army arsenal. The MGR-3 was a small and compact surface to surface artillery rocket, armed with a nuclear only warhead and fired from a mono-rail incorporated onto a trailer and was a lighter version of the Honest John. The system could be towed by a jeep or ¾ ton tuck. It had a length of 14 feet 5 inches, and a range of over 11 miles (18 km).

MGR-3 Little John in launch configuration.

MGR-3 Little John in traveling configuration.

M388 "Davy Crockett"
The M388 Davy Crockett was one of the smallest nuclear weapons developed in the 1950s, and fielded for use against Soviet troops.

The M388 munition used a version of a very small sub-kiloton device. The Davy Crockett could be launched from two types of launchers: the M28, with a range a little over 1 mile (2 km), or M29, with a range of 2.5 miles (4 km). Both weapons used the same projectile, and could be mounted on a tripod launcher or carried by truck or armored personnel carrier, operated by a three-man crew.

Production of the Davy Crockett began in 1956, and deployed with U.S. Army forces from 1961 to 1971. Versions of the W54 warhead were also used in the Special Atomic Demolition Munition project and the AIM-26A Falcon.[1]

U.S. officials view a Davy Crockett casing.

M338 Davey Crockett mounted on ground tripod launcher.

Striking the Enemy Deeper

The surface-to-surface guided missiles also called SSMs included a variety of types from short-range missiles used against fortifications and other hard, pin-point targets, to the long-range missiles capable of attacking area targets deep inside enemy territory, a distinct advantage over cannon and the free rocket.

The speed of the ballistic missile and its independence of weather in the target area gave it a unique advantage to some aircraft delivered weapons. Army guided missile systems were responsive to the ground commander; however some systems required greater time for placement, preparation for firing such as fueling, and guidance operations. Some missile systems could be employed more rapidly and were more flexible than nuclear cannon. The SSMs in the U.S. Army inventory were the Lacrosse, Corporal, Sergeant, Redstone, Lance and the Pershing missile.

MGM-18 "Lacrosse"

The Lacrosse originally was developed by the U.S. Navy to fill a U.S. Marine Corps requirement for a short-range guided missile to supplement close-support artillery. The Joint Chiefs of Staff determined that the U.S. Army would be responsible for short-range ballistic surface-to-surface missile development. Shortly thereafter, the Lacrosse was officially turned over to the U.S. Army.

The M4 Lacrosse system fired the MGM-18, a mobile close-support missile designed for use against hardened point and area targets. It was a solid propellant missile 20 feet long, 2 feet in diameter, and weighed over a ton. This missile was accurate to 19 miles (30 km). It was guided to the target by a forward observer, and quick to respond to fire missions.

MGM-18 Lacrosse in launch configuration.

MGM-5 "Corporal" Missile
The Corporal held many "firsts." It was the first operational guided missile, and the first to be approved for a nuclear payload. The Corporal could deliver either a nuclear or high-explosive warhead up to a range of 86 miles (138 km).

The Corporal was a deep corps support missile. It was 45 feet long 3 feet in diameter. It was a liquid fueled missile which fired from a vertical position and used a combination of preset guidance and radar command. The first U.S. Army Corporal battalion was deployed in Europe in 1955. Six U.S. battalions were deployed and remained in the field until 1964, when the system was replaced by the solid-fueled MGM-29 Sergeant missile system.

MGM-51 Corporal during a demonstration, setting up for launch configuration.

MGM-29 “Sergeant”

The Sergeant was a short range ballistic missile (SRBM) replacement to the Corporal. it was 30 feet long and utilized solid propellant which provided better safety and storage capability. At the time it used advanced inertial guidance to navigate to the target. The Sergeant was fielded in 1962, deployed overseas by 1963, and only carried a nuclear warhead. It was replaced by the MGM-52 Lance and the last U.S. Army battalion was deactivated in 1977. This missile was highly mobile and could be placed and fired by a small crew under all conditions of weather and terrain.

MGM-29 Sergeant.

PGM-11 “Redstone”

The PGM-11 Redstone was a mobile liquid fueled missile designed to support the field army by attacking targets up to a range of 201 miles (about 323 km). The Redstone was 65 feet long and had a massive 6 foot diameter. It used inertial guidance to navigate to the target. Having a long range, its firing position could be placed to the rear combat zone far out of enemy range. The Redstone missile was in active service with the U.S. Army from June 1958 to June 1964. Some Redstone missiles were modified in the mid to late 1960's for follow-on special test projects.

For its role as a U.S. Army field artillery theater ballistic missile, Redstone earned the nickname "the Army's Workhorse."

PGM-11 Redstone shortly after launch.

MGM-52 "Lance"

The MGM-52 Lance was a mobile field artillery tactical surface-to-surface missile system, often called a "combat ballistic missile." It was used to provide both nuclear and conventional fire support. The Lance was 20 feet long, and had an operational range of about 75 miles (about 120 km).

The first Lance missiles were deployed in 1972, replacing the less reliable Sergeant SRBM. The firing rate per unit was approximately three missiles per hour. This speed provided the U.S. Army with a very formidable SRBM force.

In 1973, the Lance replaced the MGR-1 Honest John system and the MGM-29 Sergeant. It was deactivated in 1992 with the signing of the INF Treaty in 1987, the U.S. Army began withdrawing Lance missiles from Europe. By 1992, all nuclear Lance warheads were in storage awaiting destruction.

The Lance used one of the first warheads to be battlefield-ready with an "enhanced radiation" (neutron bomb) capability. Once removed from active service, Lance was used as a target drone.

MGM-52 Lance going into in launch configuration.

MGM-31 "Pershing" Family of Missiles

Pershing[2] was a family of solid-fueled two-stage medium-range ballistic missiles (MRBM) designed to replace the Redstone missile as the U.S. Army's primary theater-level weapon deployed by the U.S. Army Field Artillery Corps. The Pershing systems lasted over 30 years from the first test version in 1960 through final elimination in 1991.

In the military science of ballistics, circular error probable (CEP)[3] or circular error probability is an intuitive measure of a weapon system's accuracy. It is defined as a circle, centered about the mean, whose boundary is expected to include 50% of the population within it.

MGM-31 Pershing I
In service 1960–1986

Number Built	24 tactical launchers 754 missiles, (including Pershing IA)
Blast Yield	Variable yield nuclear warhead
Operational Range	Over 450 miles (724 km)
Accuracy	Under 1,400 ft (427 meters) (CEP)

MGM-31A Pershing IA
In service 1969–1986

Number Built	180 tactical launchers, 754 missiles (including Pershing I)
Blast Yield	Variable yield nuclear warhead
Operational Range	Over 450 miles (724 km)
Accuracy	Under 1,400 ft (427 meters) (CEP)

MGM-31A Pershing II
In service 1973–1981

Number Built	108 tactical launchers, 276 missiles
Blast Yield	Variable yield nuclear warhead
Operational Range	Over 1,000 miles (1,609 km)
Accuracy	Under 200 ft (61 meters) (CEP)

MGM-31A Pershing shortly after launch.

Atomic Demolition Munitions (ADM)
ADMs were primarily employed against material targets rather than personnel, to deter the enemy and deny use of key structures, installations and terrain. Lowest yields consistent with military and political necessity were employed to prevent collateral damage to civilian casualties, over destruction of manmade and natural features, or unacceptable radiation hazards.

Medium Atomic Demolition Munitions (MADM)[4]
Were tactical weapons designed to be used as a nuclear land mine and for other tactical purposes, such as a demolition munition with a relatively low explosive yield from the warhead. They were slightly more powerful than the bomb that destroyed Hiroshima. They were produced between 1965 and 1986.

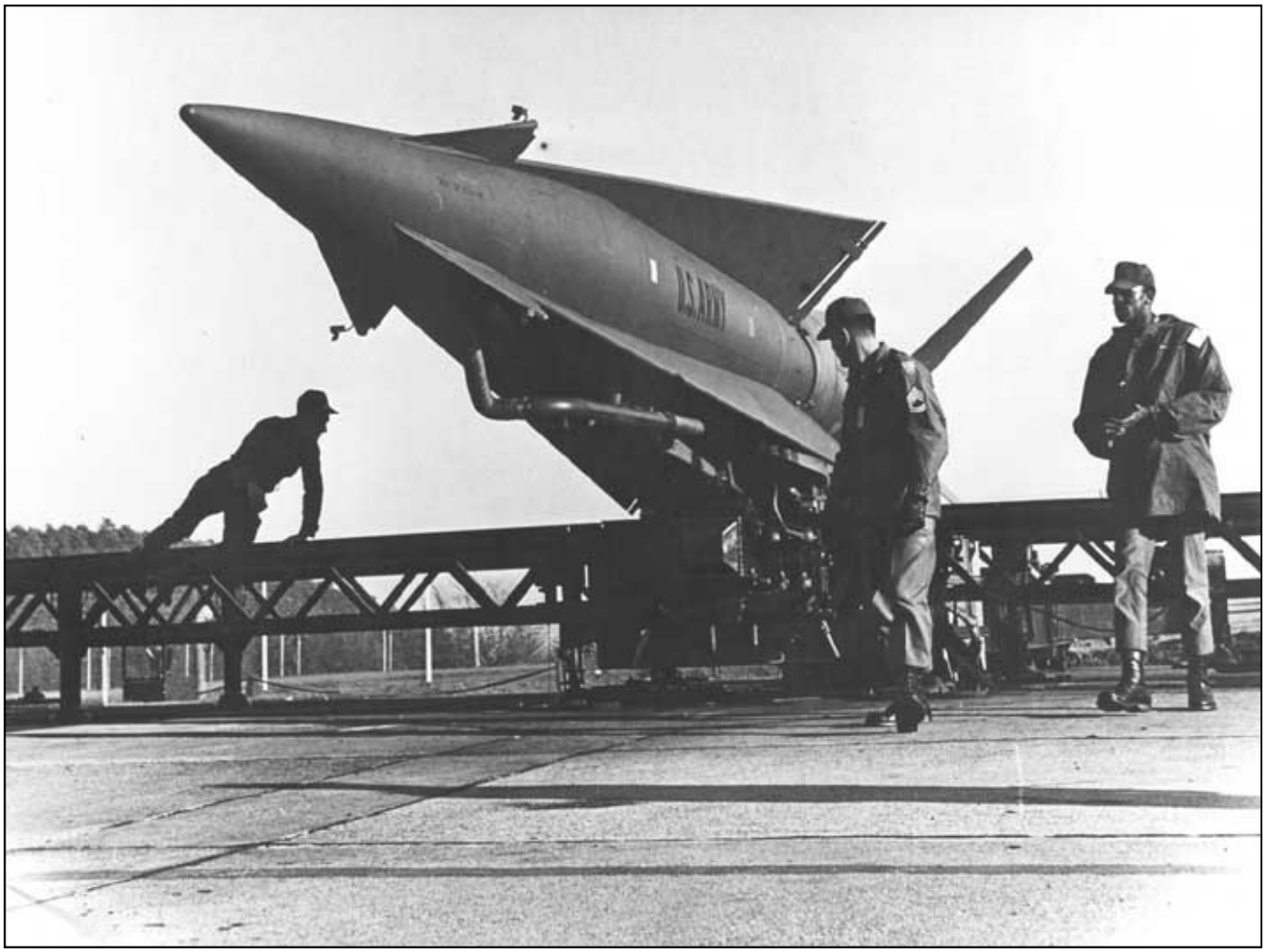
Other U.S. Army systems

The U.S. Army Air Defense Artillery (ADA) provided protection from air and missile threats, a role normally associated with the Air Forces of other countries. Nuclear missiles employed by ADA played an important part to protect the continental U.S. as well as friends and allies during the Cold War.

MIM-14 "Nike-Hercules" Missile
Nike-Hercules was a solid-fuel-propelled surface-to-air missile (SAM), used by US and NATO armed forces for high-and medium-altitude air defense. The Nike-Hercules system was developed during the Cold War to destroy enemy bombers and enemy bomber formations, as well as serve as an anti-ballistic missile system.

The Nike-Hercules Missile could employ a nuclear warhead, or a conventional fragmentation warhead. The missile was 41 feet 6 inches long with a wingspan of 6 feet 2 inches. A total of 145 missile batteries were deployed during the Cold War. The missile had a range of about 86 miles (138 km). Because of the missile's effectiveness against certain ICBMs, it was made a part of the SALT I treaty.

The U.S. Army continued to use Nike-Hercules as a front-line air defense weapon in Europe until 1983, when Patriot missile batteries were deployed.



MIM-14 Nike-Hercules.[8]

LIM-49A "Spartan"

The Spartan[5] was a U.S. Army anti-ballistic missile (ABM). It was a long-range, three-stage, solid-fuel missile that carried a thermonuclear warhead to intercept incoming enemy intercontinental ballistic missiles (ICBM) at high altitude out to a range of approximately 460 miles (740 km). The missile was launched from an underground silo and radio command guided.

The Spartan missile was in operational service for only a few months, (October 1975 to early 1976) due to high costs and the SALT I Treaty.

Sprint shortly after take off.

Anti Ballistic Missile "Sprint"

The Sprint[6] was a two-stage, solid-fuel ABM, armed with an enhanced radiation thermonuclear warhead. It was designed as the short-range, high-speed counterpart to the longer-ranged LIM-49A Spartan as part of the Sentinel program. The Sentinel never became operational, but the technology was deployed briefly in a downsized version called the Safeguard program. The Sprint, like the Spartan, was in operational service for only a few months in the Safeguard program, from October 1975 to early 1976. A combination of high costs, and congressional opposition resulted in a very short operational period.

The Sprint accelerated rapidly, reaching a speeds of Mach 10+ in seconds. It was designed for close-in defense against incoming ICBMs. As the last line of defense it was to intercept the reentry vehicles that had not been destroyed by the Spartan, with which it was deployed.

The Sprint was housed in a protective silo. To make the launch as quick as possible, the cover was blown off the silo by explosive bolts. As the missile cleared the silo, the first stage fired and the missile was tilted toward its target. The first stage burned out shortly after launch followed by the second stage fired within a few seconds of launch. Interception at an altitude taking at most a few seconds rather than minutes.

Final thoughts

During the Cold War the tactical ground commander had many nuclear delivery platforms to deter and defeat the enemy. The ability of close ground coordination and integration allowed the commander to swiftly decide on the appropriate delivery system to swing the battle to his favor. Although the U.S. Army has been out of the delivery business, it still maintains a core of experts and can deploy the Nuclear Employment Augmentation Team (NEAT) from USANCA for offensive nuclear planning. After all, should deterrence fail and the nuclear option be invoked, the ground commander like the ground commander of yesteryear would still be responsible for what happens on the ground and how the use of nuclear weapons may affect the scheme of maneuver.

ENDNOTES

1. http://en.wikipedia.org/wiki/Davy_Crockett_(nuclear_device)
2.MGM-31 Pershttp://en.wikipedia.org/wiki/MGM-31_Pershinghing
3. Circular Error Probable (CEP), Air Force Operational Test and Evaluation Center Technical Paper 6, Ver 2, July 1987, p. 1 (from Wikipedia)
4. http://en.wikipedia.org/wiki/Medium_Atomic_Demolition_Munition
5. http://en.wikipedia.org/wiki/Sprint_(missile)
6. http://en.wikipedia.org/wiki/LIM-49A_Spartan
7. http://www.smdc.army.mil/SMDCPhoto_Gallery/Missiles/124-SprintLaunch-102870.jpg
8. http://www.redstone.army.mil/history/chron2b/1957.html

CW5 Stephen A. Gomes is a Joint Nuclear Targeting Officer assigned at USANCA. He was previously assigned as the MOS 131A Targeting Technician Program Manager, Ft. Sill, OK. He is a graduate of the Joint Targeting School, Dam Neck, VA. His email address is stephen.gomes@us.army.mil

Chemical Warfare: Part I

Mr. A. Mark Diglio
Chemical Engineer, U.S. Army Nuclear and CWMD Agency

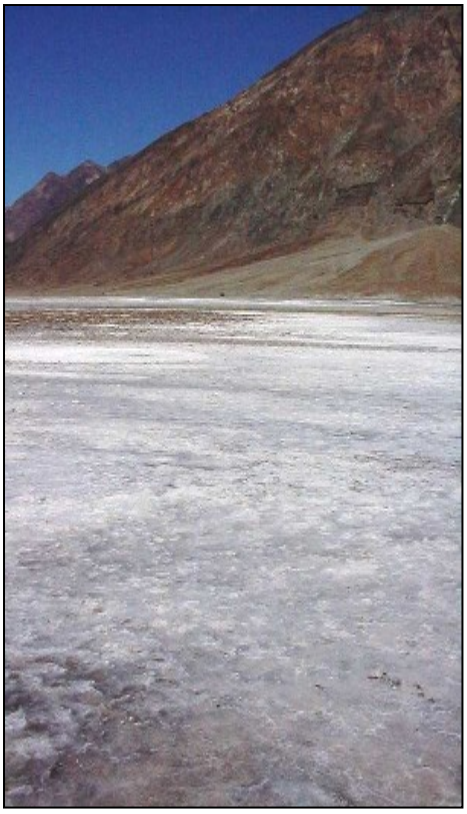
Since September 11, 2001, Combating Weapons of Mass Destruction (CWMD) has taken a deeper meaning than ever before. We must be right 100 percent of the time to avoid harm by terrorists. We must be thorough in our education, intelligence, our planning, and constantly vigilant in our resolve. Weapons of Mass Destruction (WMD) have many definitions. In general, WMD is meant to be Chemical, Biological, Radiological, and Nuclear (CBRN) materials or agents. For this series, an exact definition is unimportant except for how CWMD applies to Chemical Warfare (CW). CW is the oldest form of WMD. For this article, we will consider toxic compounds produced by biological sources as chemical agents. The dictionary defines CW as "*warfare using incendiary mixtures, smokes, asphyxiating, poisonous, or corrosive gases, oil flames, etc.*" For subsequent articles on modern CW, biologically-derived compounds will be considered a part of biological warfare to remain consistent with contemporary Department of Defense definitions. To combat the mass destruction effects of CW, it is important to be familiar with its strategic use over the ages, the means by which it is employed, and the ease in which it can be utilized in the future. This is the first in a series of articles exploring CW from its origin to modern times, and anticipated future applications will be presented in an effort to better equip the planner and Warfighter in combating the chemical part of WMD.

This first article covers a brief history of CW developments from 1000 B.C. until 1900 A.D. In the earliest times chemicals were used for fumigation, riot control, denial of fertile crop lands, demoralizing effects, denial of passage, making arrows more deadly and swaying the tide of battle. For centuries, chemicals have been deemed an inhumane form of weapon. Despite treaties denouncing its use, many countries continued to research the next generation of CW agents and some even stockpiled those agents. This led to the eventual use of CW in WWI, WWII and as recently in the war with Iran and Iraq in the 1980s. It is hoped that by providing this information, individuals will gain a better understanding of CW on both strategic and anti-terrorism fronts. These articles are prepared by pulling from a broad search of articles from the World Wide Web, books and recognized authorities. It is therefore necessary to provide a look at CW over the ages to anticipate, prepare, and plan for ways to combat CW. Relatively old methods of warfare could be used to significantly multiply CW effects in present day.

By modern standards, Wikipedia[1] defines CW as follows: "CW involves using the toxic properties of chemical substances to kill, injure or incapacitate an enemy." However, Science Clarified[2] goes into greater breadth and depth: "CW involves the use of natural or synthetic (human-made) substances to disable or kill an enemy or to deny them the use of resources such as agricultural products or foliage in which to hide. The effects of chemicals may last only a short time, or they may result in permanent damage and death. Most of the chemicals used are known to be toxic (poisonous) to humans or plant life. In some cases, normally harmless chemicals have also been used to damage an enemy's environment. Such actions have been called ecocide and are one method for disrupting an enemy's economic system." For this article, please use the Science Clarified definition as we cover a chronological review of CW development and use prior to WWI.

Ancient Times

The history of CW goes back to Ancient times. It has swayed the outcome of battles and wars for centuries. Chemical warfare dates back to



Example of land infertile by Salt.
Source: Death Valley
(photo courtesy of pdphoto.org).

the earliest use of weapons. Poisoned arrows and darts were used for hunting by primitive peoples as well as weapons in battles between tribal groups before 1000 B.C. In 431 B.C., the Spartans used burning sulfur and pitch to produce clouds of suffocating sulfur dioxide in their sieges against Athenian cities. When the Romans defeated the Carthaginians of North Africa in 146 B.C., they destroyed the city of Carthage and spread salt on surrounding fields to destroy the agricultural capability of the land (ecocide). The Romans' intent was to prevent the Carthaginians from rebuilding their city.

Greek "Sea Fire," an oil based flame that could not be put out with water depicted here in a naval conflict. [3]

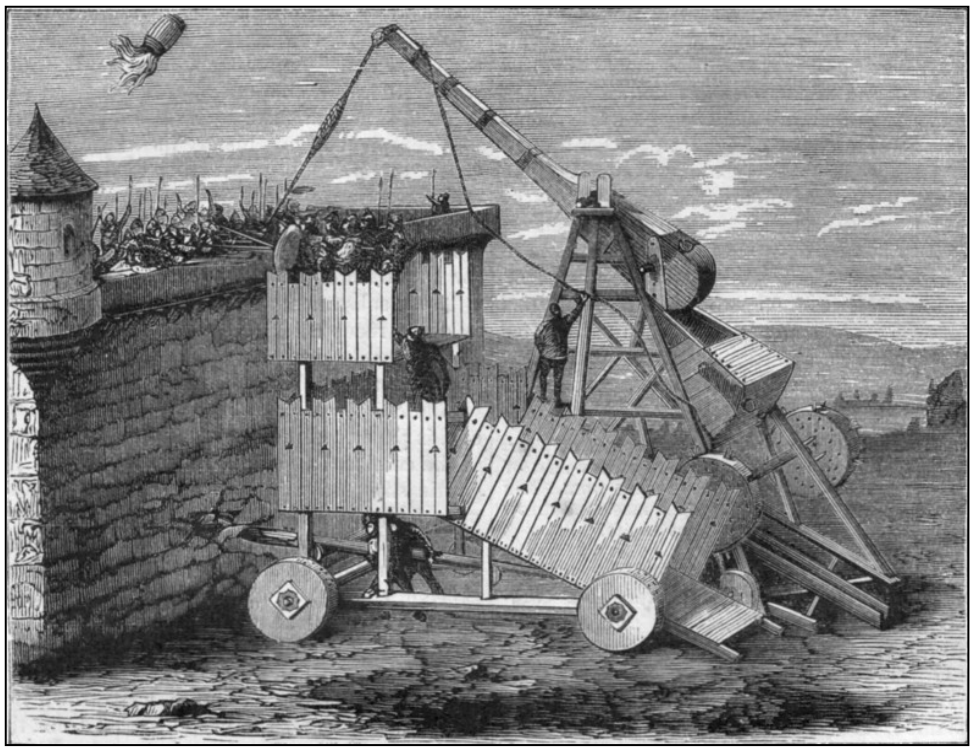
Noxious agents have been used in wars for centuries. Review of literature indicates the Chinese were the original masters of CW. As early as 1000 B.C. the Chinese used arsenical smokes to sicken enemy troops and make them combat ineffective. The Chinese reportedly used chemicals in the fumigation of dwellings to eliminate fleas, practiced by the Chinese as early as the seventh century B.C. Chinese writings contain hundreds of recipes for the production of poisonous or irritating smoke for use in war, and many accounts of their use. We know of the arsenic-containing "soul-hunting fog" and the irritating "five-league fog," made from low-burning gunpowder to which a variety of ingredients, including the excrement of wolves, was added to produce an irritating smoke. The use of a riot control agent, finely divided lime dispersed into the air, is described in a Chinese account of the suppression of a peasant revolt in 178 A.D. Delivery systems were not neglected; descriptions of weapons with such poetic names as the "poison fog magic smoke eruptor" may be found in the artillery manuals of the Chinese Army.

Writings of the Mohist sect in China, dating from the fourth century B.C., tell of the use of ox-hide bellows to pump smoke from furnaces in which balls of mustard and other toxic

Summary of CW use prior to WWI.

1000 BC	Chinese use arsenical smokes to sicken enemy troops making them combat ineffective
590 BC	Solon of Athens puts hellebore roots in the drinking water of Cirrha to kill inhabitants
429 & 424 BC	Spartans use noxious smoke during Peloponnesian War against Athenians
400 BC	Scythian archers use arrows dipped in blood and manure to prevent healing of wounds
200 BC	Carthaginians used Mandrake root left in wine to sedate the enemy
190 BC	Hannibal hurls venomous snakes onto enemy ships to panic and injure enemy sailors
178 AD	First riot control agents used by the Chinese to suppress peasant revolt
678 AD	Greeks defeat Arab fleet using "Greek / Sea fire" oil based inextinguishable fire
683 AD	Moslems siege Mecca catapulting naphtha based fire balls
1241 AD	Mongols use poison gas in the Battle of Legnica
1456 AD	Arsenic bombs, grenades and rags are fired by Belgrade defenders against the Turks
15th Century	Leonardo da Vinci proposed tossing fine sulfide of arsenic powder upon ship galleys
1618 to 48 AD	Anglo-French 30 Years War, "Stinking Jars" and toxic bombs are used in great quantities
1672 AD	Bishop of Munster used incendiary devices with belladonna to try to take Groningen

Data extracted from various sources



Greek Fire Catapult: Harper's Engraving. [4]

vegetable matter were being burned into tunnels being dug by a besieging army to discourage the diggers. The use of a toxic cacodyls (arsenic trioxide) smoke is also mentioned in early Chinese manuscripts. Gunpowder-like mixtures containing charcoal, sulfur, and saltpeter were known in China by 1044 A.D. and used primarily as incendiaries, since the proportions were not right nor were they confined for a detonation to occur. From small fireworks, the Chinese developed bombs. By 1232, the Chinese had developed rockets and a weapon they called "heaven-shaking thunder," an iron bomb attached to a chain that could be lowered from the walls of a city to explode among attackers.

It was reported by the ancient Greek, Solon of Athens, that an aqueduct from the Pleistus River was deliberately polluted with hellebore roots, a purgative (strong laxative), in 590 B.C. during the siege of Cirrha, to render the entrenched enemy unable to conduct battle. In 423 B.C., during the Peloponnesian War, Spartan allies took an Athenian-held fort by directing smoke through a hollowed-out beam into the fort. Incendiary devices and sulfur-based gases were blown by the wind onto the besieged Spartan city of Sphacteria by Demosthenes during the same war. Sparta used the toxic smoke generated by burning wood dipped in a mixture of tar and sulfur during at least one of its periodic wars with Athens. A primitive type of flamethrower was employed as early as the fifth century B.C.

The biggest use of chemicals in war in ancient times was in the area of flame weapons. A number of recipes existed for producing incendiary compositions, such as a mixture of pitch, sulfur, tow, granulated frankincense, and pine sawdust in sacks that were set alight. The most famous incendiary mixture is certainly the Greek fire of the Byzantine Empire. Greek fire is the modern name; the Byzantines called it "sea fire" and their Moslem enemies called it "Roman fire." It was an oil-based compound that could not be extinguished with water and would burn on water. This was successfully employed to defeat the Arab fleet in 678 A.D., against the Moslems again in 717 to 718 A.D. and against Russian attacks in 941 and 1043 A.D. Greek fire remained Byzantium's secret weapon against the Turks for five centuries. Later, the Turks acquired it to conquer the Greek Empire in the fourteenth century. Greek fire was used to such a degree that it could also be considered a psychological weapon. The recipients of a barrage of Greek fire could not explain how the fire would ignite spontaneously, rise up, be projected downward, or why the liquid flame could not be extinguished. The secret of Greek fire was held so closely that its exact composition has been lost to history. Those knowing the secret recipe often responded to inquiries by saying that the formulation had been revealed by an angel to the Constantines, and that any attempt to discover it would provoke the vengeance of God. It may even have been lost to the Byzantines because, when Constantinople fell into the hands of the Crusaders in 1204 A.D., Greek fire was not used.

Moslems lacked Greek fire and developed their own oil-based incendiaries. In a siege of Mecca in 683 A.D., the Umayyads used catapults to hurl naphtha-based incendiary projectiles against the defenders, accidentally setting the cloth covering the Ka'bah on fire. In 813 A.D., Baghdad would be essentially destroyed by naphtha barrels thrown into the city, and in 1167 A.D, Cairo was destroyed by naphtha pots and bombs to deny it to the Crusaders. Distillation of petroleum to produce fractions like "white water naphtha," suited for incendiaries, was also known. However, the Moslems are believed to have avoided use of toxic additives in their flame weapons because of injunctions in the Koran against poisoning the air and water.[5]

Medieval Times

In 1672, during his siege of the city of Groningen, Christoph Bernhard van Galen, the Bishop of Münster, acquired a nickname, "Bommen Berend" (Bomber Berend), for his profligate use of artillery. Among the explosive and some of the incendiary devices he used were filled with the plant Atropa or belladonna, intended to produce toxic fumes. (Belladonna means "beautiful woman" in Italian.) Also known as "deadly nightshade," it

Artist Rendition of Medieval Incendiary Conflict. [8]

is one of the most toxic plants in Europe, North Africa and Western Asia. Two to five berries in children and ten to twenty in adults are lethal, but the root is the most poisonous part. In low dose (alkaloid content below 0.001% and used as diluted extract) isolated atropine from the plant has medicinal uses. The general plant toxins in low dose can exhibit hallucinogenic effects. Higher doses are lethal.[6]

The weapons failed to prove decisive, however, because at least in part they were used without taking wind direction into account. In the end, the Bishop had to withdraw, lifting the siege on the 28th of August, an event still celebrated in the city.[7]

In 1854 Lyon Playfair, a British chemist, proposed using a cyanide-filled artillery shell against enemy ships during the Crimean War. (Cyanide, a type of “blood agent,” is a chemical compound that affects bodily functions by preventing the normal utilization of oxygen by body tissues. The term "blood agent" is a misnomer, because these agents while carried by the blood throughout the body do not typically affect the blood.)[9] The British Ordnance Department rejected the proposal as "as bad a mode of warfare as poisoning the wells of the enemy." Playfair’s response was used to justify chemical warfare into the next century:

> “There was no sense in this objection. It is considered a legitimate mode of warfare to fill shells with molten metal which scatters among the enemy, and produced the most frightful modes of death. Why a poisonous vapor which would kill men without suffering is to be considered illegitimate warfare is incomprehensible. War is destruction, and the more destructive it can be made with the least suffering the sooner will be ended that barbarous method of protecting national rights. No doubt in time chemistry will be used to lessen the suffering of combatants, and even of criminals condemned to death.”

Later, during the American Civil War, New York school teacher John Doughty proposed the offensive use of chlorine gas, delivered by filling a 10 inch (254 millimeter) artillery shell with 2 to 3 quarts (approximately 2 to 3 liters) of liquid chlorine, which could produce many cubic feet (a few cubic meters) of chlorine gas. Doughty’s plan was apparently never acted on, as it was probably presented to Brigadier General James Wolfe Ripley, Chief of Ordnance, who was described as being congenitally immune to new ideas.[10]

Discussion and planning of this kind of CW activity caused fear amongst countries in the realization of its powerful ability to impact masses. Treaties were formed to ban CW. But for fear of being at a disadvantage, each country continued to develop CW agents.

The Germans were the first to successfully use chemical agents in 1915

during WWI, which launched what is now known as the modern era of CW. The modern era of CW will be discussed at greater length in the next article in this series.

What is important to take from this discussion is the origins of CW. Prior to 1915, chemical agents were not stockpiled nor were they used for mass destruction. Instead, they were used to sway the tide of battle. Instead, poisons and incendiary devices were used to increase the effectiveness of individual weapons or to create a psychological advantage and to decrease the combat effectiveness of an enemy. Poisoning of water supplies and wells was considered barbaric by the Roman Empire and later the entire West, yet it was a frequently used technique by weaker adversaries and villagers.

Closing Remarks

Many anti-terrorist planning activities provide for protection against modern warfare CW agents such as nerve and blister agents. Combating CW analysis grows more burdensome when considering stored toxic industrial chemicals, but this topic will be explored more expansively in future articles. It is only through awareness, planning and constant vigilance that we will combat chemical WMD and ecoterrorism.

Mr. A. Mark Diglio serves as a Chemical Subject Matter Expert at the USANCA, in the G-3/5/7 at Ft. Belvoir, VA. He has a B.S in Chemical Engineering from the Pennsylvania State University and a Masters in Business Administration with a minor in Procurement from the Florida Institute of Technology. He recently served 12 years at the Chemical Materials Agency as an Associate Project Manager and expert in Chemical Demilitarization. His career began with 16 years as a Combat Developer of NBC Protective Equipment at RDECOM, an expert in air filtration and barrier materials.
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ENDNOTES

1. http://en.wikipedia.org/wiki/Chemical_warfare

2. http://www.scienceclarified.com/Ca-Ch/Chemical-Warfare.html

3. Source: http://commons.wikimedia.org/wiki/Image:Greekfire-madridskylitzes1.jpg

4. http://commons.wikimedia.org/wiki/Image:Greek_Fire_Catapult_(Harper%27s_Engraving).png

5. R. Everett Langford; Introduction to Weapons of Mass Destruction: Radiological, Chemical and Biological, Published by John Wiley & Sons, Inc.

6. Committee for Veterinary Medicinal Products, Atropa Belladonna Summary Report, The European Agency for the Evil of medicinal Products Veterinary Medicines Evaluation Unit, EMEA/MR/540/98-FINAL, December 1998

7. http://www.cbwinfo.com/History/History.html A Brief History of Chemical-Biological Warfare

8. Source: www.meristation.com Medieval II: Total War

9. http://en.wikipedia.org/wiki/Blood_agent

10. http://www.safebiology.com/biological_warfare/Chemical_Warfare.html Chemical Warfare: The rediscovery of chemical warfare

Combating WMD Resource Page

FA52 Courses of Interest

Theater Nuclear Operations Course (TNOC)

TNOC is the only course offered by a Department of Defense organization that provides training for planners, support staff, targeteers, and staff nuclear planners for joint operations and targeting. The course provides overview of nuclear weapon design, capabilities and effects as well as U.S. nuclear policy, and joint nuclear doctrine. TNOC meets U.S. Army qualification requirements for the additional skill identifier 5H. The course number is DNWS-R013 (TNOC). Call DNWS at (505) 846-5666 or DSN 246-5666 for quotas and registration information.

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Get it posted here. Send your input to dcsg3usanca2@conus.army.mil, in the Subject line: ATTN: Editor, CWMD Journal

Note: The editor retains the right to select, edit and print submissions.

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22-26 Jun 2009
21-23 Jul 2009

This course is taught at the
Nuclear Weapons School (DNWS)
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Email: DNWS@abq.dtra.mil
Fax (505) 846-9168 or DSN 246-9168

Online Registration:
https://dnws.abq.dtra.mil/StudentArea/Login.asp

USANCA's New Facility

CW5 Stephen A. Gomes
Joint Nuclear Targeting Officer, U.S. Army Nuclear and CWMD Agency

USANCA's transformation provides both Nuclear and Combating Weapons of Mass Destruction (CWMD) planning and execution expertise for the implementation of Army CWMD strategy and policy at the operational and theater levels. This allows the Army to meet joint operational requirements in achieving national objectives to combat WMD.

Project Overview

USANCA currently is within the larger footprint of the new National Geospatial-Intelligence Agency (NGA) preferred site location. As the current USANCA building is old and outdated, this was an opportunity derived by FY-07 BRAC program to secure another facility that would increase capabilities to support the transformed USANCA mission. USANCA will locate from the Engineering Proving Grounds to Bldg 238, Fort Belvoir in the South Post area. There are still some major milestones over the horizon, among them: Construction completion ~ 31 Jan 09, System testing ~ 28 Feb 09, and Furnishings, and equipment installed ~ 31 Mar 09. The new facility is scheduled to be operational on or about 15 May 09.

Renovated Bldg 238 Capabilities

The new facility was constructed with safety and security in mind. The facility will be accredited up to top secret-level and can accommodate up to 50 employees. We have 15,500 total floor space dedicated to our mission, along with two SCIF areas at 1100 sq ft. There is one large and 3 small conference rooms configurable for exercise/training use. The conference activities are separated from routine work areas to minimize impact on normal work by modular work areas. The new facility is designed for flexibility and growth, and provides the following:

Activity center
- – Large conferences, off-sites
- – Configurable Tabletops for Exercises and training

Virtual outreach
- – Virtual meeting capability – telephone, VTC
- – Connectivity up to TS level

Information sharing
- – Records and references (DTRIAC)
- – Web portal
- – Internet & telephone drops adjacent to conference areas

Work Process Transformation

We will have a state of the art communications suite with a fiber optic network Internet, voice, VTC capabilities at non-secure, secret, and top secret levels. Should we have local power outages, the new facility incorporates backup power for mission systems.

We look forward to the ribbon cutting ceremony in the coming New Year and will share that experience in another article in the Combating WMD Journal.

Excavation work at the front of the building.

Standing in doorway 114 looking into NIPR room; orange paint on the ground identifies space ESTech will need for their access system equipment (includes rack, and 4x8 plywood that will be mounted on wall)

U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency

MONA-CWZ x7850
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Deputy Director *	**x7852**
Executive Officer	x7857
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Administrative NCO	x7850
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Pershing round 32 launched from Hueco Range, Texas by A Battery, 2nd Battalion, 44th Field Artillery, targeted for White Sands Missile Range on August 20, 1963

US Army File Photo


U.S. ARMY NUCLEAR AND CWMD AGENCY
Fort Belvoir, Virginia