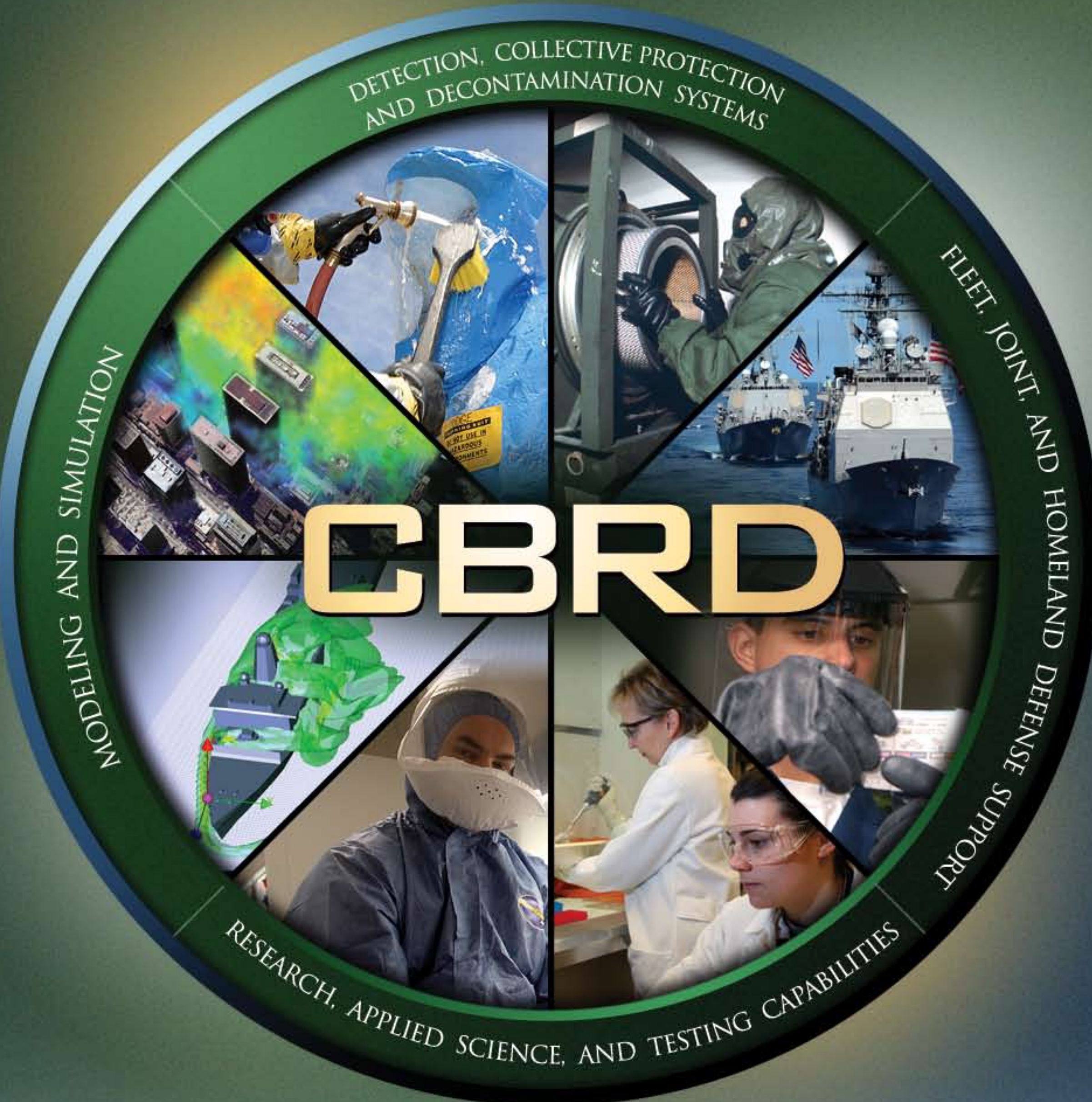
LEADING EDGE

April 2012



Chemical, Biological, and Radiological Defense

NAVSEA
WARFARE CENTERS
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LEADING EDGE

April 2012

CBRD – Chemical, Biological, and Radiological Defense

NSWCDD is proud of the CBR Defense Division's reputation for excellence in developing CBR protection systems.

A recent Centers for Disease Control and Prevention inspection, for example, deemed our CBR biosafety program "a model for other organizations."

*This same excellence is evident in the work described in the articles in this issue of the **Leading Edge** magazine.*

Captain Michael H. Smith
Commander
Naval Surface Warfare Center
Dahlgren Division

LEADING EDGE

Chemical, Biological, and Radiological Defense

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Detection, Collective Protection, and Decontamination Systems –

The best defense against chemical, biological, and radiological (CBR) weapons is to avoid the CBR contamination by preventing its release. When prevention is not successful, detection is used to identify what type, how much, and where the CBR hazard is present. When a contaminated area cannot be avoided, it is necessary to protect individuals and equipment from contamination and to decontaminate those individuals and equipment that come in contact with the CBR hazard. The Naval Sea Systems Command and its partners in the joint CBR community provide the tools and capabilities necessary to detect, protect, and decontaminate threats resulting from a CBR attack. This section addresses the specific detection, collective protection, and decontamination systems and their integration into fleet and shore assets and facilities.

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M&S provides critical information to decision makers to help them plan and respond to chemical, biological, and radiological (CBR) incidents. M&S is used to predict the hazard over time resulting from a CBR incident in order to support the ability to avoid the contamination and determine the duration of protection and the extent of decontamination that will be required. Some M&S products are intended to be fielded, whereas others are used to develop and support other fielded products. M&S is also used in the development of new capabilities to evaluate alternative designs and to supplement test data. This section addresses the development and use of M&S in providing CBR defense capabilities to the fleet.

RESEARCH, APPLIED SCIENCE, AND TESTING CAPABILITIES –

Improvements to existing systems and development of new capabilities to address future threats begin in the laboratory with research, applied science, and testing. This section provides an overview of the Naval Sea Systems Command's (NAVSEA's) state-of-the-art facilities and discusses several ongoing research, development, test, and evaluation efforts. The steady innovation of NAVSEA's research facilities advances the Navy's chemical, biological, and radiological defense capabilities to match the evolving threats.

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NAVSEA WARFARE CENTERS DAHLGREN

The Leading Edge *magazine is produced by the Naval Surface Warfare Center, Dahlgren, Virginia. The purpose of the publication is to showcase technical excellence across the Warfare Centers and promote a broader awareness of the breadth and depth of knowledge and support available to the Navy and DoD.*

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NSWCDD/MP-11/1

Statement A: Approved for public release; distribution is unlimited; PR Number 3414

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Introductions

CBRD — A Naval Priority

Captain Michael H. Smith, USN
Commander, NSWCDD

Chemical, biological, and radiological (CBR) weapons represent what are more commonly known as weapons of mass destruction—extremely deadly weapons that can affect large populations. When these weapons don't kill, they disable. Either way, they can affect the Navy's ability to execute its missions and operations. That is why the Navy places a high priority on chemical, biological, and radiological defense (CBRD) research, development, testing, and evaluation to support the Sailors, whether afloat or ashore, surface or undersea.

The CBR Defense Division at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) spearheads the surface Navy's CBRD capabilities. The Division works in partnership with other Naval Sea Systems Command (NAVSEA) Warfare Center activities and defense community members to ensure that Navy and joint warfighters are safe from the harmful effects of chemical, biological, or radiological contamination. The scope of these efforts ranges from detection and protection, to mitigation and survivability in contaminated environments. Moreover, should warfighters become exposed while operating in a contaminated environment, the Warfare Centers also arm warfighters with capabilities for decontamination.

NSWCDD is proud of the CBR Defense Division's reputation for excellence in developing CBR protection systems. A recent Centers for Disease Control inspection, for example, deemed our CBR biosafety program "a model for other organizations." This same excellence is evident in the work described in the articles in this issue of the *Leading Edge* magazine.

The articles that follow represent a wide range of programs and innovative technologies key to CBRD. In these articles, you will learn how our Navy civilian engineers and scientists are working diligently on solutions to the CBR threats that face our warfighters, as well as the population worldwide.

I invite you to explore the CBRD issue of the *Leading Edge* magazine and learn about the exciting and important work NSWCDD and others are doing in support of this most important area of defense. Given the wide array of contributions that our CBRD team is making, I am proud to say that our Navy will continue to be protected from CBR attacks, now and in the future.

Introductions

Meeting Today's CBRD Challenges

Brigadier General Jess A. Scarbrough
Joint Program Executive Officer for Chemical and Biological Defense

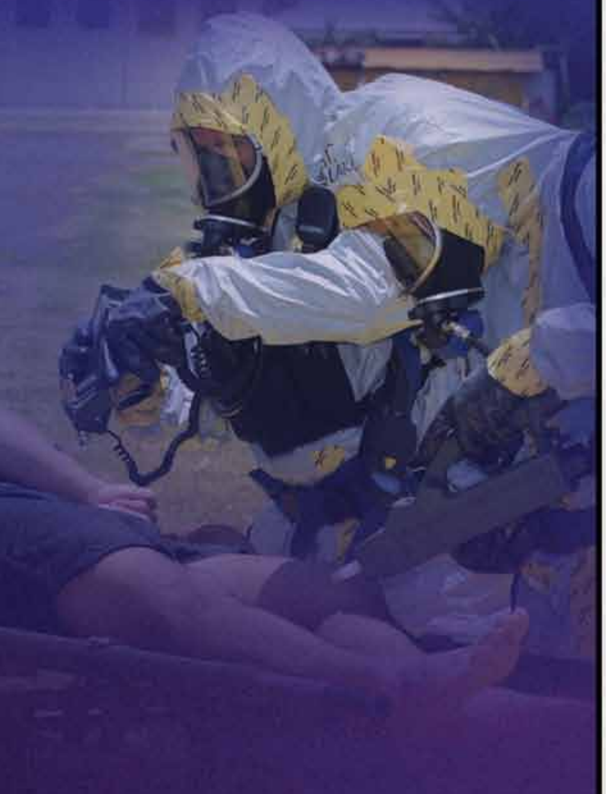
Technology and information advances over the past 50 years have resulted in a wide range of available chemical and biological agents to non-state actors with little scientific skill. Breakthroughs in chemical and biological sciences have also led to the emergence of new warfare threats. As a result, our world has never been more at risk from weapons of mass destruction than it is now. The challenge of the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) is to defend the warfighter and the nation against these threats. We are the joint service, single focal point for research, development, acquisition, fielding, and life-cycle support of chemical and biological defense equipment and medical countermeasures. The JPEO-CBD leads the battle against known, unknown, unexpected, and unseen chemical, biological, radiological, and nuclear (CBRN) threats.

Successful development of CBRN defense capabilities is very much a team effort. The resources brought to the table by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) are a critical piece of the national strategy to combat weapons of mass destruction. I have seen firsthand how the CBR Defense Division facilities, both in Dahlgren and Norfolk, support the warfighter on land and at sea by providing a full complement of capabilities that take products through their full life cycle from development to fielding and ultimate disposal. The division's top-notch laboratories—ranging from the traditional and mechanical to biosafety level 2 and 3 laboratories—support the ability of the organization's scientists and engineers to address emerging chemical and biological defense challenges. The skilled professionals within the CBR Defense Division demonstrate the Navy core values of honor, courage, and commitment through their expertise, dedication, and adaptability in meeting the ever-changing needs of our service members. When I recently toured USS *Ashland* (LSD 48) and USS *Whidbey Island* (LSD 41), I was quite impressed with the complexity of design and the seamless integration of CBRN countermeasures for shipboard use. It is clear to see just how NSWCDD has earned its stellar reputation throughout the CBRN defense community as a leader in systems engineering.

Introductions

Supporting the Navy's CBRD Needs

Michael Purello
Head, CBR Defense Division



Welcome to our Chemical, Biological, and Radiological Defense (CBRD) issue of the *Leading Edge* magazine. As the CBR Defense Division Head at the Naval Surface Warfare Center, Dahlgren Division, I am extremely proud and humbled by both the quality and quantity of work that is performed by our outstanding government and contractor team, many of whom have written articles contained herein. I hope that as you read through the following pages, you will get a sense of the technical competence and patriotic dedication that these employees give every day to our ultimate customer—the warfighter.

Because of our unique CBRD expertise at Dahlgren, our work is not limited to ships. In addition to the fleet, we apply our CBRD experience to help the Department of Defense, the joint services, and other government agencies in support of national needs. Our work covers the full range of research and development, science and technology, and testing and evaluation. From basic research to full operational capability, you will find our scientists in the lab, on a ship, and every place in between. Much of this work is showcased in the following articles.

The CBR threat is real. Chemical and biological weapons have been used in the past. Accordingly, we must guard against current and future use. That's our mission—to keep our Navy prepared and safe and to provide warfighters with the tools, systems, and equipment needed to fight and win in a CBR threatened or contaminated environment. It's an important mission necessary for keeping America's Navy number one in the world, and for helping to keep warfighters safe from the threat of chemical and biological attacks.

Acknowledgments

There are many people who worked very hard to make this CBRD issue of the *Leading Edge* magazine a reality.

I would like to thank the CX7 publishing staff and the NSWCDD Corporate Communications team, who worked hard to produce this professional document.

Without articles, we would not have a *Leading Edge*, so my thanks also go to the many authors who provided their expertise and talent, and put pen to paper to write these articles.

I'd like to acknowledge the support of my chain of command—my Department Head, Mr. John Lysher, my Commander, Captain Mike Smith, and my Technical Director, Mr. Carl R. Siel, Jr.—who have been very supportive of our work in CBRD for the Navy, joint, and national needs areas.

Finally, I would be remiss if I didn't especially recognize two individuals who can share the credit in being largely responsible for this issue of the *Leading Edge:*

Mr. Matt Hornbaker quarterbacked this effort for the Division and kept things moving forward from a Division perspective. He was also our Division liaison to Corporate Communications and Command PAO.

Ms. Sandra Wood provided a critical review of all the articles and worked with many of the authors to ensure that the articles were current and nonredundant.

With respect and thanks to all,
Mike Purello, P.E.
Head, CBR Defense Division

LEADING EDGE

CBRD

Chemical, Biological, and Radiological Defense

Why Chemical and Biological Defense Is Important

By Michael Purello, P.E.

> *You can take the most beat-up army in the world, and if they choose to stand and fight, you are going to take casualties; if they choose to dump chemicals on you, they might even win.* — General H. Norman Schwarzkopf[1]

The effects of a chemical or biological (CB) attack on a fighting force cannot be overstated. On a Navy ship, every Sailor plays a critical role. In order to fight in a chemically or biologically contaminated environment, the shipboard fighting force needs to function at its optimal level. An enemy's purpose in using CB weapons against a ship is to degrade or cease ship operations. Imagine how a ship's effectiveness might be reduced if 50 percent or more of its crew suddenly came down with the flu, food poisoning, or other debilitating illnesses. Even the threat of CB weapons can impact ship operations, as the crew would need to don individual protective equipment in case an actual attack should occur—the threat is real.

The Chemical and Biological Threat

About a dozen countries have offensive biological weapons programs in various stages from research and development to weapons stockpiles. Most of these offensive capabilities have been developed covertly, including the following countries: China, Cuba, Egypt, Iran, Israel, North Korea, Russia, Syria, and Taiwan. Similarly, 12 countries had chemical weapons production facilities, but under the Chemical Weapons Convention (CWC), pledged to destroy them or convert them to civilian uses.[2]

The chemical weapon (CW) threat remains despite the decline in the number of countries with active chemical warfare programs and the decrease of CWC-declared stockpiles. The number of countries capable of producing chemical agents has grown, and will continue to grow, as the availability of chemical production equipment increases due to the globalization of the chemical industry. The increased availability of related technologies, coupled with the relative ease of producing some chemical agents, has increased concern that their production and employment may become more attractive to states or terrorist

groups. Additionally, both state and non-state actors may utilize nonweaponized chemicals—including toxic industrial chemicals (TICs) and toxic industrial materials (TIMs)—to achieve the same goals. TICs/TIMs are usually more readily available and, in some cases, can produce the same lethal and incapacitating results as traditional CW agents.[3] Consequently, accidents or intentional attacks involving TICs/TIMs must also be considered.

Chemical, Biological, and Toxic Industrial Incidents

During the 20th and early 21st centuries, chemical and biological agents were used, and toxic chemicals were accidently released. A number of examples follow:[4,5]

- 1978—Georgi Markov, a Bulgarian defector living in London, was killed with ricin.
- 1979—The accidental release of 10 kg of anthrax spores over Sverdlovsk, USSR, resulted in at least 66 deaths.
- 1984—The Rajneeshee cult contaminated salad bars in Oregon with *Salmonella typhimurium*, resulting in 751 people suffering from food poisoning, with 45 of them requiring hospitalization.
- A Union Carbide plant accidently released a methylisocynate cloud in Bhopal, India, in 1984; approximately 3,800 people died, and thousands more were injured.
- 1980–1988—Saddam Hussein used chemical agents (e.g., mustard and tabun) during the Iran-Iraq War against the Iranians and Iraqi civilians (Kurds), resulting in thousands of casualties.
- 1994—The Japanese cult, Aum Shinrikyo, released sarin in Matsumoto, Japan, killing 7 people and injuring at least 500.
- 1995—Aum Shinrikyo released Sarin gas in the Tokyo subway system, resulting in 12 deaths and 5,000 people requiring treatment. Testimony during the Aum Shinrikyo trials indicated that they had used VX on individuals, killing at least 10 cult members and one individual outside the cult.
- 1997—Food in Texas was intentionally contaminated with *Shigella dysenteriae*, resulting in the infection of 45 people.
- 2001—Mail contaminated with anthrax spores were received in Florida; New York City; Washington, DC; and New Jersey. These letters scared the country to the point where every government mail distribution office or facility issued all its employees masks and gloves to be used as they handled, processed, sorted, and distributed mail in the office.

- 2004—This was an accidental chlorine release resulting from a train accident near Macdona, Texas.[6]
- 2005—This was an accidental chlorine release resulting from a train accident in Graniteville, South Carolina.[7]
- 2007—Multiple terrorist use of chlorine gas was reported in Iraq.[8,9]
- 2009—There were reported rumors that the Sri Lankan military used chemical weapons.[10]

In addition, 9 people died, 550 people sought medical treatment, and 5,400 people had to be evacuated from Graniteville, South Carolina, due to 54,000 kilograms of chlorine that was released by a train wreck in 2005.[11]

Some people think that the 1972 CWC provides them with protection and peace of mind. However, it is both unwise and naïve to believe that nation-state terrorists will abide by any agreements. Consequently, the threat remains and, as indicated above, is likely to continue. Insofar as no country can fight toe-to-toe with the United States in a conventional wartime scenario, a number of countries or terrorist organizations might consider using asymmetric means, such as CB weapons or TICs/TIMs to advance their interests.

Effects of Chemical and Biological Warfare Agents

The effects of chemical and biological agents depend upon the specific agent, the amount of exposure, and the mechanism of exposure, as well as the individual. The following summaries reflect generalizations of some of the major types of agents:[12]

- **Blister agent:** The effects of blister agents are often not seen for hours. In early stages of contamination, one may experience irritation and inflammation of the eyes, nose, throat, trachea, bronchi, and/or lung, as well as reddened skin, which is followed by blistering and/or ulceration, and if severe enough, death.
- **Nerve Agent:** The effects of exposure to vapor agents begin within seconds to a minute, while the effects of exposure to a liquid agent begin within 30 minutes. The effects can range from twitching, sweating, dim/blurred vision, pain, nausea, vomiting, runny nose, shortness of breath, and coughing to convulsions, loss of consciousness, and death.
- **Biological Agents:** The effects of biological agents can include:
  - Flu-like symptoms—fever, headaches, chills, pain, and fatigue
  - Gastrointestinal disease-type symptoms—vomiting, diarrhea, muscle cramps, and collapse
  - Other symptoms—rashes, skin ulcerations, respiratory problems, abnormal bleeding, and if severe enough, death

Often, the effects of a CB attack do not reveal the true impact until weeks or months later. For example, when the Union Carbide plant accidently released a methylisocynate cloud in Bhopal, India, in 1984, approximately 3,800 people died, and thousands more were injured. Since that time, many more people have died in deaths whose causes have been attributed to the 1984 accident.[13,14]

The Navy Role

A robust and comprehensive Navy CB program is necessary to ensure that the Navy can operate unconstrained in a CBR-threatened or contaminated environment. This need is attributed to several factors:

- The shift of naval operations from the blue water (open ocean) to the littorals and inland waterways has increased both the importance of, and need for, Navy CB defense capabilities. Sitting in the middle of an ocean, a ship is primarily concerned with threats from above (planes), from below (submarines), and from other ships. The likelihood of a CB attack, however, increases dramatically as the Navy operates in the green- and brown-water environment (littorals and inland waterways). Thus, the Navy needs to concern itself more with CB threats launched from land or from small craft operating along the coast or near harbors.
- Chemical and biological defense (CBD) sensors and systems have to work in concert with other complex systems on ships. Navy expertise is required to ensure that these systems are properly designed and integrated into the ship to ensure that they function properly and do not degrade other ship systems. Also, the maritime environment is a harsh environment. For example, high humidity, reflectivity off the water, sea clutter, etc., can degrade performance of the Navy's best sensors. Couple this with the corrosive effects of salt air, and it becomes clear that requirements are different for sensors made to operate on land versus the sea. These maritime environmental factors provide unique challenges to the Navy and manufacturers of CB equipment.
- Ground forces are able to leave a contaminated area after an attack and move to a safer, clean area where they can resume normal

operations. A ship can move to a different location, too, but the working environment comes with them. Consequently, they must continue to operate in the dirty environment until the ship has been adequately decontaminated. That is why 24/7 collective protection systems, operational detectors, and decontamination stations are critical.

The Way Ahead

The Navy must remain active in the Joint Chemical and Biological Defense Program to ensure that the Navy's maritime environment, operational considerations, and complex system interfaces are properly considered. The CB threat continues to exist. History provides ample evidence reflecting the employment of CB agents and TICs, such as mustard, sarin, tabun, anthrax, ricin, and chlorine. The purposeful use or accidental release of CB agents and TICs, therefore, will continue to pose a threat.

The Navy must be protected. The impact of an adversary using a CB weapon against the fleet could significantly degrade operations and could potentially result in the loss of Sailors and Marines. That, ultimately, is why CBD is important. Protecting Sailors and Marines from the effects of CB weapons requires expert knowledge of the Navy's environment, operations, and complex system interfaces. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) has the knowledge—along with the CB expertise and experience necessary—to protect the Navy and other warfighters from these types of attacks. NSWCDD's Chemical and Biological Defense Division's mission is to ensure that naval forces are armed with superior CB defense capabilities to predict, detect, and stay protected whenever the need arises.

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Technical Warrant Holder: Enabling The Navy's Warfighting Capability in a Chemical, Biological, and Radiological (CBR) Environment

By Jon Cofield

The U.S. Navy has tremendous warfighting capabilities. One way the enemy—be it a nation state or terrorist—may attempt to degrade these capabilities is through the use of chemical, biological, and radiological (CBR) weapons. A key objective of the chemical, biological, and radiological defense (CBRD) community is to provide our warfighters with the means to prevent mission degradation from CBR attacks and eliminate the enemy's incentive to use such weapons.

Department of Defense (DoD) policy requires mission-critical systems to be chemical, biological, radiological, and nuclear (CBRN) survivable. It also requires that survivability be accomplished by material measures, or that remediation of vulnerabilities be accomplished through tactics, techniques, and procedures (TTP) throughout the systems' life cycles. This policy is aimed primarily at the ability of a platform to survive and operate in a CBRN environment.[1] A related policy requires program managers (e.g., milestone decision authorities) to address personnel survivability when exposed to residual chemical, biological, and nuclear (i.e., radiation) effects.[2] Inherent in the survivability of personnel and platforms is the ability to complete the platform's mission within a CBRN environment.

The Director, Surface Warfare Division (OPNAV N86) is the Chief of Naval Operations' (OPNAV's) Executive Agent for CBRD. This office provides the organizational focus for other military services, joint staff, and DoD agencies, and coordinates with warfare sponsors. OPNAV designated the Naval Sea Systems Command (NAVSEA) as the lead systems command (SYSCOM) for CBRD programs.[3]

Technical Warrant Authority

The Navy also is an integral player in the Joint Chemical and Biological Defense (CBD) Program, which is responsible for developing CBRD equipment. The NAVSEA Technical Warrant Holder (TWH) interfaces with the Joint CBD Program through the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD)—as well as its subordinate joint project managers—to ensure that the research, development, acquisition, and support of this equipment adequately addresses the Navy's requirements, as defined by the fleet and validated by OPNAV. As the lead SYSCOM for CBRD, NAVSEA has the added responsibility for coordinating these efforts not only within NAVSEA, but throughout the Navy.

The SYSCOMs defined the role of technical authority "to support program managers and the fleet in providing best-value engineering and technical products." [4] Some key responsibilities include safety and reliability, risk management, technical options for decision makers, and stewardship of the technical community. Warrants need to interact with each other since products and systems often involve multiple technical areas. The TWH is the technical voice within the Navy and to the Joint CBD Program and the other U.S. military services both directly and through designated subject matter experts (SMEs). The CBD TWH supports the transition of CBD materiel solutions developed by the JPEO-CBD to the fleet. The TWH for CBD's scope of technical authority includes:

- Acting as the lead technical advisor to the OPNAV executive agent (EA) for CBD
- Acting as the lead technical point-of-contact for the CBD areas of:
  - Individual protection equipment (IPE)
  - Collective protection
  - Chemical and biological (CB) detectors
  - Decontamination systems
  - Integration of warning and modeling systems
  - Medical support systems
- Providing and advocating for the technical details in support of Navy requirements to the Joint CBD Program in the development of materiel solutions
- Leading and providing guidance to the CBD SMEs
- Providing guidance to ship program offices in meeting CBD requirements
- Coordinating and collaborating with the TWH for medical, climate control, and radiation
- Providing CBD execution risk/cost weighting to the program manager
- Assessing the health of the engineering agents
- Maintaining CBD specifications and standards
- Providing execution risk guidance for the:
  - Naval Air Systems Command (NAVAIR)
  - Naval Special Warfare Command (NAVSOC)
  - Military Sealift Command (MSC)
  - Naval Facilities Engineering Command (NAVFAC)

The CBD TWH's goal is to partner with the Joint CBD Program and the appropriate offices within each SYSCOM and program executive office (PEO) to provide the best products to the warfighter. NAVSEA SMEs help guide individual programs with requirements identification, decomposition, and verification.

CBD Engineering and Logistics Support Activities

CBD engineering supports Navy missions under chemical or biological threat. It can be thought of in terms of avoiding contaminated environments, protecting against contaminants when in a contaminated environment, and taking necessary actions when exposed to contaminants in order to ensure survivability. To avoid contaminated environments, warfighters need to know, through detection, where the contaminants are and where the contaminants will likely migrate. The latter is achieved through modeling and simulation or information systems (IS). To protect personnel and systems against exposure when operating in a contaminated environment, the Navy relies on prophylaxes (e.g., vaccines), IPE, collective protection systems (CPS), and protective coatings. To ensure survivability when exposed to contaminants, the Navy relies on medical countermeasures for individuals, as well as decontamination of individuals and equipment. These are also excellent examples of cross-warrant interactions as medical, climate control, radiological, damage control, and fire protection technical areas are also involved.

To address the entire scope of CBD, the technical warrant authority delegates engineering authority along the following lines:

- Detection
- IPE
- Decontamination
- IS
- CPS
- Medical Support

In addition, the TWH reaches out to the Naval Sea Logistics Center to oversee the logistics management across the full spectrum of CB defense. Key NAVSEA Warfare Center activities involved with engineering support of CB defense equipment include:

- Naval Surface Warfare Center, Dahlgren Division (NSWCDD)—located in Dahlgren, Virginia, is the lead for CB detection, CPS, CBRD IS, decontamination, and medical support. As the lead for these commodities, NSWCDD supports joint CBD research development and acquisition, fields new equipment, and ensures that Navy needs are properly addressed. They also manage the Readiness Assist Visit (RAV) efforts, which provide a readiness assessment of all CBR commodities on a ship within 90 days prior to deployment.

- Naval Surface Warfare Center, Carderock Division (NSWCCD)—located at the Ship Systems Engineering Station in Philadelphia, Pennsylvania, is the activity assigned responsibility of the In-Service Engineering Agent (ISEA) for IPE, CPS, and decontamination. As the ISEA, NSWCCD is responsible for the overall engineering, test, maintenance, and logistics requirements of fielded systems and equipment.
- Naval Surface Warfare Center, Panama City Division (NSWC PCD)—located in Panama City, Florida, is designated as the engineering agent for CB IPE. As the lead for IPE, NSWC PCD supports the joint CBD research, development, testing, and acquisition of IPE; fields new equipment; and ensures that Navy IPE needs are properly addressed. They also oversee the CBD-IPE Readiness Improvement Program (RIP), which ensures that every deploying Sailor is outfitted with the proper CBD-IPE.
- Naval Surface Warfare Center, Crane Division (NSWC Crane)—located in Crane, Indiana, is where detectors containing radioactive material are stored by authority of their Naval Radioactive Material Permit. In addition, NSWC Crane serves as the Joint Service Depot for the Joint Biological Point Detection System.

Programs to Improve Fleet Readiness

The CBD TWH implemented three complementary programs in an agreement with the Type Commands that have improved the fleet's CBRD readiness at reduced costs to the Navy. The first two programs are the CBD IPE RIP and the RAV Program. Both programs are tied to ship deployments. RIP focuses on ensuring that the deploying ships are properly outfitted with IPE. RAV addresses all CBRD commodity areas to assist the deploying ship in improving its CBRD readiness. This provides ship commanding officers with full knowledge concerning the ship's CBRD readiness. As mentioned above, NSWC PCD manages the CBD-IPE RIP, which ensures that every deploying Sailor is outfitted with the proper CBD-IPE (e.g., gas mask, suits, boots, and gloves). Prior to issuance of new equipment, each Sailor undergoes sizing of the equipment and quantitative fit testing of his or her mask using either a TDA-99M (respirator function tester) or a Joint Service Mask Leak Tester. The proper fit and sizing of the equipment is essential in order to protect the Sailor in a CB environment. The program supports all naval enterprises with fully operational equipment—provided in kit bags—which support the Navy's mission-oriented protective posture and continued operations in a CBR threat environment. Figure 1 shows a Sailor being fitted for CBR defense prior to deployment.

Concerning RAV, a RAV team from NSWCDD conducts a readiness assessment of all CBR commodities on a ship within 90 days prior to deployment. The team assesses the condition of CBR detectors, decontamination consumables, and CPS. The team ensures that the ship has been, or is scheduled to be, outfitted by RIP. It fields all CB consumables in accordance with the deployment allowance equipment lists, and it provides crew training as necessary (see Figure 2). Each ship is provided with completed checklists, a readiness review report, recommended maintenance requests, and current CBRD literature. When each ship returns from deployment, the RAV team returns to the ship and collects unexpired consumables for use on another deploying ship.

The implementation of the RIP and RAV efforts has reduced the support costs for CBRD equipment while ensuring the CBR defense readiness of deploying ships through deployment-focused CBRD support. As a result of these programs, the commanding officers of over 130 ships have deployed in

Figure 1. CBR Team Fits and Measures USS *Wasp* Sailors Prior to Deployment

Figure 2. NSWCDD Engineer Conducts Shipboard CPS Training Aboard USS *Tortuga*

recent years with the appropriate CBRD equipment and full knowledge of their CBR readiness.

The third readiness program is the CPS filter change-out program executed by NSWCDD and NSWCCD. It replaces CBR filters on a cyclic basis and assures proper installation for Sailor protection. The team procures multiple filter types for distribution, performs leaks tests to make sure all air passes through them, and trains Sailors on the detection of problems. Scheduling is particularly important with this program, as shipwide cooperation is necessary.

The TWH's role is to champion Warfare Center ideas for improvements, to increase data surety, and to increase our responsiveness to the Navy stakeholders. Increased awareness of Total Ownership Cost provides opportunities to rethink our technical options in areas such as IPE, bioconsumables, decontamination, and CPS filters. With the addition of risk management practices, the CBD team has been able to provide the CBD Program Manager with solutions that have already resulted in cost avoidance and that will result in millions of dollars of cost avoidance across the Future Years Defense Program. Many of these actions have been executed through the JPEO-CBD and with the other U.S. military services, which means that our collective efforts have DoD-wide benefits.

Future Challenges

As DoD budgets continue to tighten, the expertise and creativity of the CBD engineering and logistics support teams will be needed to maintain and improve the fleet's CBRD readiness. Coordination with Navy stakeholders is key to prioritizing Navy needs to best focus available resources. Additionally, clearly communicating Navy requirements and priorities to the joint community is critical for ensuring that Navy needs are addressed within the Joint CBD Enterprise. By leveraging TWHs and their respective authorities, the Navy's warfighting capabilities are better enabled, even in a CBR environment.

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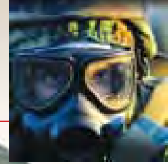
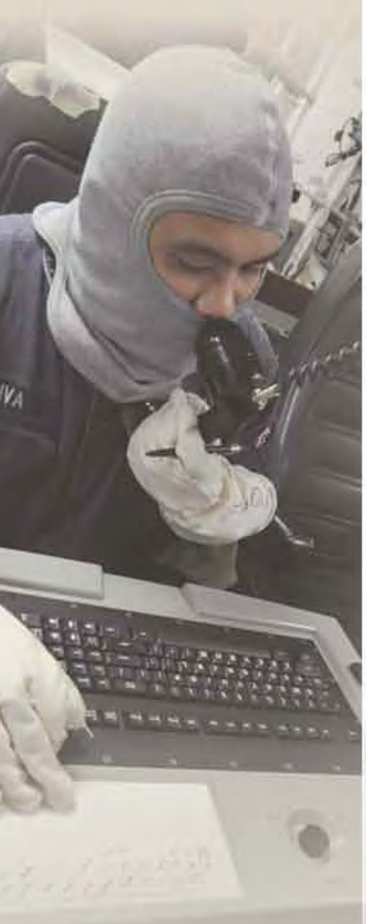


Engineering Agents for Chemical and Biological Defense Information Systems: Getting the Navy's Information Systems to the Field

By Santiel Creekmore



Recently, when an earthquake and several tsunamis damaged the Fukushima nuclear power plant, it initiated events that would lead to both airborne and waterborne releases of radioactive material. Fortunately, the Navy ships operating in the area were prepared to handle this threat. This type of event demonstrates the Navy's need for early warning, reporting, and hazard prediction capabilities. The Navy will use information systems (IS)—such as the Joint Warning and Reporting Network (JWARN)[a] and the Joint Effects Model (JEM)[b]—to provide these capabilities for nuclear (including radiological), biological, and chemical (NBC) hazards. Getting these systems from the technology development phase to an operationally proven and fielded Navy capability requires the active involvement of several key players, including the Technical Direction Agent (TDA), the Acquisition Engineering Agent (AEA), and the Logisticians for chemical and biological defense (CBD) IS. The TDA, AEA, and Logistician for CBD IS provide systems engineering support for the engineering, testing, evaluation, maintenance, and logistics requirements for the development and initial production of the Navy's CBD IS.

The Naval Sea Systems Command's (NAVSEA's) Technical Warrant Holder (TWH) for CBD has designated the Chemical, Biological, and Radiological Defense Division at the Naval Surface Warfare Center, Dahlgren Division as the TDA and AEA for CBD IS. The TWH has tasked the TDA, AEA, and Logisticians for CBD IS (collectively referred to as engineering agents (EAs) in this article) to ensure that JWARN and JEM are developed, tested, and sustained in accordance with the Navy's technical policies and standards. The EAs accomplish this by exerting influence on all acquisition activities and aspects of an IS. This article focuses on EAs' activities regarding CBD IS design, architecture, test and evaluation (T&E), and sustainment planning.

EAs and CBD IS Design and Architecture

EAs help ensure that the CBD IS interfaces and information exchanges are compatible with the Navy's command, control, communications, computers, and intelligence (C4I) systems and the Navy's system employment concepts. This compatibility enables the Navy to seamlessly exchange NBC information among its components and with joint forces (Figure 1) under the various operating conditions. EAs are tasked to find and close gaps between CBD IS design, C4I architecture, and the Navy's system employment concepts. They teamed with engineers from the Global Command and Control System–Maritime

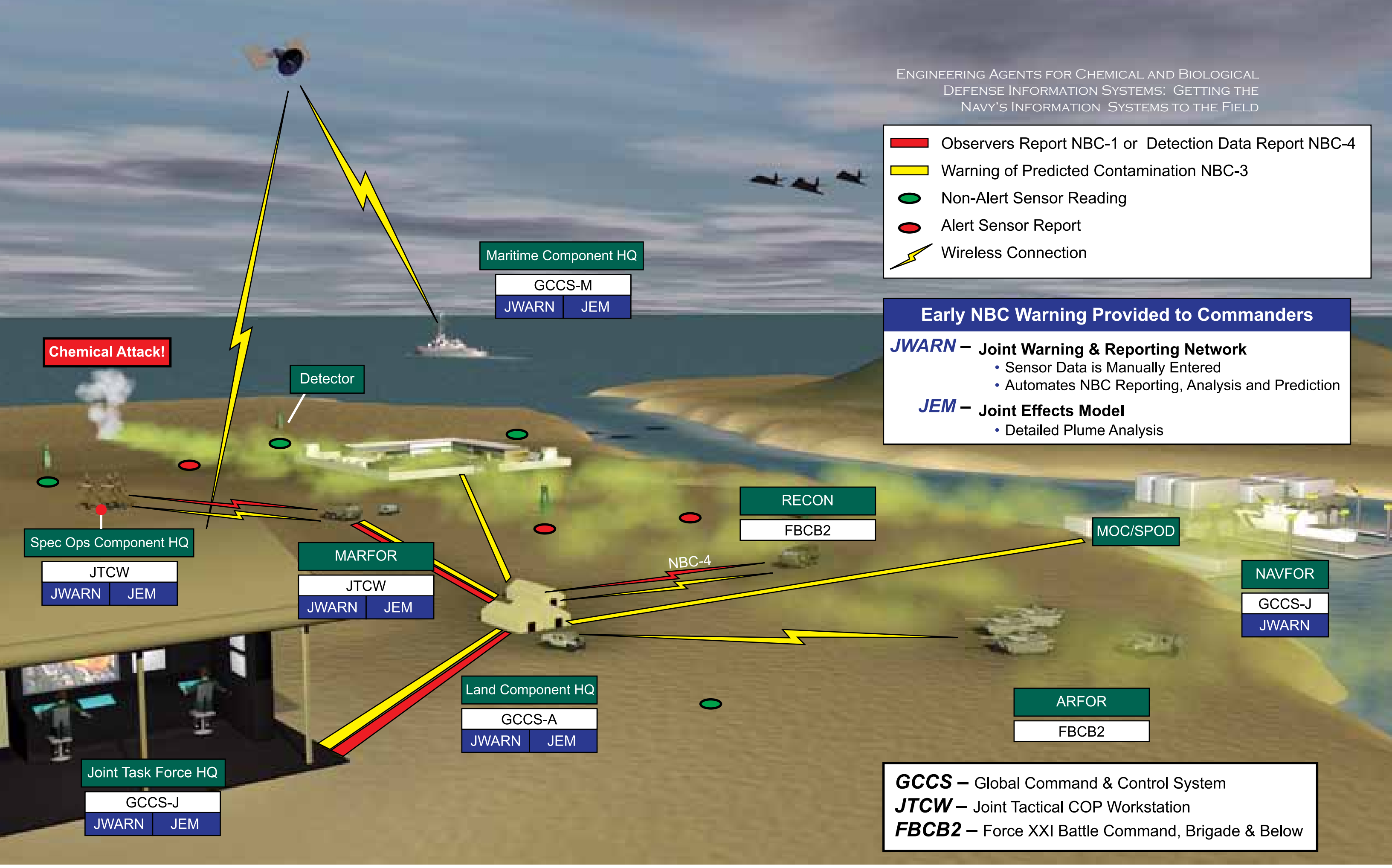


Figure 1. JWARN Information Exchanges Occurring Between Navy Components and Joint Forces

(GCCS-M) and the Tactical Messaging program offices to develop architecture for JWARN information exchanges executed under emission control (EMCON) conditions. The EAs also teamed with Chemical, Biological, Radiological, and Nuclear (CBRN) and Knowledge Dominance Action Officers within the Office of the Chief of Naval Operations to ensure that the architecture was consistent with the Navy's JWARN system employment concept. Once the architecture and details regarding implementation (e.g., communication protocols) were validated, they were provided to the JWARN developers to incorporate into the system design. In this way, EAs helped ensure that CBD IS interfaces and information exchanges support the Navy's intended use under the Navy's various operating conditions.

EAs also help mitigate the risks that ever-changing information technology (IT) and C4I infrastructure pose to CBD IS. These changes include third-party software updates, patches to interfaces, engineering change proposals, waivers, and deferrals to IT and C4I infrastructure, as well as changes in personnel qualifications/manning. The challenges posed by change can be shown by the 2009 changes to the Navy's command and control system, GCCS-M. These changes altered the GCCS-M configuration aboard several group-level and unit-level ships. The new configuration precluded the use of several software applications, including JWARN and JEM, thereby reducing the number of JWARN-capable ships. This change required the Navy to modify its JWARN system employment concept to ensure that all ships have early warning of NBC events.

To support modifications to the system employment concept, the EAs teamed with JWARN developers, JEM developers, and GCCS-M engineers to determine what information could be exchanged between JWARN-capable and non-JWARN-capable ships. The EAs and engineers found that JEM hazard predictions and JWARN's Allied Tactical Publication (ATP)-45 plots could be exchanged from the JWARN-capable ships to the common operational picture (COP) of non-JWARN-capable ships. The JWARN-capable ship would create and publish JEM shapefiles and JWARN layers in near-real time. These shape files and layers would then be published on the non-JWARN-capable ship's COP via the COP synchronization tools of GCCS-M. This information could then be used to plan egress routes and notify land-based units when the area is "clear" (Figure 2). This

Figure 2. COP with JWARN Plot (Yellow) and JEM Hazard Prediction (Blue)—The COP displays the areas that need to be contained or avoided with a NATO ATP-45 triangle of the impacted area.

concept was used to revise the JWARN system employment concept and addressed the gap in early warning created by the decreased number of JWARN-capable ships.

EAs and T&E for CBD IS

When in the field, commanding officers and emergency responders need to be able to depend upon the CBD IS information products to plan operations within NBC environments as they make potentially life-and-death decisions. To ensure that decision makers can rely on CBD IS, the EAs work closely with IS developers and operational test agencies to ensure that CBD IS systems are tested, operationally evaluated, and proven effective and suitable for Navy use prior to fielding. EAs are tasked to support all development testing and operational testing occurring throughout the CBD IS's life cycle. EAs are members of the T&E integrated product team (T&E IPT) that defines the test activities, challenges, pass/fail criteria, and resources needed to fully test each CBD IS. The EA's role in the T&E IPT is to help testers identify and close gaps between CBD IS test activities and the Navy's system employment concept. For example, the Navy's system employment concept and requirements called for JWARN and JEM software to be operated on ships with the versions of Common Personal Computer Operating System Environment (COMPOSE)[c] that transitioned to current Microsoft products (Windows 7, Microsoft Outlook 2008, etc.). JWARN and JEM, however, were developed, integrated, and tested (both developmental and operational) within a previous version of COMPOSE that contained earlier versions of the Microsoft products. The EAs worked with members of the T&E IPT, GCCS-M engineers, and COMPOSE engineers to identify potential issues associated with the change in versions (e.g., access to Microsoft exchange server) that would impact JWARN and JEM performance. The EAs also worked with the operational test agencies to develop and document a strategy in the T&E master plan (TEMP) to ensure adequate testing for JWARN within all versions of COMPOSE. Once documented within the TEMP, the T&E IPT was able to identify adequate resources to execute full testing (both developmental and operational) and ensure that JWARN and JEM are operationally proven, within all required versions of COMPOSE.

EAs monitor the CBD IS performance during developmental testing and authenticate test data collected during operational testing. By doing so, the EAs can inform the Navy's stakeholder of the technical challenges and risks that may prevent the CBD IS from meeting the Navy's needs (e.g., loss of interoperability between JWARN fielded to

Maritime Operation Centers and JWARN developed for ships).

EAs and Sustainment Planning for CBD IS

EAs help the Navy plan for sustainment of each CBD IS. Prior to fielding a CBD IS, EAs work with NAVSEA's logisticians to maintain and regularly update sustainment plans. Sustainment plans for JWARN and JEM specify when the software is installed on each ship and who performs the installation, configures the settings, trains the operator (Figure 3), maintains the software/training, and maintains a help desk for technical support. The EAs update the sustainment plan to address IT and C4I infrastructure changes, as well as program schedule and testing deviations. Through maintenance of the sustainment plan, EAs enable the Navy's stakeholders to align appropriate levels of sustainment funds for CBD IS capabilities. EAs' sustainment planning activities are critical to maintaining the fleet's readiness for CBD IS.

Engineering Agents (EAs)–Value-Added

Warfighters today are faced with a wide variety of NBC threats. Fortunately, the Navy's EAs for CBD IS work hard to see that CBD IS—such as JWARN and JEM—are properly designed, are operationally proven, and have adequate sustainment plans before they get to the field. If not for the Navy's EAs for CBD IS, Navy and joint warfighters would not be equipped with superbly designed and effective CBD IS to defend against NBC threats.

Endnote

a. JWARN is a computer-based application that integrates CBRN data and facilitates sensor information into joint and service command and control systems for battlespace situational awareness. JWARN automates the manual processes of incident reporting and hazard plot generation described in Allied Technical Publication 45. JWARN incorporates sensor-alert information and CBRN observation reports from the field, generates a plot of the hazard area, displays it on the COP, and generates the warning message.

b. JEM is a Web-based software application that effectively models and simulates the effects of CBRN weapon strikes and incidents. JEM is capable of providing warfighters with the ability to accurately model and predict the time-phased impact of CBRN and Toxic Industrial Chemical/Material events and effects. JEM supports planning to mitigate the effects of weapons of mass destruction and provides rapid estimates of hazards and effects for integration into the COP.

c. COMPOSE is the underlying infrastructure on which JWARN, JEM, and GCCS-M reside. It is a combination of commercial off-the-shelf and government off-the-shelf products that deliver directory services, E-mail, Web acceleration, office automation applications, collaboration tools, and antivirus software.

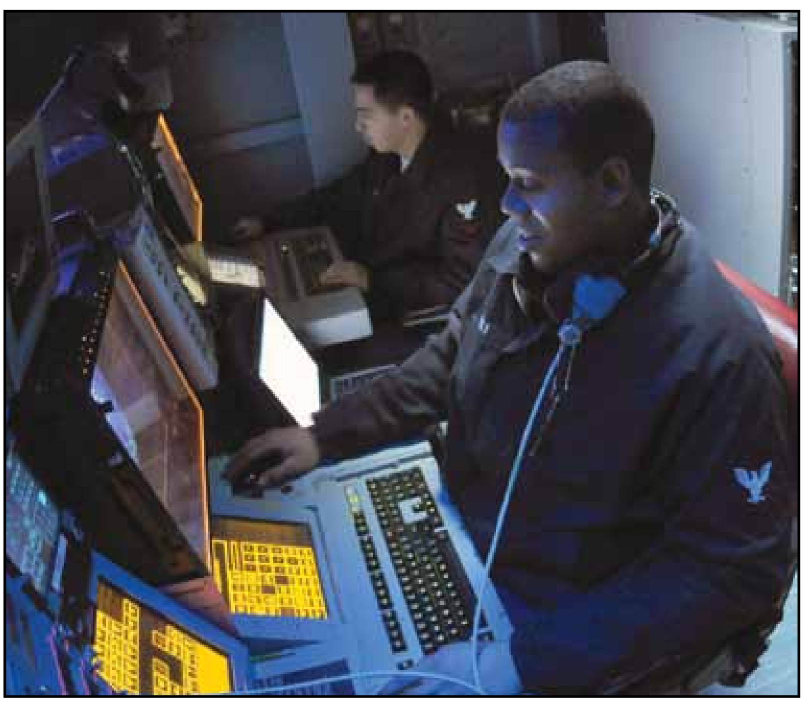


Figure 3. Operations Specialist 3rd Class David Bevels stands the auto track manager and identification operator watch in the Combat Direction Center aboard the aircraft carrier USS *Ronald Reagan*. (Photo Courtesy of U.S. Navy)

Sustaining the Navy's Chemical and Biological Detection Capabilities

By Nancy Haymes

The 2010 *Quadrennial Defense Review (QDR) Report* related that, "The potential spread of weapons of mass destruction poses a grave threat." The QDR further related that, "As the ability to create and employ weapons of mass destruction spreads globally, so must our combined efforts to detect, interdict, and contain the effects of these weapons."[1]

The 2010 QDR validated the Chief of Naval Operations (CNO) instruction entitled *Chemical, Biological, and Radiological (CBR) Defense Requirements Supporting Operational Fleet Readiness*, which included a statement from OPNAVINST 3400.10F, which references the 1997 QDR in stating that, "…weapons of mass destruction (WMD) present a grave and urgent challenge to the United States, our allies, and troops abroad."

The instruction then went on to relate:

> "Consistent with national policy and strategy, the Navy shall maintain those CBR defense capabilities required to support deterrence and enhance conventional warfighting through defensive means. The goal is to ensure that the use or threat of use of chemical or biological weapons or radiological contamination against a naval force will be a nondecisive factor in the outcome of any operation."[2]

Chemical and biological (CB) detection systems are required for Sailors to take protective actions and initiate treatment, as required, to minimize the impact of CB agents that are employed against naval forces. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) performs sustainment in support of CB detection equipment fielded to the Sailor by providing direct fleet technical expertise and assistance. NSWCDD supports sustainment by:

- Maintaining technical and logistical documentation
- Complying with legal and regulatory requirements
- Acquiring facilities for staging, storing, and maintaining fielded and radiological source detectors
- Providing configuration management of the Navy's CB detectors
- Disposing of retired systems

Example CB agent detection systems are shown in Figure 1.

Figure 1. Examples of Chemical and Biological Agent Detection Systems

Sustainment of CB agent detection systems enables:

- Sailors to operate and maintain CB systems and execute the processes that will allow fleet forces to avoid CB contamination
- The supply system to procure quality spares and repair parts to maintain detection systems
- Trainers to train the Sailor
- The support infrastructure to validate/revise doctrine, develop and execute improved business processes, develop product improvements to reduce operational and support costs, and to enhance the Sailors' operational capability

Roles and Responsibilities

NSWCDD performs sustainment of CB detectors in support of the Naval Sea Systems Command (NAVSEA), Ship Integrity and Performance Engineering Directorate, Damage Control and Personnel Protection (SEA 05P14). These functions are performed by the Technical Direction Agent (TDA), Acquisition Engineering Agent (AEA), In-Service Engineering Agent (ISEA), and Configuration Manager (CM). The TDA provides engineering and technical expertise and leadership for the Navy's CB detection systems and supports NAVSEA 05P14 in the form of briefings, technical reports, policy instructions, and white papers to support the readiness and sustainment for both shipboard and shore sites. The TDA supports all research, development, testing, and evaluation programs related to the Navy's CB detection needs.

The AEA provides budgetary, logistician planning, and sustainment of U.S. Navy CB detectors. Responsibilities include asset management, production of reports and trend analyses from performance data, improvements to logistics and processes to improve overall fleet readiness—reducing costs when and where possible—and developing and executing a demilitarization plan for all legacy CB detectors.

The ISEA provides effective management of waterfront team assets to support legacy detectors. This includes interfacing with ship install teams; monitoring cost, schedule, and performance changes as needed; and responding to routine and emergent fleet issues needing resolution. It also includes maintaining knowledgeable training assets and providing training to the Regional Maintenance Centers (RMCs) and warfighters.

The CM provides technical support to the AEA and ISEA in the form of database analysis and updates for configuration, alteration, or logistics data specific to CB detectors. This is done utilizing the Configuration Data Managers Database–Open Architecture (CDMD-OA). CDMD-OA has been designated by NAVSEA's Logistics, Maintenance, and Industrial Operations (SEA 04) as the official repository for all Navy equipment and systems. The CM interfaces with the logisticians, program manager, Alteration Installation Team, AEA, ISEA, Waterfront Team, and other technical points of contact to obtain the most accurate data in concurrence with the associated life-cycle milestone.

Legal and Regulatory Requirements

Many of the CB detectors that the Navy uses contain a radiological source, which means that the detector must comply with legal and regulatory requirements as dictated by the Radiological Affairs Support Office (RASO). RASO is a detachment of NAVSEA and is responsible for establishing policy for all radioactive material owned by the Department of Defense. Currently, the Naval Surface Warfare Center, Crane Division (NSWC Crane) maintains the Naval Radioactive Material Permit (NRMP) for CB detection systems. This permit allows for the handling and distribution of radiation source CB detectors. Compliance with the NRMP is mandated by RASO.

The NRMP requires a biyearly physical inventory of all radiation-source CB detectors. The inventory includes tracking the serial number and location of each CB detector. For fielded assets, NSWC Crane releases a naval message requiring each unit to perform this inventory and provide information back. Units that are nonresponsive to this request are subject to an external audit conducted by NSWC Crane. Possible impacts of noncompliance include fines, negative impact to the Commanding Officer's fitness reports, and the revocation of the NRMP permit, leaving the fleet without the necessary CB detection capabilities, as required by instruction. For stored assets, NSWC Crane performs the physical inspection of all assets at their facility. Following the inventory, a formal report is sent to RASO, which accounts for all units either through serial number inventory verification or through a Judge Advocate General Manual investigation of missing units.

NSWC Crane will continue to maintain the NRMP for CB detection systems until NSWCDD NRMP's are approved and assets can be legally transferred. NSWCDD is currently building a facility acceptable for staging and maintaining radiation-source CB detectors that comply with regulatory requirements.

Touching the Fleet

When a command has an issue or concern with their CB detection equipment, the ISEA is notified, and the appropriate activities are contacted. An ISEA Waterfront Team from NSWCDD has been established on both the East and West coasts to address concerns/repairs quickly and efficiently, resulting in tremendous cost savings to the Navy. This team is able to provide direct fleet technical support within hours after an issue is raised. Moreover, it can perform limited repairs on some CB detectors, such as the Improved Point Detection System (IPDS) on board ship. This significantly decreases downtime of the equipment, as well as cost per repair.

The ISEA Waterfront Team also provides individualized hands-on training and support to Navy warfighters, technicians, and support staff to increase operator and corporate knowledge of CB detectors. This includes training for RMC personnel who frequently support CB detectors. The training focuses on troubleshooting minor repairs of shipboard CB detectors. Waterfront training to the warfighter is also provided. Most training is provided by the CB Detector Schoolhouse at the Center of Naval Engineering located at the Norfolk Naval Base, the Navy's Fleet Training Centers, and Afloat Training Groups. Their support includes ensuring that the course curriculum reflects the proper operation and maintenance of fielded CB detectors. Training devices are also maintained by the RMCs and the CBR Waterfront Team to ensure that they are fully operational and represent the current configuration of fielded CB detectors.

Sustainment Supports Readiness

NSWCDD, in partnership with NSWC Crane, works to ensure that naval warfighters can continue to rely on their CB detection systems and are trained to use those systems in the event of a chemical or biological attack. Accordingly, by sustaining CB detection systems, the divisions are actively supporting Navy readiness.

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JCAD
Joint Chemical Agent Detector
JCAD
Joint Chemical Agent Detector
JBPDS
Joint Biological Point Detection System
CAM
Chemical Agent Monitor
CBR
Chemical, Biological, and Radiological Protection
DFU/HHA
Dry Filter Unit / Hand-Held Assay

CBRD Waterfront Team Improves Fleet Readiness

By Tara Lalonde and Ronald Roller

On 12 October 2000, terrorists used a small boat laden with explosives to attack USS *Cole* (DDG 67) while it was refueling in Aden Harbor, Yemen, resulting in the loss of 17 Sailors.[1] News of the attack devastated Americans. A photograph of the damage caused by the terrorist attack on USS *Cole* is shown in Figure 1.[2]

In reflecting on the attack, what if the terrorists had used chemical or biological weapons? Would the Sailors have been prepared? Would the shipboard systems have been operable? Would the Sailors have been trained to use the equipment?

The Naval Sea Systems Command (NAVSEA)—in response to Surface Warfare Enterprise (SWE) and Naval Air Enterprise (NAE) concerns of heightened risk of a weapons of mass destruction (WMD) attack—established the Chemical, Biological, and Radiological Defense (CBRD) Readiness Support Policy in 2007 to increase afloat fleet CBRD readiness. This policy launched the Readiness Assist Visit (RAV) Program that provides a comprehensive CBRD assessment to all ships within 90 days of deployment. The purpose of the RAV is threefold:

1. Assess all chemical, biological, and radiological (CBR) equipment and systems
2. Train shipboard personnel in operation and maintenance
3. Inventory and issue the chemical and biological warfare agent consumables

The following equipment and systems are assessed during the course of a visit:

- Collective Protection System (CPS)
- Improved Point Detection System (IPDS)
- Joint Biological Point Detection System (JBPDS)
- Joint Biological Agent Identification and Diagnostic System (JBAIDS)
- Dry Filter Unit (DFU)
- Radiological Detectors
- Portable Chemical Agent Detectors
- Decontamination

Since its inception, the RAV team has increased CBRD readiness by an average of 49 percent on more than 170 ships. A RAV team assessing the JBAIDS on board USS *Iwo Jima* (LHD 7) is shown in Figure 2.

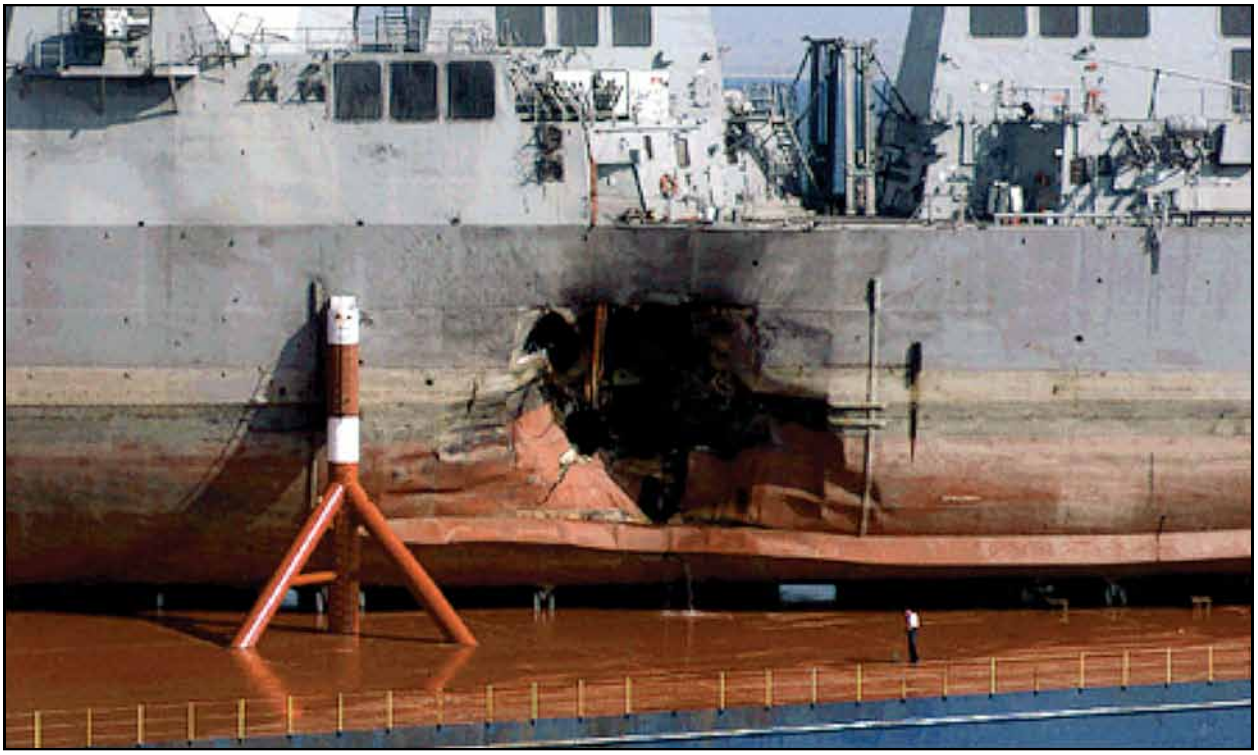

Figure 1. Damage Caused by the Terrorist Attack on USS *Cole* (DDG 67) in October 2000

In February 2009, following the success of the RAV Program, NAVSEA chartered a Navy CBRD Waterfront Fleet Support Team, which was endorsed by Fleet Forces Command and the Office of the Chief of Naval Operations. The Waterfront Team, centered at Naval Station Norfolk and Naval Base San Diego, boasts over 140 years of combined shipboard experience. In addition to the RAV support, the Waterfront Team provides:

- Centralized consumables management
- Shipboard support to CBR commodity owners
- Management of the CBRD website
- New CBRD equipment installation support
- Subject matter expert (SME) support for CBR training
- Publication and documentation SME support

Centralized Consumables Management

With warehouse space located on both coasts, the CBRD Waterfront Team is responsible for centrally managing all chemical and biological detection consumables. These consumables are very costly and have stringent shelf-life criterion, which makes it overly burdensome for the ships to individually manage. In managing the consumable material on

Figure 2. A RAV Team Assesses the Joint Biological Agent Identification and Diagnostic System (JBAIDS) On Board USS *Iwo Jima* (LHD 7)

behalf of the fleet, the Waterfront Team is able to increase readiness and maximize cost efficiencies by leveraging the RAV program to field the material to deploying ships and then return the material to a rotational pool when ships come back from deployment. All material is bar-coded, which provides the ability to track expiration dates and maximize shelf life. This alleviates the need for each ship to conduct an annual inventory, since the bar-coded inventory is automatically rolled up to the Annual Report to Congress (ARC). A storage facility in Norfolk, Virginia, that houses equipment and consumables for various CBR commodities is shown in Figure 3.

(SWOS) and the Naval Education and the Training Program Development Center (NETPDC)—filmed a CPS filter change-out on board USS *Cole*. This video will be used as a training tool to provide increased fleet awareness and shipboard support. The warehouses are also utilized to store and stage CPS filters for each change-out.

In late 2009, the Radiological Affairs Support Office (RASO) authorized a "U" radiation permit, which allows repairs of IPDS units to be conducted in the laboratories located at both warehouses. By conducting the repairs, the ship is no longer required to requisition a new unit. Consequently, this

Figure 3. Approximately 23,000 sq ft of Storage in Norfolk, Virginia, Houses Equipment and Consumables for Various CBR Commodities

Shipboard Support to CBR Commodity Owners

Various CBR commodity owners fund the Waterfront Team to provide direct fleet support on their behalf. Particularly noteworthy is the support provided to the CPS and Detection Acquisition Engineering Agents (AEAs), and to the program manager for the JBPDS. In 2010, the Waterfront Team—in conjunction with the Surface Warfare Officer School

Waterfront Team effort will save the Navy a projected $2 million annually while this system is fielded. A photograph of a CBR Waterfront Team member conducting IPDS repairs in the Norfolk, Virginia, laboratory is shown in Figure 4.

Management of the CBRD Website

The CBRD Waterfront Support Team is also responsible for maintaining the CBRD website.

Figure 4. A CBR Waterfront Team Member Conducts Improved Point Detection System (IPDS) Repairs in the Norfolk, Virginia, Laboratory

The website provides valuable information that the more than 1800 registered Sailors can access 24/7, including the most current CBR guidance and documentation, as well as a plethora of other resources. The "Ask the Expert" function included on the website allows questions to be e-mailed to the Waterfront Team; Sailors typically receive appropriate direction within 24 hours. The CBRD website allows the Waterfront Support Team to provide distance support for deployed units, including ships operating in theater.

New CBRD Equipment Installation Support

In addition to CBR sustainment efforts, the Waterfront Team also supports new equipment installations. The Norfolk, Virginia, warehouse serves as the site for the acceptance testing and inventorying of each JBPDS, JBAIDS, and Joint Chemical Agent Detector (JCAD) prior to initial fielding.

SME Support for CBR Training

Given the ever-increasing terrorist threat, training for CBR events is improving. The Waterfront Team recently helped to develop shipboard drills and scenarios in conjunction with the staff at Commander, Third Fleet. The drills help to train and assess first responders and support personnel in the collection and processing of simulated biological warfare agents—from discovery to final analysis confirmation.

Publication and Documentation SME Support

Existing doctrine, as promulgated in the *Surface Force Training Manual*, mandates shipboard training in a CBR environment. For many years, the manual was tailored for scenarios that no longer reflect the current "real-world threat." Liaisons with the Commander, Naval Surface Forces (CNSF); the Afloat Training Group (ATG); the numbered fleet commanders; and the CBRD Waterfront Support Team have resulted in an updated version to be released soon. The revision includes mandatory drills for biological warfare and a more robust self-assessment to be conducted by ship personnel on CBR systems and equipment.

Emergency Life Support System

At the request of the CNSF, the CBRD Waterfront Team recently joined in a teaming effort with the Naval Surface Warfare Center, Panama City to include assessment and training of the Self-Contained Breathing Apparatus (SCBA) charging systems during the RAV. This system provides breathing air to emergency responders on board ship in the case of fires and/or toxic gas emissions. Although SCBA systems fall outside of the CBRD scope, cost efficiencies are realized by utilizing RAV, since the team is already on board the ship conducting an assessment and training of the CBR equipment.

Conclusion

In today's world of terrorist threats, ships must be capable of operating in a CBR environment. The possibility of a CBR attack on a naval ship is no longer remote. For many years, it was the responsibility of the ship's damage-control organization to equip the ship for all CBR and damage-control contingencies. Today, the CBRD Waterfront Team outfits each ship with the necessary CBR equipment and supplies prior to deployment, and trains Sailors in the operation and maintenance of all CBR systems and equipment. Though the CBRD Waterfront Support Team is a relatively new initiative, the proven increase in readiness and knowledge of Sailors demonstrates that the program is paramount in establishing and maintaining readiness for the warfighter on the front line.

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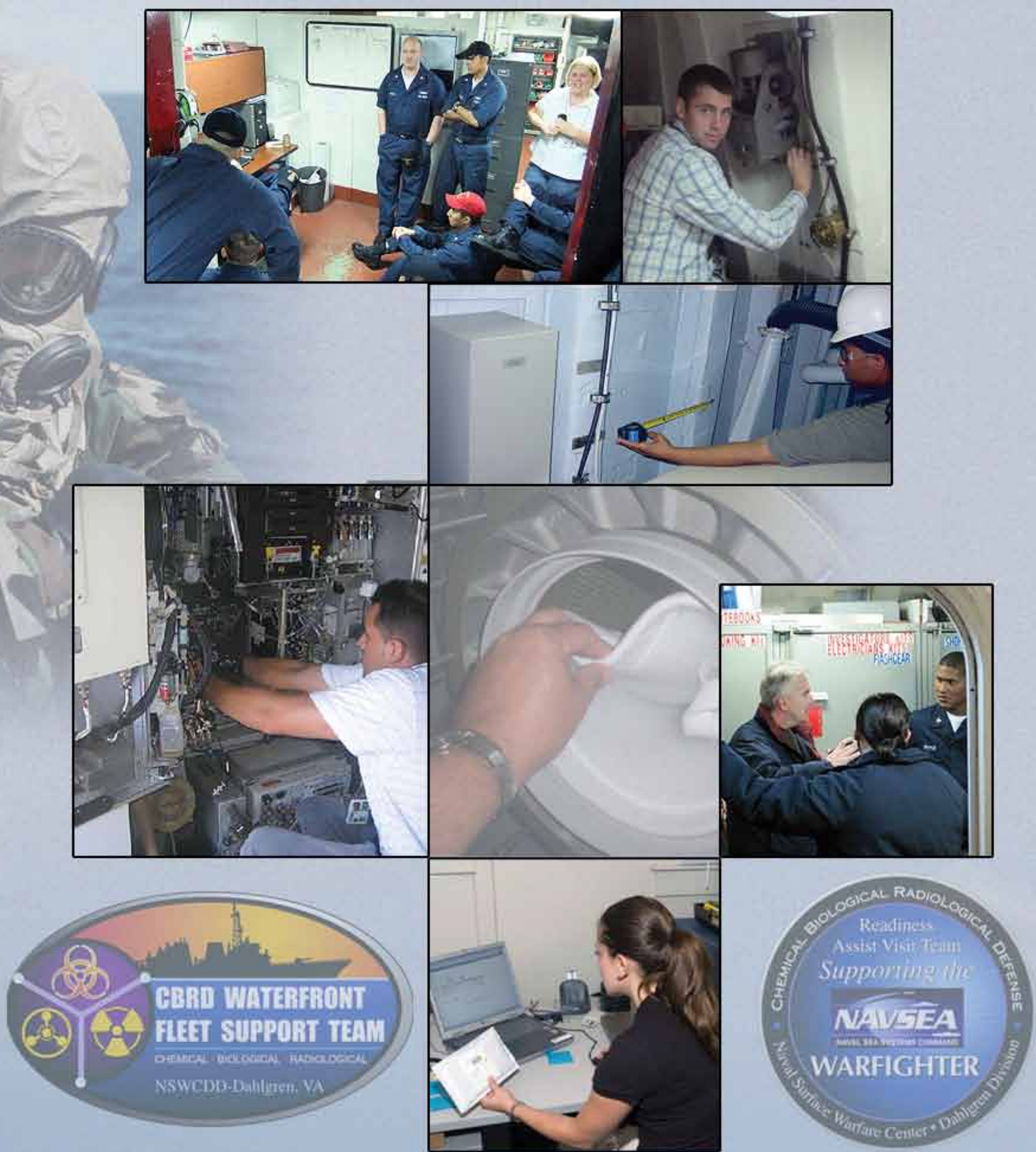
CBRD WATERFRONT
FLEET SUPPORT TEAM
CHEMICAL · BIOLOGICAL · RADIOLOGICAL
NSWCDD-Dahlgren, VA
Chemical Biological Radiological Defense
Readiness
Assist Visit Team
Supporting the
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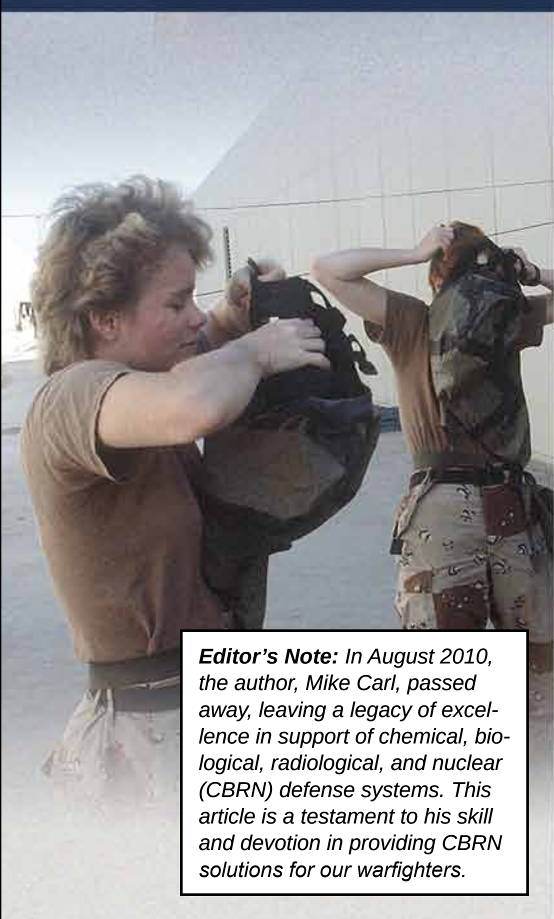
WARFIGHTER
Naval Surface Warfare Center • Dahlgren Division

Chemical and Biological Defense Individual Protection Equipment Materiel Readiness Improvement Program

By Michael Carl



Editor's Note: *In August 2010, the author, Mike Carl, passed away, leaving a legacy of excellence in support of chemical, biological, radiological, and nuclear (CBRN) defense systems. This article is a testament to his skill and devotion in providing CBRN solutions for our warfighters.*

Introduction

The ever-changing challenges in supporting Overseas Contingency Operations have forced the Navy to make radical changes in the approach for equipping forward-deployed and deploying naval forces. In what has become an extremely fast-paced environment, the warfighters were in desperate need of a logistics support solution that ensured they were consistently provided with fully serviceable individual protection equipment (IPE)—capable of preventing or reducing individual exposures when faced with chemical, biological, radiological, and nuclear (CBRN) threats. To deal with this challenge, a partnership was formed between the Navy's resource, requirements, and materiel development offices. This partnership has been focused on improving the materiel readiness and sustainment affordability of this vital equipment. Combining principles drawn from the concepts for reduction of Total Ownership Cost and LEAN thinking, the Naval Sea Systems Command (NAVSEA); the Office for Chemical and Biological Defense; and the Naval Surface Warfare Center, Panama City Division (NSWC PCD), Extreme Environments and Life Support Branch, have implemented an extremely successful business transformation for the management of the Navy's IPE assets, known as the IPE Readiness Improvement Program (RIP). The foundation that makes the IPE RIP successful is based on three core concepts:

1. IPE kit bags, one per each warfighter
2. Quantitative fit testing and sizing of the individual warfighters for proper-fitting chemical protective clothing and masks
3. Centralized management of the Navy-wide IPE assets

Readiness Improvement Program (RIP)

The concept of the RIP began in 2002. At that time, combatant commanders realized that they had an urgent need to:

- Promote the capability to have their warfighters have their protective gear close at hand (see Figure 1)
- Give better care to the equipment
- Aid in the accountability of the equipment

In response to warfighter feedback, the NAVSEA Office for Chemical and Biological Defense and the NSWC PCD, Extreme Environments and Life Support Branch analyzed various alternatives for meeting the combatant commander needs. The most noteworthy alternative identified by this working group was the RIP. The most attractive feature of the program is the fact that it would not only address combatant commander needs, but it would also ensure that forward-deployed and deploying forces were provided with properly sized IPE ready for immediate retrieval in response to the dictated mission-oriented protective posture (MOPP) condition, which includes a fully serviceable, properly fitted chemical protective mask.

In order to meet the combatant commanders' need to have protective gear close at hand, give better care to the equipment, and aid in the accountability of the equipment, it was necessary to provide the equipment as a serialized kit that could be issued to each individual warfighter (see Figure 2).

Legacy Process—Prior to RIP

This legacy process, as reflected in Figure 3, provided limited accountability, and unsatisfactory materiel and operational readiness, and was a burden to the warfighter. This is greatly due to limited oversight and inaccurate inventories of equipment assets.

Current Process

It was clearly evident that the forces deploying in support of Operation Iraqi Freedom (OIF) were not at adequate chemical and biological defense (CBD) readiness levels, and that the typical way of doing business would not support the

Figure 1. Individual Protection Equipment (IPE): Protective Gear

Figure 2. Individual Protection Equipment (IPE): Serialized Kit

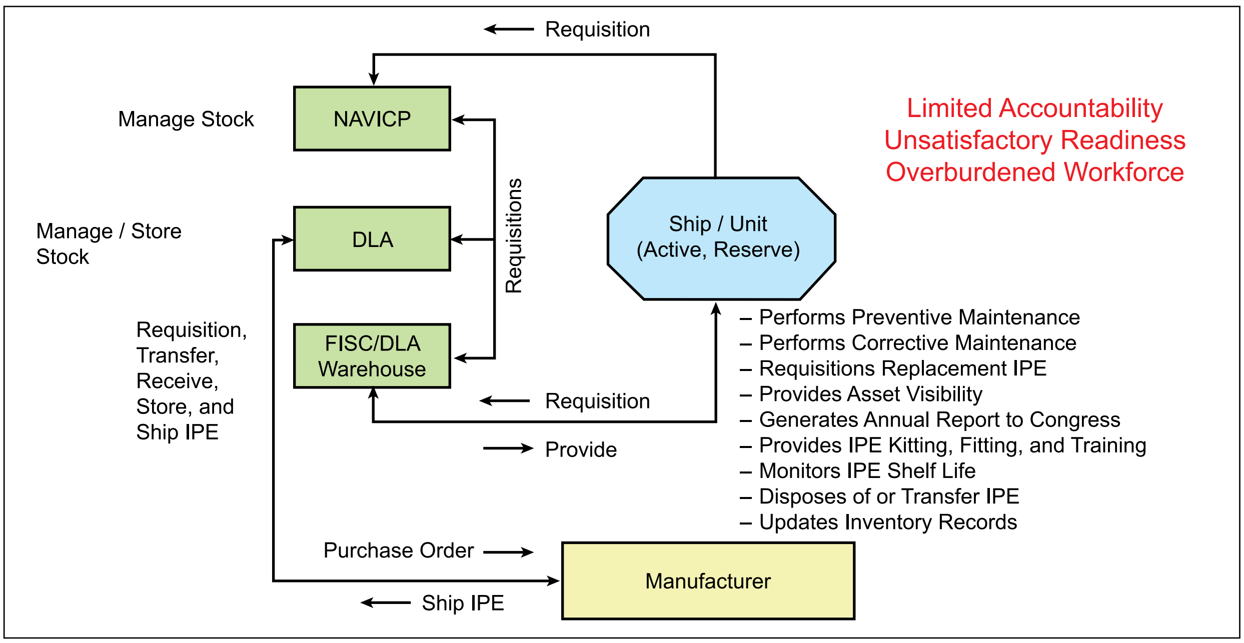


Figure 3. Legacy Process

immediate requirements for OIF or future CBD operations. The partnership, by implementing policy and doctrinal changes, morphed the operations and support (O&S) processes for maintaining the Navy's IPE into the current process reflected in Figure 4. The key components of the process are to provide centralized asset management and to conduct fit-testing and sizing operations, ensuring that forward-deployed and deploying forces are, in fact, provided with properly sized IPE ready for immediate retrieval in response to various MOPP conditions, and that this equipment is fully serviceable with a properly fitted chemical protective mask.

The IPE Commodity Area is a diverse organization that is strategically positioned to fully meet the demands of the Navy Warfare Enterprises. The organizational structure selected provides the most favorable cost, as compared to the amount of resources, facilities, response time, etc., that is required and provided. The Navy IPE support organization and locations are depicted in Figure 5.

Centralized Assets Management

The foundation that makes the IPE RIP successful is the centralized management of the Navy-wide assets, and the cornerstone of the management of these assets is the NAVSEA Consolidated Storage Facility (CSF), which is located at Fort Worth, Texas. This is a Government Services Administration (GSA)-owned/customer-leased facility that is approximately 240-K square feet of completely utilized space.

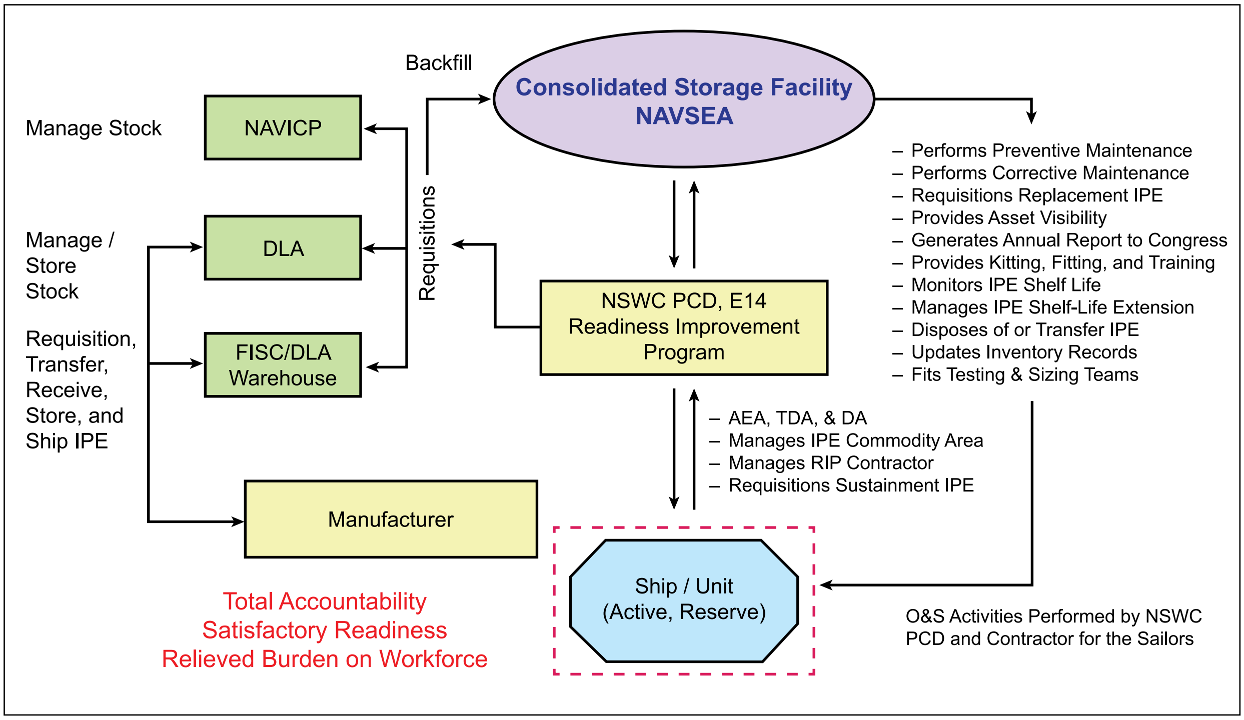


Figure 4. Current Process

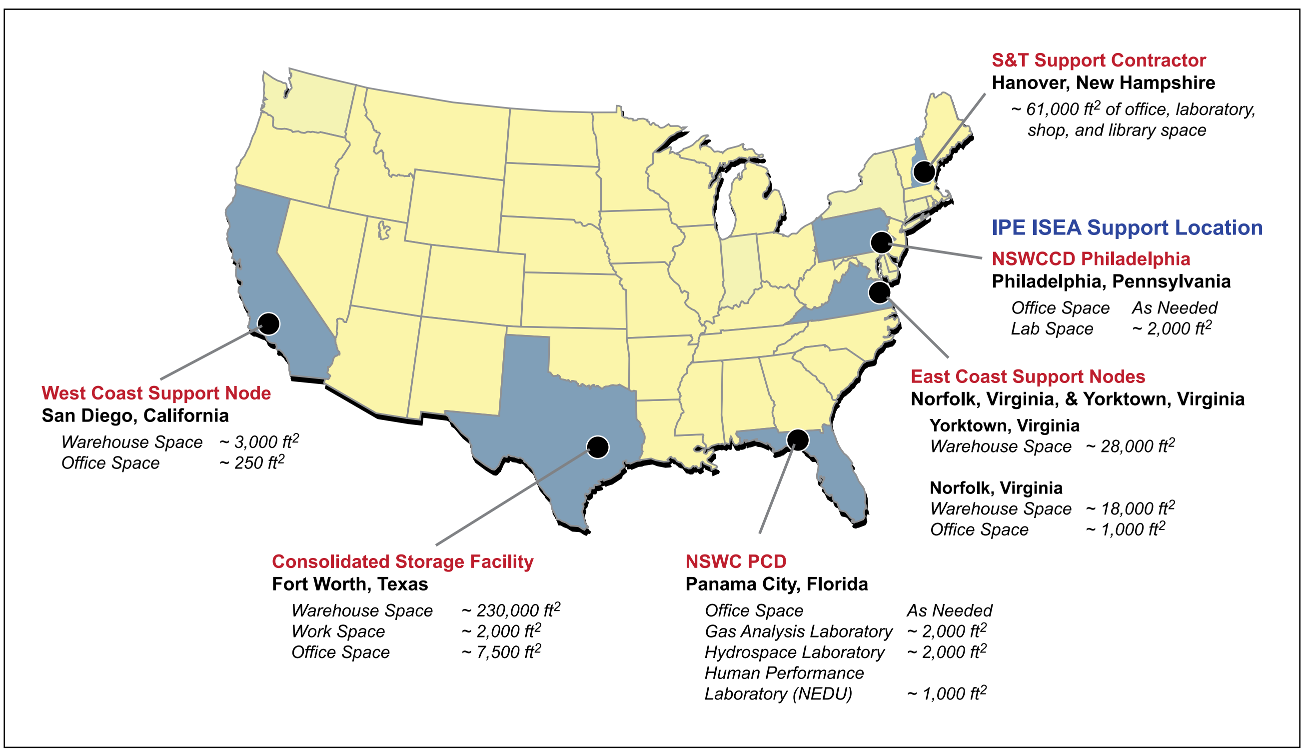


Figure 5. Navy IPE Support Structure and Locations

Personnel at the warehouse locations provide total end-item support, including:

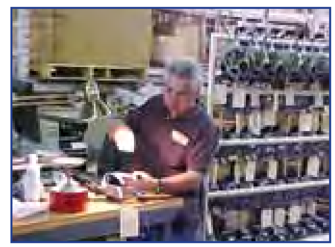
- Inspecting for serviceability of chemical protective equipment and mask
- Cleaning and sanitizing protective mask
- Testing mask utilizing the TDA-99M or the new Joint Service Mask Leakage Tester (JSMLT)
- Laser etching the masks with a bar-code serial number
- Assembling and disassembling equipment
- Bar-coding other IPE
- Packaging for shipment
- Assembling generic and individual IPE kits
- Managing inventory
- Managing shelf life
- Providing asset visibility for the annual reports to Congress
- Procuring spare parts and repair parts
- Providing maintenance and repair services

The basic workflow process for the management of the Navy's centralized IPE assets is depicted in Figure 6.

IPE is delivered to the CSF
(a)

IPE is sorted
PMS is performed
(b)

IPE is bar-coded
Masks are laser-etched
Information is entered into IMS
(c)



Assessments are performed
(d)

Tests are conducted
(e)

IPE is kitted
Designated kits are returned
Excess gear is returned to stock
Information is entered into the IMS
(f)

Figure 6. Centralized Assets Management Basic Process

Fit Testing and Sizing

During fit testing and sizing (see Figure 7), the following activities are performed:

- Perform protective mask sizing and quantitative fit testing using JSMLT
- Perform IPE sizing and fit verification
- Provide a data file populated with mask and IPE sizing data
- Have the individual sign a page 13 containing fitting, sizing, and personal data
- Provide training on the conduct of mask fitting and IPE sizing with designated personnel
- Provide training on the operation of the TDA-99M or JSMLT with designated personnel

Conclusion

The NAVSEA CBD IPE RIP has been a colossal success in maintaining a high level of materiel and operational readiness that is affordable, providing the Warfare Enterprise with the capability to operate effectively and decisively in the face of CBRN threats.

Implementing the RIP—and thereby redirecting the O&S requirements for the inventory, care, and maintenance of this vital equipment—has enabled a severely undermanned and overburdened warfighting community to focus on the more crucial aspects of their missions: training, logistics support, and execution. Plus, not only is the materiel and operational readiness consistently sustained at combat-ready levels, but the overall Navy's Total Ownership Cost has been significantly decreased.

Sailors fit tested with masks

Sailors sized for proper-fitting IPE

Figure 7. Fit Testing and Sizing

Shipboard Isolation and Quarantine: Protecting Sailors From Infectious Diseases

By John Garmon

Ensign Rodgers was relieved of his duties just after midnight in the signal room due to his disruptive coughing. As he made his way down to medical, he collapsed and began coughing up blood. Even to the untrained seaman who helped him to medical, Rodgers' condition clearly represented something unusual.

Naturally occurring or maliciously spread infectious diseases pose a direct threat to warfighters, ships, and the fleet. Doctors and corpsmen are trained to methodically diagnose patients using their knowledge, resources, and contacts to handle infectious diseases, but without proper facilities and protocol, many Sailors remain at risk.

Given the Navy's global presence, the preceding example of a shipborne infectious disease outbreak is a real possibility. The Severe Acute Respiratory Syndrome (SARS) epidemic in 2003 represented an actual example that put many Navy personnel in the Pacific region at high risk of being exposed to the deadly disease. A subsequent review of medical protocol and emergency response plans for infectious disease outbreaks clearly indicated that there was a need for an isolation and quarantine capability aboard U.S. Navy ships. Figure 1 shows the aircraft carrier USS *George Washington* (CVN 73) being moved by tugboats to a pier in Busan, Republic of Korea.

In 2005, Commander Third Fleet (C3F) sponsored a limited-scope evaluation of a temporary shipboard isolation and quarantine (SIQ) capability. The evaluation assessed the feasibility of using existing damage-control equipment (de-smoking fans, smoke curtains, etc.) and commercial high-efficiency particulate air filter and ultraviolet air purification equipment to meet Centers for Disease Control and Prevention (CDC) recommended guidelines for air exchanges, directional airflow, negative pressure, and air-cleaning requirements. Engineering support for this effort was provided by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), and medical support was provided by the Naval Health Research Center (NHRC). The ship's damage control equipment was found capable of meeting the CDC guidelines; however, poor access for medical personnel and environmental control of the space were identified as obstacles to ensure proper patient care if the capability was required for more than a 24-hour period. A makeshift anteroom aboard CVN 76 for the 2005 experiment is shown in Figure 2.

Figure 1. 100721-N-2013O-422 BUSAN, Republic of Korea (21 July 2010) Tugboats move the aircraft carrier USS *George Washington* (CVN 73) to a pier in Busan, Republic of Korea. This is the first port visit for *George Washington* during its 2010 summer patrol in the western Pacific Ocean and the second visit to Busan by the ship since October 2008. (U.S. Navy photo by Mass Communication Specialist 3rd Class Charles Oki/Released)

Figure 2. Makeshift Anteroom for the 2005 Limited-Scope Evaluation

The evaluation revealed that the commercial air-purification equipment performed well, but was not suitable for shipboard application due to size, weight, and noise factors. In their final report, NHRC staff identified elements that were essential for proper patient care. They also identified the need to examine doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) elements in relation to the potential SIQ capability. Some of the recommendations made by NHRC included:

- A vestibule for controlled entry and exit
- Sufficient storage for personal protective equipment
- Personal hygiene supplies
- Proper food and laundry delivery/removal processes
- Access to toilet and shower facilities

These capability gaps were confirmed by C3F as the "next steps" in developing the SIQ capability.

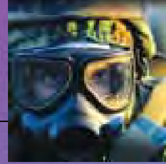
Developing this capability for the fleet was given a higher priority in 2009, as influenza virus H1N1 spread around the world and became a potential threat to fleet readiness. In response, a SIQ Limited Objective Experiment (LOE) was approved by the Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense and was subsequently funded by the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD). Objectives of the current LOE are to:

- Identify materiel and nonmateriel solutions for establishing SIQ capability on the Navy's large-deck amphibious ships
- Develop tactics, techniques, and procedures (TTPs) and medical protocol that can be used in conjunction with SIQ space
- Analyze DOTMLPF impacts of providing SIQ capabilities to the fleet

The SIQ LOE Team completed a 3-day tabletop exercise in May 2010 to evaluate the preliminary TTPs, identify potential materiel requirements, and begin to list DOTMLPF impacts. The final phase of the LOE was a live experiment on board a Navy ship to test the revised TTPs using a SIQ area mock-up provided by JPEO-CBD and NSWCDD. A photograph of the SIQ LOE live experiment is shown in Figure 3.

In line with the original objectives, the LOE should result in a more mature understanding of the DOTMLPF impacts, TTPs, and materiel requirements. The goal is to protect warfighters from the spread of infectious disease and maximize fleet readiness by providing the foundation for this isolation and quarantine capability. Once achieved, warfighters will benefit from safe and effective SIQ capabilities that protect them from exposure to infectious diseases.

Figure 3. 100819-N-7282P-001 SAN DIEGO (19 August 2010) Sailors aboard the amphibious assault ship USS *Makin Island* (LHD 8) transport a simulated patient infected with a contagious disease from an experimental isolation unit during a Limited Objective Experiment. The 3rd Fleet sponsored evolution focused on developing new ways to isolate and quarantine Sailors suspected of contracting a contagious disease. (U.S. Navy photo by Mass Communication Specialist 2nd Class Phillip Pavlovich/Released)



Joint Project Manager for Protection Leverages NSWCDD's Systems Engineering and Integration Expertise in New Trail Boss Role

By Jorge Hernandez

When the Joint Program Executive Officer for Chemical and Biological Defense (JPEO-CBD) identified the need for a single point of contact resident within his office to integrate chemical, biological, radiological, and nuclear defense (CBRND) capabilities into major defense acquisition programs (MDAP), the Joint Project Manager (JPM) for Collective Protection and the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) were the first choice.

The JPEO-CBD established the MDAP Trail Boss in response to a 2006 General Accounting Office (GAO) Report. The GAO report found that the integration of CBRND capabilities was not consistent across the nine major weapons systems and platforms reviewed. This inconsistency resulted in duplication of effort and an increased risk to the warfighter due to interoperability issues.[1] The Trail Boss concept ensures consistent integration of CBRND capabilities across the military services by:

- Building partnerships for the integration of technology
- Building consensus for major governance and acquisition decisions
- Being responsible for horizontal integration across the enterprise

In January 2011, the JPM offices for Collective Protection, Individual Protection, and Decontamination converged into a single organization, the JPM Office for Protection. At the same time, the JPM Office for Protection became the MDAP Trail Boss. The MDAP Trail Boss is responsible for facilitating research, development, testing, procurement, operations and sustainment, and delivery of CBRND systems in support of platforms designated CBR mission critical, as well as those requiring CBRND capabilities.

The MDAP Trail Boss focuses on coordinating with the supported program manager early in the acquisition process to ensure that their CBRND capability requirements are adequately addressed in a way that minimizes redundancy of effort across the Department of Defense (DoD) throughout the life cycle of the platform. MDAP supports the development of chemical, biological, radiological, and nuclear (CBRN) concept of operations (CONOPS) for the host platform, which can then be used, along with capability documents and the projected threat, to derive the platform's CBRND requirements. The MDAP Trail Boss is divided into five product areas:

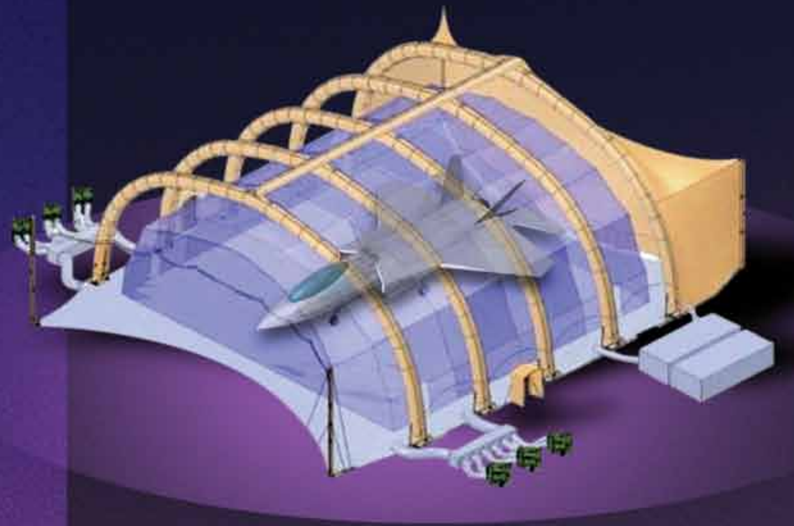
1. Ground Mobile (i.e., ground vehicles)
2. Ships
3. Aircraft (e.g., rotary and fixed-wing)
4. Fixed Site (i.e., buildings)
5. Transportable (i.e., portable shelters and gear worn by the warfighter)

To assist in executing the MDAP Trail Boss responsibilities, the JPM for Protection assigned NSWCDD the role of Director for CBRN Survivability and MDAP Support (currently held by the author). This position is supported by a team of NSWCDD system engineers. This Systems Engineering Team documents the requirements derived from the CONOPS and the program's capability documents, along with the methods to be used to validate these requirements in a Requirements Traceability Matrix. By leveraging the expertise across the JPEO enterprise, the CBRND requirements are then used to identify the total family of subsystems and components from the JPEO-CBD portfolio, which satisfy platform CBRND capability requirements within the platform's cost, schedule, and performance parameters. This family is known as the CBRND capability set (CapSet). For example, the MDAP Trail Boss is working closely with the Joint Strike Fighter (JSF) program to develop a chemical and biological (CB) defense CapSet to meet the program's survivability and force protection requirements (see Figure 1). The JSF Operational Requirements Document (ORD) requires that the aircraft must be designed to facilitate pilot survivability and facilitate decontamination when exposed to CB agents. To address these critical requirements, the MDAP Trail Boss and his partners are developing a CB defense CapSet consisting of a flight mask and an aircraft decontamination system for use in the JSF live fire testing.

The MDAP Trail Boss's use of the systems engineering process ensures consistent application and integration of CBRND capabilities throughout the DoD. This process prevents duplication of effort, assists programs in achieving their CBRN survivability requirements, increases interoperability amongst the various platforms, and affirms that CBRND systems are sustainable throughout the life of the platform. As more platforms integrate CBRND capabilities, the joint force commanders will see a significant increase in CBRND situational awareness, enhancing the Soldier, Sailor, Airmen, and Marines' ability to continue effective operations in the presence of a CBRND threat.

Reference

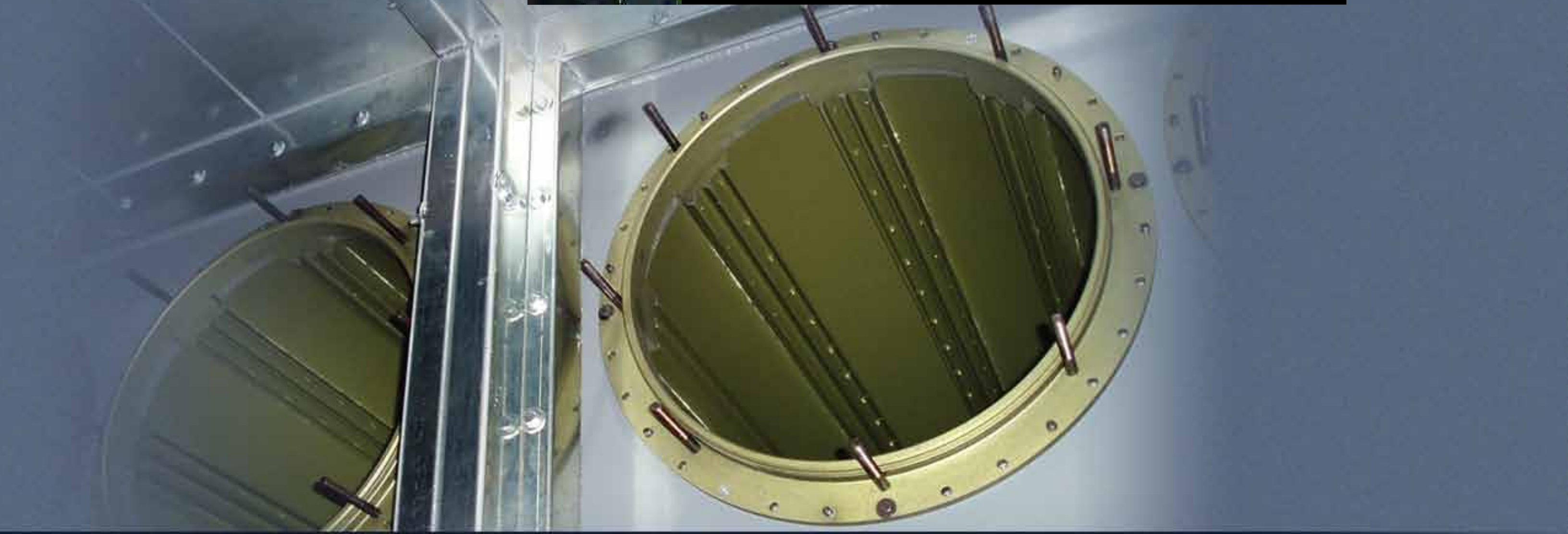
1. *Chemical and Biological Defense: DoD Needs Consistent Policies and Clear Processes to Address the Survivability of Weapon Systems Against Chemical and Biological Threats*, Report to Congressional Committees, GAO report GAO-06-592, April 2006.



JSF Decontamination System

Joint Service Aircrew Mask - JSF

Figure 1. The Joint Strike Fighter Chemical and Biological Defense CapSet



Fixed-Facility Chemical, Biological, and Radiological Defense (CBRD): Protecting Building Occupants From Airborne Threats

By Kevin Cogley and Walter Dzula

Chemical, biological, and radiological defense (CBRD) systems are utilized in many government and Department of Defense (DoD) buildings to protect occupants and equipment from airborne chemical, biological, and radiological (CBR) threats without requiring evacuation or the donning of personal protective equipment (see Figure 1). These systems utilize specialized filtration, detection, notification, and decontamination equipment to provide safe working environments for facilities such as command and control centers, communication nodes, and medical facilities.

Personnel from the CBR Protection and Integration Branch of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) lead multiple CBRD integration projects at DoD and government facilities. These projects have varied from small-scale retrofit efforts to multimillion-dollar construction programs in locations ranging from the Washington, D.C., metropolitan area to facilities overseas in multiple areas of responsibility. Working under the umbrella of the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD), NSWCDD partners with other organizations—including Edgewood Chemical Biological Center, the U.S. Army Corps of Engineers, and other sponsors and programs—to develop and field facility CBRD systems. Working with these partners, NSWCDD personnel develop and field optimal solutions and systems that support critical missions, reduce life-cycle costs, and shape the future of fixed-facility CBRD.

Facility CBRD System Design

Effective CBRD systems in facilities provide a significant level of protection for building occupants against internal and external threats. These systems range from robust architectures that ensure mission continuity to low-impact design changes that increase protection and support evacuation. They also affect the long-term impact of restoration after an attack, as CBRD systems can reduce the spread of contaminants in a facility, reducing the time and cost of remediation.

In 2008, the DoD published Unified Facilities Criteria (UFC) 4-024-01, *Security Engineering: Procedures for Designing Airborne Chemical, Biological, and Radiological Protection for Buildings*.[1] This document, developed by the U.S. Army Corps of Engineers

Figure 1. Artist's Rendering of a Notional Government Facility With Integrated CBRD Systems

with the support of other DoD activities including NSWCDD, provides minimum criteria and design guidance for facility CBRD systems. UFC 4-024-01 is intended for building owners, antiterrorism/force protection (AT/FP) specialists, and architects and engineers to ensure that facilities include equipment and design elements to protect against CBR threats. The document focuses on systems that provide occupants with protection for mission durations of days to weeks, as well as low-cost measures that can be implemented at any facility to provide some level of protection for occupants. The measures described in UFC 4-024-01 include enhanced measures beyond those described in another DoD document, UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*.

The CBRD systems implemented at most mission-critical facilities include:

- Equipment to provide for the collective protection of occupants
- Detection of threats inside and outside the facility
- Means to decontaminate personnel

Facility collective protection systems provide contaminant-free areas within a facility, enabling personnel to move about freely without individual protective equipment. These systems include air filtration using military-grade carbon and high-efficiency particulate arresting (HEPA) filters, which remove chemical and biological agents, radiological particles, and many toxic industrial chemicals (see Figure 2). Collectively protected spaces are maintained at an overpressure (generally less than 0.5 inches water gauge (inwg)) with respect to surrounding areas; such low overpressures reduce the fan and filtration equipment costs and are generally unnoticeable to the general public. Detection systems must be capable of detecting threats in low quantities in the air. These detectors are often located at intakes and interior areas such as corridors and lobbies. Additionally, detectors may be located in fixed positions around the facility perimeter, providing an early-warning standoff detection capability. Facility missions with a requirement to in-process personnel during a CBR event also incorporate entry decontamination. These solutions range from stand-alone systems that can be expediently set up to fully integrated decontamination stations permanently installed in a building.

Although the measures discussed can present a significant capital and sustainment cost, relatively simple modifications, such as those listed in UFC 4-010-01, can greatly increase its protective posture. One such modification is the location of

Figure 2. CBR Collective Protection Filter Housings Installed in a Facility

a building's outside air intake. Consider that many airborne threats are heavier than air and collect in low-lying areas. Shifting facility air intakes to the highest possible point will greatly reduce the potential for contaminants to enter the building's airstream. Second, many facilities utilize air shutoff switches located in lobbies and public areas. When an airborne threat is identified, activation of these switches can rapidly shut down the building's outside air supply, thus allowing facility occupants to shelter in place until the threat has passed. Finally, extensive sealing of a building's envelope is being widely adopted in both the government and commercial sectors. By reducing air leakage through walls, windows, and roofs, two benefits are realized:

1. The building is better suited to block the infiltration of airborne threats.
2. Energy efficiency is increased by limiting the loss of conditioned air.

A widely used target for envelope leakage is 0.25 cubic feet per minute of air per square foot of envelope area (CFM/ft^2) at 0.30 inwg of overpressure—a significant improvement when considering that many buildings today have envelope leakage rates of 1.0 CFM/ft^2 and greater.

Challenges and Opportunities

Facilities present a significantly different operating environment from traditional military CBRD platforms such as ships, shelters, and vehicles. Facilities also pose unique challenges to system designers, as well as opportunities not available in other systems.

First, consider the challenge of protecting the wide array of personnel that occupy a given protected facility. In most government or DoD buildings, occupants range from military personnel with extensive experience and training in crisis management and operation in CBR environments, to civilian and contractor personnel who may not have similar education or background, to visitors and guests who may not have any familiarity at all. Moreover, facility populations will vary throughout the day.

Second, consider the tenant-landlord arrangements being implemented today as part of a service-based approach at many installations, which can present conflicts between building operators and tenant missions regarding CBRD requirements. System designers and operators must take into account the static nature of facilities. Unlike other platforms, such as ships and vehicles that can move to avoid a threat, buildings are fixed in location.

Finally, consider that many facilities that house critical missions are high-profile and are often in the public eye. This high-profile visibility increases the probability of an attack and necessitates taking measures to ensure that protection systems remain invisible and seamless within the facility.

The unique nature of fixed facilities also can present opportunities for CBRD systems. CBRD systems can benefit greatly from the mature building construction industry, as products and methods are often developed in industry that can be applied to building CBRD systems. Additionally, the pharmaceutical, clean room, manufacturing, and nuclear markets significantly overlap with CBRD and frequently develop dual-use products that can be used in building protection systems.

Need for System Integration

Traditionally, fixed-facility CBRD efforts have been highly compartmentalized, with each function (such as collective protection, detection, or decontamination) focusing only on its respective area (see Figure 3). In these cases, the equipment and systems did not communicate, interact with, or utilize the functions of other areas. This stove-piped approach often resulted in increased costs due to redundant functions or gaps in protective posture. Building managers were also frustrated by this approach because they had to serve as the general contractors, as well as integrated CBRD subject matter experts for their facilities.

With these issues in mind, the integration of subsystems into the overall protective strategy for the building is critical. Thus, a systems engineering approach ensures that the protection system meets the mission needs and that the integrated solution is greater than the sum of its parts. Integration teams must consider materiel solutions, as well as the development of concept of operations, sustainment, and training. This systems engineering effort must focus on developing an integrated architecture that utilizes components or subsystems to provide CBRD. Integration is complex and requires expertise in engineering design, systems engineering, and operational planning.

The need for integration of CBRD in fixed facilities becomes critical as major programs address CBR survivability requirements for fully integrated weapons systems. NSWCDD is home to the office of the Product Director, Fixed CBR Survivability (PD-FCS) within the Joint Project Manager for Collective Protection (JPM-ColPro), one of nine

Figure 3. Typical Fixed-Facility Command and Control Center

JPMs reporting to the JPEO-CBD. The PD-FCS serves as the lead for fixed-facility CBRD efforts throughout the DoD, including coordination between partner agencies, development of design guidance and practices, and oversight of development and integration efforts.

Path Forward for Fixed-Facility CBRD

Solutions for future fixed CBRD systems must balance the need for increased protection for building occupants, while considering the long-term cost and impact of these systems. Key areas of interest to the user community include:

- Increasing the capabilities of currently fielded equipment and methods
- Developing lower-burden systems that can effectively and affordably protect a wider building population
- Providing opportunities for reduced operations and maintenance cost

These key areas, when implemented in new and existing facilities, offer the potential to significantly impact the future of fixed CBRD. Additionally, efforts are underway to investigate the use of protective architectures and facility heating, ventilation, and air-conditioning (HVAC) systems to mitigate the effect of releases in buildings. These efforts increase building CBRD through the use of detection-based airflow modifications using fans, dampers, and exhaust systems. In these cases, a detector alarm can trigger changes within a facility, such as shutting down air-handling units, activating standby filtration units or exhaust systems, or generating tenant alarms. By automatically implementing measures based on detection triggers, the spread of contaminants inside the building can be minimized. Ongoing efforts by NSWCDD engineers seek to optimize these integrated architectures and field systems in test locations.

Recently, PD-FCS—with Joint Project Manager Guardian (JPM-Guardian)—fielded a low-impact protection system at an installation in the Washington, D.C., metropolitan area. This system operates with outside air systems in low speed (approximately 15 to 30 percent) in normal operations using a variable-frequency drive system, and ramps to full speed in a threat environment. This mode reduces the energy consumption of the fan system during normal operations and is intended to extend the operational life of the CBR filters for several additional years. This system remains under study to determine long-term benefits.

As part of another effort, PD-FCS, with JPM-Guardian, constructed and tested a fixed collective protection test bed intended to evaluate facility design and operation parameters (see Figure 4). As part of this effort, the project team constructed a filtration and air-movement system, and a 1,300-ft^2 test structure with airflow, differential pressure, and

Figure 4. Fixed-Facility Test-Bed Structure in the Test Chamber

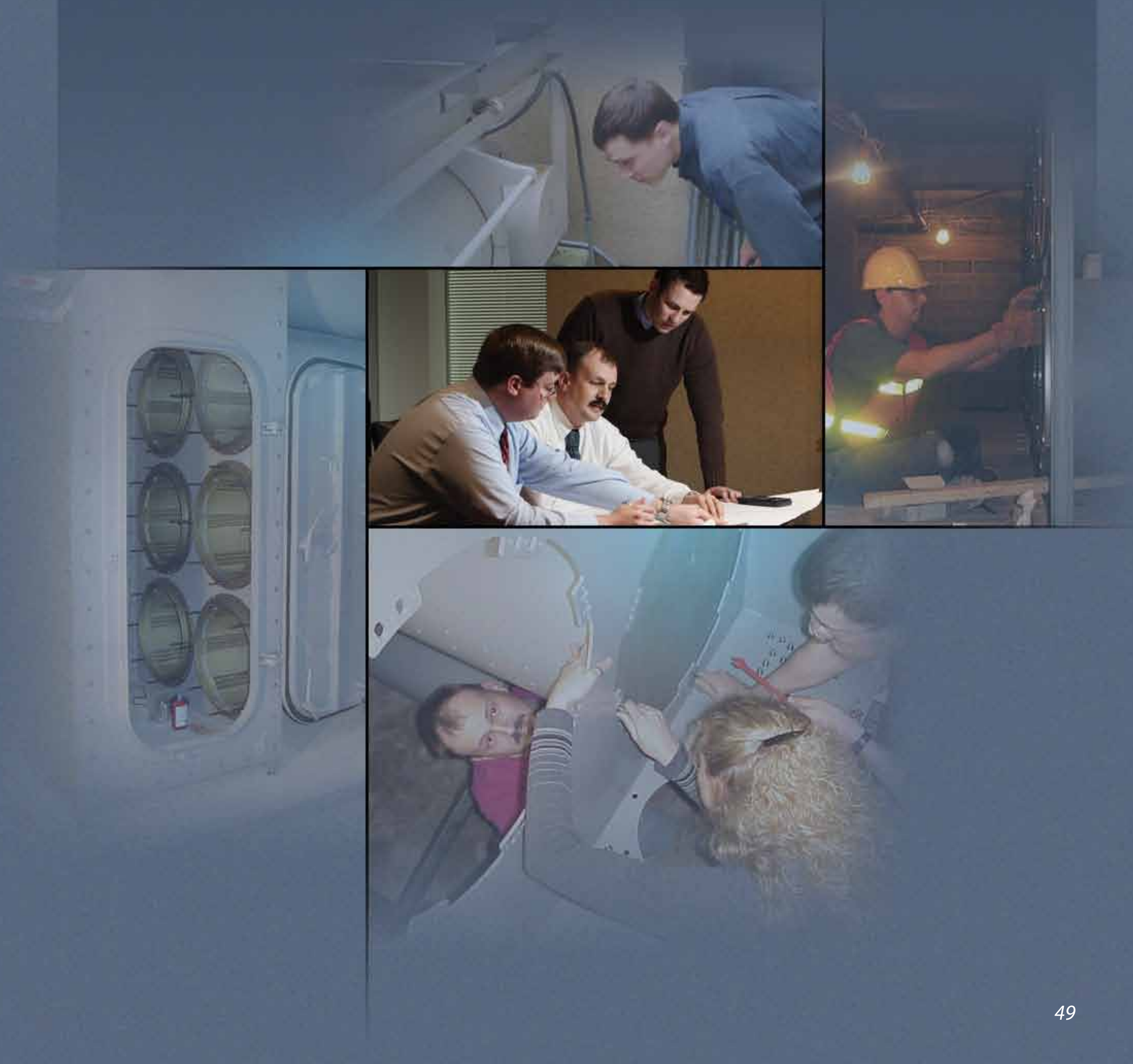
chemical sensors. This package was placed inside a test facility and exposed to an external chemical simulant challenge. During this testing, the overpressure, leakage, and wind speed were varied to determine the impact on building protection. Testing and analyses are ongoing, but results at this point are already proving valuable to system designers. Future testing plans include biological agent testing, additional chemical simulant testing, and experimentation with new architectures and technologies.

Conclusion

CBR and nuclear attacks remain a threat to DoD and government assets, including fixed facilities. Implementation of CBRD systems at these sites can result in sustainment of mission, personnel protection, and reduction of scope and time for postattack remediation. When considered carefully during building design, construction, and renovation, these systems can be implemented with significant effectiveness and relatively minimal impact to tenant operations and life-cycle cost. NSWCDD engineers continue to lead the development, design, and fielding of these critical life-safety systems, and will continue to partner with industry, DoD, and other government agencies to further fixed-facility CBRD.

Reference

1. Unified Facilities Criteria (UFC), *Security Engineering: Procedures for Designing Airborne Chemical, Biological, and Radiological Protection For Buildings*, UFC 4-024-01, 10 June 2008.



Biological Defense Quality Assurance Sample Technical Laboratory

By Andrew Sobota

Following the anthrax letter attacks against Americans in October 2001, a sustained monitoring capability was emplaced for important potential targets of bioterrorism in the National Capital Region (NCR). It also became necessary at that time to establish a capability to rapidly analyze quality assurance (QA) samples for biological defense, as environmental sampling capabilities throughout the NCR highlighted several operational challenges for the Department of Defense (DoD). Screening associated with the anthrax letters of 2001 and other perceived threats quickly forced the DoD gold-standard laboratories—such as the United States Army Medical Research Institute of Infectious Disease (USAMRIID) and the Naval Medical Research Center (NMRC)—away from their mission of routine research and development, and occasional sample analysis, to analytical production facilities. Although available laboratories successfully accommodated the nation's needs, their staffs were inundated as the high volume of samples produced by the NCR sampling effort easily overloaded the laboratories beyond the sampling capacity that these organizations were designed to perform. Moreover, timely analysis within these laboratories was constrained by limited available laboratory space, personnel, and analytical instruments.

In response to these challenges, the Joint Program Office (JPO)—now the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD)—deployed the Dry Filter Unit (DFU) as a sample collection system. The DFU is used to collect aerosolized particles on filters. While some filters can be screened using a hand-held assay (HHA), similar to a pregnancy test, analysis of such a large number of filter samples requires production-level laboratories dedicated solely to the analysis of the filters. The JPO worked with the Pentagon and other government agencies to create a contractor-owned and -operated facility. Midwest Research Institute (MRI) was awarded the contract to operate the NCR laboratory.

NCR Laboratory

The NCR laboratory is one of many laboratories that constantly analyze environmental samples for the JPEO-CBD Lab-QA Program. The NCR Laboratory actively employs a proven and optimized set of standard operating procedures and detection assays transitioned mostly from USAMRIID, a gold-standard laboratory. To provide additional confidence about the quality of the analysis performed within the NCR laboratory, the JPEO-CBD established a QA, testing, verification, and validation program (Lab-QA Program) in 2002 to monitor the performance of the laboratory. Since that time, environmental monitoring expanded to a regional laboratory that supports samples collected for:

- The Installation Protection Program (JPM-Guardian)
- Operations at the Edgewood Chemical and Biological Command (ECBC), Edgewood, Maryland
- Operations undertaken by the National Guard Bureau's Civil Support Teams (CSTs)

The Lab-QA Program is oriented for laboratories utilizing government reagents for routine environmental biological hazard testing but also can provide rapid testing when required. The Lab-QA Program currently exists in two parts:

1. Development and management of the strategy for QA and proficiency test (PT) samples using a Lab-QA Program contractor under the discretionary guidance of the JPEO-CBD.
2. Production and distribution of the QA and PT samples using a quality assurance sample technical laboratory (QA lab). The Lab-QA Program allows the results of the laboratory to be presented with increased confidence that the results are accurate and that standard operating procedures are being followed.

Analytical testing of samples ranges from initial screening using the HHA to more comprehensive laboratory analysis utilizing real-time polymerase chain reaction (PCR) and/or electrochemiluminescence (ECL) immunoassay techniques. These techniques assist in determining the presence or absence of a particular threat. Figure 1 shows a scientist operating the BioVeris M1M, which is used for ECL to detect bacteria, viruses, and toxins/proteins.

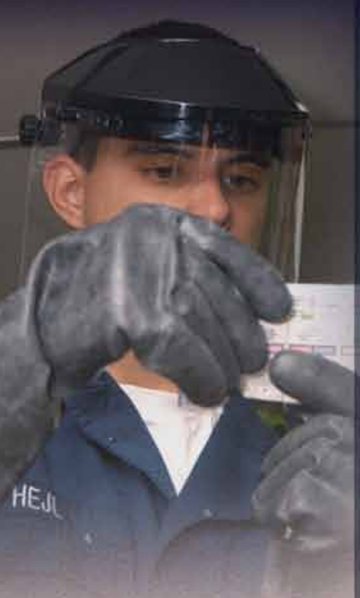
A major facet of establishing and maintaining the credibility of an analytical laboratory is the ability of the laboratory to detect samples spiked with known inactivated targets at a known concentration. QA samples serve as the positive and negative controls that are required for the validation of any laboratory experiment. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) serves as the QA lab for the Lab-QA Program. The QA lab prepares the sample blanks and spikes used by the analytical laboratories for routine analysis, PT, and special studies, as determined by the JPEO-CBD. The sample spikes contain inactivated biowarfare threat agents supplied by the Critical Reagents Program (CRP). The QA samples are designed to evaluate whether or not the analytical laboratory meets the JPEO-CBD's expectations for long-term false-negative and false-positive rates. The QA sample results generated must meet minimum statistically relevant acceptability standards, and the analytical laboratory's performance must be consistent with other peer laboratories.

Beyond supporting the Navy, the DoD and the Department of Homeland Security (DHS) recently entered into an interagency agreement specifying that the QA lab will provide QA samples to both agencies on a weekly basis. There are 29 Laboratory Response Network (LRN) laboratories that support the DHS BioWatch Program. During any given week, the QA lab could ship anywhere from 33 to 90 small boxes containing QA or PT samples. The NSWCDD QA lab, therefore, represents an important and integral part of an overall process to help ensure that the American people are protected from the threat of biological warfare attacks.

Figure 1. Scientist Operating the BioVeris M1M Used for Electrochemiluminescence (ECL) to Detect Bacteria, Viruses, and Toxins/Proteins

Field Activity Support to the Naval Treaty Implementation Program

By Matthew J. Hornbaker



The United States is signatory to over 60 treaties and agreements pertaining to arms control, many of which have the potential to impact U.S. Navy and Marine Corps programs. These treaties are important international confidence-building measures that enhance global and regional stability. All U.S. Navy and Marine Corps programs are required to adhere to arms control compliance requirements, obligations, and constraints as an integral part of their planning, acquisition, and operational processes.

The Naval Treaty Implementation Program (NTIP) provides the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN (RDA)) comprehensive support for the oversight of arms control implementation, compliance, and verification. Under the NTIP Compliance Assessment Program (CAP), senior military and civilian personnel assess U.S. Navy and Marine Corps programs to identify and resolve potential arms control compliance concerns. If necessary, NTIP provides inspection planning, preparation, and on-site support.

Chemical, biological, and radiological defense (CBRD) program managers need to maintain heightened awareness of treaties and agreements that pertain to CBRD. The Chemical Weapons Convention (CWC), for example, prohibits the development, production, acquisition, stockpiling, transfer, and use of chemical weapons. The Biological Weapons Convention (BWC) prohibits States Parties from developing, producing, stockpiling, acquiring, or retaining biological agents, toxins, or weapons. The Open Skies Treaty obligates States Parties to accept unarmed aerial observation flights of their national territory using aircraft equipped with sensors and recording devices.

Under the terms of the arms control agreements ratified by the United States, Navy and Marine Corps activities and facilities are candidates for comprehensive, intrusive, international verification inspections. For example, the CWC contains a provision whereby

a State Party can question another State Party's compliance and request a short-notice, on-site inspection, referred to as a CWC Challenge Inspection. In the event of a treaty-related activity—such as a CWC Challenge Inspection or an Open Skies observation flight—NTIP provides assistance to a command, installation, or program. A command is not allowed to deny or delay one of these events. Consequently, scheduled exercises, operations, and tests may be interrupted, delayed, or canceled in order to support the affected activity's compliance requirements. NTIP steps in to help ensure that treaty obligations are met while simultaneously safeguarding national security.

In the event of a CWC Challenge Inspection, NTIP deploys an Assistance Team comprising three integrated teams:

1. Treaty Management Center (TMC) Team
2. Point of Entry (POE) Team
3. Tiger Team

Each of these teams works closely with the facility commander's inspection planning staff for the duration of the event. The TMC functions as the central source of authority and information; it deploys Assistance Team personnel to the affected facility to collect, record, and compile inspection-related information. The POE Team serves as liaison between NTIP and the host command's security office. The Tiger Team facilitates communication, supports preparation activities, and performs analysis of the compliance concern. Figure 1 shows an inspection team preparing to enter an ammunition storage bunker during a CWC Challenge Inspection exercise.

To execute its mission, NTIP utilizes several field activity support offices staffed by personnel from the:

- Naval Air Weapons Station (NAWS), China Lake, California
- Naval Surface Warfare Center, Dahlgren Division (NSWCDD), Dahlgren, Virginia
- Naval Surface Warfare Center Indian Head Division (NSWCIHD), Indian Head, Maryland

Field Activity personnel assist NTIP by providing equipment and subject matter expertise to support NTIP Tiger Team training exercises and stand by to support in the event of a Challenge Inspection.

Figure 1. An Inspection Team Prepares to Enter an Ammunition Storage Bunker During a CWC Challenge Inspection Exercise

NAWS China Lake is a Navy-operated, airborne weapons testing and training range located in California at the southeastern base of the Sierra Nevada Mountains. NTIP support personnel in China Lake comprise the Non-Strategic Treaty Coordination Office. They are organizationally aligned with the Naval Air Warfare Center, Weapons Division (NAWCWD), a NAWS China Lake tenant command. The Non-Strategic Treaty Coordination Office is positioned to serve as an "Advance Team" to support NTIP activities on the West Coast by arriving prior to the main NTIP Assist Team to initiate coordination efforts. The Non-Strategic Treaty Coordination Office maintains a backup of NTIP's two critical treaty support systems: Treaty Information Management System (TIMS) and the Treaty Library System (TLS). The team also conducts regular Open Skies, CWC, and CAP training and outreach efforts to ensure that research, development, test, and evaluation (RDT&E) personnel and acquisition program managers understand their arms control responsibilities.

NSWCDD is a premier RDT&E center, specializing in integrated warfare systems, weapons and ammunition, sensor systems, directed energy, and asymmetric defense systems.

The NTIP support team at NSWCDD is attached to the Chemical, Biological, and Radiological (CBR) Defense Division within the Asymmetric Systems Department. The CBR Defense Division is the U.S. Navy's lead laboratory for nonmedical CBRD activities. NSWCDD's NTIP personnel primarily support the Tiger Team in the area of sampling and analysis of materials found at an installation. They assist the self-monitoring, base escort, and base preparation teams as needed. NSWCDD supports NTIP annual data calls by capturing program details for all NSWCDD programs involving chemical, biological, riot control, or nonlethal defense capabilities. The team also conducts arms control training efforts to educate management and the workforce about treaty considerations and obligations affecting their programs.

NSWCIHD provides RDT&E and in-service support of energetic materials for warheads, propulsion systems, ordnance, pyrotechnic devices, and fuzing for Navy, joint forces, and national sponsors. The Treaty Support Branch of NSWCIHD provides technical, administrative, and logistical support to NTIP. The TIMS (see Figure 2) used by the NTIP Assistance Team to help to plan inspections and monitor perimeters, sites, buildings, and inspection progress, was developed by the Treaty Support Branch. NSWCIHD maintains facilities and equipment to serve as a backup TMC should NTIP offices be unavailable. Much of the work at NSWCIHD is focused on chemicals, propellants, explosives, and special weapons support. This makes the site uniquely positioned to provide comprehensive training opportunities.

Effective international arms control measures enhance national security in a number of ways. Increased transparency among nations about the size, composition, and operations of their military forces can reduce incentives and opportunities to attack; these agreements can also be used to build confidence and trust among historic adversaries. The direct result is fewer regional conflicts that can escalate to involve U.S. forces. In an era of declining defense budgets, arms control agreements stretch Pentagon dollars and complement U.S. force structure objectives by placing limits or restraints on U.S. and other nations' activities. Finally, slowing or preventing the spread of CBR weapons and delivery systems reduces the likelihood that they will be acquired by terrorist organizations, thus reducing the threat to the U.S. homeland.

The comprehensive oversight of arms control implementation, compliance, and verification that NTIP provides is an invaluable component of our nation's defense. NTIP team members within the field activities provide technical expertise, as well as guidance and clarification on efforts involving the use of chemical, biological, nonlethal, and riot control materials. Field activity support teams routinely participate in NTIP training exercises to ensure the NTIP Assistance Team maintains a high level of readiness and proficiency to assist Navy and Marine Corps installations. NTIP support personnel at the field activities are committed to ensuring the U.S. remains in compliance with all treaties and agreements while simultaneously safeguarding our nation's fielded and emerging technologies.

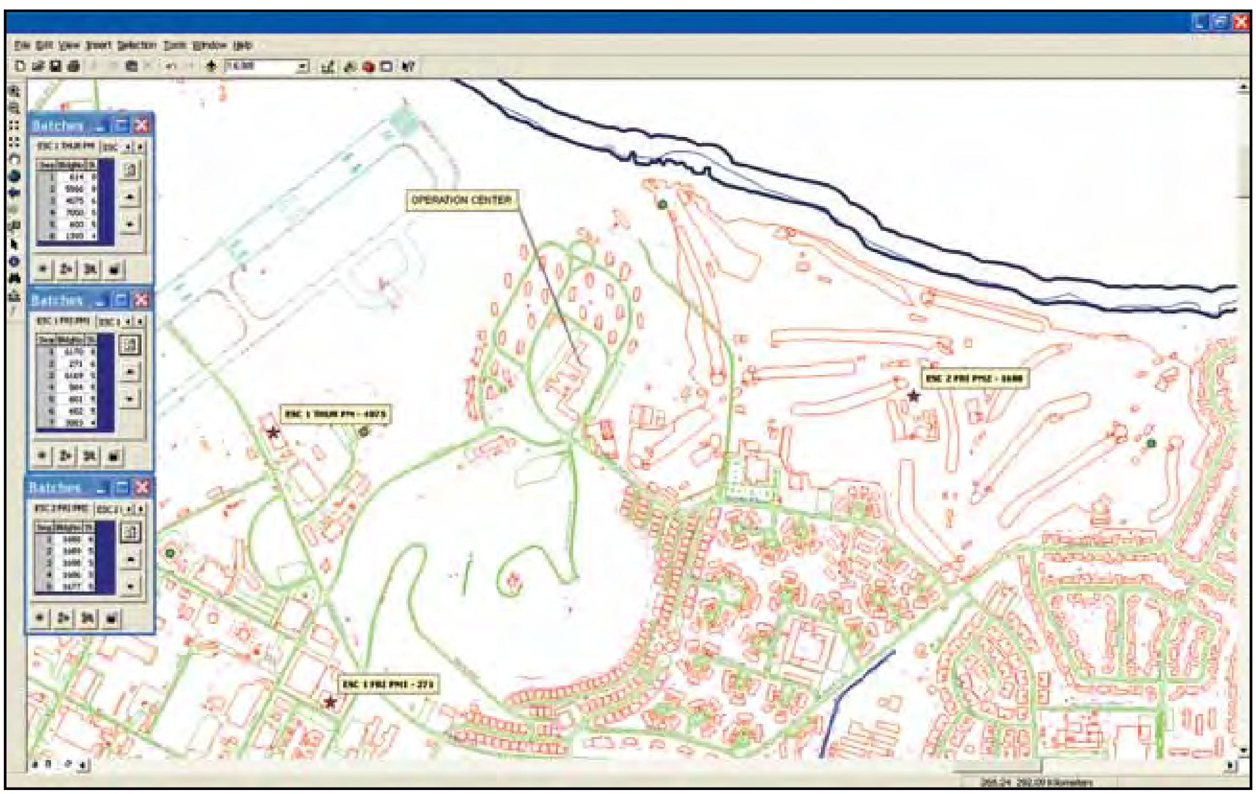


Figure 2. Inspection Tracking Using the Treaty Information Management System (TIMS)

Is Your Program Arms Control Compliant?

By Angela Mersiowsky

All Department of the Navy (DON) activities and programs are required to be compliant with international arms control treaties and agreements.[1] These programs, projects, and/or activities run the gamut from basic bench-top research—such as chemical and biological decontamination and detection technology—to weapon systems, delivery platforms, and dual-use technologies. The program, project, activity manager, or principal investigator is responsible for ensuring that his or her program, project, and/or activity has been reviewed for arms control compliance. Program information is reviewed by arms control treaty experts at the Naval Treaty Implementation Program (NTIP) office. To determine arms control compliance, program information is compared and assessed against all applicable treaties in which the United States is a signatory, as well as U.S. policies. Anytime a Navy or Marine Corps equity is involved, no matter which branch of service or government agency has the lead on the program/project, the DON has an arms control compliance obligation to ensure its participation is arms control compliant. Acquisition practitioners, requirements officers, and operational planners should apply proven acquisition and operational business practices by integrating the NTIP into the risk management process and mitigation plans. Issues of a potential compliance concern, if not addressed and resolved early, can have serious, programmatic cost ramifications, program cancellation, or allegations of violating binding international agreements. All DON stakeholders are responsible to ensure that work performed, regardless of the program sponsor, has been reviewed for arms control compliance and received an arms control compliance certification by NTIP. Program, project, activity managers, or principal investigators cannot self-certify.

Who Reviews the Programs?

All systems developed or acquired by DON shall be reviewed by the Director, Strategic Systems Programs (SSP) via the NTIP Office, with the advice of the SSP Office of General Counsel (OGC), to certify compliance with arms control agreements.[2] NTIP is assigned the responsibility for coordinating DON (U.S. Navy (USN)) and U.S. Marine

Corps (USMC)) implementation and compliance for designated treaties worldwide. NTIP supports all DON organizations with expert arms control implementation and compliance assistance. The Compliance Assessment Program staff conducts comprehensive compliance assessments of USN and USMC programs, which consider over 40 treaties and agreements, as well as U.S. policy, statutory, and regulatory obligations at no cost.

How Does a Program Obtain an Arms Control Certification?

The Naval Surface Warfare Center, Dahlgren Division (NSWCDD); the Naval Surface Warfare Center, Indian Head (NSWCIH); and the Naval Air Weapons Directorate, China Lake (NAWDCL) are NTIP Field Activities. A program, project, activity manager, or project lead can submit acquisition programs, research and development projects, concepts of operation, and exercises in need of certification to the on-site treaty point of contact (POC) located at one of the designated field activities or directly to NTIP. NTIP field activity POCs help to ensure that all appropriate program documentation is current and technically descriptive. Program documentation can be in the form of statements of work, white papers, articles, and even scientific abstracts, etc. NTIP conducts arms control compliance assessments (ACCAs) at every stage of the acquisition life cycle (see Figure 1), as it is a requirement for each milestone review.

What Is the Compliance Assessment Process?

The compliance assessment process consists of a thorough review of current technical/descriptive program documentation from NTIP and SSP OGC against arms control treaties, agreements, U.S. statutory regulations, and policy documents to determine arms control compliance. If causes for concern are identified, the program manager is consulted, and the program, project, or activity may be presented to the Naval Arms Control Review Board (NACRB). Members of the NACRB include representatives from Headquarters Marine Corps, Secretary of the Navy, Chief of Naval Operations, Judicial Advocate General, and Naval Criminal Investigative Services. If the NACRB endorses the NTIP assessment conclusion, they may recommend that the program be presented to the appropriate Treaty Manager at the Office of the Secretary of Defense, Acquisition, Technology, and Logistics (OSD (AT&L)), who will convene the Compliance Review Group (CRG). The CRG makes the final compliance decision on programs that raise a reasonable compliance concern. If there are no causes for concern, the program is certified compliant by NTIP. A depiction of the compliance assessment process is shown in Figure 2.

The treaty field activity POC or NTIP tracks the progress of the compliance assessment review and coordinates with the program, project, or activity. In the case of classified programs, NTIP personnel are appropriately cleared and have access to Secret Internet Protocol Router Network (SIPRNET) accounts and other classified electronic means in order to accommodate receiving documentation.

For more information about the Compliance Assessment Program, visit NTIP online at www.ntip.navy.mil. You can also reach NTIP by telephone at 888-867-5880.

References

1. *Implementation of, and Compliance with, Arms Control Agreements*, USD(AT&L), Department of Defense Directive (DODD) 2060.1, 9 January 2001.
2. *Implementation and Operation of the Defense Acquisition System and the Joint Capabilities Integration and Development System*, Secretary of the Navy Instruction, SECNAVINST 5000.2D, 16 October 2008.

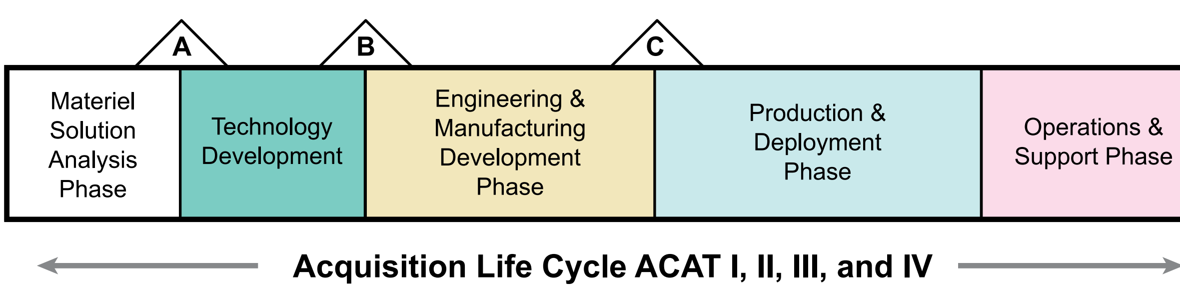


Figure 1. Arms Control Compliance Assessments (ACCAs) and certification are conducted throughout the entire acquisition life cycle; certification is required at each milestone.

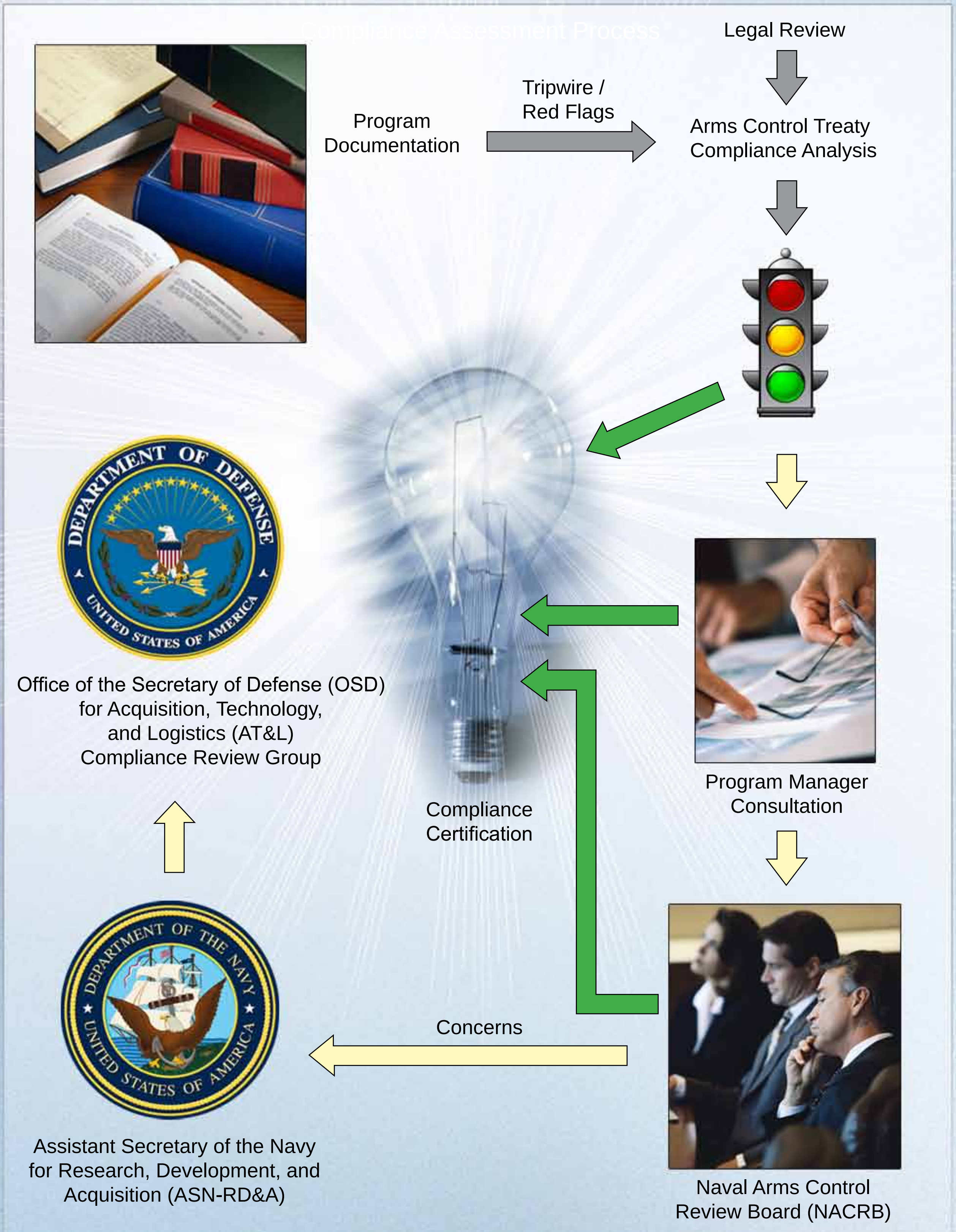


Figure 2. Depiction of the Compliance Assessment Process

Homeland Defense Partnerships: Major City Fire Departments Reach Out to Shipboard Collective Protection Expertise

By Richard Warder

The magnitude of the September 11, 2001, terrorist attacks on the World Trade Center and the Pentagon opened the nation's eyes to homeland defense challenges never before encountered. In the aftermath of the attacks, the difficulties experienced by first responders exposed numerous capability gaps and vulnerabilities, especially for city fire departments.

The attacks also intensified the concern over the possible terrorist use of weapons of mass destruction (WMD) in U.S. cities. Some major city governments—given fire department readiness levels—identified emergency services capability shortfalls that likely would be encountered before, during, and after a chemical, biological, radiological, or nuclear (CBRN) event. The Seattle Fire Department (SFD) and the Fire Department of New York City (FDNY) were the first to field capabilities upgrading their CBRN readiness posture by the acquisition of new fireboats with a collective protection system (CPS).

Shipboard Collective Protection System (CPS)

A shipboard CPS generally operates full time and is seamlessly integrated with a ship's heating, ventilation, and air-conditioning system. The CPS provides protected areas within airtight, controlled boundaries, referred to as a citadel. High-pressure fans, coupled with special CBRN filters, provide a continuous, contaminant-free environment within the citadel. The CBRN filters capture or neutralize harmful CBRN particulates, liquids, and vapors prior to the air's entry into the citadel. Additionally, the high-pressure fans keep the citadel at an increased pressure over that of the exterior ambient conditions, which prevents contamination from entering the protected areas. An overview of a CPS is shown in Figure 1.

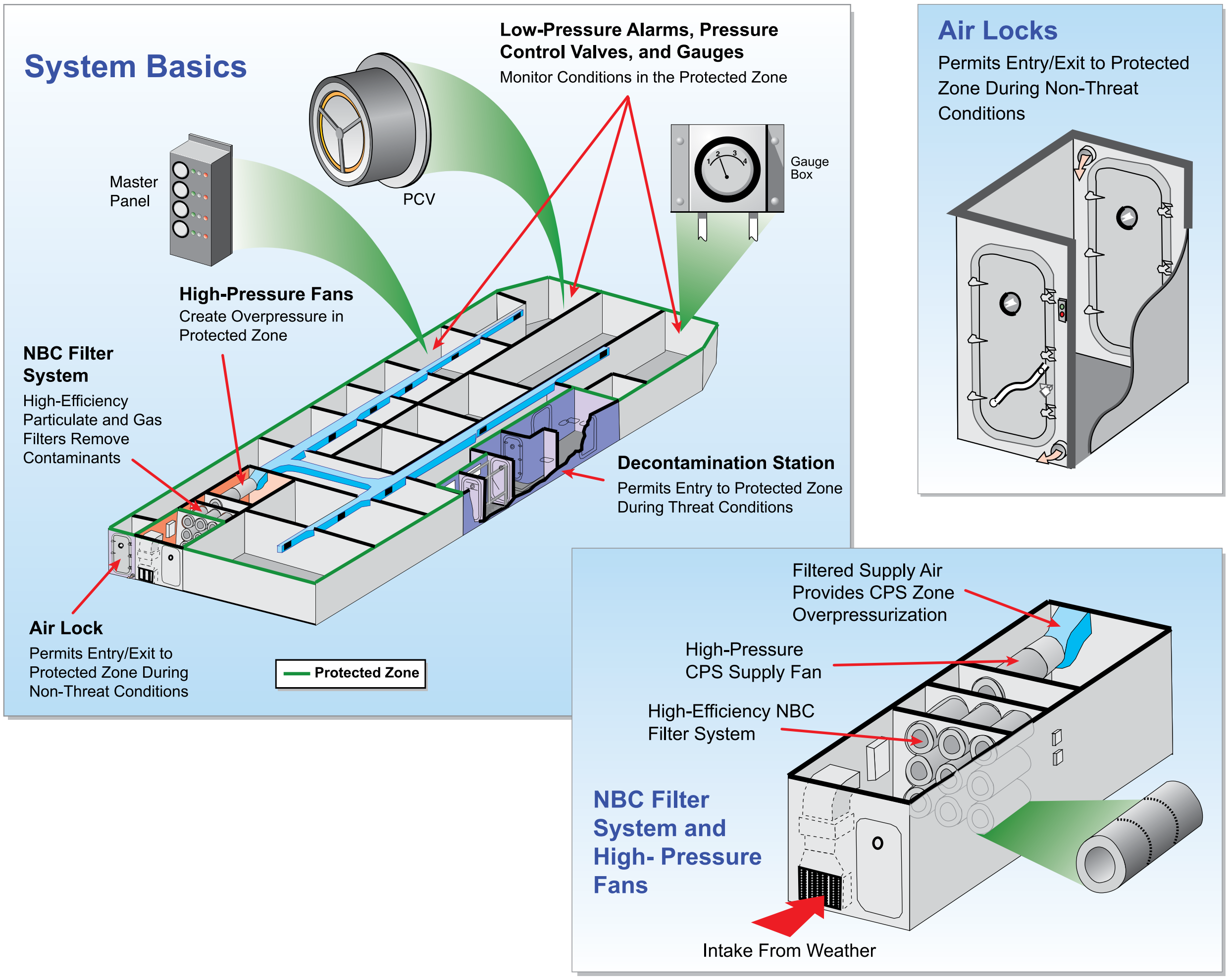


Figure 1. Overview of a Collective Protection System

Controlled access to the citadel via air locks and decontamination stations prevents the ingress of contamination and allows personnel to move in and out of the protective areas. Thus, CPS allows firefighters to perform their duties more effectively and efficiently while not hindered by cumbersome personal protective equipment (e.g., masks, suits, gloves, and boots). A decontamination station is included in case firemen have been exposed to contaminants outside of the protected areas. A decontamination station and shower is shown in Figure 2.

In 2007, the SFD received two new fireboats to upgrade their maritime firefighting capability. The new fireboats were outfitted with a CPS capability, the first such system fielded to a local government's fire department. The SFD contacted the Joint Project Management Office for Collective Protection (JPMO-ColPro) and requested technical assistance for this new capability. SFD leadership realized that specialized assistance was needed to ensure that firefighters understood the proper operational and maintenance requirements for the new system.

The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) Chemical, Biological, and Radiological Protection and Integration Branch engineers and other Navy shipboard CPS experts met with SFD's Captain Chris Dahline and Chief Engineer Dick Chester to address the fireboat's CBRN system. NSWCDD engineers assessed the fireboat's systems and provided operational, maintenance, and performance feedback to fire department personnel. The Fireboat *Leschi* is shown in Figure 3.

Concurrently in 2007, the FDNY was in the planning stages to acquire two new fireboats with the same CBR capability as the SFD. Since the FDNY had no prior experience fielding these specialized systems, the FDNY requested the advisement of NSWCDD CPS subject matter experts and contracted NSWCDD as the technical advisor for the CBRN system acquisition for their new

Figure 2. Decontamination Station and Shower Aboard the SFD's Fireboat *Leschi*

Figure 3. The *Leschi*, built in 2007, is a 108-foot fireboat that can shoot 22,000 gallons of water per minute and travel at 14 knots.

fireboats. In discussions about shipboard CPS, Battalion Chief Jim Dalton remarked,

> "In the future, the FDNY fireboats may encounter the same threats as the U.S. Navy…I want on my boats the same CBRN system design as the U.S. Navy."

During 2007, at the Joint Chemical-Biological Decontamination and Protection Conference and Exhibition, FDNY Battalion Chief Ed Bergamini remarked in his address to conference attendees,

> "I am a fireman but I know where we are lacking. I needed engineering and technical support to help solve my problems, and for that I went to the experts at JPMO-ColPro and NSWCDD for their expertise and knowledge."

Subsequently, FDNY's first fireboat, *Three Forty Three*, was commissioned in May 2010, and the second fireboat, *Fire Fighter II*, was commissioned in December 2010. The partnership fostered between the FDNY and NSWCDD serves as a model for how the Department of Defense's expertise can transition to meet the needs of homeland defenders and first responders. Fireboat *Three Forty Three*—named in honor of the 343 firefighters who perished on September 11, 2001, in the terrorist attack on the World Trade Center—is shown in Figure 4.

New threats to homeland security require special equipment and procedures to ensure that the nation's first responders are well-equipped to handle any emergency. As was learned from capability gaps identified following the September 11, 2001, attacks, civilian first responders must be prepared to operate in dangerous CBRN environments. In working to close these gaps, collaborative relationships between the Department of Defense and civil support agencies facilitated the development and fielding of unique protection systems and the training of first responders necessary to protect citizenry in the event of a CBRN event. As a result, the SFD and FDNY are now equipped with the best CBRN protection systems available and are well prepared to meet CBRN challenges.

Figure 4. FDNY Fireboat *Three Forty Three*

Chemical and Biological Detection for the Fleet

By Daniel C. Driscoll

Today's warfighter is faced with a broad spectrum of threats ranging from conventional battlefield weapons commonly associated with armies or fleets fighting "force on force" battles, to asymmetric threats more likely to be employed in terrorism or guerilla warfare. Of these latter threats, weapons of mass destruction (WMD) have captured the attention of the public and the news media in recent years. Ironically, neither of these threats represents anything new from the standpoint of technology; the Department of Defense has been concerned with countering these kinds of threats for decades. The question of how to detect and counter chemical and biological warfare agents goes back to the days of the Cold War. The Soviet warfighting doctrine of that era included plans to make heavy use of both chemical and biological weapons. In response, the U.S. military developed tools, techniques, and procedures to fight in a chemical, biological, or radiological (CBR)-contaminated environment. With the fall of the Soviet Union in 1991, the nature of the threat changed in the sense that massive use of WMDs on the battlefield became much less likely, but the experience of the Gulf War that same year, and the growth of the global terrorist threat in the years since, have demonstrated that the threat remains.

The Historical Chemical Threat: Chemical Warfare Agents (CWAs) and Toxic Industrial Chemicals (TICs)

Chemical warfare can trace its origins to ancient times when toxic fumes from burning vegetation or sulfur were used in siege warfare.[1,2] However, it wasn't until World War I (WWI) that toxic chemicals were deliberately used on a massive scale to at least attempt to affect the outcome on the battlefield. By the end of the fighting in 1918, thousands of deaths and many thousands more injuries—many of which caused permanent disabilities—resulted from the use of mustard gas (H). Many countries, including the United States, continued to manufacture and stockpile mustard agents for decades afterward.[3] Figure 1 shows a battery of dug-in Livens projectors, with one gas shell and its propellant charge shown in the foreground, followed by Table 1, which reflects casualties from gas during WWI.

Figure 1. A Battery of Dug-In Livens Projectors with One Gas Shell and Its Propellant Charge Shown in the Foreground[4]

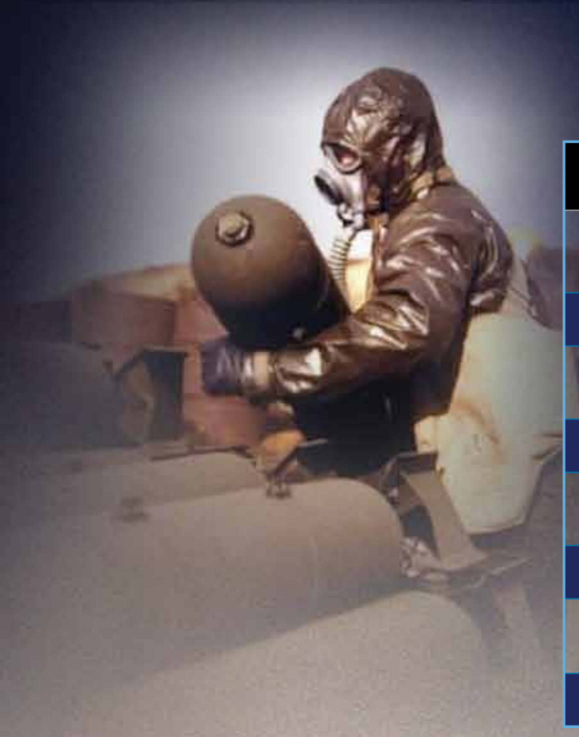


Table 1. Casualties from Gas During WWI[3]

Country	Total Casualties	Deaths
Austria-Hungary	100,000	3,000
British Empire	188,706	8,109
France	190,000	8,000
Germany	200,000	9,000
Italy	60,000	4,627
Russia	419,340	56,000
USA	72,807	1,462
Others	10,000	1,000

During World War II (WWII), German scientists—who began their work in the 1930s looking at organophosphorous compounds for better insecticides—formulated the G-series nerve agents more commonly referred to as "nerve gas." While these were never used, and chemical weapons in general were not employed to any great extent during WWII, nerve agents were recognized to be a potentially very effective weapon. With the onset of the Cold War, nerve agents, together with mustard and later VX (a more lethal form of nerve agent), were stockpiled as the standard chemical weapons arsenal by the United States, the USSR, and their respective allies.

Another class of chemical threats is TICs. While the G and V series nerve agents and mustard are dedicated weapons requiring the resources of a state actor to produce and maintain, TICs, as their name indicates, are industrial products that can be found anywhere in the world where significant industrial activity is conducted. Traditional CWAs are much more toxic than most TICs, but the large quantities of TICS that may be present at an industrial site can still pose a significant threat as tragically demonstrated in the Bhopal, India, disaster in 1984.[5] The Bhopal disaster was an industrial catastrophe that took place at a pesticide plant owned and operated by Union Carbide in Bhopal, Madhya Pradesh, India. Around midnight on 2–3 December 1984, the plant released methyl isocyanate (MIC) gas and other toxins. The official immediate death toll was 2,259; the government of Madhya Pradesh confirmed a total of 3,787 deaths related to the gas release. Others estimated that 8,000 died within the first weeks, and that another 8,000 have since died from gas-related diseases.[5] Whether through accidental release, as in the case of Bhopal, or by deliberate release due to terrorism, sabotage, or collateral damage due to military operations, TICs have the potential to cause significant casualties.

The Historical Biological and Disease Threat

As with the chemical threat, the threat posed by biological agents has its roots in ancient times in siege warfare. Throughout history, attempts have been made to employ disease as an ally on the battlefield, though usually with limited success. Like the chemical threat, the evolution of a significant credible biological threat came in the 20th century and reached a peak during the Cold War. Biological weapons were not used in combat either in WWI or WWII, but during the Cold War, a variety of threat agents were developed and stockpiled. Since the end of the Cold War, with the rise of asymmetric warfare, the biological threat has evolved and remains a threat today.

A compelling measure of the threat posed by biological weapons is reflected in the effects of disease throughout history, which can be traced from the plague of medieval times through the nearly 225,000 deaths by disease among Civil War soldiers[6] and, later, victims of the Spanish influenza outbreak in 1918 that killed more people than were killed during WWI.[7] While weapons were developed and deployed throughout the 20th century, detection technology lagged behind the development of the CWAs, with no significant ability to sense the presence of agents until the 1970s, other than by the smell and the sound the ordnance made when delivered. Not until the arrival of the M8A1 detector and M8 paper (circa 1978), followed by chemical reaction-based detection in the M256 kit,[8] did the warfighter have something more effective than his nose. Just as with the threat posed by CWAs, the fleet must be prepared to protect Sailors from the threat of biological warfare agents, as well as naturally occurring diseases, such as H1N1.

Detection of the Contemporary Chemical Warfare Threat

Chemical weapons today can be disseminated by means of explosive ordnance—such as artillery rounds, missiles, and bombs—or through improvised explosive devices. Aerial sprayers or clandestine spray release are possible as well, though perhaps less likely due to the possible presence of counterfire. Chemical dissemination is also possible through vapor, airborne respirable aerosols, liquid on surfaces, or as contamination absorbed into soil or water. In response, detectors have been developed to detect the presence of chemical agents—whether in the immediate vicinity of the users (point detection), remotely, or as standoff detection.

M256 Kit and M8/9 Paper

M8 (or M9) paper is used to detect the presence of liquid chemical agent on surfaces, or the paper can be secured on surfaces to detect the impact of agent droplets. The paper is embedded with chemically reactive dyes, which produce a characteristic color change unique to the kind of agent present when exposed. So, for example, if the M8 paper turns red, that indicates the presence of a blister agent (mustard). If it turns orange to light yellow, that indicates the presence of the G nerve agent (the VX nerve agent will turn it dark green). The M256 kit, shown in Figure 2, is a two-component detector kit: M8 paper and a chemical reagent-based detection sampler that reacts to the presence of chemical agent vapors by producing color changes when the reagent ampoules are broken open and exposed on the sampler card.

The combination of M8 paper and the M256 kit are used on board ships for postattack monitoring and for surveys conducted by damage control teams walking predetermined routes through the ship after an attack. M8 paper can be affixed to surfaces on the exterior of the ship and monitored for color changes to indicate the arrival of aerosols. For vapor exposures, if the M256 sample turns blue for example, that indicates a nerve agent. An intense blue-purple color indicates mustard gas. An olive-drab color indicates lewisite.

Ion Mobility Spectroscopy (IMS)

IMS is a technology used to detect the presence of chemical vapors in air. This is accomplished by ionizing a sample of air drawn into the detector and then analyzing the sample by first ionizing the constituents of air and then measuring the transit time of cluster ions formed in the ionization region across a constant electric field inside the detector in order to determine the mobility of the sample species. Molecules of differing sizes, polarizabilities, and electron affinities will have distinct times to cross the field region, so they produce a characteristic IMS signature. Compared to other analytic techniques, such as mass spectroscopy, IMS is simple, relatively cheap, and can be packaged in a lightweight sensor. For this reason, IMS detectors have been employed for a number of missions, including limited shipboard use. An example of an IMS cell is shown in Figure 3.

The Chemical Agent Monitor (CAM), the Improved Chemical Agent Monitor (ICAM), and the Automatic Chemical Agent Detector Alarm (ACADA) were among the first IMS detectors developed for use by the military. Designed for use by the Army in land-based missions, they have seen Navy use by expeditionary and other ashore activities. The Joint Chemical Agent Detector (JCAD) is in use with deployed Navy units in expeditionary, explosive ordnance disposal, and medical missions. It is employed to survey interior and exterior spaces, surfaces, equipment, and personnel, and provides users with the capability to automatically detect, identify, localize, and alarm to the presence of acute levels of CWA vapors by agent class. In each of these examples, a set of performance requirements must be met while also meeting survivability, reliability, and cost demands within a harsh operating environment. The JCAD is shown in Figure 4.

The Mk 26 Mod 0 Improved Point Detection System (IPDS) is an IMS detector that was developed to monitor the ship's exterior and has been in service with the fleet for over 10 years. As the Mk 26 Mod 0 reached the end of its service life, an Improved Point Detection System – Life-Cycle Replacement (IPDS-LR) was selected. Testing was completed as planned in 2010, and installation of IPDS-LR on Navy ships commenced in late 2011. IPDS is designed to detect the presence of CWAs at the immediate exterior of a ship; IPDS-LR will fill this same mission without loss of performance and with superior reliability and maintainability. A depiction and functional description of the IPDS-LR System is shown in Figure 5.

Figure 2. The M256 Kit shown being used by Soldiers in mission-oriented protective posture gear. The kit, as issued, is shown on the right.

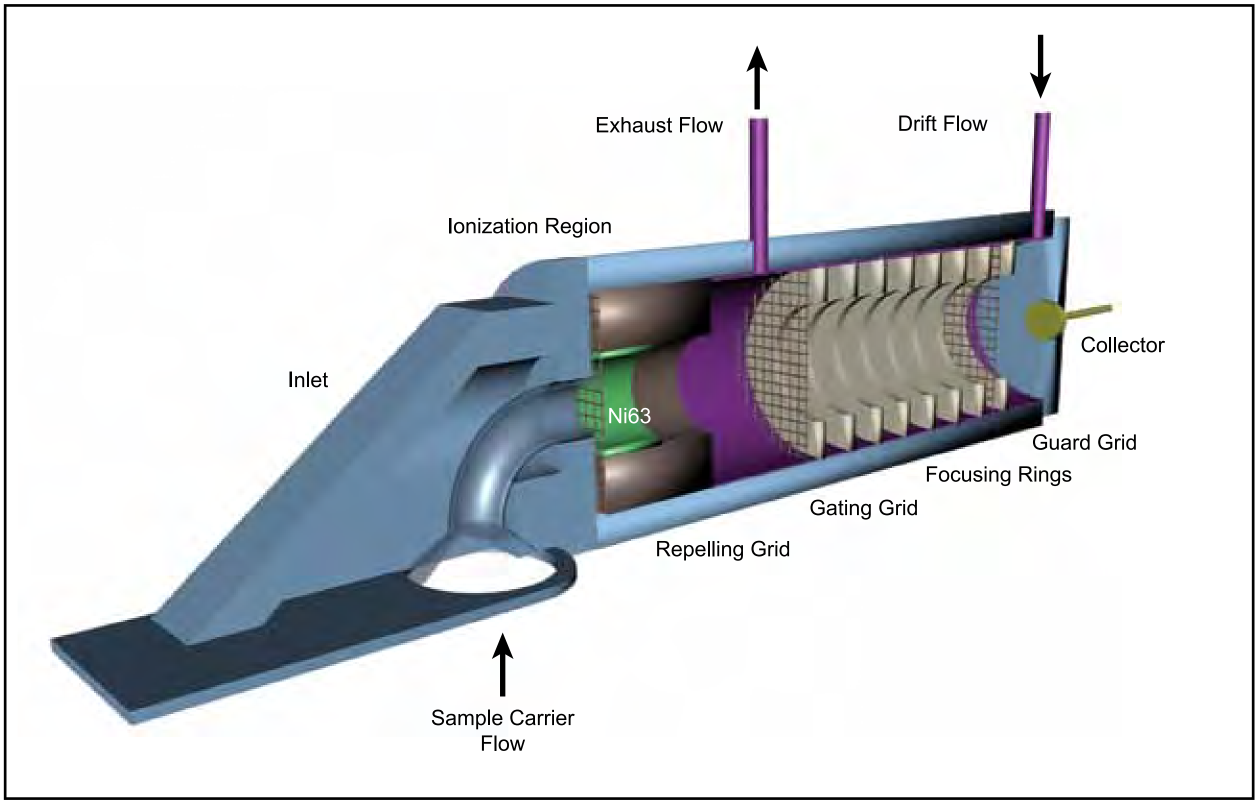


Figure 3. Example of an IMS Cell

Figure 4. Joint Chemical Agent Detector (M4) (JCAD)

Detection of the Contemporary Biological Warfare Threat

Biological threats can be present as either respirable aerosols or in other forms, such as drinking water, or they can be spread by human contact (communicable diseases). Responding to this spectrum of biological threats requires diverse technologies, each tailored to the type of sample to be interrogated and the environment in which it will be used. Three systems that are currently being procured and fielded to the fleet are the Joint Biological Point Detection System (JBPDS), the Joint Biological Agent Identification and Detection System (JBAIDS), and the Joint Chemical, Biological, and Radiological Agent Water Monitor (JCBRAWM), which address the areas of airborne threats, medical/confirmatory, and waterborne threats, respectively. The JCBRAWM and handheld assay ticket are shown in Figure 6.

In addition to the JBPDS, detection of bioaerosols in air is also addressed by the Joint Biological Tactical Detection System (JBTDS) being developed to fill a flexible deployment, surveillance, and monitoring mission currently being covered by

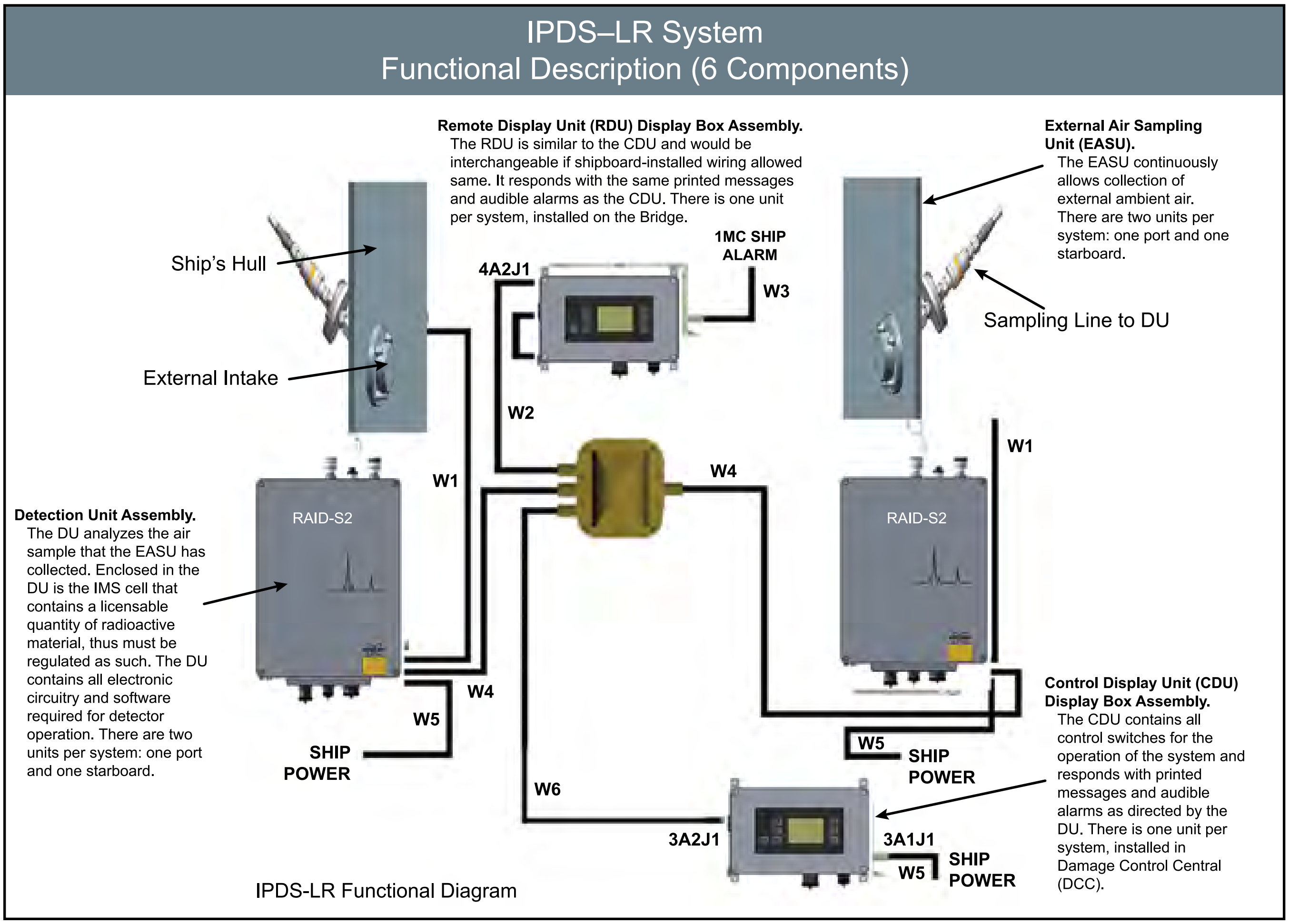


Figure 5. IPDS-LR external air sampling units sample exterior air and transfer it to the detector units (DUs) for analysis. Two exterior points are sampled and alarm/status is communicated to two points in the ship: Damage Control Central and the Bridge.

dry filter units and deployed in the fleet, as well as a number of continental U.S. facilities.

While chemical detection allows for direct interrogation of the target species by a chemical or physical interaction, the more complex nature and larger size of biological species introduces an added level of complexity to biological detection. Each system named above requires that a sample first be collected, and then a separate detection and identification (ID) step—relying on either antibody capture of the agent antigen or genetic amplification (recombinant DNA)—is necessary to make a presumptive or confirmatory detection of the target agent. The JBAIDS and JCBRAWM detectors do not specifically target detection of agents in air. The JBAIDS is a confirmatory detection and ID system that primarily targets medical samples. JBAIDS employs polymerase chain reaction to amplify and identify the genetic material of the target agent. The JCBRAWM interrogates water samples for two biological agents (ricin and staphylococcal enterotoxin B (SEB)) via a hand-held assay antibody ticket and, for gross alpha and beta radiological contamination, by distilling the water sample on a heated planchet, followed by reading with a radiation detection, indication, and computation (RADIAC) device.

Just as with chemical detection, it is desired that remote or standoff detection of biological species in air be available. Additionally, as in the chemical case, the preferred approaches to this problem have been to use optical techniques, such as Light Detection and Ranging (LIDAR), to interrogate suspect aerosol clouds. The Joint Biological Standoff Detection System is in a second increment of development. Unlike the chemical case, direct interrogation of the target by electromagnetic radiation does not permit a species ID. The best that can be done with the current state of the art is a determination of whether the target is of biological origin.

Figure 6. The Joint Chemical, Biological, and Radiological Agent Water Monitor (JCBRAWM) and Hand-Held Assay Ticket

The Way Ahead

The Naval Surface Warfare Center, Dahlgren Division (NSWCDD), working through the Joint Program Executive Office for Chemical and Biological Defense, is developing and fielding a range of systems to address the full spectrum of chemical and biological threats. Beginning with intelligence of an adversary's intentions, and continuing through multiple layers of detection from remote or standoff detection to point detection for both inside and outside the ship, Sailors need to be protected by a robust set of detection technologies addressing a spectrum of chemical and biological threats. Through NSWCDD's participation in the joint program, the Navy is able to leverage other services' development efforts which, together with research, development, and systems engineering, are providing the fleet with a suite of detectors addressing these requirements. Future efforts will enhance this suite of detection capabilities.

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M4 Joint Chemical Agent Detector (JCAD)

By Harold Bannister

U.S. military forces have not experienced direct exposure to chemical warfare agents (CWAs) or toxic industrial chemicals (TICs) in decades despite the fact that a number of nation states possess capabilities for producing and deploying CWAs. Still, adversary countries, non-nation states, warlords, or terrorist organizations may one day deploy CWAs or TICs against U.S. warfighters in the form of a poor man's nuclear weapon. If such a hazardous or contaminated environment were to occur, Navy and joint warfighters will be prepared because of a suite of detectors, including the improved hand-held CWA and TIC vapor detection capability.

Current Detection Capabilities

Current lightweight detectors within the Navy warfighter inventory are the M256 Chemical Paper Kits, the Improved Chemical Agent Monitor (ICAM), and the Automatic Chemical Agent Detector Alarm (ACADA), shown in Figures 1 through 3, respectively.

The M256 kit provides confirmation of the presence of chemical agents. Although the M256 kits are very reliable, they require 30 minutes or more to process a sample. When the warfighter is in need of quick and accurate detection, the alternative is to use the electronic detectors (ICAM and ACADA). Both electronic detectors are currently in use by all U.S. military forces. The ICAM and the ACADA utilize radiological sources and ion mobility spectrometry (IMS), an analytical technique used to separate and identify ionized molecules.

Navy regulations require the tracking of radiological sources, such as the minute quantities found in the ICAM and the ACADA. The radiological tracking process includes an annual inspection, which adds additional overhead cost to the Navy's sustainment. Both the ICAM and the ACADA can detect CWAs and TICs within several minutes, which illustrates the advantage over the M256 kits. The warfighters, however, need faster CWA and TIC detection capabilities. Moreover, they require a chemical detector that is lightweight; accurate; has no radiological source; is able to detect nerve, blood, and blister agents; and produces fewer false alarms.

Joint Chemical Agent Detector (JCAD)

The M4 JCAD is a commercial solution in response to the CWA and TIC agent detection requirements of the Joint Program Executive Office. Weighing in at a little more than 3 pounds, the M4 JCAD is a hand-held, portable, nonradiological source

Figure 1. M256 Chemical Paper Kits

Figure 2. Improved Chemical Agent Monitor (ICAM)

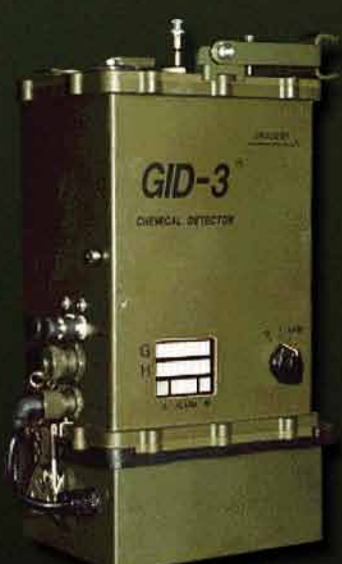


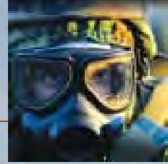
Figure 3. Automatic Chemical Agent Detector Alarm (ACADA)

chemical detector. It uses IMS technology to alert the warfighter of CWA and TIC vapors by drawing air from the surrounding area into an internal chamber where positive and negative charged ions are separated to identify the presence of nerve, blood, and blister agents. Commercial AA batteries power the M4 JCAD, which supports reducing sustainment cost to the warfighter. The M4 JCAD contains no radiological sources like its predecessors, ICAM and ACADA. With no radiological sources, an annual radiological inspection of the M4 JCAD is not required, further reducing the Navy's sustainment cost.

The M4 JCAD provides the warfighter with a detection alarm within seconds vice the ICAM and ACADA response time of several minutes. The JCAD is shown in Figure 4.

The Navy's Explosive Ordnance Disposal, Bureau of Medicine, and Construction Battalions (Seabees) received the first increment of M4 JCADs in March of 2009. By September of the same year, the Navy reached initial operational capability. In the near-term, the Navy will retire the ICAMs and ACADAs and replace them with JCADs as soon as full operational capability is achieved in fiscal year 2011. Equipped with JCAD's capabilities, the warfighter will be better protected, given the more rapid detection times and increased capabilities that JCAD provides in the face of serious chemical agent threats.

Figure 4. Joint Chemical Agent Detector (JCAD)



The Joint Chemical, Biological, and Radiological Agent Water Monitor (JCBRAWM)

By Brian Patrick

U.S. joint forces (JF) need to be able to detect the presence of chemical, biological, and radiological (CBR) contamination under a variety of conditions and circumstances. The Joint Chemical, Biological, and Radiological Agent Water Monitor (JCBRAWM) Program was initiated to enhance the current capabilities by providing an additional portable detection capability for individuals to test water sources. When fully developed and fielded, the JCBRAWM will be used for water treatment monitoring, water distribution monitoring, and water preconsumption situations. It also will be used to determine the presence, quantity, and identification of agents in local water sources (lakes, rivers, creeks, wells, and water purification and distribution points) that JF might encounter. Water treatment monitoring facilities will use the JCBRAWM to verify that the water, before and after processing, does not contain CBR agents at established detection levels. Water distribution monitoring also will use the JCBRAWM to determine if stored or distributed water is contaminated. Detection and identification of biological agents and radiological contamination in water are required to protect forces across the range of military operations (e.g., conventional war, combating terrorism, peace enforcement, and peacekeeping). A soldier on patrol in Afghanistan is shown taking a drink of water in Figure 1. JCBRAWM Increment I provides this capability by augmenting the currently fielded M272 Water Testing Kit. The JCBRAWM Program covers the interval from now through the near future, with future growth possible in later time frames.

The currently fielded U.S. Navy (USN) M272 Water Testing Kit was designed to detect chemical warfare agents (CWAs). It cannot be modified to detect biological agents or radiological contamination. As a result, chemical reconnaissance units; most medical units; or units with a water purification, transportation, and distribution mission can currently detect and identify CWA contamination in water. The detection of biological agents and radiological contamination in potable water historically has been difficult to employ. The JCBRAWM, however, is contributing to the overall biological and radiological defense concept by providing crucial detection, identification, quantification, and warning information about biological and radiological hazards in water prior to distribution to JF for consumption or use. The M272 Water Testing Kit is shown in Figure 2.

The JCBRAWM will be fielded in four increments. Increment 1 will provide for the detection and identification of two biological agents using immunoassays and the detection of gross alpha and beta radiation using components of fielded Radiation Detection,

Figure 1. U.S. Army Staff Sgt. Ricardo Saldana, from Blue Tank, 1st Platoon, Delta Company, 1st Battalion, 4th Infantry Regiment, drinks some water during a patrol in Lamal, Afghanistan, 22 June 2010. 100622-A-8335T-080 (U.S. Army photo by Staff Sgt. William Tremblay/Released)

Figure 2. M272 Water Testing Kit

Indication, and Computation (RADIAC) meters and probes. Follow-on JCBRAWM increments are planned to enhance detection of additional biological, chemical, and radiological agents, to include replacement of the M272 Water Testing Kit and provided inline monitoring capability.

The JCBRAWM Increment 1 kit provides detection capability for two biological agents and gross alpha and beta radiological contaminants in water. The system is provided to the JF in two configurations:

1. M329: Used by the U.S. Army (USA), this all-inclusive kit contains components to sample and monitor water supplies for biological agents and alpha/beta radiation. The M329 kit (NSN 6665-01-560-2158) is intended for personnel with no IM-263 RADIAC meter or the DT-695/PDR-77 beta probe. The M329 JCBRAWM is shown in Figure 3.
2. M330: This is the same kit as the M329 kit, but without the RADIAC meter and probe. This kit, the M330 is designed for use by USN personnel who are already equipped with an IM265/PDQ RADIAC meter and a DT-304/PDR Beta Probe. M330's hand-held assays (HHA), sample collection, and testing components are identical to the M329. The USN also currently utilizes M8/M9 chemical contamination detector paper (not part of the JCBRAWM) to monitor for CWAs on board USN ships; the M272 water monitor is utilized for shore-based activities.

In keeping with USN and JF initiatives to improve overall safety for sea- and shore-based personnel, and to protect the warfighter from contamination after a CBR attack or an inadvertent release of CBR contamination in close proximity to USN and JF commands, the JCBRAWM

Figure 3. The M329 Joint Chemical, Biological, and Radiological Agent Water Monitor (JCBRAWM)

will be operationally deployed to detect biological and radiological water contamination. The M330 JCBRAWM Water Monitor is shown in Figure 4.

Radiological Detection

The radiological detection component of the JCBRAWM Kit consists of a separate RADIAC meter and probe, and is used to detect and identify gross alpha and beta radiation contamination in water. A sample is prepared by placing a known volume of water in a planchet (a small shallow metal container in which a suspected radioactive substance is deposited for measurement of its activity), which is then evaporated (by a heater) to eliminate the masking capability of the water. The planchet containing the evaporated sample is cooled and then tested. The probe is placed directly over the planchet, and a sample count is taken for 1 minute. Prior to testing, the RADIAC meter must be prepared by performing preoperational procedures, a meter response test, and a background count. If the sample count is at least 600 counts per minute greater than the background count, appropriate personnel must be notified so that mitigation procedures can be implemented. The beta probe is sensitive to beta and gamma radiations, so gamma needs to be subtracted. The type of contamination is determined by shielding the sample (using an attenuator) and taking another count. The difference between the unshielded count and the shielded count is the gross amount of alpha/beta radiation contamination.

Biological Detection

The biological detection component of the JCBRAWM is the HHA. Each immunoassay ticket consists of three important functional areas:

1. The Control Area
2. The Detection Area
3. The Sample Well

Each provides the field capability to test two biological agents in water. A water specimen is collected, and several drops of the sample are dispensed into the oval-shaped sample well on the ticket. The water then flows across the paper strip inside the assay assembly. A line should form at the control area indicating that the ticket functioned correctly, and lines may or may not form in the detection area, depending on whether an agent has been detected or not. After 15 minutes, but no longer than 20 minutes, the results are interpreted by observing

Figure 4. The M330 JCBRAWM Water Monitor

and comparing both the control and the detection areas. HHA tickets are shown in Figure 5.

Conclusion

The JCBRAWM is an important joint asset. It allows a ship or shore installation to take on water in an emergency, even if on foreign soil where a terrorist attack may occur. The JCBRAWM will give USN commanders confidence that their Sailors will not fall victim to incapacitating or lethal doses of CBR agents in potable water. The current water testing kit used by the USN was designed to detect CWAs and cannot be modified to detect biological or radiological contamination. The JCBRAWM will provide the USN with the capability to not only detect CWAs, but to also detect two biological agents and gross alpha and beta radiological contamination in a rapid time frame, thus giving commanders better situational awareness. Future variants of JCBRAWM will add more chemical detection capabilities and ultimately replace the existing fielded M272 Water Testing Kit. The JCBRAWM is intended for use by USN and JF during wartime and emergency operations. The JCBRAWM will eventually be fielded to every USN ship, as well as to select shore installations.

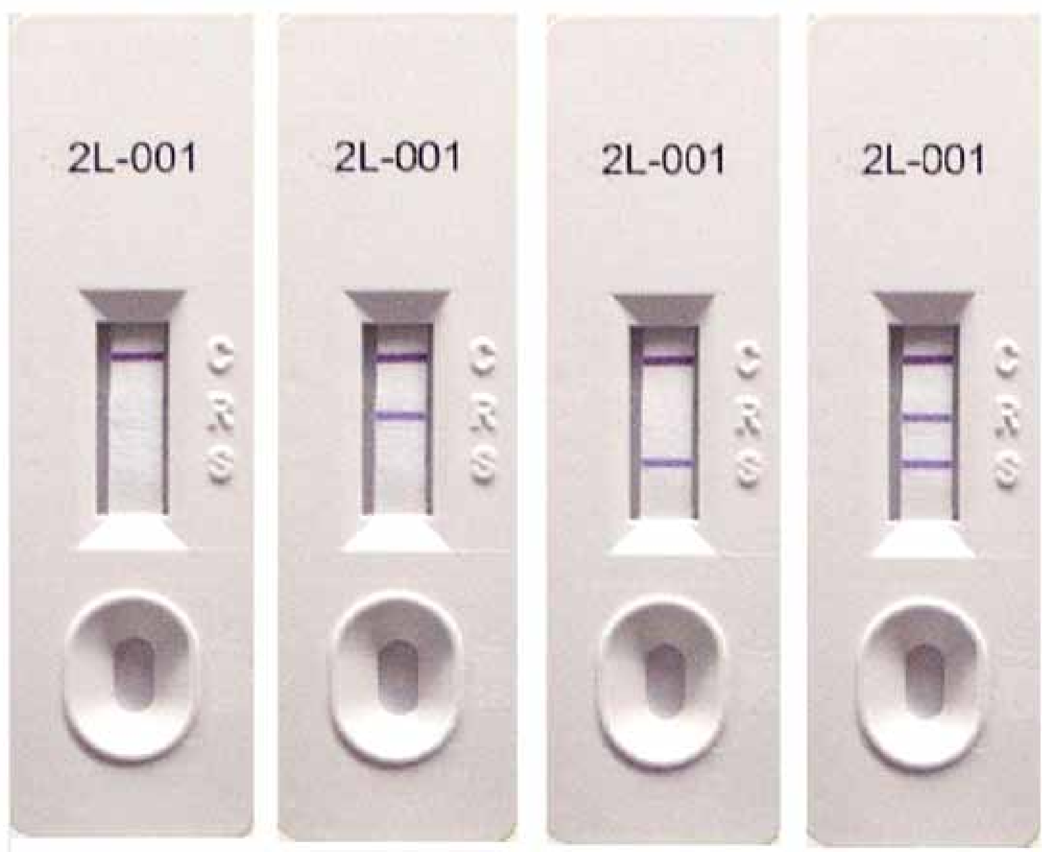
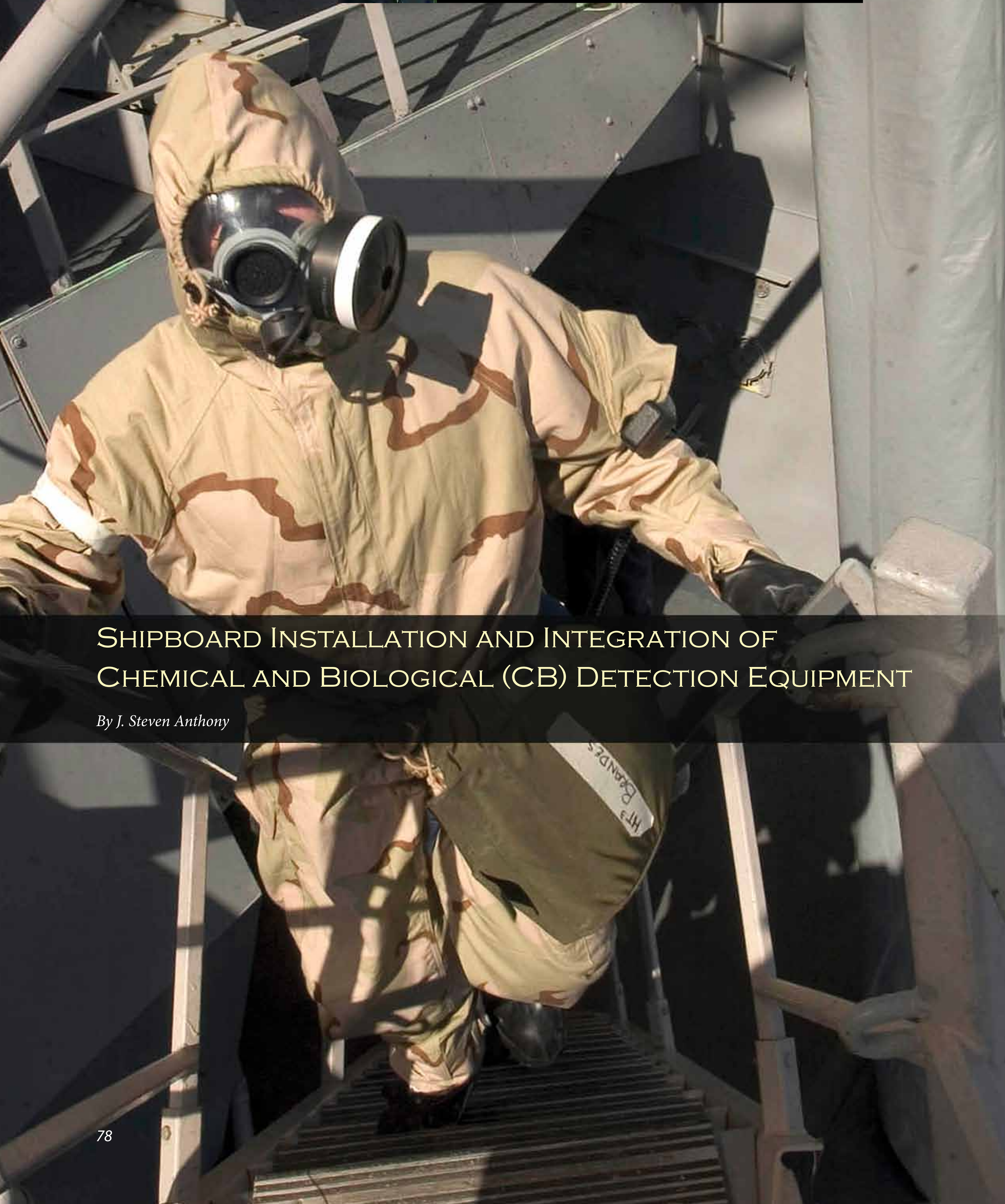


Figure 5. HHA Tickets



Shipboard Installation and Integration of Chemical and Biological (CB) Detection Equipment

By J. Steven Anthony

The Naval Surface Warfare Center, Dahlgren Division's (NSWCDD's) Chemical, Biological, and Radiological (CBR) Defense Division is responsible for protecting the fleet from chemical and biological (CB) threats. One of its responsibilities is to perform shipboard installation and integration of CB detection equipment in support of requirements to integrate CB detectors. Currently, the CBR Defense Division is fielding three systems to the fleet. These are the Joint Biological Point Detection System (JBPDS), the Joint Biological Agent Identification and Diagnostic System (JBAIDS), and the Improved Point Detection System – Life-Cycle Replacement (IPDS-LR).

Joint Biological Point Detection System (JBPDS)

JBPDS provides a 24-hour biological agent detection capability that detects, identifies, and warns of biological warfare agents (BWAs), allowing time for warfighters to take preventative measures or apply prophylactic measures. The system has the ability to connect to navigational and meteorological equipment, detect up to 10 BWAs during a mission and, most importantly, can save the sample for further confirmation analysis. Through FY11, 51 of the systems have been successfully installed on a variety of ship platforms (i.e., DDG, LPD, LSD, LHA, and LHD). Installations are scheduled to continue through FY15, with a total of 88 installations scheduled. The JBPDS is shown in Figure 1.

Figure 1. JBPDS Shipboard Installation

Joint Biological Agent Identification and Diagnostic System (JBAIDS)

JBAIDS provides positive identification and diagnostic confirmation of BWAs. Essentially, the sample from JBPDS can be analyzed by JBAIDS for confirmatory purposes. Additionally, JBAIDS provides H1N1 virus diagnostic capabilities, which was the principal reason for executing an accelerated fielding schedule. A 3-year fielding schedule for JBAIDS was accelerated to fielding all of the systems to the LHA, LHD, and CVN hulls within 1 year. Systems were to be fielded prior to the ships leaving for deployment. Nearly 95 percent of the systems (19 total) will have been installed by the conclusion of FY10. JBAIDS is shown in Figure 2.

Figure 2. JBAIDS System

Improved Point Detection System – Life-Cycle Replacement (IPDS-LR)

IPDS-LR is a fixed-site chemical warfare agent (CWA) point detector used to detect the presence of chemical nerve and blister agents external to the ship. The system was designed to increase maintainability and reliability while reducing false alarms caused by common shipboard interferents. IPDS-LR will be fielded to CVN, MCM, DDG, LHA, LHD, LPD, and LSD classes through FY16. Consequently, installation and integration costs will be reduced, as IPDS-LR is a form/fit/function replacement for the currently fielded IPDS system. IPDS-LR is shown in Figure 3.

Acquisition, Fielding, Maintenance, Sustainment, and Training

All three of these systems are in various stages of their acquisition life cycle, which encompasses all aspects of research and development, production, fielding, and eventual sustainment or disposal. NSWC Dahlgren is responsible for these systems

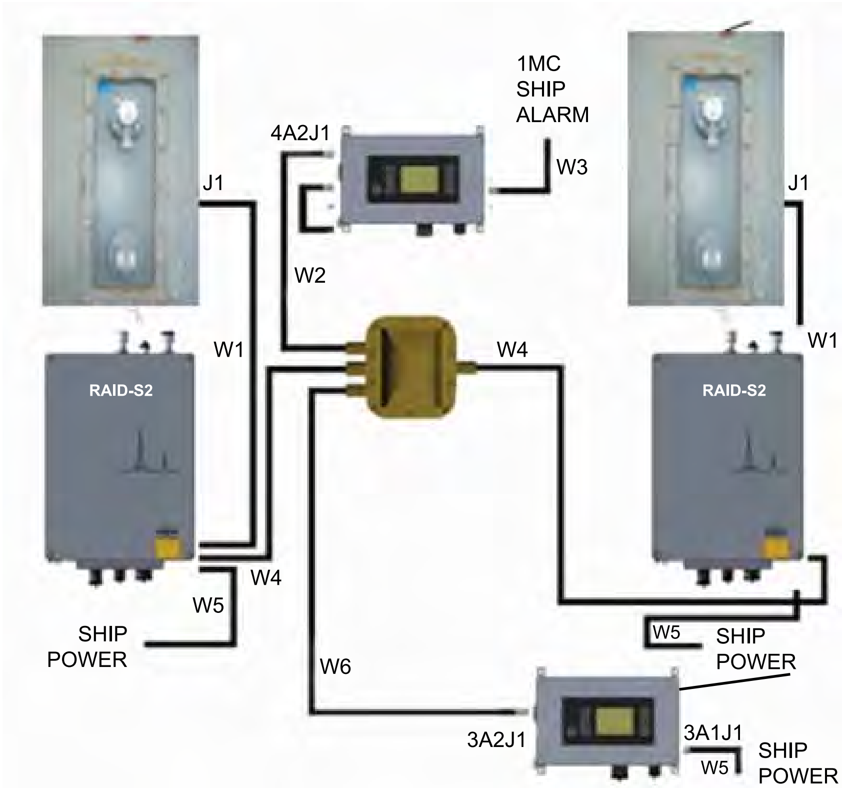


Figure 3. IPDS-LR System

from "cradle to grave." IPDS-LR has passed all of the testing requirements (i.e. shock, vibration and electromagnetic interference) and has shown that it will survive and operate in a combat environment. The first system was installed in the fourth quarter of FY11 with 25 installations currently planned for FY12. JBAIDS is nearing the end of its fielding schedule, where the system is moving into the operational sustainment portion of its life cycle. Proper installation of the systems, in addition to training, underlies the success of these systems. The ability to maintain, sustain, and support the systems throughout their life cycle is equally important. These responsibilities are also performed by the CBR Defense Division throughout the life of the equipment. JBPDS is currently halfway through its fielding schedule. Initial training is provided at the conclusion of each installation. Fielded systems will be maintained only to the extent that the users have been trained to perform necessary preventive maintenance. This is extremely important as life-cycle costs are reduced, and operational readiness is increased.

Shipboard Installation and Integration Planning

Shipboard installation and integration of CB defense systems must closely follow the processes and procedures as delineated by Technical Specification (TS) 9090-310F, *Alterations to Ships Accomplished by Alteration Installation Teams*. Any change that is performed to a ship is referred to as an alteration and is subjected to the preplanning milestones and requirements as directed by the Navy Modernization Plan. These requirements are not optional and must be strictly followed. Ship Change Documents (SCDs) must be generated within the Navy data environment, explicitly describing the alteration that will be performed. Technical assessment teams, integrated logistical officers, and budgetary personnel all review the SCDs for technical merit, schedule execution, costs, and maintainability. Approval is not granted until logistical documentation, testing, and ship installation drawings (SIDs) have been generated and approved. Development of these SIDs is performed by the planning yards for integration of the system on a particular hull. Close interactions are made with the planning yards to answer technical questions that arise. These SIDs detail how the systems integrate with the ship and show how potential problems must be handled in order to integrate the systems properly. Interactions are conducted between the planning yards and the Ship's Force to affirm that there will be minimal impact to the ship. The preplanning activities are not trivial and require approximately a year of effort.

Shipboard Installation and Integration Execution

Initially, coordination is made with the Ship's Force to ensure that the ship is aware of the system that they will be receiving. The installation team is responsible for answering any questions or concerns that the ship may have about the system. Prior to arrival, a walk-through and ship check is conducted to make sure that the system will be installed as described by the SIDs.

Many times, difficulties exist where slight deviations must be made from the drawings and accurately reflected in the as-built configuration. The difficulty is that space on ships is very limited and some of the systems—JBPDS, for example—occupy a significant amount of space in one of the ship's compartments.

The Alteration Installation Team (AIT) must provide the ship a plan of actions and milestones for execution of the installation. This is provided for accountability to the planning coordinators to affirm that the installation is progressing according to schedule. For JBPDS, each installation requires approximately 3 weeks to execute. This represents the time from arrival on ship until the time when check-out is complete.

Arrangements are made with the shipyard to make sure that all necessary industrial services are available. Welding and grinding are some of the principal services needed for the installations. Final items needed prior to installation initiation are the generation of a Readiness to Start (RTS) message and check-in with the designated Regional Maintenance Center (RMC). The RTS notifies all concerned of the arrival of the AIT and the system they will be installing. The RMCs are responsible for being aware of alterations that are occurring on a particular ship. They will not allow the installation to proceed unless all logistical documentation, drawings, and other required items are complete.

During installation, it is the responsibility of the AIT On-Site Installation Coordinator (OSIC) to ensure that the system is installed according to plan and on schedule. To accomplish that, an in-brief is initially scheduled with the ship to define the scope of work and level of effort. The OSIC is responsible for performing "go/no go" inspections of work performed to make sure that the system is installed professionally and properly. Additionally, situational reports and photos are used to document the daily production.

At the conclusion of the installation, there are items that must be performed prior to officially turning over the system to the ship. Occasionally, small changes are made to the SIDs, which must be accurately reflected. These "redlines" are then submitted to the responsible Planning Yard to reflect that the accurate "as-built" configuration is captured. This is imperative in order to make certain that the Acquisition Engineering Agent responsible for sustainment possesses the most accurate data—primarily for instances where troubleshooting might be necessary. A completion report is generated, per NAVSEA TS, to confirm that:

- An out brief has been scheduled
- Training dates are set
- Cable pathways have been properly performed
- System operational and verification testing have been performed
- Spares associated with the equipment have been properly turned over to the ship[1]

The goal is to certify that the ship is left in the same condition as before the installation.

Shipboard installation and integration of CB detection equipment on ships is necessary to protect ship crews from CB threats so they can perform their respective warfighting missions. By properly installing, integrating, and maintaining these systems—in addition to training crews on the proper maintenance of the systems—warfighters are not only safer, but naval readiness is enhanced.

Reference

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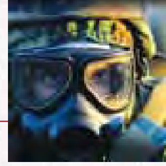


Joint Biological Point Detection System: The Navy's Program for Biological Defense

By Mark V. Brown

Biological weapons are armed with some of the most dangerous diseases known to man. These weapons are at the forefront of terrorist threats to world safety and peace. The Navy has chosen the Joint Biological Point Detection System (JBPDS) to protect its fleet and personnel from biological threats. JBPDS is a modular suite of equipment that provides commanders with the ability to detect and presumptively identify biological warfare (BW) agents in near real time. The suite fully automates the biological detection, sample collection, and identification functions, which enables Sailors to perform other critical duties. When complete, JBPDS will be installed on approximately 119 surface ships, providing commanders with the frontline knowledge necessary to effectively mitigate the aftereffects of BW agents. The JBPDS is shown on USS *The Sullivans* in Figure 1.

The Threat

Many nations that are considered unfriendly toward the United States have the capability to deliver biological weapons. In a traditional declared war, we can expect to encounter a biological threat from several potential enemies. Unfortunately, biological weapons offer a relatively cheap and effective means of offsetting U.S. military and economic power, and are thus attractive to anti-American terrorist groups. Such groups may not have the capability to deliver biological weapons on a military scale but could attempt to infect a ship, a port, a military base, or a symbolic or valuable civilian target if their desire for revenge or glory were sufficiently strong. Whether the delivery of biological agents is caused by a state or a terrorist group, the need for preparedness is acute, and rapid identification is the key.

Program History

In 1997, the Department of Defense launched a joint program to develop and field a biological detection system, which had two primary characteristics: speed of identification and automation. In order to proceed in an orderly and manageable fashion, the program's oversight process was divided into four functional areas, each led by a uniformed service. During the early development period, the design effort was led by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) as the designated Navy agent for this function. Test planning and oversight was an Air Force responsibility. Requirements development fell to the Army, and logistics was assigned to the Marine

Figure 1. JBPDS on USS *The Sullivans*

Corps. While project management was undertaken by an Army officer assigned to the Aberdeen Proving Ground, the chain of command was truly joint in nature since the responsible acquisition official was, and is, the Joint Program Executive Officer for Biological Detection, currently an Army general officer.

The first Navy JBPDS was installed on USS *Comstock* in the summer of 2000. Many design flaws and performance deficiencies were found in this first variation. Consequently, the JBPDS team went back to the drawing board to engineer a more successful system. The next Navy installation occurred in the fall of 2001 with a better system but not quite ready to support a ship's mission.

Over the next 3 years, from 2001 to 2004, the JBPDS went through extensive design changes to increase both performance and robustness. NSWCDD played a major role in this design to ensure that unique Navy needs were addressed. As a result, the current Navy shipboard JBPDS incorporates hardware responsive to the maritime environment.

Finally, Operational Evaluation was undertaken by Operational Test and Evaluation Force on board USS *The Sullivans* in September 2004. Following a positive evaluation, the detection system was approved for shipboard use. Installations subsequently began on DDG and amphibious ship classes, and today there are 38 shipboard units installed, with a total of 119 planned installations. JBPDS is the first and only joint chemical or biological detection system to be fielded by the Navy.

Installation and Local Hardware Support

Installation and integration of JBPDS into the shipboard environment requires about 7 man-weeks. A supporting stand is built off-site and installed where the ship structure is sufficiently robust to support the total operating weight of 295 pounds (plus stand). Occasionally, modifications to the existing structure must be performed to ensure this robustness. Fiber optic cable is run to the two remote controllers (one in Damage Control Central and one in the Combat Information Center) and to the navigation system. The superstructure is pierced to accommodate two inlet stacks and two exhaust ports, with welded brackets provided to affix the supporting structure for the ports. A small refrigerator is installed to store operating consumables, inlet ducting is lagged to minimize condensation within the duct, the internal bulkheads are relagged, and the space is painted where necessary. Finally, the unit is connected with shipboard power (120 volt) using an essential power circuit.

Training and Support

The Navy Program Manager for biological detection had the foresight to set up a team to completely support such a unique system. JBPDS Team Navy provides the ship and Sailor with complete system support anywhere in the world. This support includes new equipment training, predeployment training, reach-back troubleshooting, repairs, and logistics.

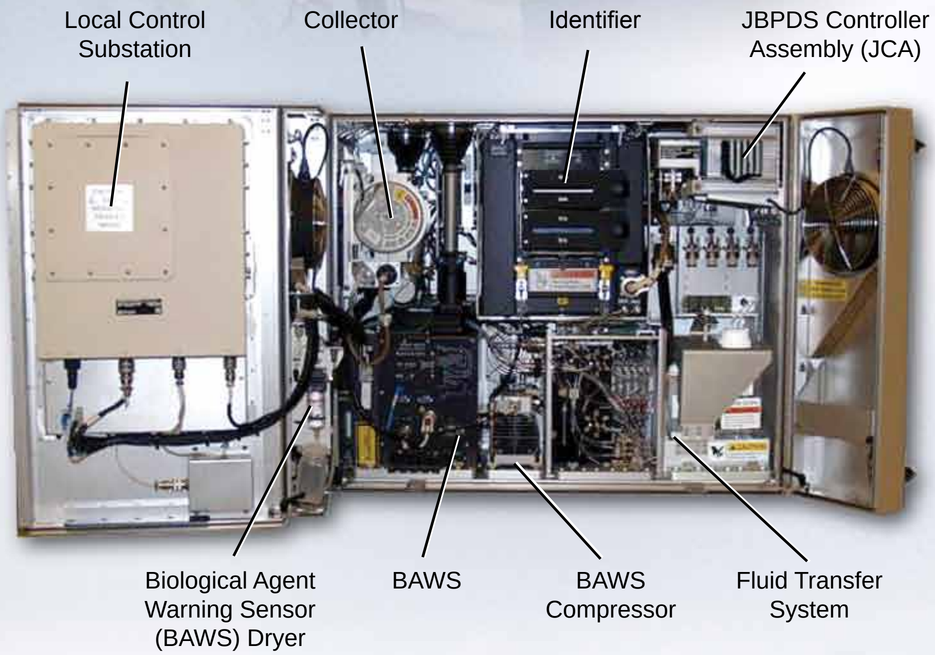
After an installation, JBPDS Team Navy provides ship personnel with the required training to operate and maintain the JBPDS. This training consists of 40 hours of classroom and hands-on training to include troubleshooting, operations, and preventive maintenance services. Corrective maintenance consists primarily of removing and replacing any of six repairable components identified by operating software fault indications. Preventive maintenance involves cleaning intakes and operating the system to verify full functionality. This requires 2 hours bimonthly. A JBPDS Team Navy training session is shown in Figure 2.

Both of these efforts were undertaken by the Navy JBPDS Program Manager in response to the need to augment the chemical/biological course taught at the Navy school in Fort Leonard Wood, Missouri.

Accordingly, specialized Navy repair activities (equipment and labor) were established in fleet concentration areas in Norfolk and San Diego. The establishment of these repair activities is designed to provide real-time support to JBPDS-equipped platforms to increase equipment availability and decrease downtime. JBPDS Team Navy operates these activities and has personnel with specialized technical expertise. Performing system repairs at the subcomponent level saves the Navy thousands of dollars each year.

Biological agents are insidious because the human body does not recognize their presence until well after exposure. In most cases, the onset of physical symptoms will occur several days or weeks after initial contact, and by the time the disease is recognized, it is well established and considerably past the time when medical attention is most effective. For the shipboard warfighter, the message is clear—prompt identification of biological agents and associated treatment will prevent the loss of personnel and help maintain mission readiness. JBPDS is the Navy's system of choice to combat the devastation that may be caused by a biological attack.

Figure 2. JBPDS Team Navy accomplishes follow-on or predeployment training via tailored operator and maintainer courses using JBPDS systems installed at Naval Stations Norfolk, San Diego, and Mayport. This training is conducted when requested. Refresher training is available using course material located on the Navy Knowledge Online system.


Local Control Substation
Collector
Identifier
JBPDS Controller Assembly (JCA)
Biological Agent Warning Sensor (BAWS) Dryer
BAWS
BAWS Compressor
Fluid Transfer System

Accelerated Fielding of the Joint Biological Agent Identification and Diagnostic System (JBAIDS) to Large Deck Ships

By Rose Hayden

The H1N1 influenza pandemic of 2009 directly impacted the missions of USS *Ronald Reagan* (CVN 76) in late spring 2009 and USS *Bataan* (LHD 5) and other Navy ships by summer 2009. Because of the close quarters of a shipboard environment, a respiratory illness such as influenza spreads rapidly and renders personnel unable to perform their normal duties. As a result, scheduled exercises may be canceled, or deployments may be postponed until the situation is mitigated.

The 2009 pandemic of H1N1 influenza began in March 2009 with an "influenza-like illness" that spread rapidly within Mexico, and a nationwide alert for Mexico was issued in April. As the illness in Mexico was confirmed to be H1N1, the first reported cases in the United States were announced. The H1N1 strain was anticipated to become pandemic in a short period of time due to its infectiousness and its exposure to a population that traveled freely to other areas of the world. As new outbreaks were anticipated, and no vaccine was available, by August 2009, Vice Admiral Gortney stated "an urgent need to expedite" and requested the accelerated fielding of the Joint Biological Agent Identification and Diagnostic System (JBAIDS) to provide ship medical personnel the H1N1 diagnostic capability on forward-deployed ships. The Office of the Joint Project Manager for Chem/Bio Medical Systems provided H1N1 support equipment to supplement the JBAIDS package and assisted in the acceleration process to field JBAIDS to the ships.

Flu is a serious illness, as each year a number of people—usually the older population or persons with pre-existing conditions—die after contracting a flu virus. For seasonal influenza, 90 percent of the deaths are of persons 65 years or older. Nonetheless, previously healthy individuals also die each year from flu and its complications. Unlike the other influenza strains, H1N1 primarily impacted children and younger adults. Data taken from April to July of 2009 shows the infection rate of H1N1 to be 20 times higher for the age group of 4 to 25 years compared to the age group of 65 years or older. Of patients hospitalized with H1N1 influenza, 41 percent of the deaths were of patients 25 to 49 years old, compared to 9 percent of patients 65 years and older.

Each year, projections are made of which strains of flu are most likely to impact the population based on observations of emerging and existing illnesses. Once strains are identified, a vaccine is prepared to incorporate elements of the combination of strains in the annual flu shot. Over a relatively short period of time, however, flu strains can change and combine. Genetic material of a virus can change, or parts of different flu viruses can combine during infection in a host, and a new strain (with changed or combined genetic material) can emerge to be transferred to the next host. That is why the flu shot is updated annually, and why a person may retain some immunity to a current flu from previous flu shots. The 2009 H1N1 strain contained components of human, swine, and avian flu viruses.

Following the initial confirmations in Mexico and the United States, the Centers for Disease Control (CDC) mapped the areas of H1N1 influenza cases with frequent updates over the months as H1N1 rapidly spread throughout the world. The H1N1 diagnostic assay, provided by the CDC, was adapted and tested for use on JBAIDS and received Food and Drug Administration authorization for emergency use in August 2009. Concurrently, a new vaccine for H1N1 was prepared to be administered in addition to the annual flu shot. Although the Navy JBAIDS fielding plan prior to 2009 did not include the delivery of medical diagnostic assays for clinical specimens, JBAIDS does have the capability to perform a diagnostic identification of H1N1 in a clinical specimen aboard ship.

JBAIDS is the program of record to meet the need for confirmatory testing of possible contamination by biological warfare agents aboard ship. Hand-held assays for presumptive testing of biological warfare agents from environmental samples are utilized to provide a quick-look result in minutes. However, these assays do not have the accuracy needed to justify the medical treatment of the crew. JBAIDS utilizes polymerase chain reaction technology, which is more accurate than the antigen-antibody-based technology utilized in the hand-held assays. JBAIDS provides confirmatory identification in a matter of a few hours. For legal and forensic purposes, a sample can also be sent away to a definitive laboratory, but this more thorough identification can take weeks, which is too long in order to begin implementation of protective measures for the warfighter aboard ship. With contamination or infection by known biological agents, specific symptoms can be anticipated, appropriate medication for prophylaxis or treatment can be identified, likely course of illness or contamination can be anticipated, and the appropriate protective posture can be implemented. JBAIDS is shown in Figure 1.

The acceleration of JBAIDS fielding required attention to several items, as the logistical, training, personnel, and financial plans assumed a 3-year time frame. While the modification and testing of the H1N1 assay for use on the JBAIDS platform was underway during spring 2009, personnel at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) responded to the possibility of accelerating the fielding by addressing the shortest time possible to get the H1N1 diagnostic capability with JBAIDS to the ships. This included the renegotiation of contracts to acquire

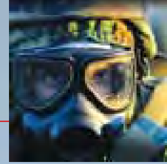
Figure 1. Joint Biological Agent Identification and Diagnostic System (JBAIDS)

the hardware and perishable consumables in a shorter time frame, the surge in training by the JBAIDS schoolhouse to accommodate additional Navy JBAIDS operators, the surge in provision of operator support, and the accelerated install process (with all the coordination and work needed to formally install a system aboard ship). After all time requirements for the different aspects of fielding were identified, the JBAIDS fielding schedule was compressed from 3 years to 9 months. With receipt of the Vice Admiral's request to accelerate fielding in August 2009, NSWCDD was poised to respond immediately with the 9-month fielding schedule.

Since the initiation of the accelerated fielding of JBAIDS, an effective vaccine for H1N1 has been produced and administered. In Figure 2, a hospital corpsman is shown preparing to administer an H1N1 flu vaccine aboard the amphibious assault ship USS *Bataan* (LHD 5).

The availability and administration of the H1N1 vaccine allayed many of the fears of the effects of H1N1 globally; however, NSWCDD's ability to rapidly mobilize the H1N1 diagnostic capability to the ships emplaced an infrastructure for the next pandemic should another strain mutate or should a new biological threat present itself. Consequently, naval warfighters will be better protected from future biological threats.

Figure 2. ATLANTIC OCEAN (5 December 2009) Hospital Corpsman 2nd Class Eric M. Garneau prepares to administer an H1N1 flu vaccine aboard the amphibious assault ship USS *Bataan* (LHD 5). (U.S. Navy photo by Chief Mass Communication Specialist Anthony Sisti/Released)



Improving Reliability of Shipboard Chemical Agent Detection

By Christopher Bara and Brian Flaherty

Chemical warfare agent (CWA) detection is a priority for U.S. Navy warfighters. Detecting an attack and having the capability to alert the crew to the presence of CWAs is critical in saving lives and minimizing harmful exposure. Currently, the U.S. Navy uses the Improved Point Detection System (IPDS) to provide its ships with automated CWA detection.

IPDS uses ion mobility spectrometry (IMS) as its chemical detection technology. This technology ionizes the chemical agent and then sorts the ions based on molecular size and shape in an electric field in order to produce a spectrum. The algorithm compares this spectrum to reference spectra and identifies the chemical. The IPDS has components located on both port and starboard, and samples through external air intakes in the ship's hull. The system analyzes the external air for a chemical agent. If the detector identifies a chemical agent, it sends a signal that displays an alert at both the ship's Damage Control Central (DCC) and the bridge. The system also interfaces directly to the ship's chemical alarm, which broadcasts an audible shipwide alarm to alert the crew of a CWA.

The current IPDS, fielded in 1999, provides automated shipboard chemical detection; however, issues of obsolescence, maintainability, and the resulting increase in repair time drove the requirement for a replacement system. A review of the current IPDS established that it was neither technically feasible nor cost-effective to refurbish the existing system. The original equipment manufacturer no longer supports the IPDS, and the current system is susceptible to false identification to many normal chemicals in the shipboard environment. Moreover, Navy analysis indicates that the current IPDS will be unsupportable by 2014, thus requiring fielding of a replacement to begin in 2011, well in advance of the Next-Generation Chemical Agent Point Detector system's initial fielding in 2020. Consequently, the Navy's senior chemical biological defense (CBD) leadership requested the Joint Program Executive Office for Chemical Biological Defense (JPEO-CBD) to develop and field a life-cycle replacement to provide protection for this interim period.

The Joint Project Manager for Nuclear, Biological, and Chemical Contamination Avoidance—working with the Navy's chemical, biological, radiological, nuclear, and high-yield explosive (CBRNE) Action Officer and Naval Sea Systems Command

(NAVSEA) CBD Technical Warrant Holder—have worked to select and evaluate a potential commercial off-the-shelf (COTS) solution to this fleet request. Titled the Improved Point (Chemical Vapor) Detection – Life-Cycle Replacement (IPDS-LR) effort, the joint team evaluated multiple candidates in an open competition. The joint team evaluated the candidate systems based on each system's ability to meet the requirements set forth in the original IPDS Operational Requirements Document (ORD). This was supplemented with a robust performance specification and CWA surety detection capability using the more recent U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) information. The IPDS-LR system also needed to be able to be packaged to meet form/fit/function requirements to allow reuse of current shipboard IPDS installation foundations. Despite utilizing the same basic IMS technology, the IPDS-LR demonstrated the ability to meet the requirement for mean time between false alarms. Figure 1 shows the IPDS-LR component image compared to IPDS.

IPDS-LR system testing consisted of extensive production verification testing (PVT). The PVT emphasized Navy shipboard maritime environment and reliability, availability, and maintainability (RAM) events, since it was the prime program initiator. The team collected over 14,000 hours of underway and in-port test time to support the RAM analysis utilizing multiple ships (and ship classes) stationed from both Norfolk, Virginia, and San Diego, California, areas. Additional data collection continued aboard ships in forward-deployed locations. The shipboard test data verified that the IPDS-LR had improved on the deficiency of IPDS in both RAM and shipboard mean time between false alarms. In conjunction with shipboard testing, the team conducted laboratory testing against known interferents to determine the shipboard chemical to false identification relationship. To date, IPDS-LR has demonstrated the ability to meet the Navy's false-alarm frequency, as well as its RAM criteria. While the current concept of operations (CONOPS) is based on short-term continuous operation, IPDS-LR PVT testing systems operated continually when aboard ship, as well as during operational service-life testing. Additionally, the current IPDS CONOPS states that IPDS should not be operated in the rain. However, to fully characterize the IPDS-LR performance and to reduce the workload on the Sailor, the test plan dictated continuous system operation—even during rainy weather.

In the course of this test, one significant RAM issue surfaced. During rainy weather, the air sampling system often pulled water through the inlet nozzle (i.e., system air-sampling inlet and exhaust nozzle are part of the External Air Sampling Unit (EASU) component). The EASU is the only part of the system on the outside of the ship. All other

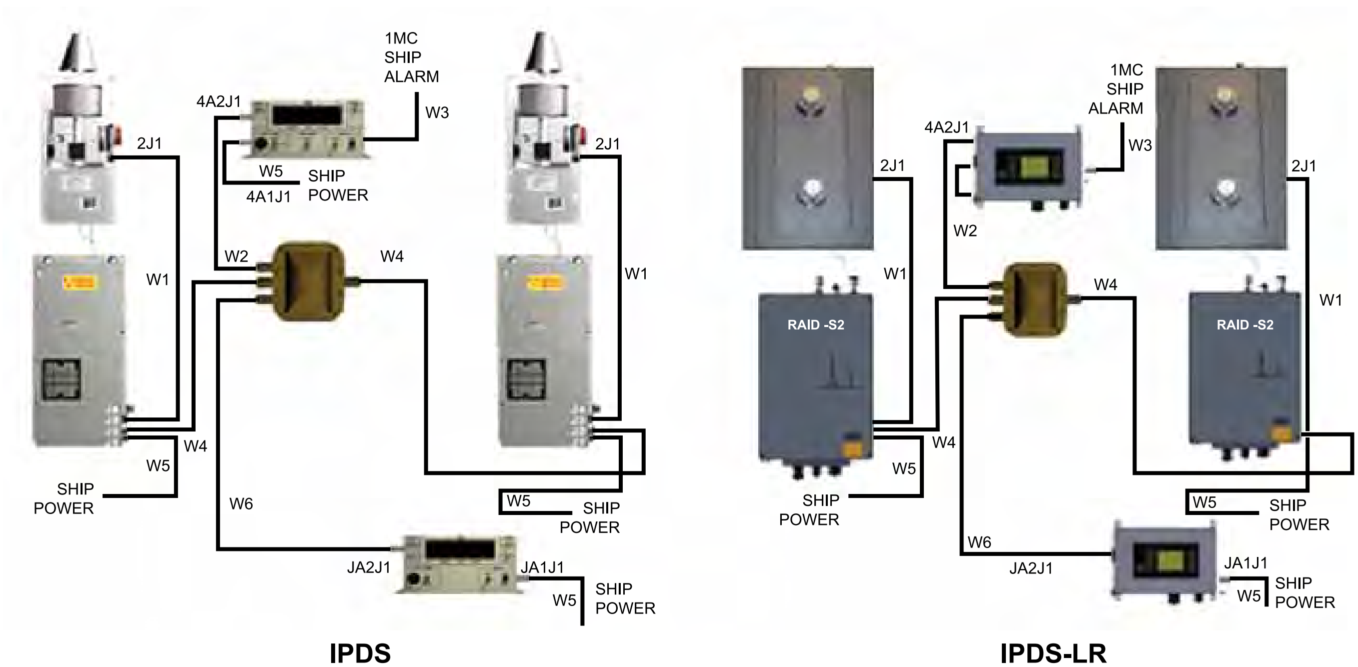


Figure 1. IPDS/IPDS-LR Components

components, including the detection units, are internally located. In several cases, rainwater saturated the sampling-line membrane filter. The resulting blockage of airflow would then cause the sampling pump to shut down (system self-protection mode) and require the detection unit to be offline until the water blockage was cleared (via system backflush or manual membrane drying). The self-protection mode prevented water from penetrating this membrane filter and damaging the pump.

Nevertheless, as this issue occurred repeatedly in wet situations, the IPDS-LR team and the IPDS-LR manufacturer developed and implemented a design change on the inlet nozzle. The original design consisted of four small holes, in close proximity, allowing blockage by water droplets running down the ship's bulkhead onto the inlet assembly. The new inlet nozzle has a large, flared opening designed to separate the water droplets, while still allowing access to collect air. Figure 2 shows a side-by-side comparison of the old and new nozzle designs. Follow-on shipboard testing with the new inlet nozzle resulted in no further water ingestion problems. Additionally, airflow "smoke" testing validated that the new nozzle design would not negatively impact the sampling airflow getting to the detector.

The team analyzed IPDS-LR shipboard PVT data to determine system performance with respect to false identification alarms. The IPDS ORD states that the system shall operate with an average not to exceed one false alarm per mission, where a mission is a period of continual operation lasting between 24 and 144 hours. As mission length can be variable, this analysis considered the maximum and minimum number of missions during the test periods (dividing 24 and 144 hours, respectively, into the test duration for maximum and minimum number of missions). The IPDS-LR met this specification.

PVT evaluations also included CWA surety performance, environmental survivability, and operational service life (maritime/salt air environment), as well as shipboard shock, vibration, and electromagnetic interference (EMI) qualification.[1] As the IPDS-LR is considered an essential shipboard system, the shipboard mounting must allow it to survive and continue to operate after a dynamic impact simulating attack by large munitions. This dynamic impact must not cause the mounted system to break free and become a projectile hazard. Follow-on operational test and evaluation (FOT&E) included challenging the IPDS-LR system with a CWA simulant (methyl salicylate) in an operationally relevant environment, with the ship both in port and underway. These trials occurred during August 2010. All PVT and FOT&E results are being reviewed, and a decision will be made regarding the procurement of additional IPDS-LR systems. Assuming IPDS-LR is deemed acceptable for fielding to the U.S. Navy, production system deliveries will occur from 2011 to 2015.

Reference

1. *Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*, MIL-STD-810F, January 2000.

Original Inlet

Redesigned Inlet

Figure 2. IPDS-LR Inlet Design Change

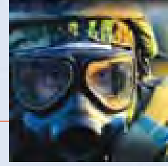
U.S. Navy Ships Get Chem-Bio Protection

By Robert Snodgrass, Anton Fionov, Jeffrey Donovan, and Eric Arcement

Mission accomplished… the Marine Battalion Landing Team successfully secured the beachhead. It was a difficult task, but the Marines were up to the challenge. The mission was complicated by the enemy's use of chemical munitions in their artillery attacks. Initial indications suggested it was the nerve agent VX. There were casualties, but the Marines were ready, trained, and equipped to fight in a chemical, biological, and radiological (CBR) environment. Triage and casualty decontamination operations were conducted on shore, and the casualties were evacuated back to the amphibious ready group for more definitive treatment. Once aboard the amphibious assault ship, the patients were processed through the ship's collective protection system (CPS) casualty decontamination station and into the medical collective protection zone for further medical evaluation and treatment. Treatment of all Marine casualties was successful. Notwithstanding, without the extended CPS installed on the amphibious assault ship, the Marines in this hypothetical scenario might not have been so fortunate.

The Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) funded the installation of additional CPS capability on 15 amphibious ships as part of the CPS Backfit Program. This program retrofits U.S. Navy ships with reliable CPS to protect the warfighter and ensure mission success despite the CBR threat from adversary nation states and terrorist organizations.

The CPS provides areas protected from CBR contamination, called CPS zones, where the crew can continue operations unencumbered by individual protective equipment. CPS consists of three main components: filtration, overpressurization, and controlled access. Filtration provides clean air—free from CBR agents—to the zone. Overpressurization of the zone assures that the clean air leaks out of the zone, preventing contaminated air from leaking in.



Controlled access is provided through decontamination stations and air locks, which allows decontaminated personnel to enter and exit the zone while maintaining the overpressure.

Many ship classes are built with CPS already installed; however, some classes were built with limited coverage or no CPS at all. The crews of amphibious ships, operating close to shore while receiving potentially contaminated Marines, have increased risk of exposure to CBR threats. The CPS Backfit Program retrofits CPS zones onto these amphibious warfare ships in order to reduce the impact of exposure to CBR threats.

The CPS Backfit Acquisition Program Manager (APM), based at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), manages the CPS Backfit Program for the Joint Project Manager for Protection, who reports directly to the JPEO-CBD. The CPS Backfit Program has developed CPS zone designs for each ship class, which protect key mission functions. The designs have been optimized to balance the amount of area protected with the intrusiveness and complexity of the system installation. The CPS Backfit APM works with the Program Executive Office (PEO) Ships, Naval Sea Systems Command and the ships' planning yards to adapt the class designs to each ship. In addition to improving performance, the APM works to reduce installation and life-cycle costs at every opportunity to ensure that the government is receiving the maximum value for its investment.

Figure 1. CPS Backfit and Planning Yard Representatives collaborate to develop the quickest and most cost-effective solutions to installation challenges.

Figure 2. CPS Backfit Representative Performing CPS Quality Assurance

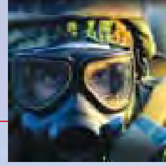
The CPS Backfit APM assigns on-site representatives (see Figures 1 and 2) to serve as the face of the program throughout the installation. The on-site representatives resolve all technical issues and questions that arise. These on-site representatives manage the costs associated with installation problems and design changes to ensure that costs are contained. Also, the on-site representatives facilitate communication among the disparate organizations involved in the ship's availability, including:

- PEO Ships
- Ship's Force
- Naval Sea Systems Command
- Planning Yards
- Regional Maintenance Centers
- Shipyard Contractors and Subcontractors

The on-site representatives address any concerns Ship's Force may have with the system or its installation and ensure that the ship understands the new capability, and that the crew is fully trained to use and maintain the system.

The CPS Backfit alteration (Navy-speak for modifications and upgrades to existing ships) is complex and intrusive. The installation significantly impacts the ship's structural design; heating, ventilation, and air conditioning (HVAC) systems; and electrical systems. A typical CPS Backfit alters numerous spaces to create the new CPS zone, which requires significant structural modifications. Leaky sheet-metal bulkheads are removed and replaced with 42,000 lb of airtight steel bulkheads to form the new CPS decontamination station and up to 13 new air locks. Additionally, sheet-metal doors are replaced with watertight steel doors along the boundary of the zone. Multiple existing fresh-air supply systems are removed and replaced with CPS filtered-air supply systems in completely new fan rooms that house the filters, fans, heaters, cooling coils, and other equipment needed to bring the CPS filtered air into the zone. The other ventilation systems in the zone are completely reconfigured to tie into the new fresh-air supplies. In total, over half a mile of ventilation ducting is rerouted, up to 21 fans are replaced with new fans, and numerous HVAC components are upgraded. Furthermore, 25,000 ft of electrical cable are installed to provide power to the new ventilation equipment and other electrical equipment relocated in support of the new bulkheads and ventilation.

The 15th and final programmed installation for the CPS Backfit Program is scheduled for completion in 2015. The JPEO-CBD has invested more than $141M to provide the Navy amphibious fleet the required capabilities to continue critical operations in a CBR environment. Accordingly, Marines and Navy warfighters will have the best shipborne CBR defenses available to protect them from the threat of CBR contaminants.



The Navy Shipboard Collective Protection System (CPS): Not Just for Chemical-Biological-Radiological Defense Anymore

By Mike Pompeii

What Is a Collective Protection System (CPS)?

Most U.S. Navy ships are equipped with a special ventilation system called the Collective Protection System (CPS). CPSs were originally designed to protect personnel and equipment inside ships from chemical, biological, and radiological (CBR) attacks. Collective protection works by using special filters to remove any contaminants from intake ventilation air and then providing a slight overpressure inside the CPS zone to prevent entry of contaminants through any leak paths. In a typical CPS zone on a ship, contaminated outside air is drawn in, cleaned by special filters, and distributed throughout the zone. Air locks and special decontamination stations are used by personnel for exiting and entering the CPS zone, respectively. Figure 1 shows the layout of a typical CPS zone.

The Known Roles of CPSs

Without CPS, many missions would be extremely difficult or impossible to accomplish in a CBR-contaminated environment. Imagine a crew trying to perform work while wearing cumbersome protective clothing, especially in command and control or medical areas. Moreover, collective protection is essential for missions in warm or hot weather because protective clothing can be worn only for very short periods of time. Personnel in CPS zones do not need to wear cumbersome gas masks or protective clothing, which can degrade mission accomplishment.

Testing has shown shipboard CPS to be very effective at protecting a ship and its crew from CBR warfare agents.[1,2] Deadly chemical nerve agents such as sarin, soman, tabun, and VX, along with blister agents such as sulfur mustard, nitrogen mustard, and lewisite are completely filtered and removed by CPS. Biological warfare agents such as anthrax, tularemia, and botulinum toxin are completely removed as well. Collective protection is also very effective at removing all radioactive dirt, dust, and particles that result from a nuclear blast.

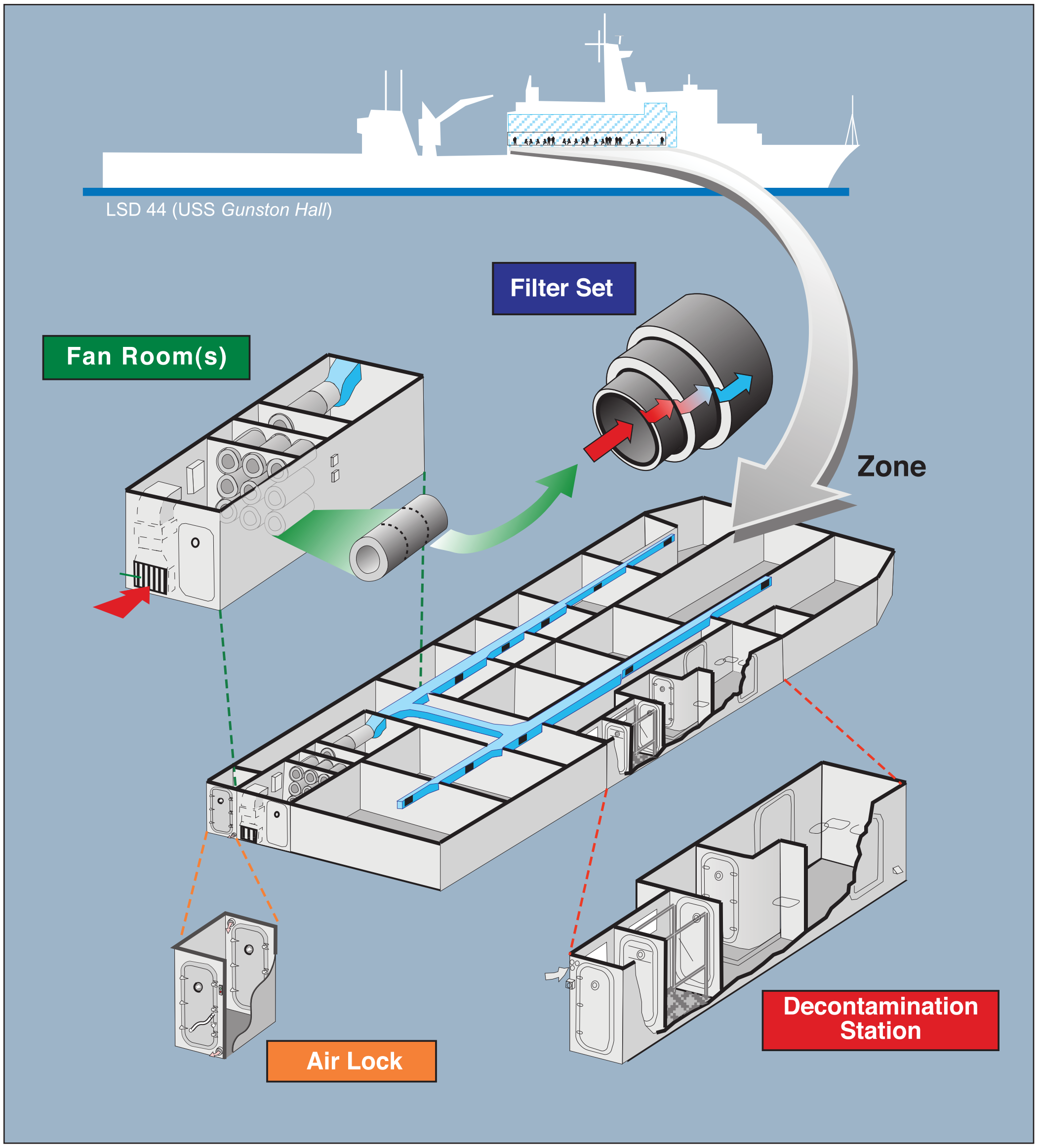


Figure 1. Layout of a Typical Collective Protection System Zone

The Top Ten Generally Unrecognized Roles of CPS

The roles, benefits, and costs of CPSs historically have been misunderstood. In addition to its original CBR defense role, CPS has taken on many new roles over the last 15 years, as increasingly more ships have been outfitted with CPS and have become dependent on CPS in areas other than CBR defense. Shipboard systems and procedures have become dependent on CPS in different ways and for different purposes. These unforeseen and unrecognized benefits of CPS have been both direct and indirect, while providing valuable protection, battle damage, and cost- and labor-saving advantages to our ships.

Ship program managers need to carefully consider all aspects of shipboard CPS from a total ship systems-engineering viewpoint. This includes the primary and secondary benefits, other shipboard system dependencies, and the significant amount of unrealized life-cycle cost and manpower savings for U.S. Navy ships provided by CPS.

The top ten generally unrecognized roles of shipboard CPS are discussed in the following paragraphs.

1. *Protection from toxic industrial chemicals (TICs)*—Toxic chemicals used by industry are abundant and are shipped daily in large quantities over highways, rail lines, and waterways. Use of these TICs by terrorists or

accidents is very feasible, and CPS provides the ships with this needed protection.

2. *Protection from petroleum fumes*—Crews must also be protected from noxious petroleum fumes while operating in areas of major oil leaks (for example, the Gulf of Mexico spill in 2010) or sabotaged oil wells (for example, in Operation Desert Storm in 1991). CPS effectively provides this protection to the ship.
3. *Protection from terrorist use of radiological dispersion devices (dirty bombs)*—Radioactive particles from dirty bombs can travel significant distances and render large areas uninhabitable for many years. Again, CPS is very effective at protecting the interior ship spaces from these types of weapons or releases.
4. *Protection from battle and smoke damage*—Immediately after the terrorist attack on USS *Cole* (see Figure 2), the ship's CPS was responsible for limiting smoke and soot damage to just one of the ship's four CPS zones. This greatly enabled rescue and repair efforts and saved an estimated millions of dollars in equipment, cleanup, and repair costs. Quoting from USS *Cole*'s Damage Control Report,

   "In the blast area mostly between frame 220 and 174 damage was everywhere. Debris, trash, the smell, soot-covered bulkheads, etc. It was simply throughout. But outside the area, if you had not known better, it looked as if it was a different ship. Bulkheads were clean, along with just about everything."

   The report went on to say:

   "All the debris that covered the outside of the ship had been filtered out, and the over pressurization inside had either minimized or completely protected the unaffected areas of the ship. Collective protection had worked and protected this crew in maybe a completely different faction then (sic) thought of in the beginning."

   The report also included details on how the CPS enhanced the recovery efforts that took place both immediately after the attack and during near- and mid-term repair and recovery efforts.[3]
5. *Rapid de-smoking and smoke control during and after fires*—CPS zones can be quickly configured to use its overpressure to rapidly purge (in seconds) any smoke from any area within a CPS zone. For example, on a DDG-class ship, the damage control and firefighting team can simply open all interconnecting doors for each of the three

Figure 2. Damage to USS *Cole* From a Terrorist Attack: The CPS greatly enhanced rescue and recovery efforts and also limited the extent of damage on the ship.

or four CPS zones to form one large zone and then open the door or hatch closest to the source of the smoke. All smoke will be purged through that door or hatch in a matter of seconds.

6. *Protection from dust storms*—CPS routinely provides protection of interior spaces from dust and sand storms commonly encountered in the Southwest Asia area. Without CPS, the ship's crew must perform extensive clean up of interior spaces after such storms. The Damage Control Assistant (DCA) aboard USS *Barry* (DDG 52), an Arleigh Burke-class guided missile destroyer, when referring to a recent deployment, said:

   "CPS helped keep the ship clean, even in some of the worst environmental conditions. We shook out the prefilters after a dust storm, and continued to check them on a regular basis. I couldn't imagine going through that deployment without CPS; it would have been a nightmare to clean the ship."[4]

   Figure 3 shows a dust storm over the Persian Gulf.

7. *Increased crew health, habitability, and comfort*—Since the crew is basically living and working full-time in a clean-room environment, they are always breathing purified air and are exposed to virtually no environmental pollutants, pollens, or dust.
8. *Higher electronics reliability due to a dust-free environment*—It is a well-known fact that most electronics failures are caused by a dust buildup from electrostatic forces, causing excessive heating, short-circuiting, and subsequent early failure of electronic components.[5] A ship is full of sophisticated electronics and is highly susceptible to dust buildup and electronics failures. The CPS system provides

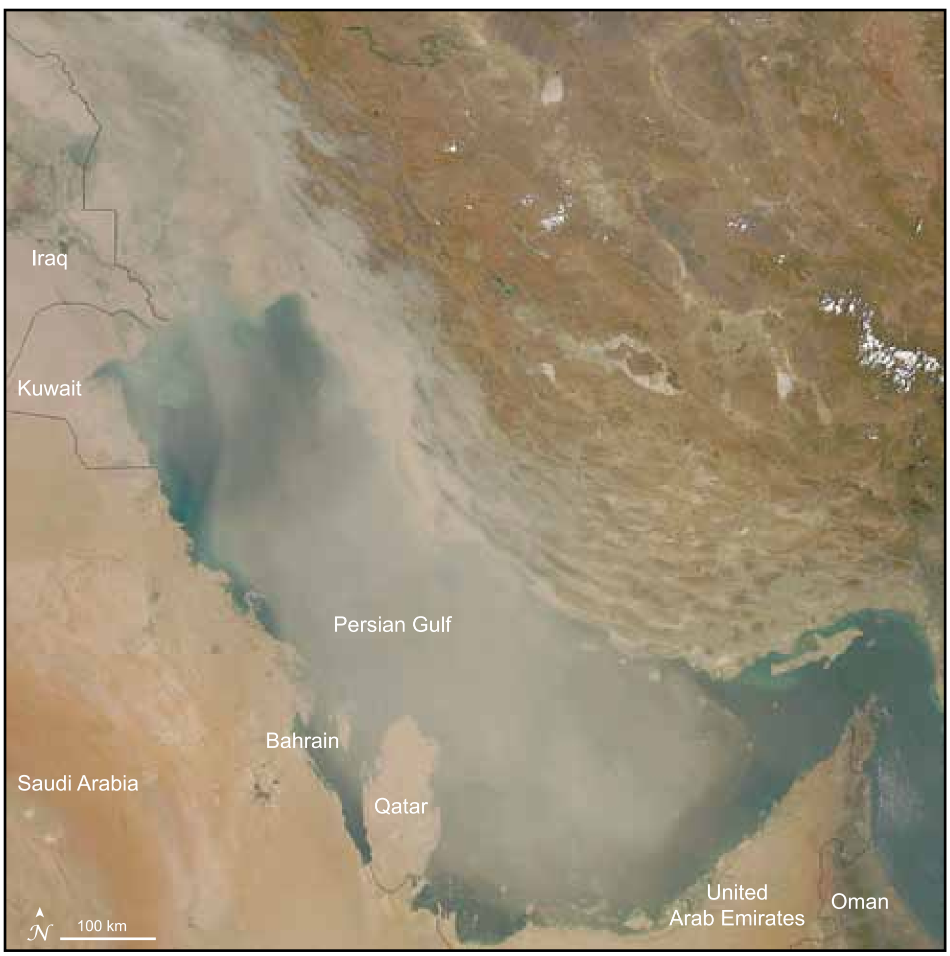


Figure 3. Satellite View of a Typical Dust Storm Often Encountered by Navy Ships

an almost completely dust-free environment inside the ship. So without CPS, one must include a significant life-cycle cost increase to account for these higher electronics failure rates. This cost savings is complex and very difficult to quantify, however, due to the number of uncontrolled variables involved in any type of CPS/non-CPS comparison test. Figures 4 and 5 show the effects of dust buildup on electronics.

9. *Less maintenance for combat systems and electronics*—Excessive dust loading not only reduces the reliability of electronics, but also increases the maintenance hours required for those exposed electronics. Without CPS, one must include significant life-cycle cost and maintenance hour increases to account for the increased dust load present on any air-cooled electronics in non-CPS zones.
10. *Less general cleaning hours by the crew*—Have you ever been on board a ship with CPS? If you have, it is very obvious how clean it is compared to a ship without CPS. That's because most of the dirt and dust inside a ship comes in through the ventilation system, and the CPS filters it all. Without CPS, one must significantly increase the crew maintenance hours required for cleaning due to the significantly increased dust load. This is especially critical for new and mandated reduced-shipboard manning initiatives. In addition, CPS zones require no ductwork cleaning, while non-CPS zones require extensive and time-consuming duct cleaning approximately every 2 years. Cost is significant and varies by ship type.

How Much Does CPS Actually Cost to Install and Operate?

The initial installation cost and the life-cycle cost of CPS historically has been misunderstood. A common misconception is that "CPS is too expensive" to install on a ship when, in fact, it really is not. CPS uses much of the same ductwork, recirculation systems, and exhaust fans that are used in non-CPS shipboard ventilation systems. The only significant difference between CPS and non-CPS ventilation systems are the filters, the filter housings, high-pressure fans (versus low-pressure fans in non-CPS systems), and air locks used in CPS. Therefore, when calculating the cost of CPS, the cost estimator must subtract the cost of a complete conventional shipboard ventilation system.

The true extra cost of CPS was analyzed in a 2002 report and found to be approximately $168 per cubic feet per minute (CFM) more when compared to a conventional shipboard ventilation

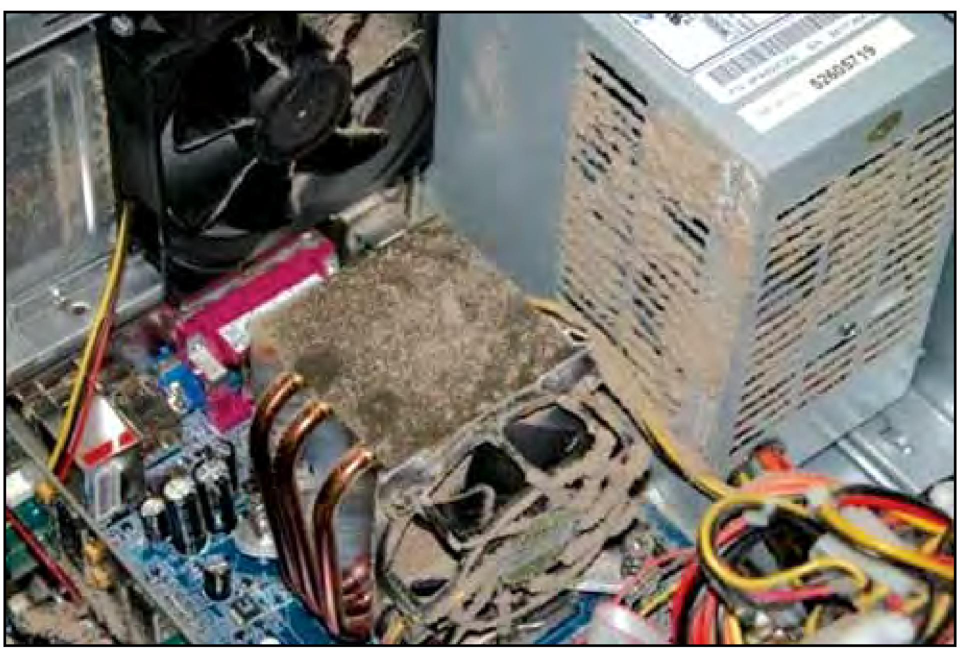


Figure 4. Typical Dust Buildup in an Electronic System

system.[6] For a destroyer-sized ship with two large CPS zones and two medium-sized CPS zones, this equals about $3 million in extra costs. Smaller sized ships and/or ships with fewer than four CPS zones would, of course, cost significantly less.

The support and logistics cost of CPS also has been historically misunderstood. For logistics, the only consumable items that the ship needs to purchase are disposable prefilters. These prefilters last from 3 to 6 months, are easy to replace, and cost about $25 each ($2 thousand to $4 thousand per year for a DDG 51). The main CBR filters last 3 to 5 years, are paid for by the Office of the Chief of Naval Operations (OPNAV), and are installed and tested by the Naval Sea Systems Command (NAVSEA). Ships, therefore, do not pay for these more expensive filters. Other maintenance actions required for CPS are very similar in type and numbers as compared to maintenance for a conventional shipboard ventilation system. The total life-cycle cost of CPS for each ship, therefore, is relatively low. Notwithstanding, these correct cost factors must be used by ship program offices to determine the true cost of installing CPS on their ships.

Summary

A CPS has many valuable and important shipboard benefits besides CBR protection. Accordingly, CPS provides a significant amount of unrecognized life-cycle cost and manpower savings for U.S. Navy ships. That said, a total ship systems engineering approach must be used when considering CPS installation and coverage on new or existing ship classes. The primary benefits, the secondary benefits, other shipboard-system dependencies, and the overall reduction in life-cycle cost provided by shipboard CPS—all must be considered when designing, building, and backfitting our ships. The lives of our Sailors depend on it.

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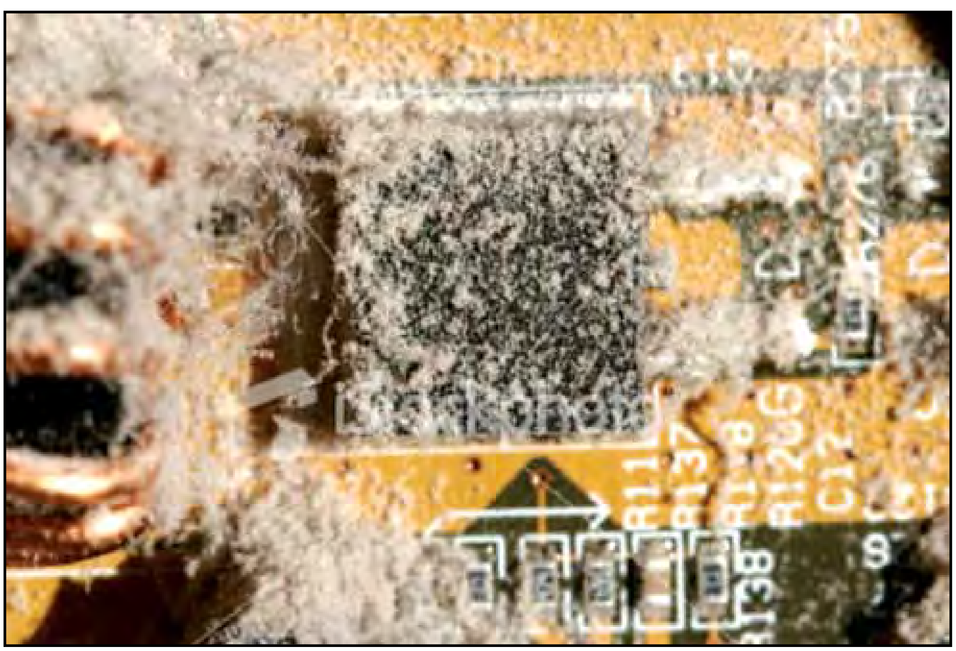

Figure 5. Dust Buildup on a Typical Electronics Board

The Impact of the Environment on Collective Protection Filters

By Carlos Murillo

Collective protection filters are utilized throughout the military for various applications from naval vessels, military installations, and mobile platforms such as tanks to portable shelters like field hospitals. These filters are installed in ventilation systems to protect warfighters and civilians from chemical, biological, and radiological attacks. An area of great concern is a filtration system's ability to remove chemicals from the airstream as the filter ages over time. Understanding environmental effects, therefore, is critical to the success of military technologies, especially in the area of filtration.

The impact of pollution has become an important variable that needs to be considered in the life cycle of military-relevant filtration systems. Filters don't just absorb chemical and biological warfare agents; they also filter out chemicals normally found in the atmosphere: sulfur dioxide, ammonia, paint remover, industrial solvents, partially combusted diesel fuel, and more. For this reason, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) scientists analyzed filters from Navy vessels and land-based facilities that were exposed to heavy construction and pollution to identify contaminants. Filter samples not only were evaluated for their remaining filtration capacity, but they were also analyzed to identify chemicals that had been absorbed by the carbon media over time. This analysis required an understanding of how filters function.

A collective protection filter is a set comprising a High Efficiency Particle Arresting or High Efficiency Particulate Air (HEPA) filter and a carbon filter collectively known as the M98 filter set. HEPA filters provide an excellent means of removing an extremely high percentage of biological and particulate material (both solid and liquid) from the air. HEPA media consists of a nonwoven sheet fabricated from glass and polymeric fibers. The sheet is pleated to allow more filter material in a smaller space. The fibers remove particles from the air by mechanical trapping that includes sieve effects, impaction, interception, and diffusion processes, in addition to static charge effects.[1] The M98 filter set is shown in Figure 1.

The carbon portion of the collective protection filter is made of activated coal-based carbon that has been impregnated with metallic salts. The carbon media filters the air stream by removing harmful vapors, chemical contaminants, and normal atmospheric pollution (e.g., sulfur dioxide). These harmful chemicals are removed by physical adsorption into the micropores of the carbon granules,[2] as well as by chemical reaction with impregnants deposited on the carbon media. As a guideline, chemicals that have

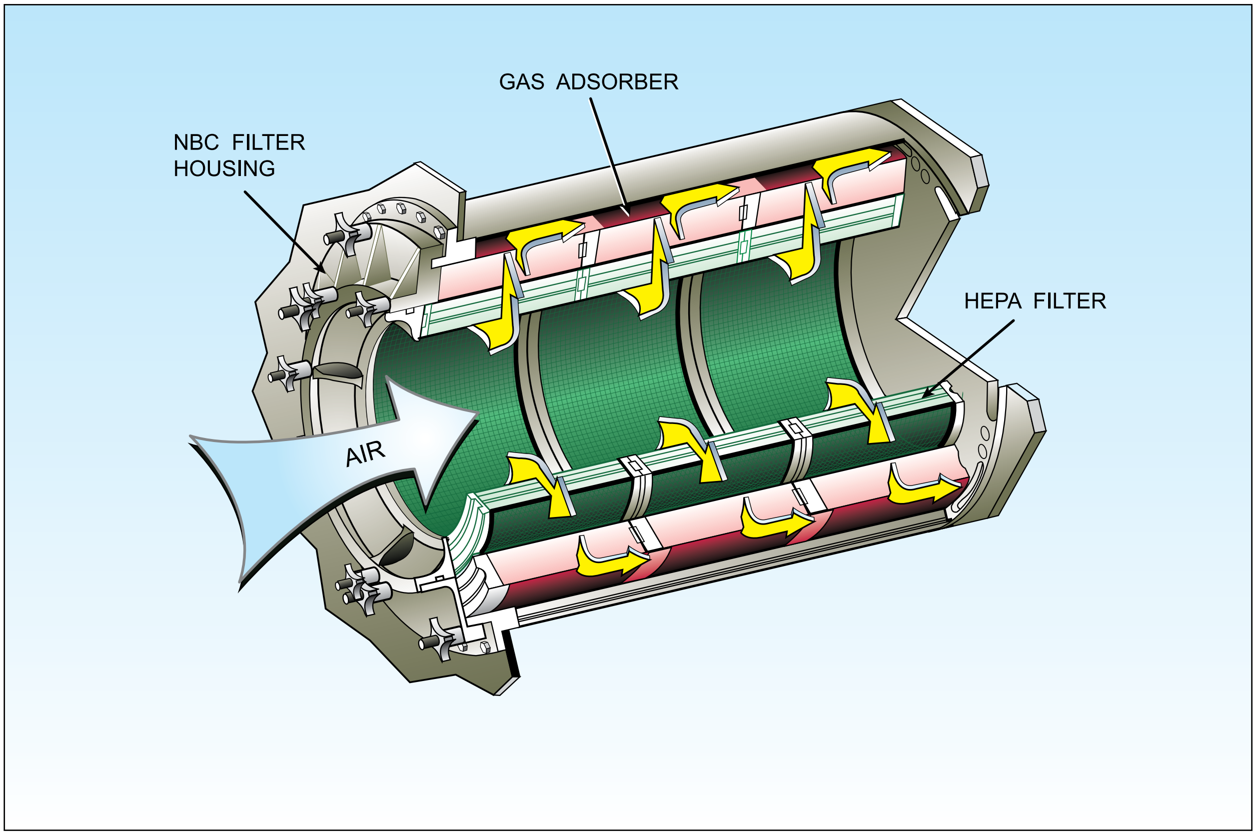

Figure 1. M98 Filters Installed in Series

low vapor pressures (approximately 10 mm Hg or less) are removed by physical absorption onto the pores of the carbon media. For chemicals with high vapor pressures (greater than 10 mm Hg), purification of the airstream is accomplished by chemical reaction of the gases with the metallic salts on the carbon media.

As previously mentioned, military installations and naval vessels employ carbon filters installed in their ventilation systems as a form of protection against chemical, biological, and, radiological attacks. However, as time progresses, the protection levels of these filters begin to degrade.[3] The main causes for diminished levels of protection include:

- Access to reactive sites has been blocked by adsorbed contaminants
- Metallic salts have reacted with acidic type pollutants
- Reactive salts have migrated due to moisture adsorption

These causes are of great concern since naval ships are continuously exposed to humid air and high pollution levels in ports. Consequently, vessels periodically need to have their filters replaced. Land-based facilities, too, can be exposed to high levels of humidity and pollution from various sources such as automobiles, cleaners, smokers, and construction, or when remodeling occurs.

As an example, NSWCDD scientists and engineers removed a filter from a military installation that had been exposed to construction and pollution. The carbon media was removed and analyzed. The analysis was performed using gas chromatography–mass spectroscopy (GC-MS). GC-MS is a combination of two techniques that are combined to form a single method for analyzing mixtures of chemicals. GC separates the different compounds within a sample, and then MS is utilized to characterize each of the individual compounds. By using this technique, scientists can identify and characterize the chemicals that desorb off of the carbon media when it is heated to high temperatures. The chromatogram of a sample is shown in Figure 2. The x-axis is the retention time, and the y-axis is the signal intensity, which is directly related to the concentration of that compound in the sample. The values shown by the peaks are elution times—the time required for the compound to exit the chromatography column. Every chemical has a unique retention time.

MS characterizes individual compounds by the mass-to-charge ratio of the individual fragments

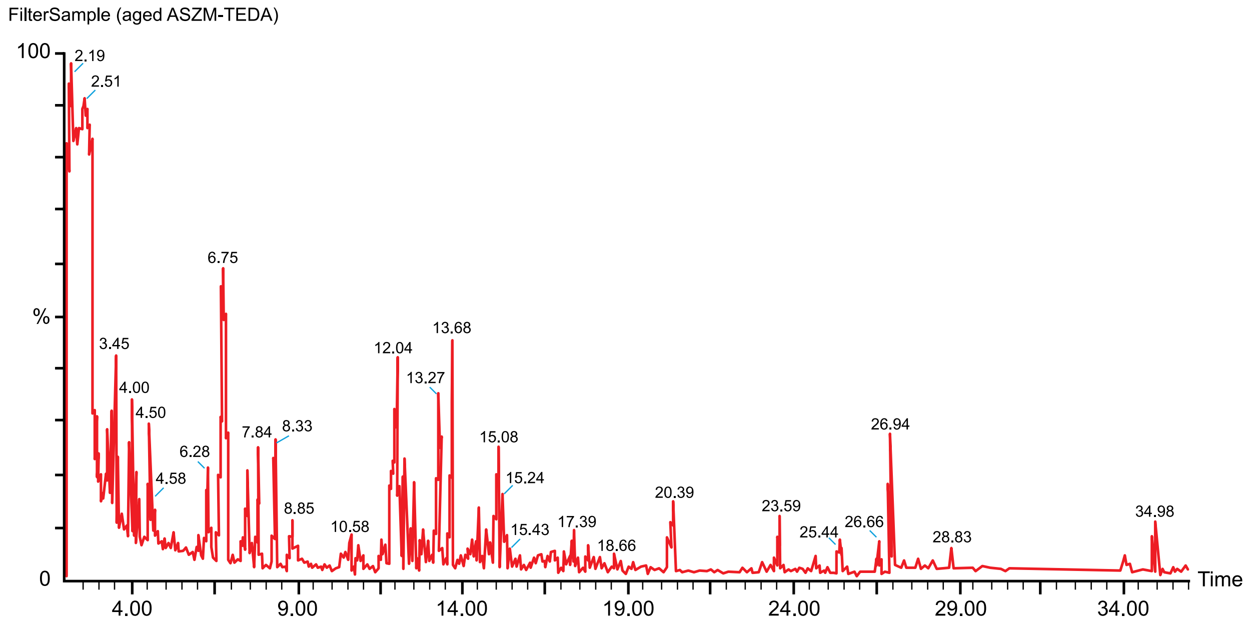

Figure 2. A Chromatogram of a Carbon Sample From a Filter

that compose the molecule. As the individual compounds exit the GC column, they enter a mass spectrum detector. In this detector, the chemical collides with a stream of electrons that break the molecule into fragments. The mass spectrum produced by a given chemical compound is essentially the same every time; it is a fingerprint for a molecule. Figure 3 shows a mass spectrum along with a match from the chemical library.

Analysis results of the filters exposed to combustion and pollution showed that a significant amount of chemical was adsorbed onto the media. Knowing that the filter tested was exposed directly to construction, the obvious conclusion was that these compounds represented a mixture of pollution and chemicals found in a construction area, perhaps combined with some naturally occurring environmental compounds. Scientists focused on products used in construction and found in pollution, such as paint thinners, caulking, and fuel byproducts. They found that the primary components of a typical brand of paint thinner include:

- Either naphtha or Stoddard solvent
- A benzene derivative, such as 1,2,4-trimethylbenzene or xylenes (dimethyl-substituted benzene)

Secondary components—such as alcohols, esters, and ketones—are found in some paint thinners. Fuel byproducts can be classified in two categories: tailpipe emissions and evaporative emissions.[4] Tailpipe emissions are the byproducts created in the normal operation of machines. The makeup of the emissions is dependent on the initial composition of the fuel used. Byproducts of incomplete combustion must also be considered in tailpipe emissions. Evaporative emissions represent all other emissions aside from tailpipe emissions,

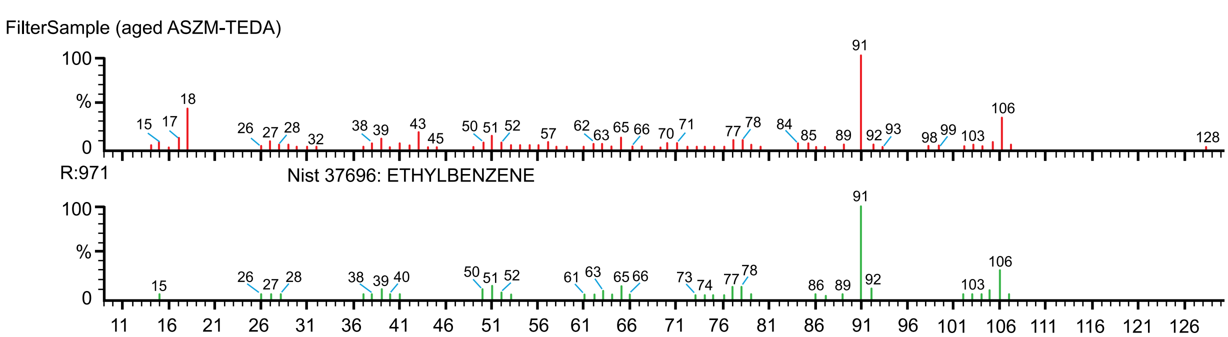

Figure 3. A mass spectrum of ethylbenzene along with the standard spectrum from a chemical library—ethylbenzene is a compound that can be found in fuel, paints, and tar.

such as resting emissions and leaks. These emissions usually are characterized by high content of smaller hydrocarbons.[4] The chemical composition of vehicle-related volatile organic compound emissions includes a large variety of compounds that were analyzed and that fit into eight basic groups:

- N-Alkanes
- Isoalkanes
- Cycloalkanes
- Alkenes
- Aromatics
- Acetylene
- Oxygenates
- Carbonyls

Almost all of the chemicals found on the filter fit into one of these eight categories.

Conclusions

Since the capacity of the filter is based on absorption volume, it can be hypothesized that pollution due to construction and vehicle exhaust can have a direct impact on the capacity and lifetime of a filter. This is also critical for navy vessels, as they make port calls to various locations throughout the globe. Some nations have fewer environmental regulations than the United States, which corresponds to an increase in exposure to toxic air pollution. Consequently, the results of this analysis are of significant value to the armed services because these conclusions enable scientists to design solutions for longer filter life or help shape filter change-out timelines. That has the potential to save the Navy millions of dollars in material and maintenance costs while providing warfighters with the protection they need.

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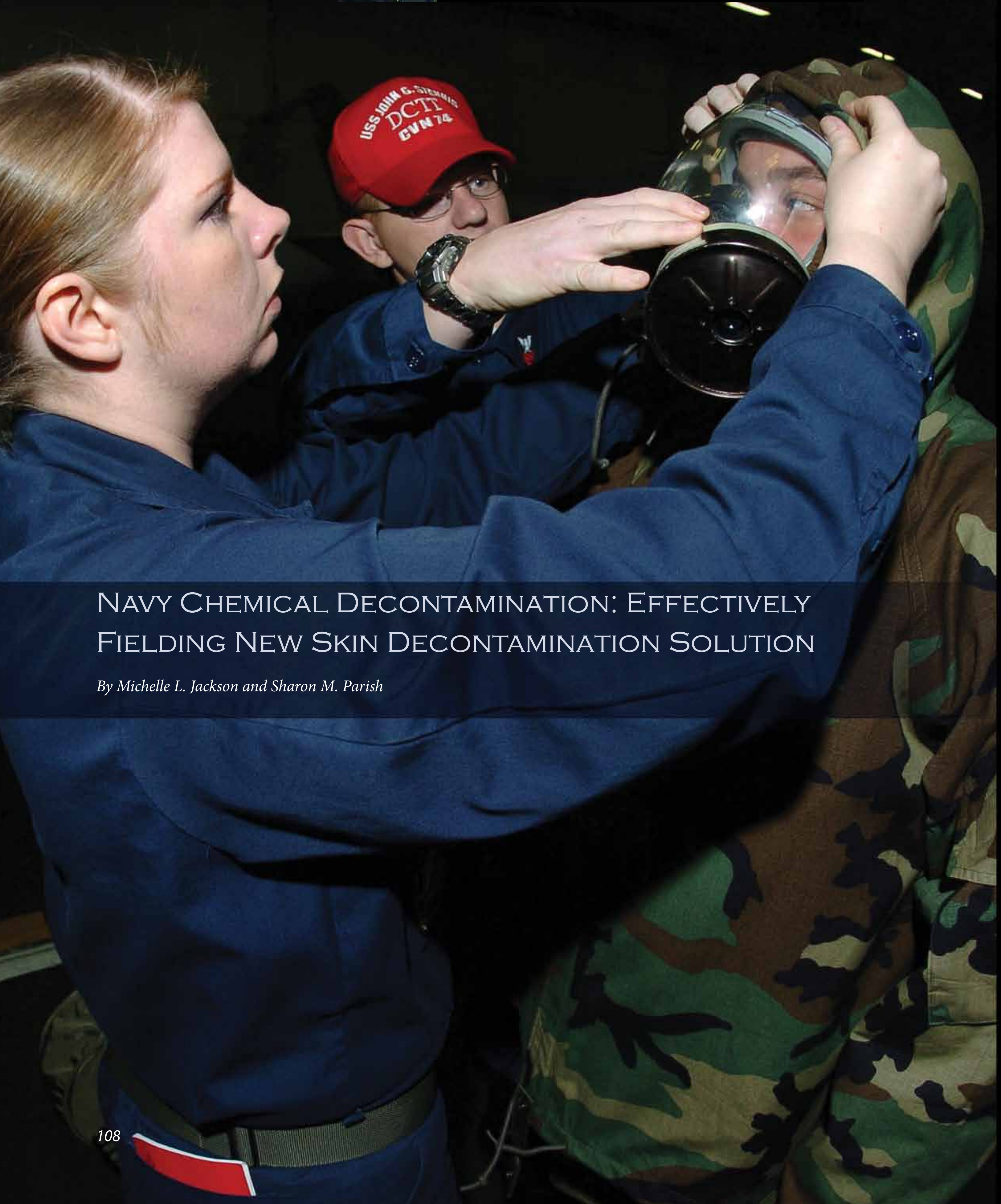

Navy Chemical Decontamination: Effectively Fielding New Skin Decontamination Solution

By Michelle L. Jackson and Sharon M. Parish

The Navy has used the M291 Skin Decontamination Kit since the early 1990s. An absorbent of chemical agents, an M291 kit contains six individual pads impregnated with a charcoal-like, resin-based power. The M291 Decontamination Kit is shown in Figure 1.

The Joint Service Personnel Decontamination System (JSPDS) Program launched a search for an upgraded skin decontamination system, ultimately selecting a commercial product—Reactive Skin Decontamination Lotion (RSDL). The Federal Drug Administration approved RSDL as a skin decontaminant, as it provides warfighters with a greater decontaminating capability than M291 for the nerve agents VX and soman (GD), and for the mustard blister agent (HD). Moreover, one application of RSDL is contained in one packet instead of two, as with M291, thus simplifying the process required for applying skin decontaminant. An opened packet of RSDL is shown in Figure 2.

While RSDL provides increased capabilities, it poses sustainment challenges for the Navy. Specifically, RSDL exposed to a static temperature of 120°F or greater has an operational life of 24 weeks. However, if the static operational temperature is less than 120°F, the operational life of RSDL

Figure 1. M291 Decontamination Kit

Figure 2. An opened packet of Reactive Skin Decontamination Lotion (RSDL) is shown with the applicator. The applicator is used to apply the RSDL onto equipment or personnel to decontaminate chemical agents.

is 24 months. Given that typical Navy deployments last longer than 24 weeks, the Naval Sea Systems Command's (NAVSEA's) Naval Surface Warfare Center, Dahlgren Division (NSWCDD) was tasked to assess operational temperatures that RSDL would likely be exposed to during operational deployments. The intent of this effort was to see if actual temperatures stay below 120°F and to estimate the useful operational life under actual fielding conditions.

NSWCDD championed this effort, which employed Universal Serial Bus (USB) Temperature Dataloggers from Extech Instruments Corporation to monitor operational temperatures. The temperature dataloggers are placed on board ships in decontamination station areas and inside individual protective equipment kit bags for ground forces. Issued through the Readiness Assist Visit team and the Readiness Improvement Program, the dataloggers provide the ability to estimate operational temperature exposure to RSDL if placed in these areas. Placement of dataloggers in these areas is significant because operational temperatures can vary within the course of a day for both ashore and afloat operational environments. Notwithstanding, the JSPDS program used mean kinetic temperature (MKT) as a simplified way of expressing the overall effect of temperature variation once RSDL is removed from controlled temperature storage. The advantage of using the MKT is that it takes into account short temperature excursions above 120°F that may not reduce the operational life to 24 weeks. The benefit of a 24-month operational life for unused RSDL is that it can be reissued within the span of the 24 months, which results in a cost savings to the NAVSEA Decontamination Program.

Additionally, the Joint Program Executive Office for Chemical and Biological Defense has developed a time temperature indicator (TTI) to include on RSDL packets when manufactured. TTIs incorporate MKT to accurately determine the service life limits of RSDL exposed to various temperatures. TTIs, therefore, assist with RSDL management by providing visible information reflecting product quality. An example TTI is shown in Figure 3.

The temperature analysis provided by NAVSEA's Dahlgren and Carderock warfare centers will aid decontamination support decision makers in determining how much RSDL the Navy needs to procure each fiscal year, which will further aid in developing a more accurate RSDL sustainment budget. More importantly, this analysis will help to ensure that warfighters afloat and ashore continue to be equipped with the most effective skin decontamination solution despite fluctuations in operational temperatures over time.

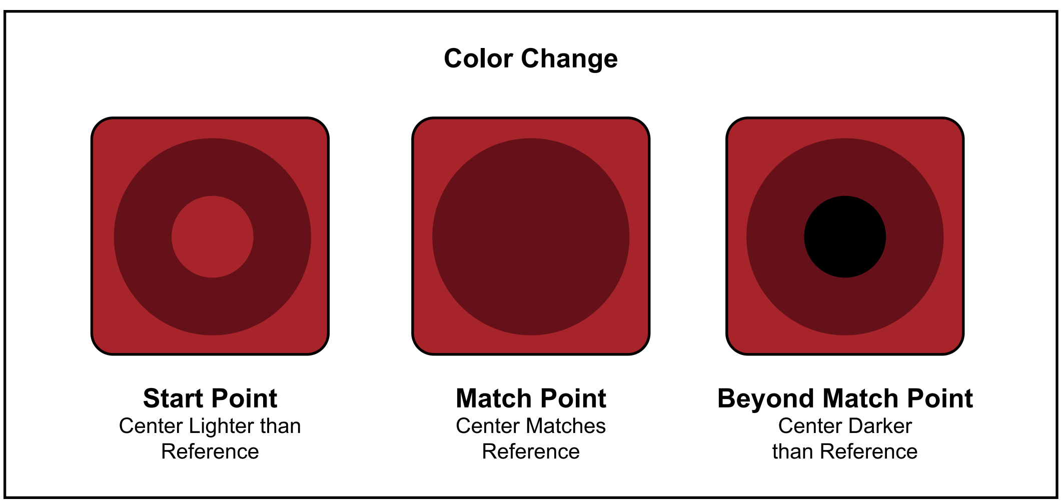

Figure 3. Time Temperature Indicator


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Validation, Verification, and Accreditation Challenges for the Joint Effects Model (JEM)

By Russell P. Brown

Scientists and engineers routinely use modeling and simulation (M&S) in the course of their work. M&S provides decision makers with information in the context of military operations, and its use is becoming more frequent. Department of Defense (DoD) regulations require M&S to be verified (did we build it right?), validated (did we build the right thing?), and accredited for each intended use and environment (can we use what we built to do what we want, where we want, and by the people we want to use it?).[1] This article will describe the Joint Effects Model (JEM) and its verification, validation, and accreditation (VV&A).

What Is the Joint Effects Model (JEM)?

The JEM is a computer model that predicts the hazards and toxic effects that can result from enemy use of chemical, biological, radiological, and nuclear (CBRN) weapons, as well as from releases involving toxic industrial chemicals (TICs) or toxic industrial materials (TIMs). JEM is the first model of its kind to be verified, validated, and accredited for use by DoD. Users of the JEM define or select a specific release from one of the incident source models (ISMs), and the JEM then transports the material downwind while calculating natural dispersive behavior. Once the location and amounts of hazardous material have been computed and stored, JEM then computes the severity of the hazard and displays it to the user.

What Can JEM Be Used for?

The JEM has a large number of intended uses as shown in Figure 1. Warfighters can use the JEM for operational uses—defensive planning, reacting, and being aware of CBRN incidents. Warfighters can train with the JEM, too. Analytical users, who are typically DoD analysts, can use the JEM to develop tactics, techniques, and procedures while including any effects CBRN weapons might have on the numbers and kinds of military units, weapons, and/or defensive equipment needed in the future.

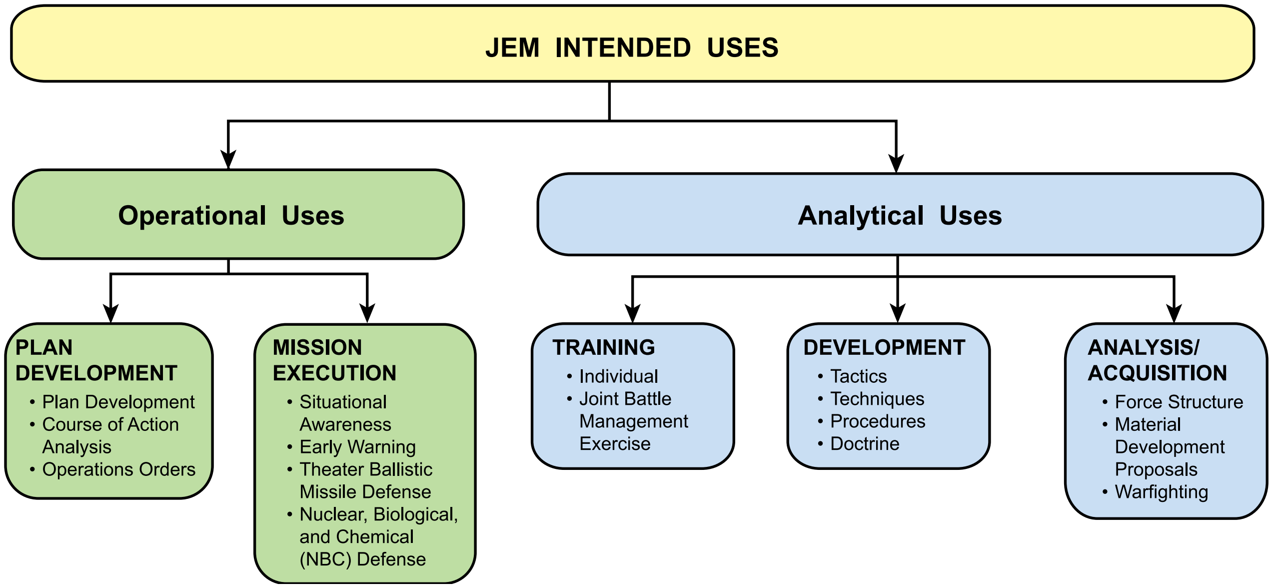

Figure 1. Joint Effects Model (JEM) Intended Uses

Incident Source Models (ISMs)

JEM capabilities are defined by the incident types (ISMs) that can be modeled. The ISMs in JEM are:

- Chemical/Biological Weapon Strike (CBWS)—models the results of chemical or biological bomb, missile submunition, rocket, and artillery attacks (see Figure 2). Aerosol sprayer attacks are also included. Outputs include:
  - Surface Dosage
  - Surface Deposition
  - Concentration
  - Integrated Concentration
  - Probability of Casualties
  - Probability of Mortality
  - Probability of Infection (biological agents only)
- Chemical Stored Weapon Incident (CSWI)—models accidental releases at facilities where U.S. chemical weapons are stored pending disposal. Outputs are the same as for CBWS except for surface deposition.
- Chemical or Biological Facilities Strike (CBFS)—models standard, conventional munition attacks on chemical or biological production or storage facilities, with three levels of fidelity (Quick Calculation, Damage Category, and Detailed Model). TIMs are included as "agents" in the damage category option. Outputs are the same as for CBWS.
- Chemical-Biological High-Altitude Release (CBHAR)—models bulk chemical and submunition theater ballistic missile payloads released at altitudes over 20.5 km. Outputs are the same as for CBWS.
- Radiological Dispersion Weapon Detonation (RDWD)—models "dirty bombs" where radiological materials are dispersed by conventional explosives. Outputs include radiation dose, radiation concentration, radiation deposition, and surface deposition.
- Nuclear Weapon Detonation (NWD)— models selected NWDs. Outputs include radiation dose; probability of casualties; and the effects of blast, heat, and prompt radiation (which excludes radioactive fallout).
- Nuclear Reactor Facility Release (NRFR)—models releases by, and selected accidents in, nuclear reactors. Outputs are the same as for RDWD.
- Nuclear Weapon Incident (NWI)—models the release of special nuclear material from a weapon that has not produced a nuclear yield. Outputs are the same as for RDWD.
- Analytical Release Incident (ARI)—models any release, provided the necessary parameters are known or postulated. This ISM represents JEM's ability to model nonstandard incidents. Outputs include surface dose, surface deposition (liquids), concentration, and integrated concentration.

The JEM is to be used operationally by all U.S. military services, individually and as part of joint operational task forces, as well as by analysts working in or for the DoD. The program can reside within an organization's unique command and

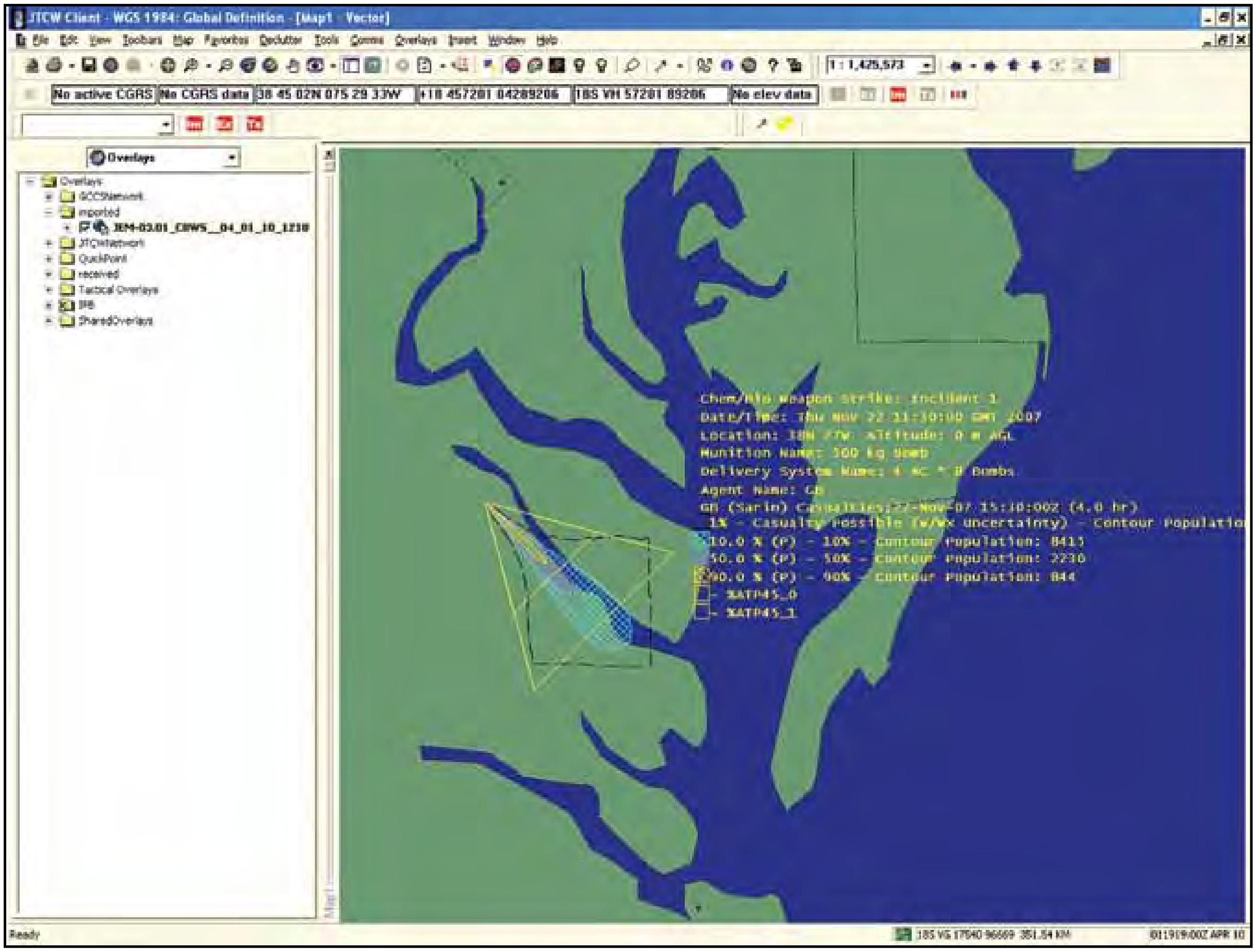

Figure 2. Sample JEM hazard prediction from 32 bombs each filled with 500 kg of the nerve agent Sarin. The yellow triangles show the "old" method of estimating the hazard. The dotted black lines show the possible uncertainty in wind direction. The colored contour plots show three different levels of Sarin toxicity predicted by JEM.

control system, and it can also be installed on a laptop or desktop computer with a Windows operating system.

VV&A in General

The goal of VV&A is accreditation, which is simply a statement saying whether or not a model meets all of the acceptability criteria for the model's intended uses and can be used with or without limitations.

Accreditation limitations are usually the uses that could be attempted by users but should also include uses for which the model is ***not*** suitable, should only be used with caution, or should be used only by subject matter experts. The intended uses are necessary in order to develop acceptability criteria (defining "good enough"); these, in turn, are used to identify verification and validation (V&V) tasks. Validation can be broken down into data validation, method validation, and output validation. Figure 3 depicts a generalized VV&A process.

Intended Use(s)

The intended uses of any particular M&S drive the type and kind of V&V that is done; otherwise, V&V—not to mention development—would never end. Thus, the intended uses of a model or simulation are critical. The intended uses must be specific, and there must be things associated with the intended uses that can be measured or counted.

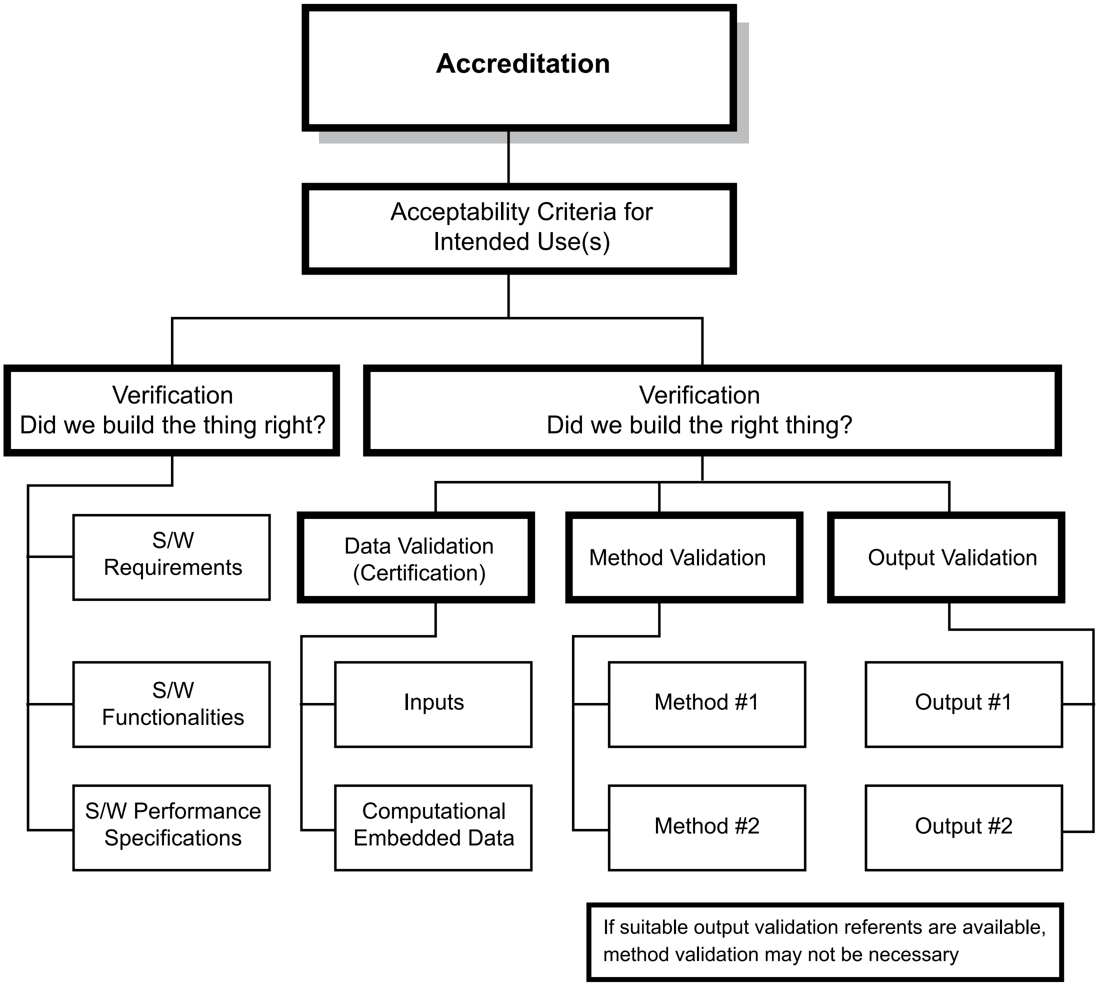

Figure 3. General VV&A Process

At first glance, it is not obvious that the JEM's intended uses can be measured or counted. However, what permits each of the intended uses are predictions of the location and severity of some kind of physical process (a dosage, concentration, or deposition) leading to some toxic effect.

Verification

For any model, verification is the process by which bits of computer code are checked to make sure that the code is doing what the programmer intended it to do. For example, are the correct constants and variables being used in an equation? Is the correct equation being used to compute a particular quantity? Are the correct units being used? Are unit conversions being done correctly? These are the types of questions that are asked in verification. Since JEM is also a DoD acquisition program, as well as a computer model, verification also asks if JEM meets its requirements. In response to this question, the JEM Test and Evaluation team performed development testing on the program to ensure that the stated requirements were met. This served as a system-level verification of the model.

Data Certification

All models have input data; most models have embedded data. JEM input data falls into two categories: incident specific and material specific. Incident-specific data describes the what, where, and when of an incident. This data does not have to be certified. The material-specific data, however, does have to be certified. The material-specific data in JEM refers to the physical properties of the hazardous materials JEM can model. Examples of these properties include vapor pressure, density, molar

mass, boiling point, etc. Material toxicity and how it varies with concentration and exposure time are also examples of material-specific properties that must be certified. The certification process usually involves identifying an authoritative source (e.g., a textbook or technical report) for a particular property to see if the correct value is being used. Examples of embedded data include the gravitational constant (G) or the ratio of a circle's circumference to its diameter (π). Any and all uses of constants like these must be checked to determine if they are correct and consistent.

Output and Method Validation

Ideally, output validation—where model predictions and real-world data can be directly compared to each other—is the preferred method of validation. However, when real-world data does not exist, method validation is used. This approach requires that subject matter experts go through the code to make sure that the correct equations and methods are being used. If possible, intermediate quantities calculated by the program before displaying the final results are compared to existing data. This is known as method validation. For example, one JEM output is the probability of casualties from a bomb filled with nerve gas. Obviously, field experiments designed to capture this kind of data are unthinkable; therefore, intermediate data (like the amount of nerve agent deposited on the ground per square meter or a 10-min dosage measurement) is compared to the predicted values.

JEM VV&A Challenges

The VV&A effort for JEM was quite challenging for a number of reasons and revolved around the validation. Not only does JEM predict very complicated real-world behavior (the transport and dispersion of hazardous materials), it must do so in a complex operational environment when used by nonscientists in time to provide useful information to decision makers. JEM is a large program (over 1 million lines of code, including comments), with a great deal of both input and embedded data. Probably the most difficult challenge faced during VV&A for JEM was the fact that for some outputs, like the probability of casualties following an attack, there was no data that can be used for output validation.

Validation "by Parts"

The nature, complexity, and validation challenges of JEM led the JEM Program Office to develop a VV&A strategy called validation "by parts." Figure 4 shows the natural "parts" of JEM.

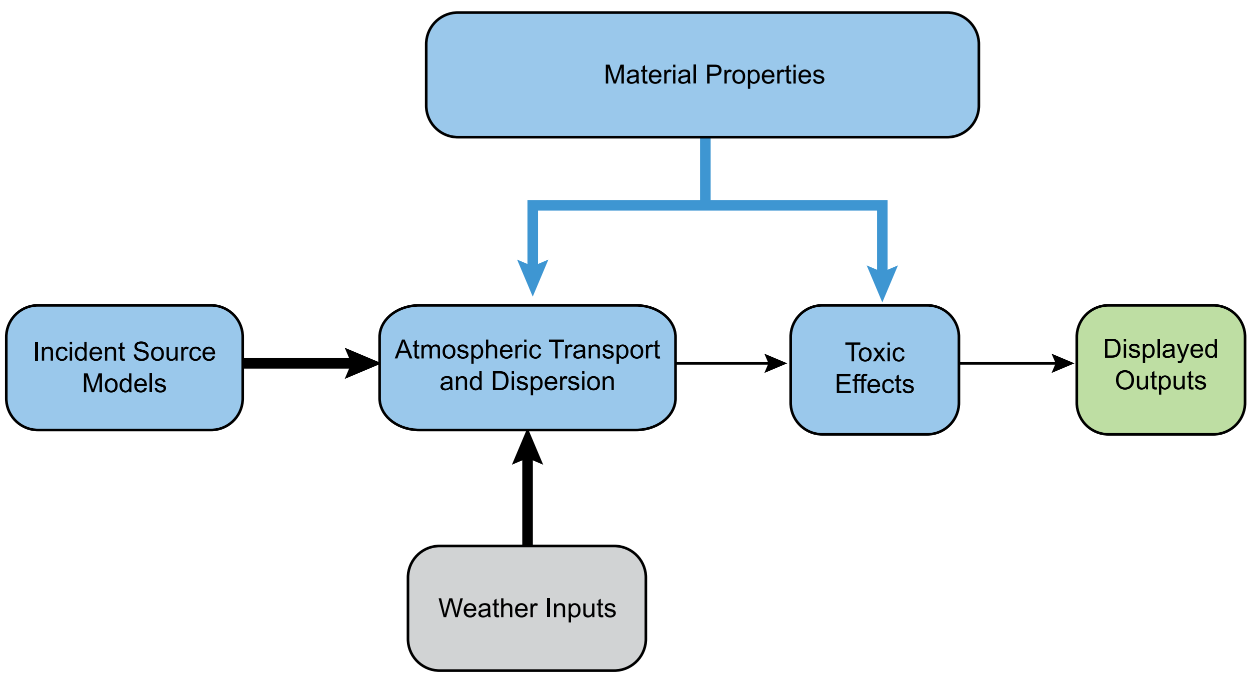

Figure 4. JEM Parts

Atmospheric transport and dispersion is the key process that enables everything else and the process (in terms of what is modeled) that will have the most influence on the outputs. Thus, a separate output validation effort was conducted on the JEM atmospheric transport and dispersion engine using high-quality field trials specifically designed to test these kinds of models. The separate validation of the atmospheric transport and dispersion engine allowed the examination of each ISM. Since data for all of the available outputs for the ISMs was not available, the method validation approach was used. This method compared available data to intermediate outputs (like dosage or deposition) and relied on independent subject matter experts to ensure that the correct science was used and to capture any limitations present. Dosage and deposition data for some chemical weapons—dating from the 1950s and 1960s—was available, likewise for historical nuclear weapon tests. However, this data was not intended to be used for model validation and reiterated the need for subject matter experts. This approach was also used to validate the science behind the calculation of toxic effects. Most existing data is based on historical animal testing, which also required review by subject matter experts.

Conclusion

While the VV&A of JEM was extremely challenging, the model was successfully accredited, with limitations, for use by all of the DoD by the Joint Program Executive Office for Chemical and Biological Defense (JPEO CBD) on 15 August 2007. Since then, the JEM Program Office has been providing U.S. warfighters with the JEM that they can use with confidence to predict the hazards and toxic effects that can result from enemy use of CBRN weapons, as well as from releases involving TICs or TIMs.

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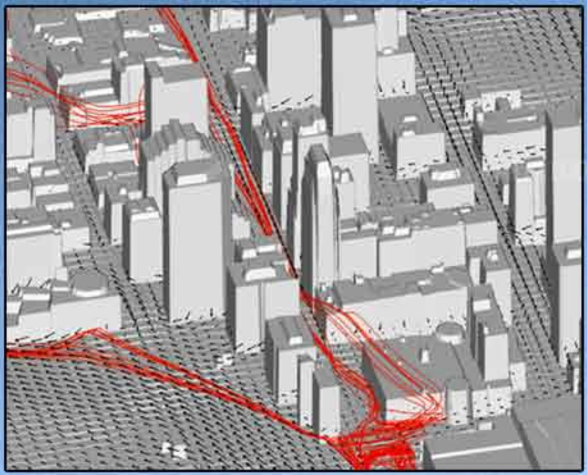
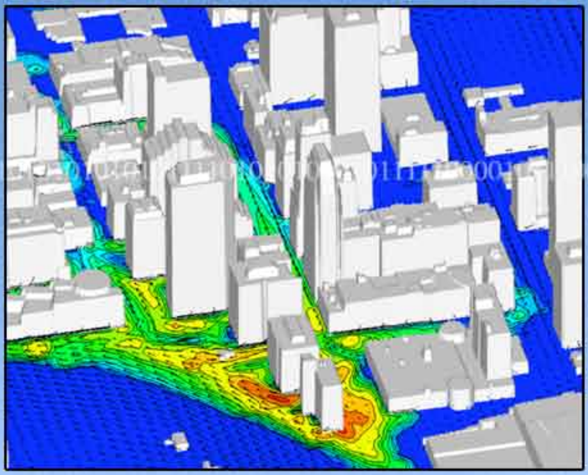


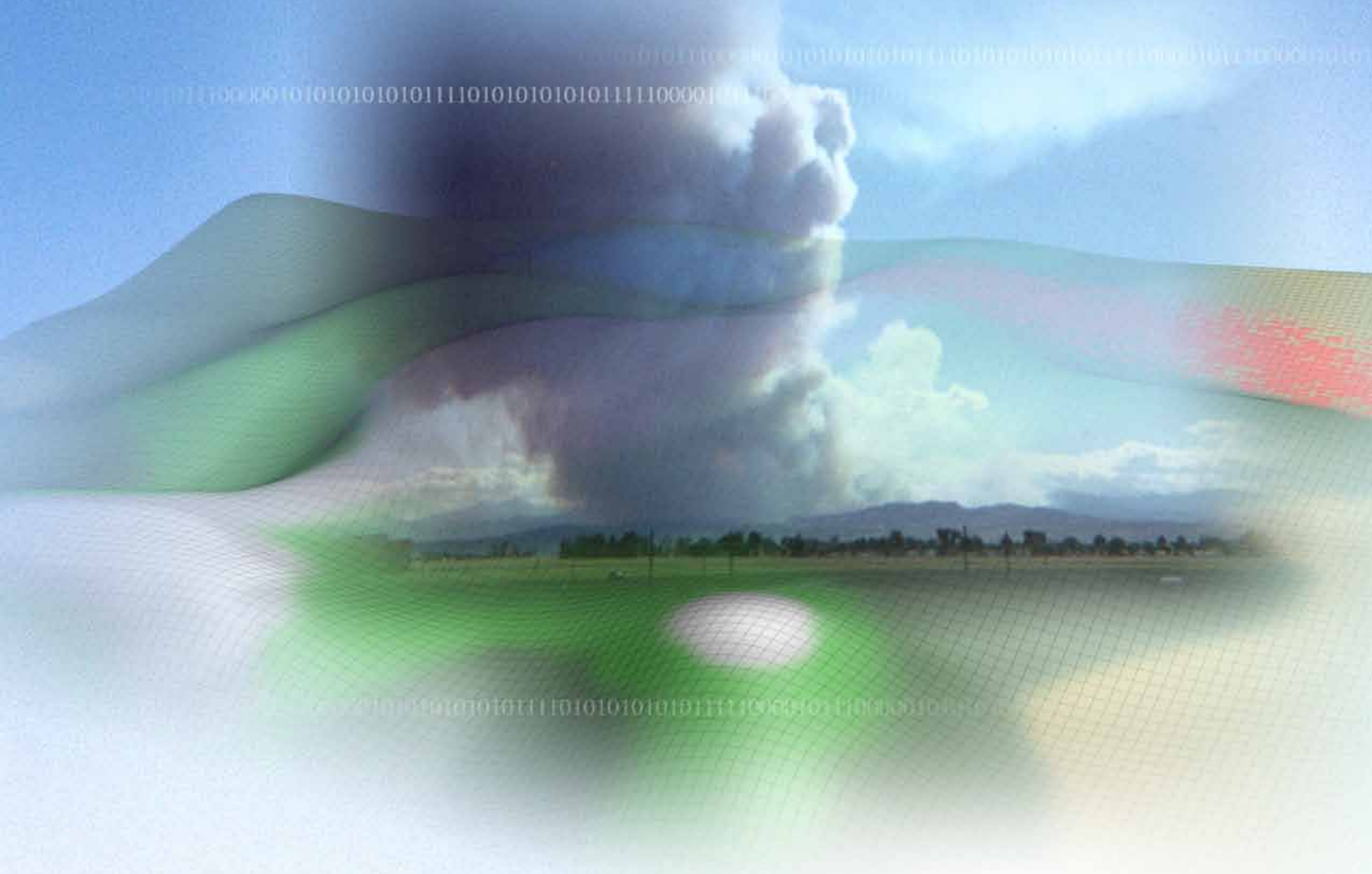


Independent Verification and Validation of MESO for the Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC) Program

By Gaurang R. Dävé and Cesar Smith

A 155mm artillery shell containing mustard gas explodes in the suburbs of Washington, DC. A thick, yellow-brown cloud forms and slowly moves downwind. Thousands of people are in its path.

Fortunately, this scenario did not take place near a metropolitan area or military base. It occurred within the confines of a Navy computer laboratory at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), located in Dahlgren, Virginia. NSWCDD's Chemical, Biological, and Radiological (CBR) Defense Division employs state-of-the-art computer modeling and simulation (M&S) to perform hypothetical scenarios using mathematical and scientific principles to predict what would happen in the real world. In addition to providing added safety to the warfighter and the general population, M&S saves time and money. NSWCDD scientists and engineers perform M&S in support of the Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC) Program.



The Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC) Program

The purpose of the TACTIC Program, managed by the Defense Advanced Research Projects Agency (DARPA),[a] is to provide the U.S. military with the capability to protect the warfighter from chemical and biological warfare agent threat clouds on the battlefield. The goal of the program is to provide a system that can rapidly detect and identify the presence of a typical threat cloud and provide a countermeasure to that cloud that will kill it before it reaches the intended target.[1] Accordingly, TACTIC aims to develop models that accurately simulate the transport, dispersion, and interaction of threat agents and counteragent aerosols or vapor clouds on the battlefield and in urban areas. CBR Defense Division researchers, in support of the TACTIC Program, use models to predict the effectiveness of such countermeasures. They currently are working to determine whether or not the Mesoscale Model (MESO) is better than traditional hazard prediction models.

The MESO

The MESO—developed by ITT Industries located in Colorado Springs, Colorado—is currently being validated by the CBR Defense Division. MESO can theoretically produce results that model behavior that is closer to the real world since it takes into account the "randomness" of plume movement through an environment. It also has the potential to provide higher fidelity results without the need for intense resources, such as computational fluid dynamics, required by other models. Other models, such as the Vapor, Liquid, and Solid Tracking (VLSTRACK) Computer Model, employ a Gaussian-based calculation, whereas MESO employs random walk tracer particles.[b] In Gaussian-based code, the main vehicle for calculations is the center point for concentrations and its distribution. With random-walk tracer-particle code, the concentration is represented more discretely with the use of individual particles.

To further illustrate this difference, assume, for instance, a group of people watching a football game. We can take one person's observations into consideration and assume that they represent the observations of the group. On the other hand, we can take into consideration each individual's observations. Obviously, the more people we take into account, the higher the details of the football game observations.

Going back to the models, VLSTRACK will produce a result that best describes the plume and is probably good enough for most cases. However, MESO will theoretically produce higher fidelity results and can take into account more factors, such as differences in terrain (hilly versus flat), 3-D wind fields, and variations in ground cover (i.e., vegetation).

Figure 1 shows example output from a Gaussian-based puff, as produced by the VLSTRACK Computer Model. The color inside the cloud represents higher concentration. The smaller cloud represents the plume after 30 seconds, and the cloud on the right shows how the plume has grown in size after 5 minutes.

Figure 2 is an example of MESO output showing how it interacts with terrain. Also, notice how each red dot represents the particle tracers and their location within a three-dimensional domain.

In determining whether the MESO is better than traditional hazard prediction models, the first step is to study the procedure used to validate previous models, such as VLSTRACK. Studying this procedure provides the ability to look at lessons learned and leverage existing methodologies, as well as looking back at the benchmark to see how well the new model must perform. Field trial data is then gathered and analyzed, followed by a translation of this data into the model's inputs. After the inputs are generated, the model is run, and the output is compared to the field trial reports. The last step is to take these comparisons and calculate a series of statistics, which will determine how well the model predicted a simulated incident. Subsequently, if researchers determine that MESO provides better prediction technology than existing models, then that determination serves as the basis for implementing MESO into programs such as TACTIC. The goal for TACTIC is to be able to accurately model the movement and interaction of clouds; the validation effort determines if MESO is the right tool for that job.

Verification and Validation

There are risks associated with using M&S to simulate events such as the opening scenario above. How do we know that the model will accurately predict the size, shape, and orientation of the mustard cloud? Does the model take into account real-world factors such as weather, terrain, vegetation, etc.? To ensure that the model is behaving appropriately and is accurate, therefore, it has to be verified and validated using field trial data. In general, field trial data is obtained by releasing an agent or simulant in an open, unpopulated test range. Sensors are placed throughout the range and data, such as concentration amounts, are collected. This collected data indicates locations where the agent was found and in what quantities. This effort

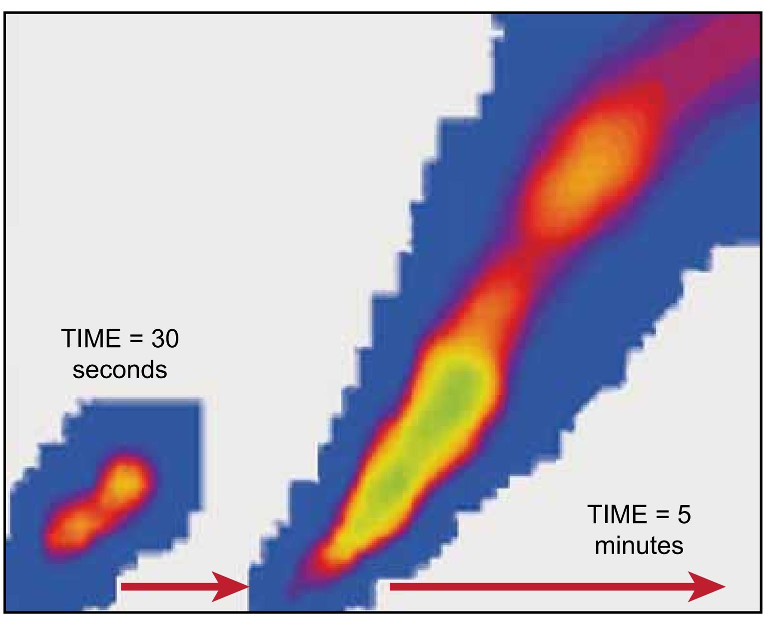


Figure 1. Gaussian Puff Example

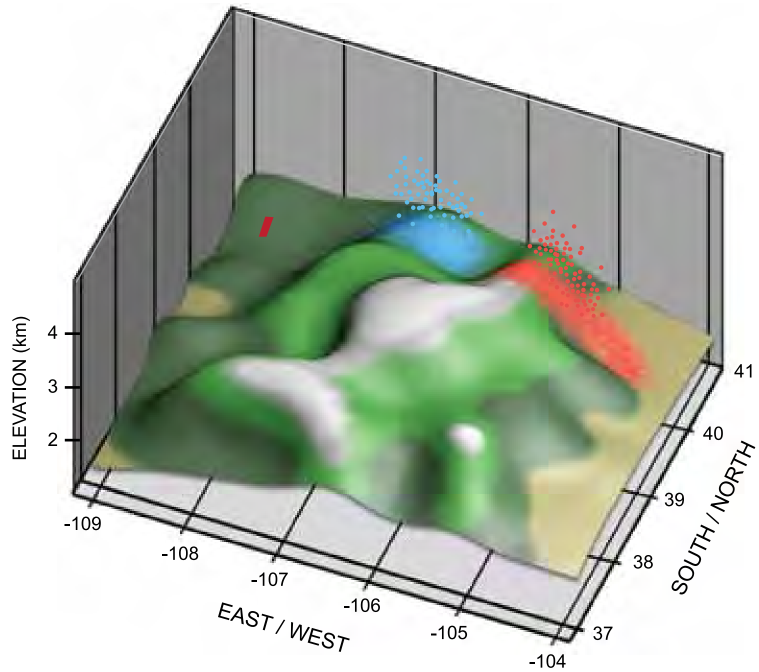


Figure 2. The MESO: Random-Walk Tracer Particles

requires analyzing the trial data, creating and running scenarios within the software that emulate the parameters in the trial, and performing a statistical analysis of the results.

Using the parameters collected at the test site (e.g., wind speed and direction, temperature, time of day, agent quantities, relative humidity), a run can be performed using a mathematical computer model. The output from this model is compared to the data collected from the field trial. After obtaining a series of statistics from this comparison, engineers can decide how accurate the model is in predicting the hazard.

Notwithstanding, there are concerns in using this method of validation. Probably the biggest concern is comparing model outputs with data that is over 50 years old. The reason data is so old is because testing using live agents is prohibited. Moreover, the means for collecting and processing the data were limited and crude by today's standards. One way of addressing these concerns is to use a variety of test data, including more recent field trials. Additionally, the statistics derived from analyses are averaged over the entire field trial set, which diminishes the effect of "bad data."

Conclusion

In the future, TACTIC will be able to provide the warfighter with the capability to evaluate the effectiveness of various chemical and biological "defeat" mechanisms—countermeasures intended to neutralize, kill, or decontaminate a chemical or biological threat. The use of M&S within the confines of a computer laboratory saves time and money, and potentially can save lives. State-of-the-art models, such as MESO, are being studied by the CBR Division to determine model effectiveness when predicting chemical or biological attacks. As a result, answering the question of what would happen if a 155mm shell containing mustard gas actually went off near populated areas may just be a matter of a few clicks of the mouse. Ultimately, warfighters will benefit by being better prepared in the face of chemical and biological threats.

Endnotes

a. The views, opinions, and/or findings contained in this article are those of the author and should not be interpreted as representing the official views or policies, either expressed or implied, of the Defense Advanced Research Projects Agency or the Department of Defense.

b. The VLSTRACK Computer Model provides approximate downwind hazard predictions for a wide range of chemical and biological agents, and munitions of military interest. VLSTRACK features smart input windows, which check input parameter combinations to ensure that a reasonable attack is being defined, and simple and informative output graphics, which display the hazard footprint for agent deposition, dosage, or concentration. Source: http://www.ofcm.gov/atd_dir/pdf/vlstrack.pdf

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What if a Terrorist Attack Releases a Toxic Industrial Chemical?

By Timothy J. Bauer

On 6 January 2005, a train wreck in Graniteville, South Carolina, led to the rupture of a 90-ton chlorine railcar, resulting in the release of 54 tons of chlorine.[1] Over 5,000 people in the lightly populated area were evacuated, over 500 people sought medical treatment, and 9 people died. This accident led to concern among city planners, emergency responders, the transportation industry, the chemical industry, the Department of Homeland Security (DHS), and the Department of Defense (DoD) about potential terrorist attacks on chemical railcars and tanker trucks transiting an urban area, or chemical storage tanks near an urban area. A comparison of modern hazard-assessment model predictions at the time consistently suggested that lethal concentrations from large releases of chlorine would persist within the plume of toxic vapor beyond 6 miles downwind.[2] As the spread of the expected plume moved rapidly through an urban area, results indicated that hundreds of thousands of persons would need to be evacuated.

Such a large evacuation effort would be impractical for emergency responders. Further, records of toxic effects from accidents like that in Graniteville suggest that the downwind hazard area is much shorter than the hazard assessment models predict. The nine deaths in Graniteville all occurred within half a mile of the accident. Likewise, deaths during the World War I Battle of Ypres, France, on 22 April 1915 resulted from several thousand chlorine cylinders along a 4-mile-long trench and were limited to within less than a half mile of the release trench.[3] Even the over 2,000 deaths in Bhopal, India, that resulted from the 3 December 1984 release of 40 tons of methyl isocyanate occurred within less than 2 miles; the large number of deaths were associated with the high population density rather than the downwind distance of that highly toxic chemical.[4]

To address the large discrepancy between recorded toxic effects and model predictions, the Transportation Security Administration (TSA) assembled a group of subject matter experts from the chemical industry, transportation industry, national laboratories, academia, emergency response organizations, DHS, DoD, and the intelligence community. A meeting was held on 8–9 November 2006 in McLean, Virginia, and was co-chaired by a representative from the Naval Surface Warfare Center, Dahlgren Division (NSWCDD).[5] Discussion focused on the release of chlorine from a 90-ton railcar and the identification of knowledge gaps associated with such a release. The most important knowledge gaps fell into three categories:

1. Characterization of the vapor source resulting from the liquid jet
2. Human toxic effects
3. Reaction and removal of the chlorine vapor with surfaces and air as it travels downwind

Each is discussed below.

Vapor Source Characterization

Survivors of the Graniteville accident reported that chlorine vapor remained in the release area for at least 2 hours. The chlorine vapor plume also followed the path of the valley within which Graniteville is located, which was somewhat different from the wind direction at the time of the accident. The chlorine was thus heavily influenced by the terrain features, along with the buildings and vegetation in the release area. Conversely, hazard prediction models all assumed that the liquid jet would mix with passing air and be carried downwind as a long vapor plume. These modeling approaches agreed with data from field trials involving large releases of toxic industrial chemicals (TICs), such as ammonia; but those releases occurred over flat desert terrain under a fairly high wind speed. Field trials also were limited by available test sites and the requirement that the wind direction remain steady and predictable for safety reasons.[6]

One theory addressing these additional features, developed by NSWCDD in 2008, was that large TIC masses of vapor and aerosol released over a short time period would pool into a large cloud at the release site and give off vapor into the passing air over an extended time period.[7] This pooling was likely enhanced by the presence of buildings, vegetation, and terrain depressions in the release area. The significance of having a long-duration source of vapor instead of a short-duration plume was that the concentration of the chemical was lower and less toxic, especially when coupled with the human toxic effects described in the next section. TIC vapor plume formation versus pooling at the release site is shown in Figure 1.

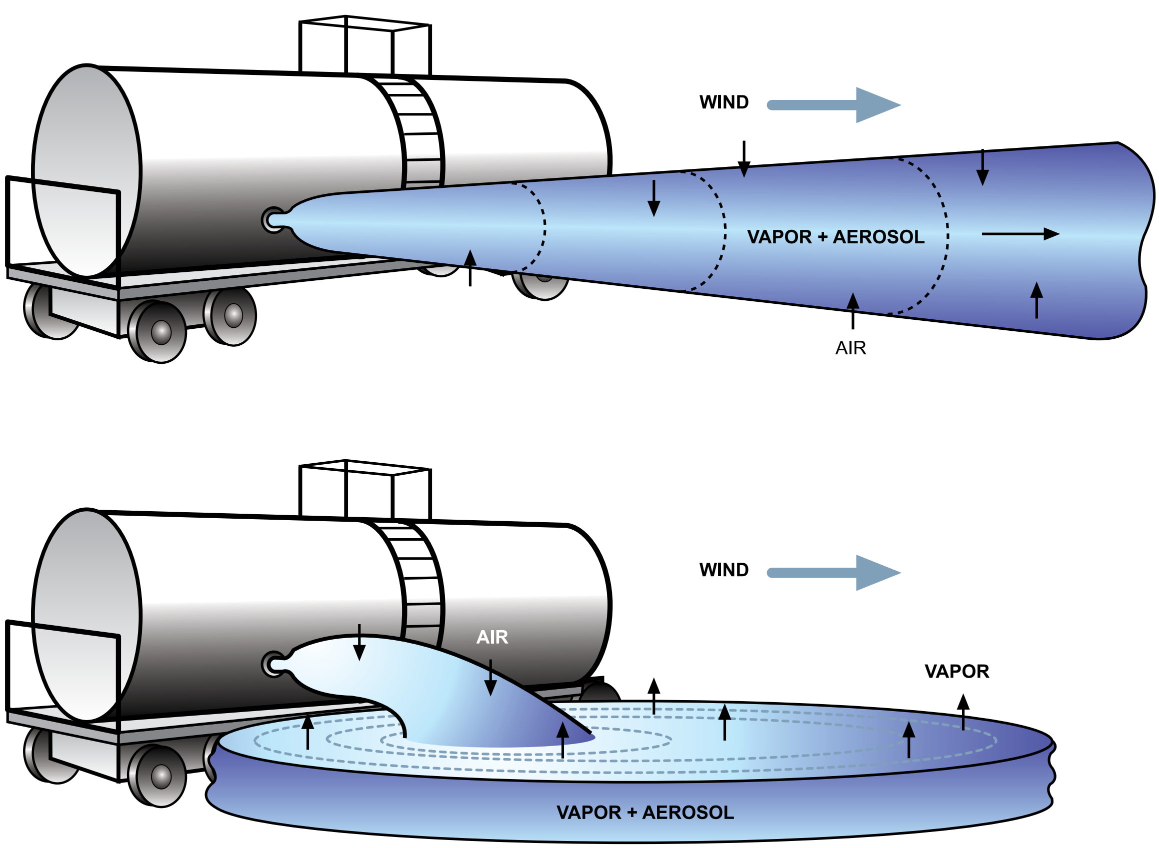

Figure 1. TIC Vapor Plume Formation Versus Pooling at the Release Site

Human Toxic Effects

The model predictions used to estimate the downwind hazard areas were based on chemical concentrations. The concentrations of interest were the Acute Exposure Guideline Levels (AEGLs) developed for the Environmental Protection Agency.[8] For a given chemical, there are AEGLs for life-threatening, serious, and irritating effects. Human toxic responses are a function of exposure (which combines concentration and duration) rather than just concentration, so there are AEGLs for a range of exposure durations ranging from 10 minutes to 8 hours. The problem with the AEGLs identified by the subject matter experts was that they are set for the most sensitive subpopulation rather than the average person. Thus, the AEGLs cannot be used to estimate expected casualties from a TIC attack or accident.

An important aspect of human toxic responses is that, for one-time acute exposures, the human body can slowly expel or otherwise counter a toxic chemical. A high concentration received over a short duration, therefore, is more toxic than an equivalent exposure involving a low concentration over a longer time period. This "toxic load" approach reveals why lowering the vapor concentration at the release location, as discussed above, can dramatically reduce the size and length of the downwind hazard area. Even if the TIC does travel downwind as a high-concentration plume, use of higher toxicity values appropriate for the average person and the toxic load approach with existing hazard prediction models will greatly improve model output.

The importance of proper source characterization and toxicity estimation can be demonstrated using a scenario involving the release of 2,500 pounds of hydrogen cyanide in downtown Baltimore, Maryland.[9] In this scenario, the number of persons requiring medical attention ranged from 1,288 within the model contour to 22,182 if a simple circle is drawn. The length of the contour is approximately 1 mile. If the toxic load approach is then used with toxicity values for the total population distribution (as opposed to the most sensitive subpopulation), the length of the contour decreases to less than a quarter mile, decreasing the number of persons requiring medical treatment to 32. Figure 2 shows the hazard area with an appropriate source characterization but using the current

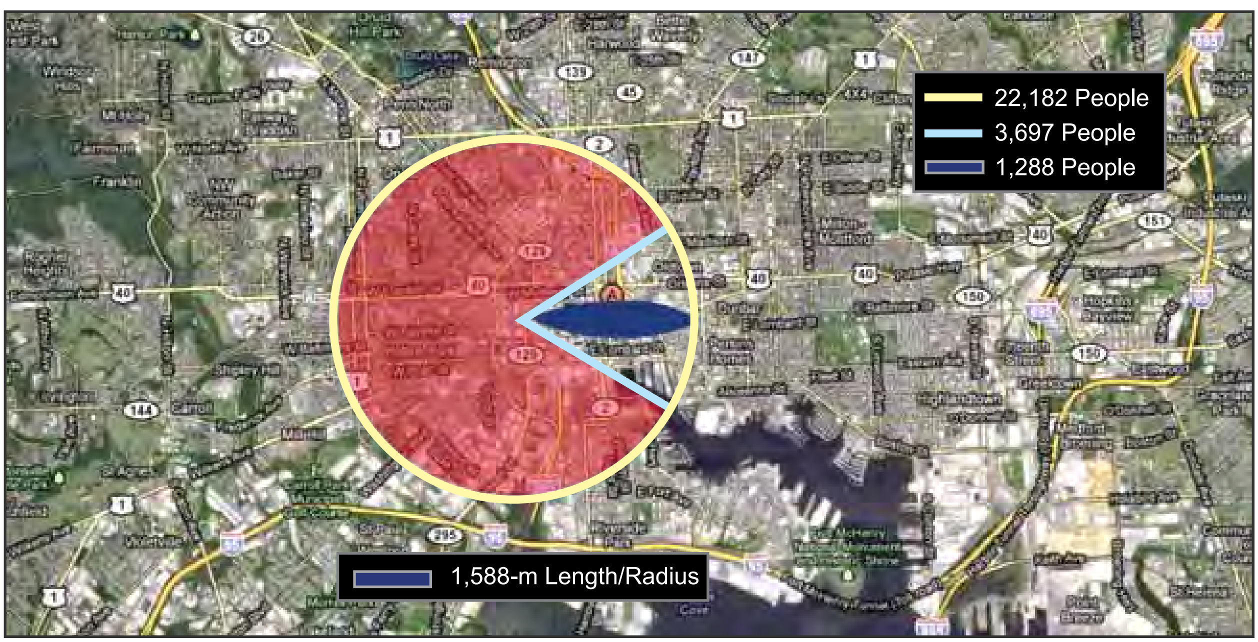

Figure 2. Baltimore Incident Concentration Hazard Area Estimates

AEGL approach. Figure 3 shows a contour with the toxic load approach with toxicity values for the total population distribution.

Reaction and Removal Mechanisms

The chlorine vapor at Graniteville penetrated the ground at the release site and had to be neutralized with large amounts of lime. As the chlorine vapor traveled downwind, it corroded exposed metal surfaces, such as doorknobs and electrical transformers. The vapor reaction with surface materials formed a different compound, pulling mass out of the vapor plume and lowering its concentration. TICs can also potentially react with water vapor or air pollutants to form less toxic compounds. Some vapor absorbed into porous materials. One issue with absorption is that once the plume has moved on, the TIC may then desorb from within the surface. This would result in a lower concentration but not a lower total vapor mass. Although some TIC reaction data exists, the data were generated for pollution monitoring purposes using very low TIC concentrations rather than the high concentrations relevant to attacks and accidents. Data are still needed on how far and how fast the relevant reactions will occur to estimate how much mass is removed from the plume as it travels downwind.

Current Research Efforts

There are now quite a few groups that have become interested in TIC incidents, and NSWCDD provides subject matter expertise, as well as modeling and analysis support to almost all of them. The TSA group of experts assembled for the November 2006 meeting mentioned earlier has held together and expanded, and holds regular teleconferences. Helping to plan chlorine and ammonia field trials has been key to maintaining the group. The following agencies and task forces are among the groups NSWCDD supports:

United States

- The Toxic Industrial Chemical/Toxic Industrial Material (TIC/TIM) Task Force was established by the Joint Program Executive Office for Chemical and Biological Defense in 2007 to develop a prioritized list of TICs and then to determine the potential hazard of TICs if used in a terrorist attack against forward-deployed troops.[10]

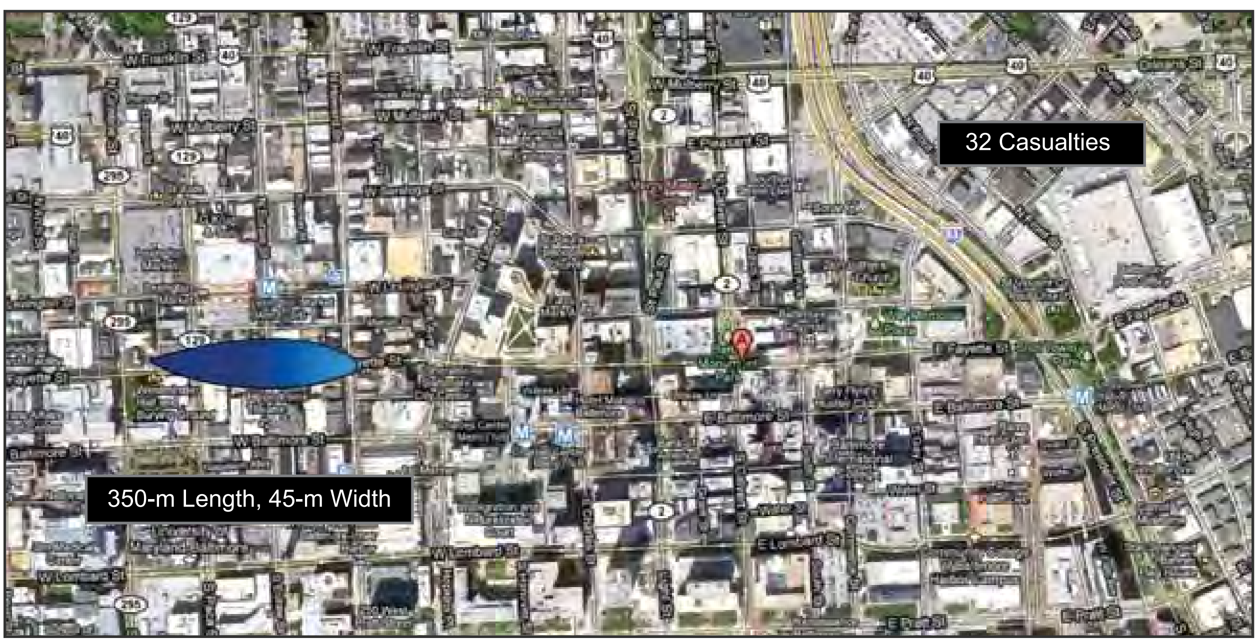

Figure 3. Baltimore Incident Final Casualty Estimate

- The Defense Threat Reduction Agency (DTRA) assembled a group of subject matter experts in 2007 to determine the shortcomings of the TIC source module in their Hazard Prediction and Assessment Capability Model, and to recommend improvements.[11]
- The U.S. Army National Ground Intelligence Center conducted the Wild Stallion field trials at Dugway Proving Ground (DPG) releasing chlorine from 1-ton tanks in October 2007; these tests were conducted in response to the terrorist attacks in Iraq employing similar 1-ton chlorine tanks.[12]
- Like the DoD TIC/TIM Task Force, the DHS Chemical Security Analysis Center (CSAC) developed a prioritized list of TICs of concern for terrorist use against homeland security.
- The Advanced Tank Car Collaborative Research Program involves government and industry working together to design rail tank cars that either resist puncturing or result in a greatly reduced hazard area if the TIC contents are released.
- The U.S. Army Edgewood Chemical and Biological Center (ECBC) evaluated toxicity data for both the TIC/TIM Task Force priority TIC list and the CSAC priority TIC list to provide toxicity values to use with the toxic load approach for both DoD and DHS hazard area analyses.

International

- The Joint Industry Project is a European collaborative effort, which began in 2001 to measure the characteristics of jets of chemicals stored as pressurized liquid, such as chlorine.[13]
- The North Atlantic Treaty Organization (NATO) System Analysis and Studies 061 Panel (SAS-061) was assembled in 2006 to analyze the hazards of potential terrorist actions against allied troops. The scenarios evaluated included a terrorist attack on a chlorine tanker truck outside of a NATO camp.[14]
- The NATO Challenge Sub-Group is now evaluating the concentration challenge to NATO protective equipment resulting from the terrorist attacks defined for the TIC/TIM Task Force scenarios.
- The European Defense Agency is setting up a testing and model development program to address release of TICs in an urban environment.

Considerable coordination and collaboration across all domestic and international groups has been established. NSWCDD is a member of most groups.

Jack Rabbit Test Program

The most significant effort to date to generate data necessary to improve downwind hazard area estimation was the set of field trials conducted at DPG during the period 27 April through 21 May 2010. Funding was provided by TSA and managed by ECBC; the project was operated by CSAC, and the trials were conducted by DPG.[15] The test design (Figure 4) was created by NSWCDD and the Norwegian Defense Research Institute (FFI).

NSWCDD and FFI took advantage of an existing collaborative effort to work on Project Jack Rabbit. The field trials were intended to prove or disprove the NSWCDD theory regarding pooling of chlorine (or other TICs transported as pressurized liquids) vapor and aerosol at the release location, so the design included a circular pit designed to shelter chlorine and ammonia against the wind flowing over it. The test geometry was refined by FFI using computational fluid dynamics modeling.[16] The instrumentation was specified and positioned by the TSA group of subject

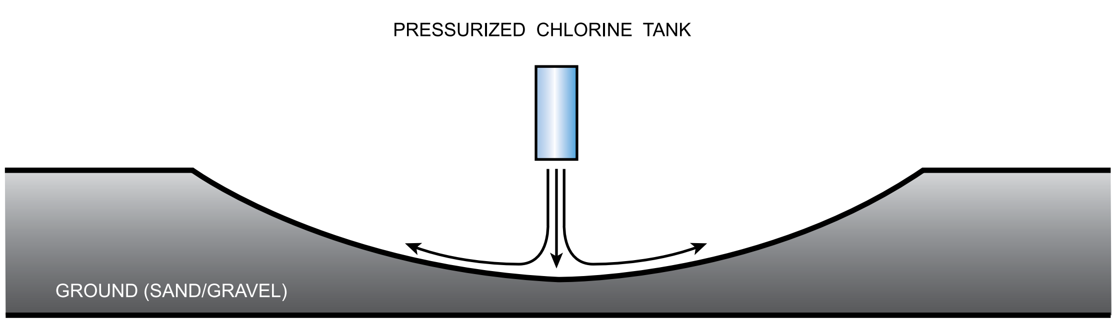

Figure 4. Jack Rabbit Test Design

matter experts. Four trials each were conducted with chlorine and ammonia involving the rapid release of 2 tons of liquid directed downward into the pit. NSWCDD and FFI provided on-site modeling and analysis support during the trials. The trials did result in chlorine and ammonia pooling in the pit and releasing vapor into the passing air, supporting NSWCDD's theory that large TIC masses of vapor and aerosol released over a short time period would pool into a large cloud at the release site and give off vapor into the passing air over an extended time period, suggesting that the chemical concentration would likely be lower and less toxic.

As a result of this important finding, in conjunction with the extensive measurements taken during the Jack Rabbit field trials, hazard assessment models will be better equipped to predict or respond if a terrorist attack releases TICs, and warfighters will be much better protected from these types of attacks.

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Defending Against the Unseen – Chemical and Biological Building Protection Challenges

By Matthew G. Wolski and Stephen S. Voynar

Imagine if a building could defend its occupants from chemical and biological (CB) threats, using a very limited number of sensors, while not triggering false alarms every time someone arrives on the premises with an aromatic lunch or a new perfume. Given the wide array of CB threats to American facilities throughout the world, sensitivity settings aside, key protection questions remain. How can military commanders plan to protect facilities from CB threats? And, how can teams of first responders respond safely should an incident occur?

As a hypothetical example, consider a military barracks located on a base 5 km from a nearby chemical plant processing methyl isocyanate (MIC). The proximity of this type of plant to a military installation is of great concern—especially since MIC is the same chemical released from a Union Carbide plant in Bhopal, India, in 1984 that killed thousands of people. Figure 1 shows a chemical plant (located in West Virginia) similar to the plant in Bhopal, India.[1]

Building Protection Challenges

In addressing these key building protection challenges, a single, hypothetical building scenario will be used in this article and presented from the perspective of the military commander. Knowing the dangers posed by MIC, the commander of the facility needs to ensure that his people are well protected.

Many challenges confront the commander and other warfighters when trying to protect personnel from the unseen threats posed by CB agents. The first challenge is discovering that a chemical or biological event occurred and determining where it occurred. Most important is to ensure survival of the building's inhabitants. Another key challenge is having confidence in the organization's ability to perform its mission. In addressing these challenges, fortunately, commanders have several powerful, effective toolkits and modeling programs at their disposal to assess threats and courses of action to protect against or minimize the effects of a chemical or biological event.

Modeling and Simulation (M&S) Tools

Over the years, M&S tools have been used to assess the indoor air quality (IAQ) of buildings. IAQ includes the amount of contaminant entering and leaving a building over time. To assess IAQ, single-zone models (also known as box models) have been used, as

Figure 1. Two workers were fatally injured when a waste tank containing the pesticide methomyl violently exploded, damaging a process unit at the Bayer CropScience Chemical Plant in Institute, West Virginia.[1]

well as multizone and full computational fluid dynamics (CFD) codes. Each of these capabilities has benefits and drawbacks.

An example of an IAQ tool is the CONTAM model developed by the National Institute of Standards and Technology (NIST). CONTAM is a multizone model that can be described as a simplified macro model of a building. CONTAM determines airflow and contaminant movement within a building. A building can be modeled as one or more zones (boxes) of uniform temperature, pressure, and concentration. Each zone can represent a single room, hallway, or portion of a larger room. CONTAM calculates air pressure and airflows within each zone of a building, and then it calculates the movement of contaminants between each zone. After a user configures a moderately complex building, a CONTAM simulation can be executed within a matter of minutes.

When performing an analysis of a building, there are five main steps:

1. View the building as a system of multiple unique zones
2. Create a "model" representation of the building
3. Determine the important building components and create data for each component
4. Execute one or more simulations
5. Analyze the results

This analysis process seems simple and straightforward, but each step can contain numerous challenges that need to be addressed and solved. In an attempt to simplify this process, the Immune Building Toolkit (IBTK) was created. IBTK is a component of the Immune Building Program, which was sponsored by the Defense Advanced Research Projects Agency (DARPA). IBTK was integrated with CONTAM to leverage its ability to calculate movement of CB agents within a building. Contamination from outside of the building and weather data can be supplied from other models, such as the:

- Advection and Dispersion of Vapor, Evaporating Droplets, and Solids model (ADVEDS) (a government-owned CFD model)
- Vapor, Liquid, and Solid Tracking (VLSTRACK) model (a government-owned Gaussian puff model)
- MESO-RUSTIC model (a government-sponsored building-aware Lagrangian particle model)

These models calculate outside contamination entering a building through leakage paths. Analysis tools included in the models provide detailed reports about the level of building exposure, costs

of designed protective solutions, and protective device performance during simulations. Output can be displayed in tabular format, in graphical charts, or 3-D displays.

Challenges: Data-Driven Analysis

Users might have several purposes in mind for modeling the interior of a building. They might want to assess the effectiveness of various building protection strategies. They might want to estimate the overall building protection level and cost associated with protection strategies, or they might want to search for an optimal protective solution. Regardless of the purpose, before users can perform any kind of analysis, data is required.

Developing an internal model of any structure can be challenging, as much needed information might not be available or complete. In most cases, a building's layout is available only in two-dimensional computer-aided design (CAD) files or on paper. Consequently, without visiting the structure, analysts might not know if the building was built as originally designed, if the doors and windows leak, if air is really being supplied to each room, or if any modifications to the building have been done. IBTK attempts to address the two-dimensional challenge by implementing a capability to read the Industry Foundation Classes (IFC) format, which is becoming an international standard. IFC is a standard for representing 3-D, real-world objects—such as buildings—and sharing that information among different software tools. Unfortunately, this standard is still evolving, and not everyone in the United States is using this file format yet. This challenge is more significant in multizone and CFD models than it is to the much simpler single-zone box model. Thus, sometimes the box model is much more attractive, since all that is necessary is the bulk air exchange rate (how fast the building changes its air). Data for the hypothetical example in this article is shown in Table 1 and is annotated on Figure 2. It suggests that 10,000+ gallons of MIC from a chemical plant could pose a significant threat from a distance of 1–10 km. For comparison, data is also provided for the agents phosgene, ricin, sarin, and anthrax.

Additional challenges are introduced with creation of a "smart building" capable of defending itself against detected threats without assistance from humans. To protect occupants, sensors and alarms need to be smart enough to use active and passive protection systems capable of adapting to a variety of situations and threats. They also need to alert security and safety teams in a timely manner. Many of the available sensors are not able to be networked and used in a smart-building setup. Those that are capable would need to identify threat contaminants efficiently and quickly without triggering false alarms. Most smart-building sensors are too expensive to place within every room of a building. IBTK and other tools, such as the Probabilistic Algorithm for Sampler Siting (PASS), offer realistic, cost-effective methods for placing sensors. Capabilities such as these are designed to define the optimum sensor locations with a limited number of sensors to defend against a defined set of threats. In turn, this decreases response time.

Another challenge involves filtering the air that feeds the building, a form of passive protection. Toxic industrial chemicals (TICs) can be damaging to chemical filtration. The challenge here is the amount of data available on the efficiency of material removal from the air and what happens to the material over time. IBTK developers incorporated a useful library for typical types of doors, windows, and leakage paths along openings and through wall

Table 1. Example Threat Scenario Data

	AGENT	DEVICE	LOCATION	QUANTITY
A	Methyl Isocyanate	Chemical Plant	1–10 km	10,000+ gal
B	Phosgene	Tanker Truck	0.1–1 km	100 gal
C	Ricin	Garden Sprayer	HVAC Inlet	1 gal
D	Sarin	Water Bottle	Room	1 qt
E	Anthrax	Letter	Letter	1 g

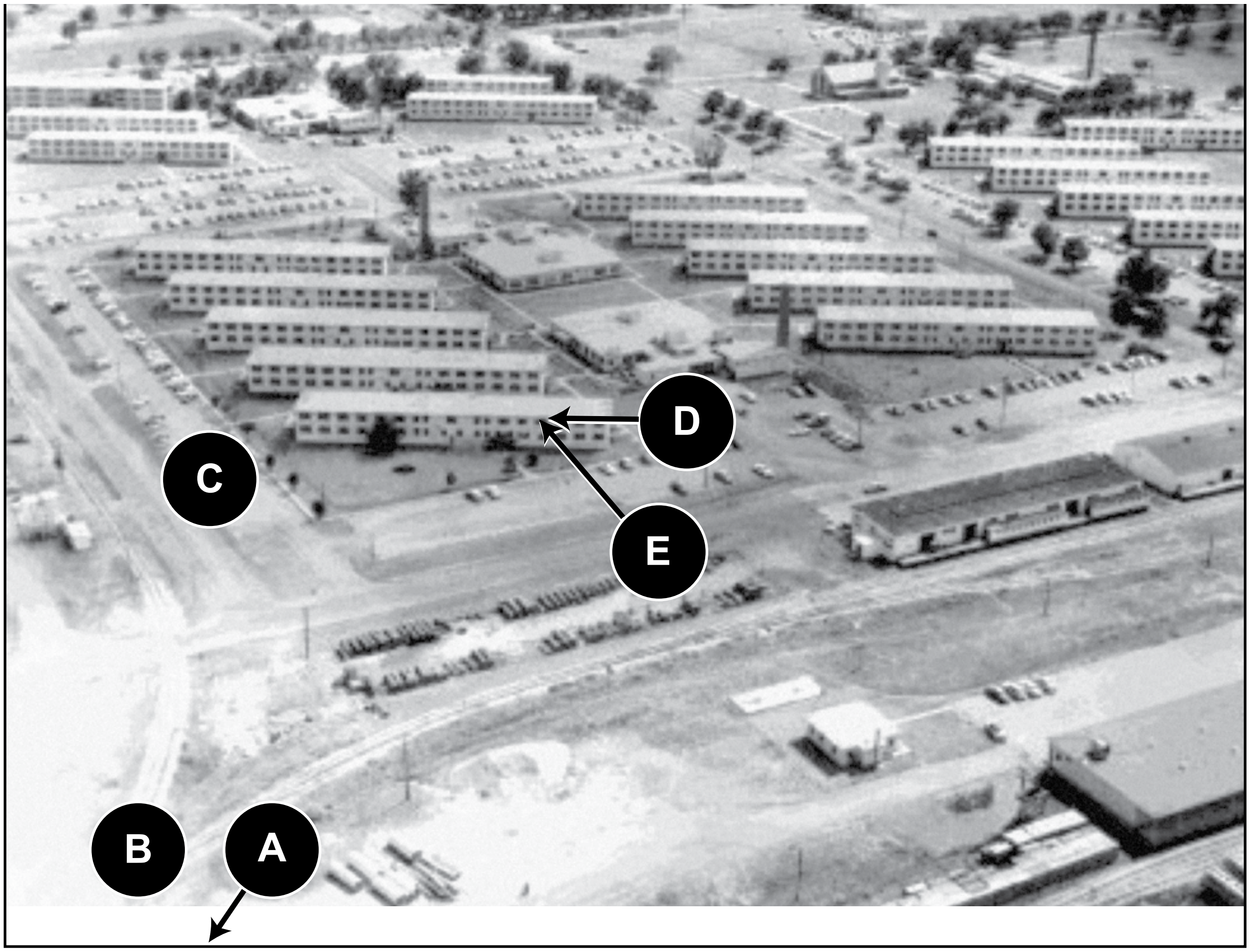

Figure 2. Threat Scenario Locations for Hypothetical Facility[2]

materials; heating, ventilating, and air-conditioning (HVAC) ducts; filtration devices; and sensors to help minimize the data challenges. Of course, when making an analysis, there are always new variables to consider.

Challenges: Threat Analysis

In our hypothetical building example, we know what the threat material is (MIC), approximately how far away it could be, and approximately how much material might be released during an event. It is actually rare for that much information to be known in advance. The remaining challenge for the analyst supporting the commander in other scenarios is to determine the most likely threats to the building. This could be gleaned from intelligence sources or from other threat assessments. Probably the biggest challenge in understanding and conveying the threat is that—unlike what we might see in a Hollywood blockbuster or an incident like Bhopal—material likely will be released in an unseen, unspectacular way.

Analyzing model results can be somewhat complicated. One metric used by the Immune Building Program is the fraction of building exposed (FBE). This metric is an estimate of the amount of the building exposed beyond a specified level; unfortunately, this metric can skew the perception of the severity of the situation. Another metric is the fraction of occupants exposed (FOE). This allows for a more targeted look at the building, where only inhabitants are counted and not the entire building; this, too, can be misleading, as the analyst can miss areas that may need decontamination or may cut off a route of evacuation. Another view is to examine zone by zone, looking at the movement of material through the building. This can be done using a number of tools: NIST developed the CONTAM Results Viewer, and the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) developed the ContamViewer, which IBTK integrated into its 3-D view (only one level at a time). There are many other ways to analyze the data beyond contamination movement. These

may include, but are not limited to, air flow, pressure differences, and temperature. Computer tool screen captures depicting the analysis process are shown in Figure 3.

Protecting Personnel: The Ultimate Benefit

As noted earlier, the hypothetical building in this example is located 5 km from a chemical plant processing MIC. An IFC file is available of the building, and basic building information has been entered into the CONTAM model. After verifying the validity of the model, a baseline analysis is performed, and it is determined that over 75 percent of the inhabitants of the building are at risk if a release occurs. Filters are then added to the main HVAC supply system. Active sensors (that can detect MIC) are also added into both the exterior and interior of the building. These sensors can trigger automatic shutdown of the HVAC supply and exhaust systems. Following the baseline, a follow-on analysis is performed, and it is determined that less than 5 percent of the inhabitants are now at risk. This analysis is presented to the base commander to determine if he or she is willing to accept that level of risk. Changes to the building are then made. Subsequently, at some time in the future, if an accidental release of MIC occurs at the chemical plant, model results can determine if the resulting cloud is sufficiently toxic to cause injury or death to individuals outside. With protections in place, all inhabitants of the protected building would be safe.

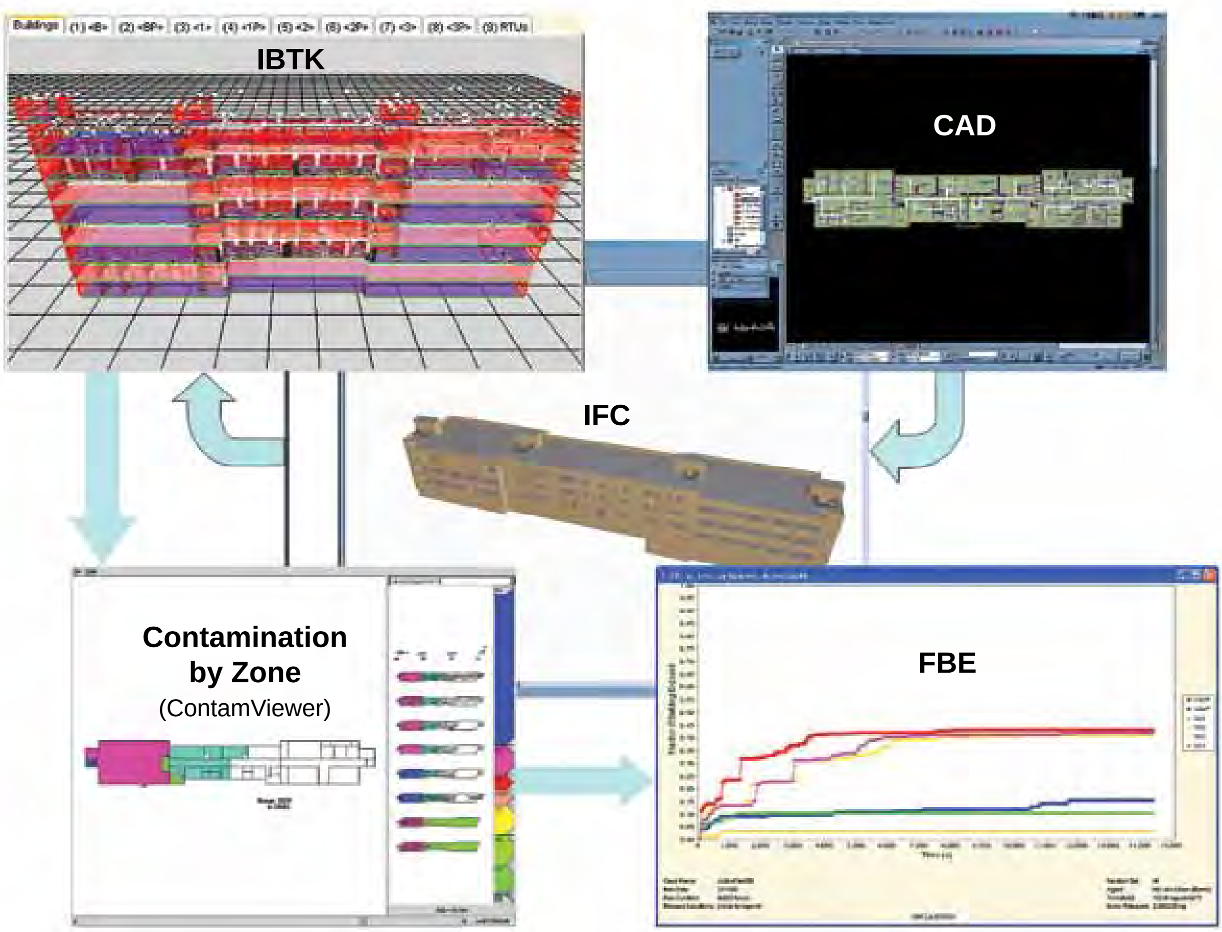

Figure 3. Computer Screen Captures Depicting an Example Analysis Process

This hypothetical situation demonstrates that tools like CONTAM and IBTK provide warfighters with a level of confidence that personnel in their facilities will be reasonably safe from a chemical or biological incident. Extending this capability to Navy ships is the next step. It can be (and has been) done. These tools enable analysts to examine threat scenarios from many points of view. Modeling analysis costs much less than full-scale testing and poses no health risks to anyone. Additionally, new kinds of metrics are being used to measure the effectiveness of a building's protection architecture in relation to its costs and maintenance. As a result, people within buildings will be safer against a variety of threats. First responders, too, will have access to improved training tools, enabling them to develop improved procedures for safely handling threats.

Interior modeling for CB defense continues today through efforts with the Joint Science and Technology Office at the Defense Threat Reduction Agency and the Department of Homeland Security. As a result of these efforts, warfighters and first responders will be much safer from CB threats.

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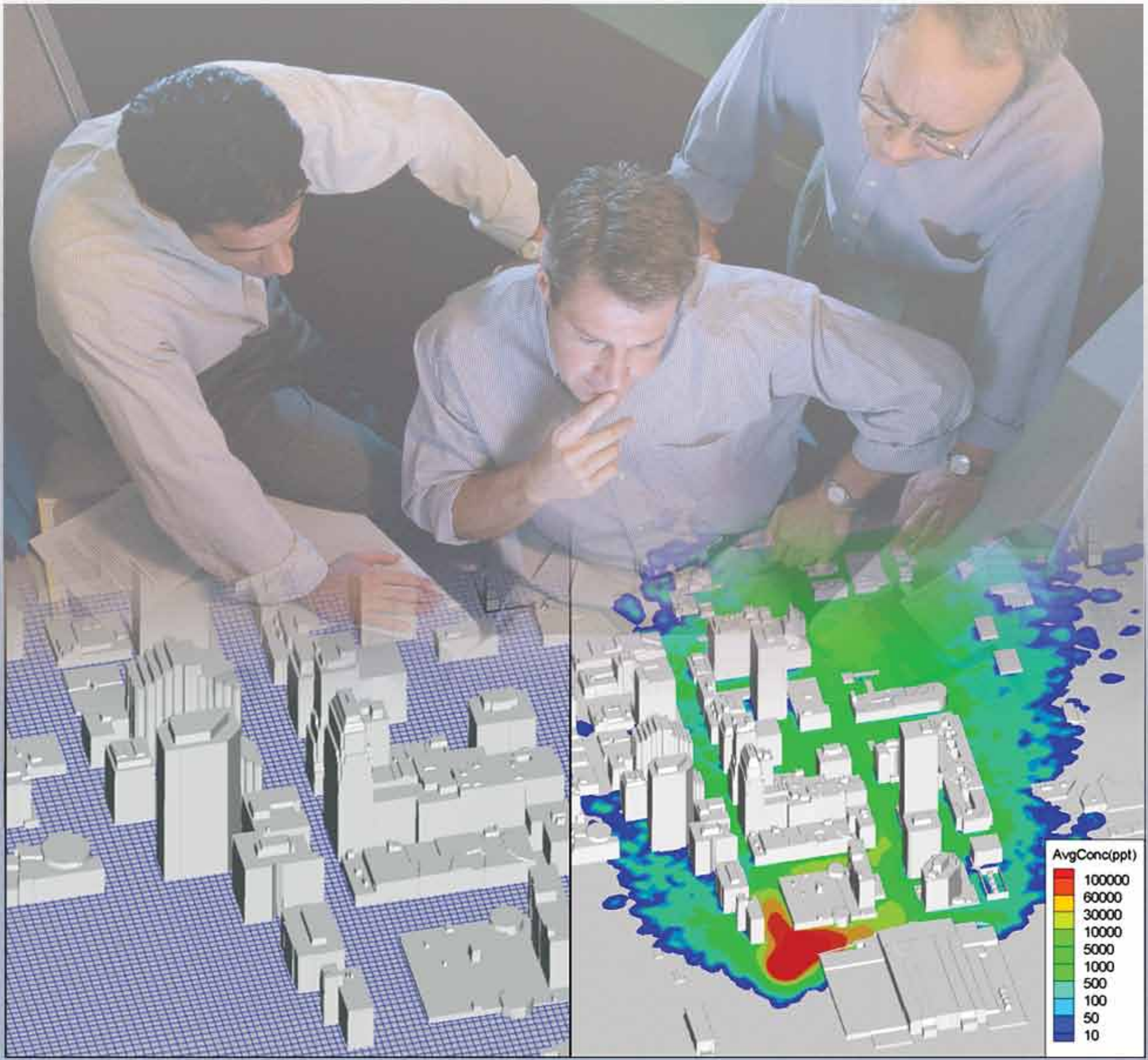
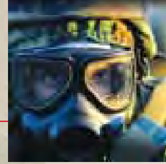
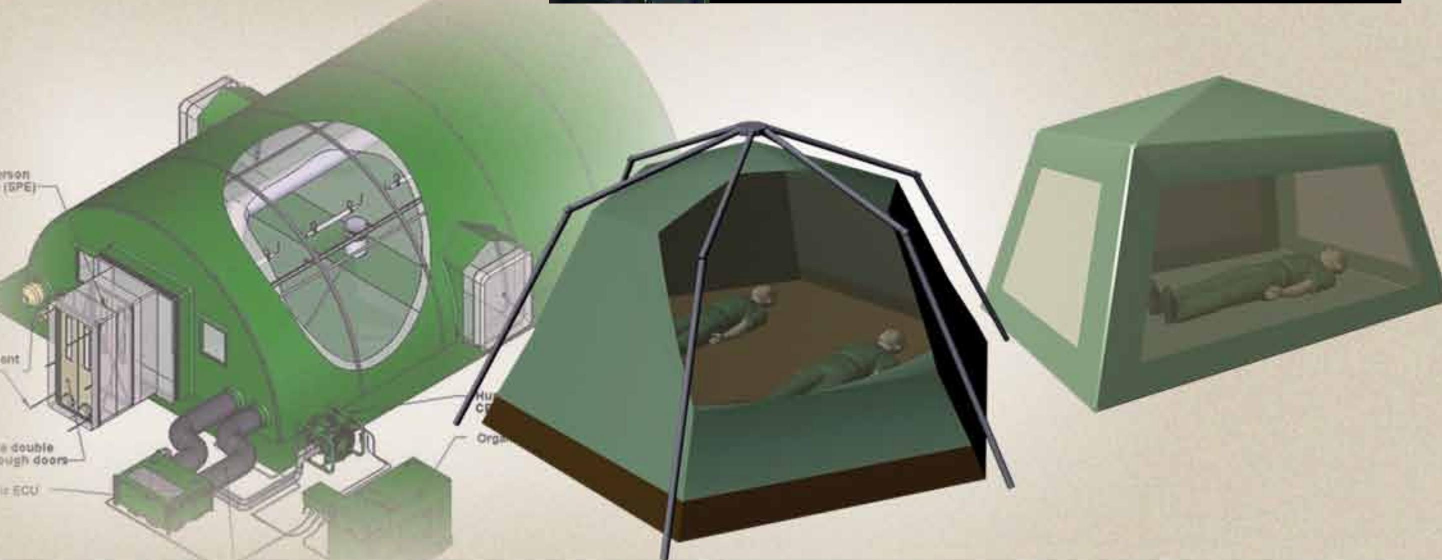
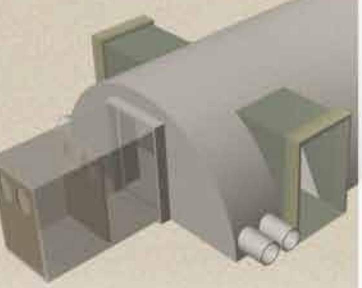






Modeling and Simulation Supports Joint Expeditionary Collective Protection (JECP) Program

By William G. Szymczak and Harold K. Barnette



Joint expeditionary forces employ two-man tents for a number of missions in areas where the adversary's use of chemical and biological agents is possible. Two-man tents for expeditionary-type missions—unlike some larger, more stationary structures—cannot make use of forced-air filtration systems. Consequently, to protect these forces, scientists and engineers from the Naval Research Laboratory (NRL), in partnership with the Chemical, Biological, and Radiological (CBR) Defense Division of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, explored the question: Can a small tent structure be designed to provide protection against biological or chemical vapor agent attacks?

The Joint Expeditionary Collective Protection (JECP) System Performance Model (SPM) is being developed in parallel with the JECP collection-of-shelters effort. SPM supports testing and evaluation through the use of computer modeling and simulation. The SPM brings together various computer models to simulate the threat, dispersion, airflow, filters, and components of the system. It supports modeling in a wide variety of environments and terrain, far beyond what is possible with live testing. Computational fluid dynamics (CFD) simulations are used to provide solutions to various SPM technical challenges.

This article describes a methodology for treating fully coupled internal/external flow through a passively filtered structure (two-man tent). Most state-of-the-art approaches to internal/external flows involve the use of separate codes for each domain, which are weakly coupled through boundary conditions. However, these approaches cannot be used directly for passive filtration, as the internal pressure is not known, and the pressure drop across the filters is required to determine the internal flow. A fully coupled solution directly resolves these issues and provides for a more accurate model for assessing the performance of passive filter systems.

System Performance Model (SPM) Approach

Filtration on a tent would have to allow for a sufficient exchange of uncontaminated air for respired carbon dioxide. For this effort, an analysis of a passive filter structure was performed. The unique aspect of this analysis was that the flow surrounding, through, and inside the tent was determined simultaneously in a fully coupled computation. The methodology and analysis presented here could be applied to a wide variety of relevant design structures.

In general, the motion of fluids is described by the Navier-Stokes equations derived in the 19th century. These equations are classified as nonlinear partial differential equations and are used for a wide range of flow applications, including weather prediction, ocean currents, the motion of stars in a galaxy, and the turbulent flow of air surrounding shelters. However, their full analysis is very difficult. The proof of the existence of solutions in three dimensions (3-D) has not been mathematically determined to this day. Thus, because of the difficult nature of the equations and the complexity of turbulent flows, solutions to the Navier-Stokes equations are approximated using computational algorithms within CFD codes.

One example of a CFD code is the Atmospheric Dispersion of Vapor and Evaporating Drops and Solids (ADVEDS) code developed at NRL and NSWCDD over the past 20 years. Although this code was originally used for external flows for ship defense from CBR attacks, it has been generalized for internal and fully coupled internal-external flow simulations through JECP structures. This code is actually a pair of codes, namely ADVED_NS for determining the Navier Stokes flow field and ADVED_T to transport particles, evaporating drops, and vapor using the predetermined flow field. A photograph of a tent and a depiction of the ADVEDS CFD grid model for the two-man tent structure is shown in Figure 1. Three Triosyn filter panels (shown in magenta) are embedded in the tent walls. The Triosyn panels are permeable, allowing fresh air to enter the structure and carbon dioxide to be purged, while filtering out contaminating agents. By determining the flow features (pressure and velocity) surrounding and through these filters, the performance of this passively filtered system can be assessed with respect to how long a soldier could survive a biological or chemical attack if protected by such a structure.

The primary technical challenges arising from flow simulations of shelters with passive filters include the resolution of thin walls and filter membranes, and the relatively low permeability of the filter components. The walls of the material fabric are approximately 3 mm, while the filters are slightly thicker (5 mm). The ADVEDS code employs a structured grid that must be fitted to the structure boundaries. This is done by mapping regions of an initially uniform grid onto the surface of the structure identified as a collection of triangles in a stereolithography file (STL) format. For internal/external flow, both the inside and outside of a thin structure must be described and mapped using different grid surfaces. By expressing the tent structure using separate STL files for its interior, exterior, and each side of the fly, a grid fitted to each surface of the shelter is constructed and smoothed with a structured grid generation code.

Permeability is measured by maintaining a constant pressure drop across the filter membrane and measuring the resulting flow velocity. The relationship between a constant pressure drop and flow velocity measured in one-dimensional experiments on a Triosyn swath is shown in Figure 2. The lines through the data points represent least squares fits[a] using linear (Darcy) and quadratic (Darcy-Forchheimer) approximations. Both models were implemented as drag force terms added to

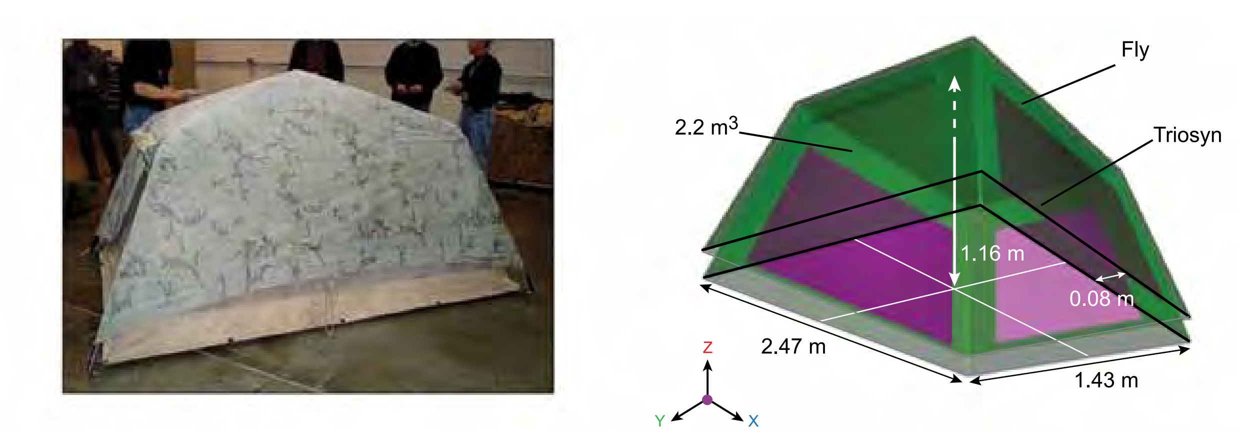


Figure 1. Photograph and ADVEDS Model of the Two-Man Tent Structure

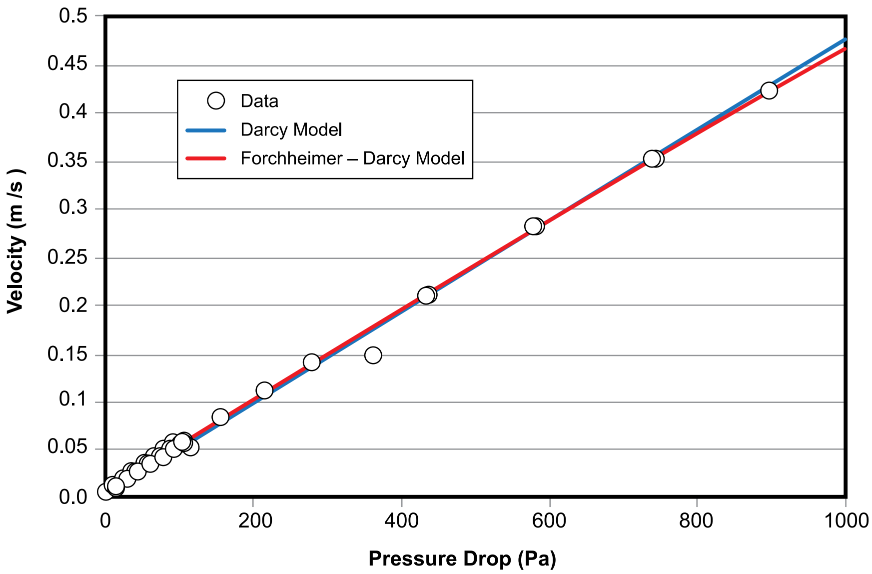


Figure 2. Measured Velocity as a Function of Pressure Drop Across a Triosyn Filter

the Navier Stokes equations and discretized within the ADVED_NS code. For this study, only the simpler Darcy model was used.

Three distinct technical challenges needed to be addressed before obtaining a CFD solution to this model:

1. In order to resolve the thin-layer material of the structure, either a very large number of small grid cells or cells with high aspect ratios with one dimension representing the thickness of the fabric is required.
2. An abrupt change in flow velocity can be expected for the flow through the filter material. For this example, the flow speed through the filter was over 300 times smaller than the external flow upstream. This large flow reduction needed to be accurately modeled to obtain the correct internal pressures and purge rate for the system.
3. The model of the filter drag represented by the data shown in Figure 2 represented a very high drag coefficient, resulting in a classical numerical analysis difficulty, known as a "stiff" system of equations. With such a system, although the variable (in our case velocity) decreased to zero very quickly, the time steps required to maintain stability for an explicit scheme were exceedingly small.

For the first challenge, researchers simply allowed the use of distorted cells so that the tent structure could be adequately described using a moderate number of grid cells. The ADVED_NS code uses algorithms that remain stable under minimal grid restrictions. The second two challenges were each related to the filter model. These challenging problems were alleviated through the use of a carefully designed implicit method, which provided stable and accurate results. Flow simulations were conducted in a domain approximating a wind-tunnel configuration, as displayed in Figure 3. The computations were performed with an inflow velocity of approximately 11.2 m/s (25 mph) representing a "high" wind-speed case.

Figure 4 shows particle paths for the computed velocity field. These velocities were determined from fluctuating velocities, which were time-averaged over a 6-s interval. In this figure, the speeds are indicated by the color palette on the right, with red being fastest (12 m/s) down to the slowest speeds in magenta and black. As can be seen in Figure 4, the wind is fastest upstream, over the top, and around the sides of the tent fly. The nearly black vortices (swirling or recirculating flows) inside the tent indicate much slower

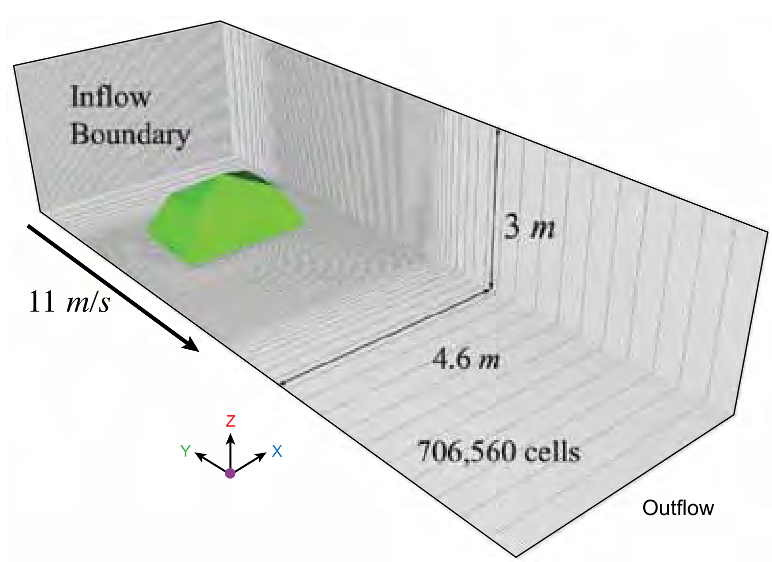


Figure 3. Grid and Domain for the Two-Man Tent in a Wind Tunnel

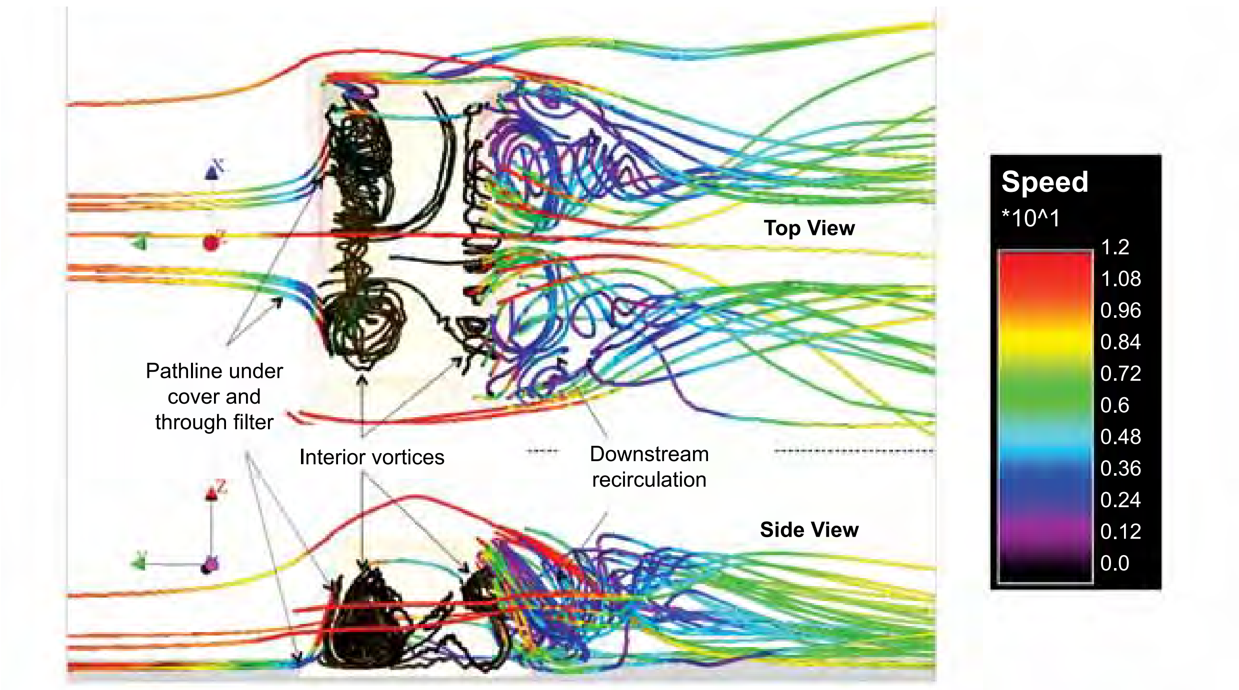


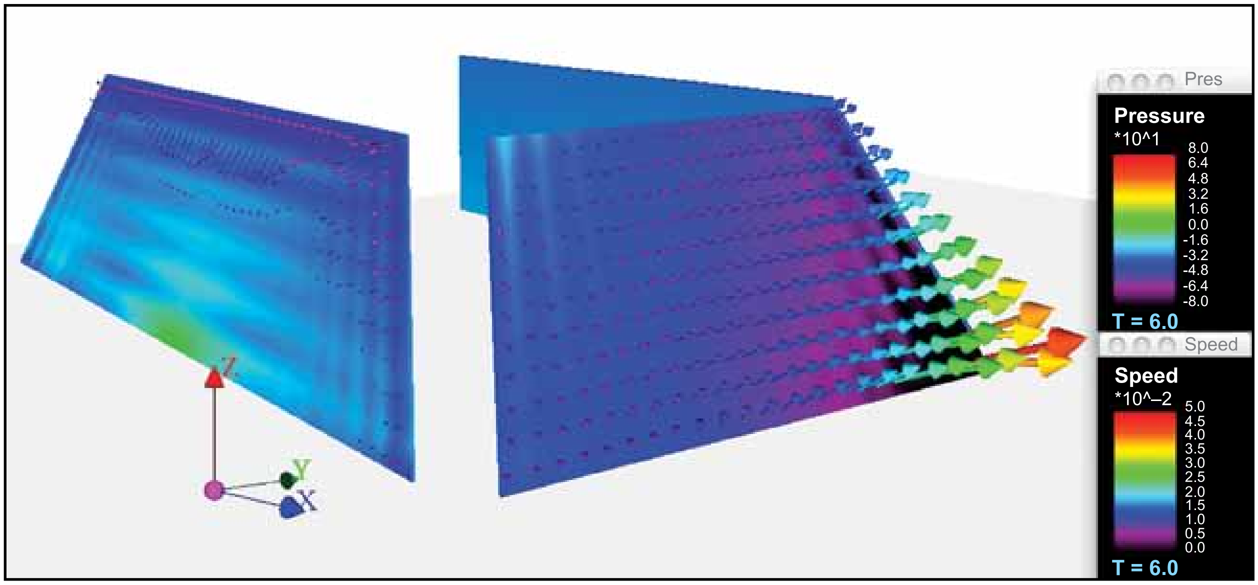
Figure 4. Top- and Side-View Particle Paths Around and Inside Tent

speeds induced by flow through the filters. Path lines traveling near the ground of the inflow side can be traced under the fly and through the top of the upstream filter. A pair of large vortices are seen in the region immediately behind the tent.

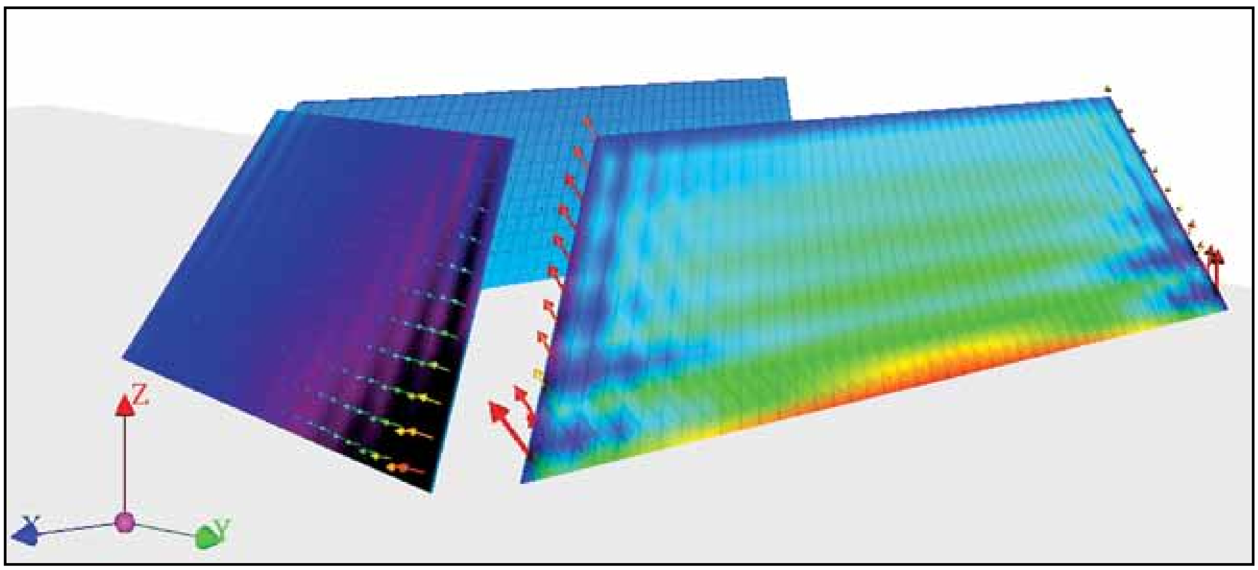
The effects of these flow patterns on the internal/external coupling is seen in Figure 5, which shows the pressures on the filter surfaces, as well as the velocities through the filters. On the side crosswind filter (5a), a very low-pressure region is formed on the lower upwind corner due to a small recirculation region. This low pressure induces the largest flow rates leaving the tent. On the downwind side (5a), flow exits the filter along the top and sides where the pressures are low but enters the filter at the center and bottom where the pressures are slightly above the internal pressure (shown as a small green patch in the top portion of Figure 5). That is due to backflow from the recirculation region. On the upwind panel (5b), the high pressures on the bottom of the filter are due to flow striking the face just under the fly. These pressures are roughly 80 pascal (pa) above ambient, corresponding to the stagnation pressure of the inflow velocity.

The velocities shown in Figure 5 can be used to determine the flow rates entering, Q_{in}, and exiting, Q_{out}, each filter region of the shelter. It is expected that these two values should be nearly equal; otherwise, the tent would tend to "blow up" if more air enters the tent than exits, or "deflate" if more air exits the tent than enters. This simple observation can be used as a verification check for the computations. Table 1 lists these flow rates and the totals for the entire structure for both the high wind speed (11.2 m/s) described previously, as well as for computations with a more moderate wind speed (5.6 m/s). In each case, the differences between Q_{in} and Q_{out} were less than 1.3 percent. The four-factor reduction in flow rates from the high to the moderate case is consistent with the expected stagnation flow pressures, which depend on the square of the inflow velocity.

If a vapor (e.g., CO_2) inside the shelter remains well-mixed, (that is, maintains a nearly uniform concentration) then its mass will be purged with a fixed exponential decay rate depending on the ratio of the flow rate, Q_{in}, to the volume of the tent interior. A more accurate determination of purge rates can be obtained using a transport code, which moves the vapor with the flow according to the laws of mass conservation. Figure 6 compares the remaining mass fractions of CO_2 in the high wind case using the well-mixed assumption to results computed using the transport code, ADVED_T. While the ADVED_T code was initialized with



(a) Downwind and Crosswind Filter Panels



(b) Upwind and Crosswind Filter Panels

Figure 5. Computed Pressures and Velocity Vectors on Filter Panels

Table 1. Values of Flow Rates (m³/s) Through the Triosyn Filters

Filter Location	High Wind		Moderate Wind	
	Q_{in}	Q_{out}	Q_{in}	Q_{out}
Upwind	8.50×10^{-3}	2.95×10^{-4}	2.29×10^{-3}	4.95×10^{-4}
Crosswind	5.21×10^{-7}	6.94×10^{-3}	0.00×10^{0}	1.80×10^{-3}
Downwind	4.97×10^{-4}	1.76×10^{-3}	7.40×10^{-5}	5.57×10^{-4}
Total Flow Rate	9.00×10^{-3}	8.99×10^{-3}	2.37×10^{-3}	2.40×10^{-3}

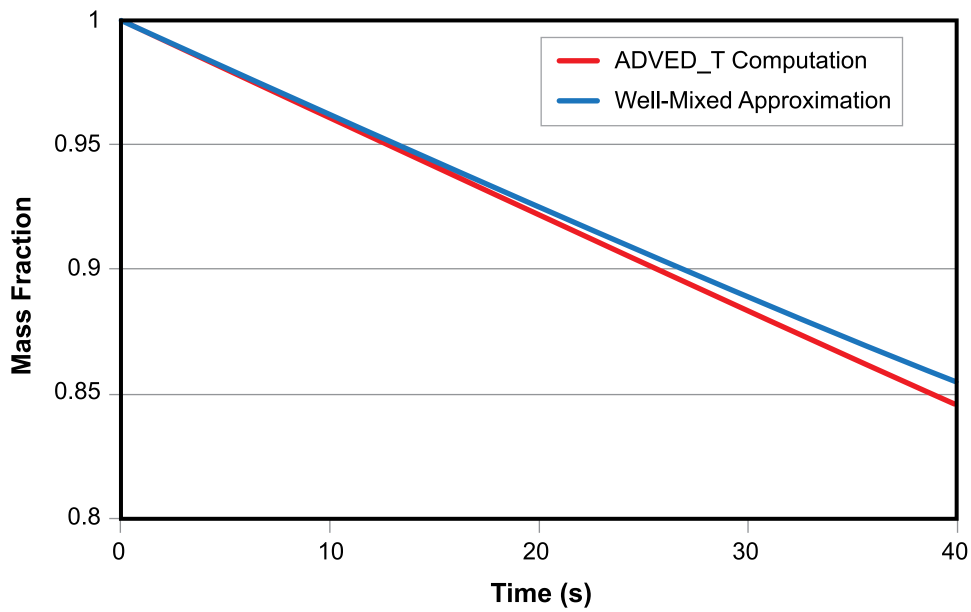


Figure 6. Mass Fraction Computed Using Both a Well-Mixed Assumption and the Transport Code ADVED_T

a uniform density of CO_2 in the interior, changes in density were allowed to evolve according to the transport equations. The ADVED_T purge rate is slightly higher than that using the well-mixed assumption because it predicted lower CO_2 densities near the regions where fresh air enters, ($Q_{in} > Q_{out}$), and consequently, higher CO_2 densities near regions where flow is exiting the tent.

With a known purge rate, the accumulation of CO_2 from internal sources (i.e., two people breathing) can be approximated directly using the well-mixed assumption. In this case, the steady-state volume of CO_2 within the tent is simply the ratio of the respiration rate to the purge rate. The steady-state value is simply the theoretical level value that will be attained after a sufficiently long time. For example, assuming a respiration rate for two average people, the steady-state concentrations of CO_2 are 934 parts per million (ppm) for the high wind case and 3472 ppm for the moderate wind case. Each of these cases fall below the Occupational Safety and Health Administration (OSHA) limit of 5000 ppm for CO_2. During a biological or chemical vapor attack, the tent will be closed, and the only fresh air entering the structure will flow through the filter areas (assuming no other leakage). This analysis shows that, at least in the moderate and high wind cases, there will be a sufficient supply of filtered fresh air entering the tent to maintain safe CO_2 levels inside the shelter.

Conclusion

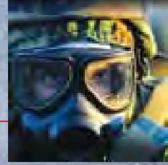
As mentioned earlier, most state-of-the-art approaches to internal/external flows involve the use of separate codes for each domain, which are weakly coupled through boundary conditions. A fully coupled solution directly resolves this issue and provides for a more accurate model for assessing the performance of passive filter systems. In providing this SPM solution, joint expeditionary forces in the future will likely be better protected while employing two-man tents in the event of chemical or biological attacks.

Acknowledgment

Roger Gibbs (BSM-Inc.) contributed to this article.

Endnote

a. "Least squares fits" computes a set of coefficients to the specified function that minimize the square of the difference between the original data and the predicting function. In other words, it minimizes the square of the error between the original data and the values predicted by the equation (http://www.synergy.com/Webhelp/Least_Squares.htm).



The Benefits of Metamodels in CBR Defense Modeling and Simulation (M&S)Products

By Harold K. Barnette

Scenario (Fictitious)

Pentagon planners quickly gathered in the war room to discuss the operational plan about to be executed in the U.S. Central Command area of operations. U.S. Army and Marine Corps forces and their associated equipment had been staged and readied for a planned attack slated to begin in just 12 hours. Key to the operation was the joint forces positioned on the left flank. If those forces were unable to execute, for whatever reason, the entire operation could fail.

Given the importance of the left flank forces to the overall operation, one contingency that war planners discussed was the possibility that the enemy could employ chemical, biological, or radiological weapons in an attempt to thwart the advance by U.S. forces. What they needed to know, quickly, was whether U.S. forces could survive the effects of a chemical, biological, and radiological (CBR) attack.

Consequently, Pentagon planners urgently tasked CBR defense (CBRD) experts located at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, to see if they could rapidly model and simulate the situation to answer the planners' critical question. Fortunately, because scientists and engineers at NSWCDD employed metamodels in their CBRD modeling and simulation (M&S) products, they could comply with the Pentagon's urgent need.

Metamodel Overview

The use of M&S products in CBRD applications harnesses the power of the computing age to provide warfighters with the best possible resources. The benefit of any M&S product, however, is proportional to the quality of the answers it provides (fidelity) and the speed at which it provides those answers. Unfortunately, these two desired M&S traits of speed and fidelity are often diametrically opposed. Typically, an increase in fidelity requires an increase in the amount and complexity of computations that a model performs, which, in turn, results in a slower simulation. It is this dilemma between M&S fidelity and speed that presents an opportunity for the use of metamodels. The relationship between fidelity and speed is shown in Figure 1.

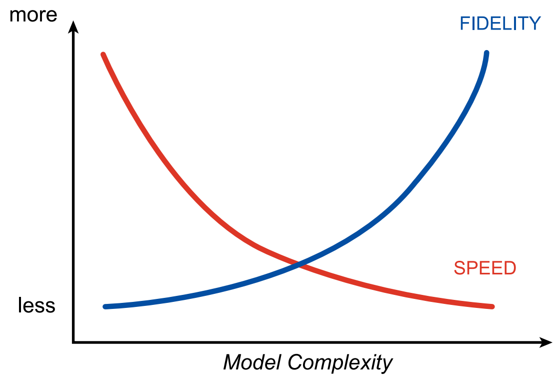


Figure 1. Relationship Between Fidelity and Speed

The prefix "meta" is used to indicate a concept that is an abstraction of another concept. In light of this, the term "metamodel" can be thought of as "a model of a model" since it provides a model of a data set derived through some systematic process. Metamodels characterize data sets by reducing them into mathematical expressions. The data sets themselves can come from different sources, such as laboratory experiments, live testing, or computer simulations.

The primary benefit of metamodeling is in its ability to closely approximate all possible outcomes based on a limited data set of known outcomes. That is why Pentagon planners, in the fictitious opening scenario, turned to NSWCDD for quick answers concerning a set of unknowns. This benefit provides a time and cost savings to the systematic process by which data is collected. Once a metamodel has been developed, it allows the user to almost instantaneously obtain an answer on the performance of the systematic process it represents.

With respect to CBRD M&S products, metamodels have the potential to characterize the results of long-running simulations—such as those that occur with computational fluid dynamics (CFD)—by using the data set that results from a planned, strategic set of runs. The end result of this is a metamodel that provides good approximations to CFD simulations that have not yet been run. Incorporation of the metamodel into a CBRD M&S product allows the product to provide CFD fidelity without the long run times.

To help illustrate the benefits of metamodeling, consider a scenario where it is desirable to predict the time at which a peak concentration occurs for a relative location from a specific threat in a specific environment. Peak time predictions can be accomplished via a metamodel developed from a limited set of simulation data. An example of results for a simple metamodel that predicts peak concentration time is shown in Figure 2. In this figure, peak concentration time values, predicted by the metamodel, are represented on the vertical axis and are correlated with the simulated data set represented on the horizontal axis. An ideal metamodel would share a one-to-one correlation with the simulated data set because there would be no difference between predicted values and the data. The correlation shown in Figure 2 shows something close to a one-to-one correlation and indicates a good metamodel.

The simulated data set in Figure 2 was derived from 19 runs that required over 300 hours of simulation time using Atmospheric Dispersion of Vapor and Evaporating Droplets and Solids (ADVEDS).[a] The metamodel was derived from the simulated data set and is a polynomial consisting of 75 terms. In this example, 99.5 percent of the peak time metamodel predictions are within 0.8 s or less of the simulated data set. Thus, additional peak-time concentrations for this particular instance can now be predicted by the metamodel almost instantaneously and reliably without the additional hours of simulation time.

Metamodel Development Process

The process of developing a metamodel consists of three primary phases:

1. Design of Experiments (DOE)
2. Data Collection
3. Data Fitting

Design of Experiments (DOE)

Conducting a DOE essentially establishes a strategic plan for data collection that identifies factor space and minimizes the number of runs. The first step in developing this strategic plan is to identify factors (i.e., wind speed, temperature, etc.) that are believed to have influence on the response of the systematic process that is being modeled. The expected range limitations associated with each factor (e.g., temperature = 5°–32°C) establish the factor space boundaries. Once a factor space has been defined, the next step is to maximize coverage throughout the factor space using a fixed number of sample points. Different techniques exist for optimizing factor space coverage for a given number of sample points. One technique that is often used is referred to as a "Latin Hypercube"—a statistical method developed to generate a distribution of plausible collections of parameter values from a multidimensional distribution. Statistical software products, such as JMP, facilitate the use of

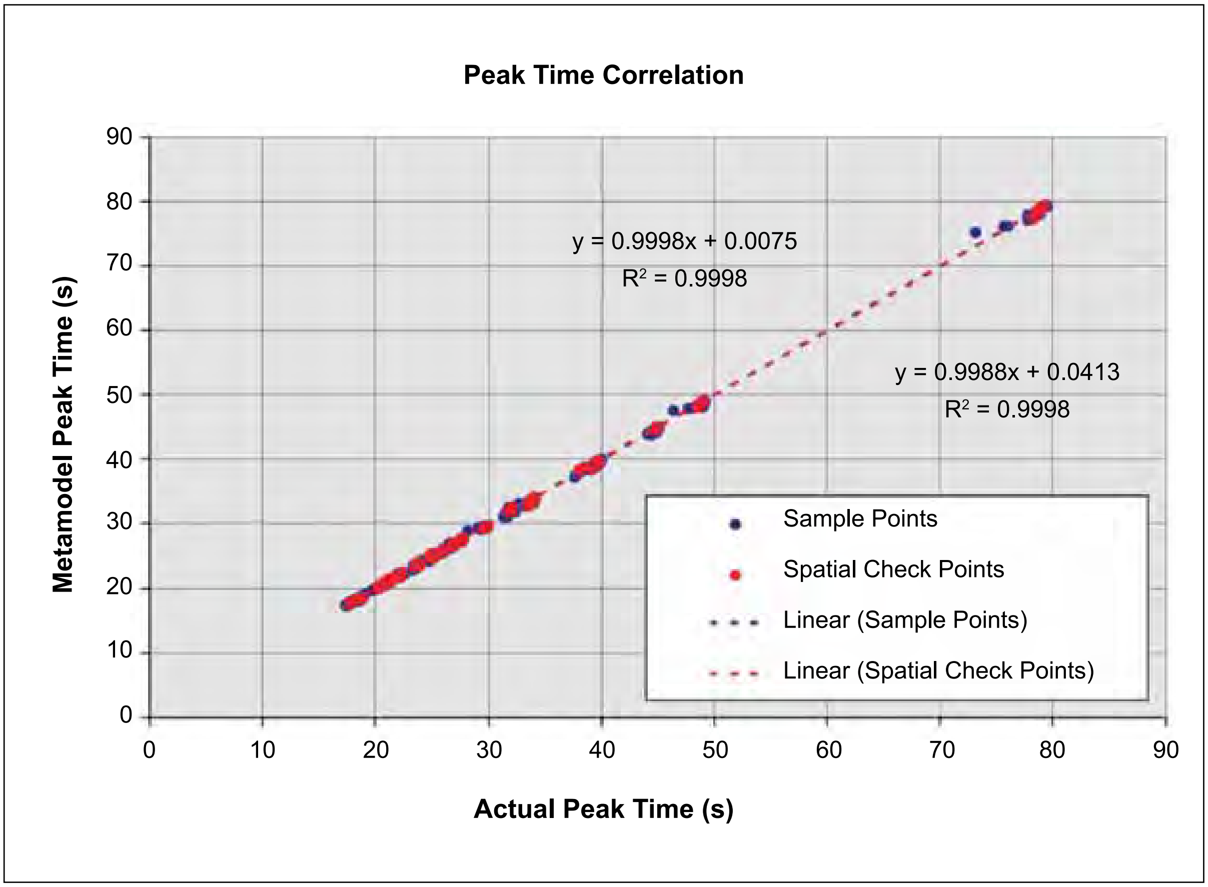


Figure 2. Peak Concentration Time Metamodel Correlation to Original Data Set

these space-filling techniques. The DOE process is shown in Figure 3.

In addition to identifying a set of sample points (from which the metamodel will be developed), a set of checkpoints should also be generated for the purpose of providing an independent assessment of metamodel error.

One question that commonly arises when conducting a DOE is, "How many sample points are enough?" This is an important question since identifying too few sample points could adversely affect metamodel error and identifying too many sample points might be too time-consuming and costly. Unfortunately, there is no easy answer to this. One rule of thumb states 10 samples per factor. A more practical approach is to answer the question, "How many sample points can be taken given a specified time and budget?"

Data Collection

This phase consists of collecting data from the systematic process that will be represented by a metamodel. The DOE provides the road map for collecting data during this phase.

Data Fitting

This is the process of fitting collected sample point data to an equation where terms comprise the factors contained within the DOE. This process should begin as soon as data becomes available to begin exploring ideas on how to fit the data. Some of these ideas may consist of data transformations that reduce metamodel error by reshaping the data to a form that is easier to work with. With each metamodel iteration, error is first assessed by comparing the metamodel prediction to the sample point results. Upon achieving an acceptable error level with respect to the sample points, the metamodel results are compared to the checkpoints. Checkpoints provide an independent assessment of metamodel error since they were not used to develop the metamodel equation. If the error level of the metamodel is acceptable with respect to the checkpoints, then the checkpoints may

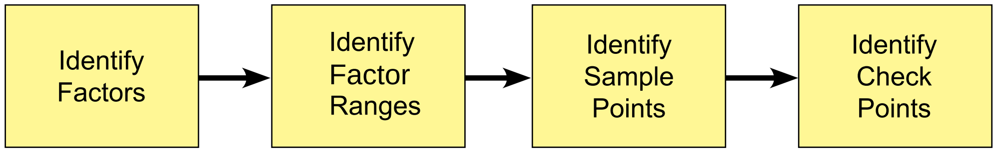


Figure 3. The DOE Process

then be utilized, along with the sample points to develop a metamodel with even less error. Figure 4 shows aspects of the data-fitting process.

Potential Metamodel Applications to the Joint Expeditionary Collective Protection System Performance Model (JECP SPM)

Metamodels are being explored for use within the JECP SPM (see Figure 5). JECP refers to a family of shelter systems that are intended to protect Joint Expeditionary Forces (JEF) and their assets by means of a versatile and transportable collective protection capability. The JECP SPM is a software tool sponsored by the Defense Advanced Research Projects Agency (DARPA) Joint Science and Technology Office (JSTO), and its development is currently being led by NSWCDD's Chemical, Biological, and Chemical (CBR) Defense Division in cooperation with other partners:

- United States Naval Research Laboratory
- University of North Carolina
- Lawrence Livermore National Laboratory
- ITT Industries

The JECP SPM models the collective protection performance of each member in the family of JECP shelters and will be used to supplement live testing. It is important that the JECP SPM provide reliable results in a timely manner, and metamodels provide a possible means of achieving this goal.

Some areas within the JECP SPM—where metamodels are being investigated—are listed below, followed by a depiction of a contaminant passing over a JECP shelter.

- Propagation of contaminants via wake effects caused by walking

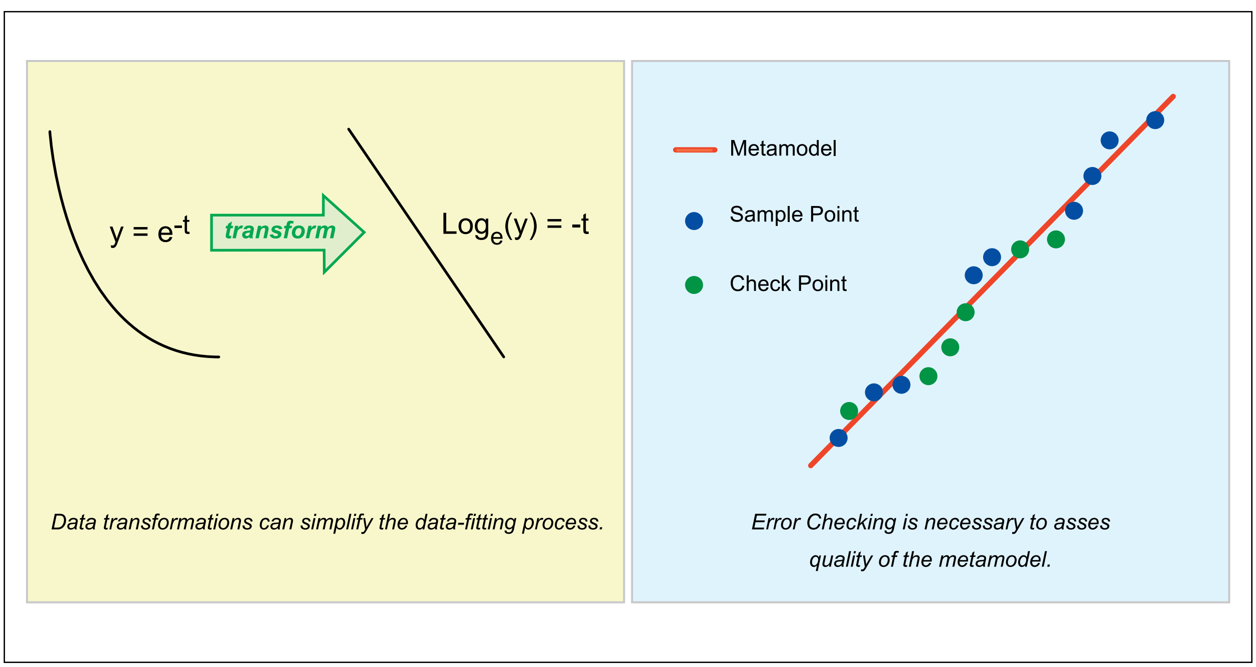


Figure 4. Aspects of the Data-Fitting Process

- Characterization of airflows and agent concentrations on the interior and exterior of a shelter
- Performance of shelter components using component test data

Conclusion

The incorporation of metamodels into the JECP SPM and other CBR M&S products could help to provide extremely fast-running simulations that yield high-fidelity results. An increase in simulation speed and fidelity would result in fewer man-hours, lower costs, and an increase in analysis quantity and quality. These benefits would arm warfighters with more reliable CBRD products.

Endnote

a. ADVEDS is a Chemical and Biological Defense CFD product developed and maintained by Dr. William Szymczak from the Naval Research Laboratory.

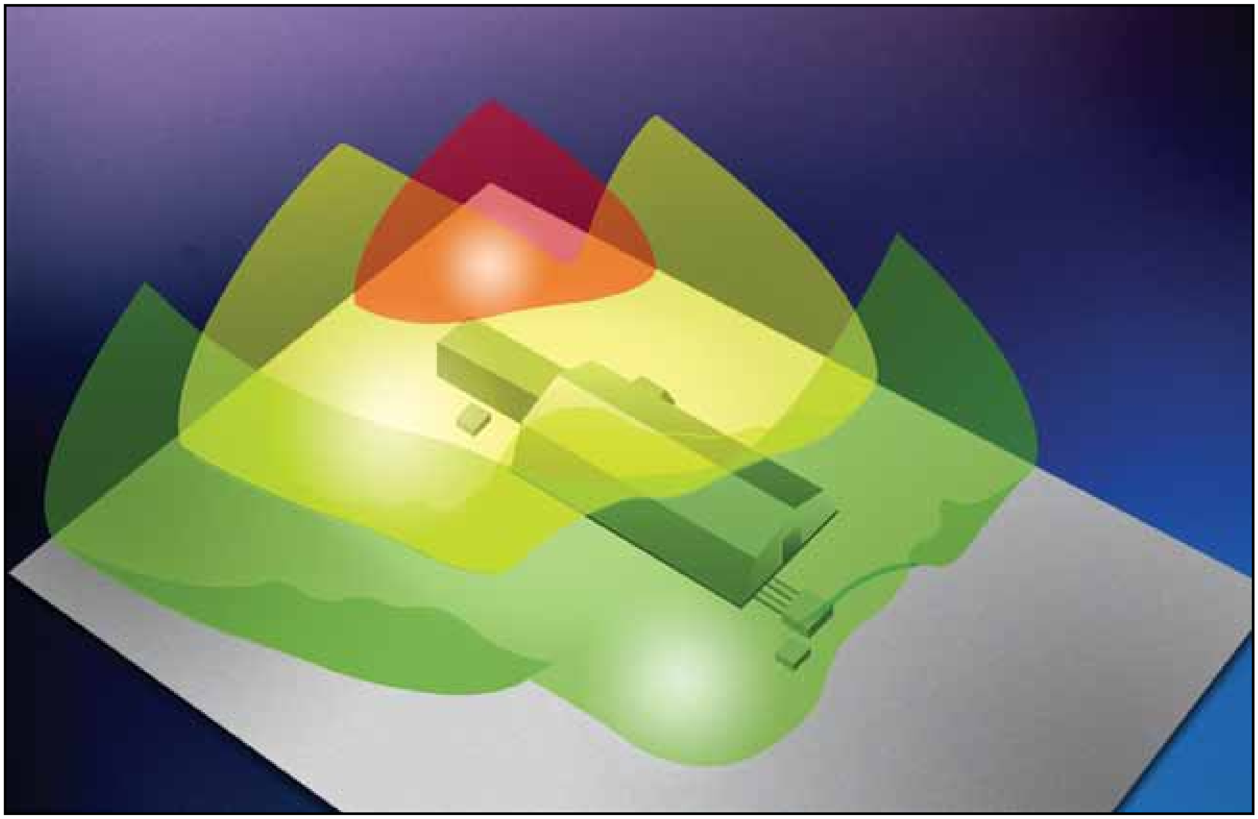


Figure 5. Exterior Concentrations Passing Over a JECP Shelter


Immune Building Toolkit - ActiveTest86
Case View Release External Environment Protective Architecture Simulate Results Help
Buildings
Building
Levels
<B>
<BP>
<1>
Zones
Threats
ProtectiveMeasures
FlowPaths
Doors
Windows
Cracks
Orifices
Other
<1P>
<2>
<2P>
<3>
Zones
Threats
ProtectiveMeasures
FlowPaths
Other
Buildings (1) <B> (2) <BP> (3) <1> (4) <1P> (5) <2> (6) <2P> (7) <3>

Modeling of Personnel Entry Into Collectively Protected Shelters

By Gaurang R. Dävé

The Joint Expeditionary Collective Protection (JECP) Program is developing a family of transportable shelter systems that will provide collective protection to joint expeditionary forces and their assets. These shelter systems range from two-person, passive filtration tents to large multiperson shelter complexes that provide active filtration and internal environmental conditioning. North Carolina State University's Department of Mechanical and Aerospace Engineering personnel are collaborating with the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) Chemical, Biological, and Radiological (CBR) Defense System Performance Model (SPM) team to research personnel entry into collectively protected shelters.

Entry of personnel into collectively protected shelters constitutes a critical point in which system protections are necessarily breached. A typical entry event starts with the removal of possibly contaminated clothing, followed by entry into an air lock that separates the area external to the shelter from the toxic-free area (TFA) inside the shelter. The air lock operates using principles of overpressure: air from the TFA or from a separate heating, ventilation, and air-conditioning (HVAC) unit flows into the air lock, increasing the inside pressure to levels higher than the external air pressure. The air flow is vented out of the air lock, moving either outside or back into the HVAC unit, where it is filtered. The overpressure helps keep contaminated air from flowing into the air lock, while the vented flow drives contaminated air out of the air lock. As a person enters the air lock, two things happen. First, the overpressure is relieved as the doors are opened, causing a strong gas jet to flow outward. Second, wakes generated by the motion of the doors and the person cause a net flow of contaminated gas into the air lock. Once the doors close, the overpressure begins to build up, and the contaminated gas is purged from the air lock.

The time required for a person to remain within the air lock depends on the size of the air lock, the volume flow rate of clean air into the air lock, and the desired amount of concentration reduction required. Typically, an air lock will be required to reduce the initial vapor concentration by a factor of 1000 or more, but the precise amount of reduction needed depends also upon the agent under consideration and on the allowable dosage limit—as described in the Military Exposure Guidelines (MEG)—that personnel can withstand. For example, 8 hours of exposure to concentration levels above 0.0038 mg/m^3 for the nerve agent VX is considered life-threatening. Air locks may be designed for single-person entry (SPE) or for multiple-person entry (MPE). MPE air locks are larger in volume and require a longer purge time for a specified level of concentration reduction. Typically, a group of people enter the MPE simultaneously, while only one person at a time enters an SPE. The design of an air lock is driven by the requirement to handle a specified number of personnel entries per hour. This, along with the air-lock volume and target concentration reduction, determines the required volume flow rate of clean air into the air lock.

The initial agent concentration within the air lock is a function of the external agent concentration: a time-dependent quantity that depends on the agent release point and on meteorological conditions. The transport of the agent into the air lock during entry depends on the wind speed and direction in the vicinity of the unit, as well as on specific details of the entry event, such as the:

- Walking speed of the person(s) entering
- Door-opening mechanism
- Level of air-lock overpressure

Other factors—such as whether personnel remove protective clothing and how such clothing is handled—can also affect agent transport by influencing the amount of time that the air-lock door remains open. Other mechanisms of infiltration include surface deposition or adsorption of agent material onto clothing and its eventual resuspension or desorption into the TFA over periods of time longer than the air-lock purge time. The air lock is not designed to be effective in this situation; therefore, the modeling activity described next does not yet handle this mode of infiltration.

To arrive at an estimation of potential hazards for shelter occupants for a given release scenario, it is necessary to predict the amount of agent mass transported into the air lock and into the TFA during the course of a personnel entry event. As the entirety of such an event may last tens of minutes, and as each stage is separated by an air-lock purge of 3 to 5 minutes, it suffices to analyze the response of a single-entry event as a function of the parameters mentioned above. The key parameter is the volume of air transferred per unit time (a volume flow rate, usually expressed as cubic feet/second). The product of this quantity with the external agent concentration (mass of agent per volume of air), integrated over the duration of the entry event, provides the total mass of agent transported into the air lock. The external agent concentration may be predicted by the Vapor, Liquid, and Solid Tracking (VLSTRACK), the Joint Effects Model (JEM), or similar strategies. Figure 1 shows a plot of external agent concentration versus time

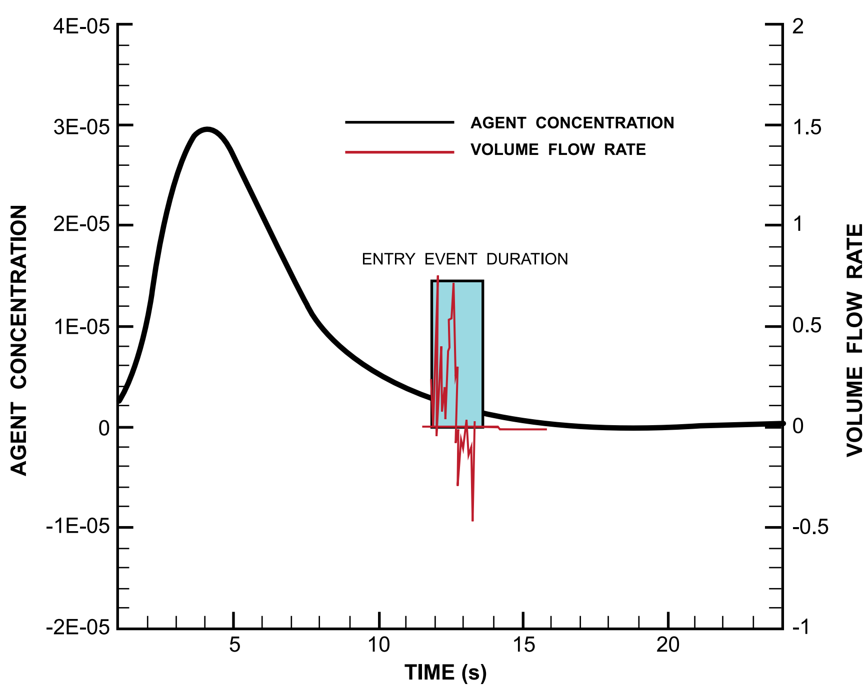


Figure 1. External Agent Concentration and Entry Volume Flow Rate Versus Time

intersecting with a curve representing the volume flow rate during entry. Agent mass can be transported into the air lock over the period of time indicated within the blue square.

A prediction of the amount of an agent transported into an air lock and the TFA during entry is a required feature of the JECP SPM being developed by NSWCDD's CBR Defense Division. As experimental data for personnel entry is generally unavailable, researchers at North Carolina State University are conducting detailed computational fluid dynamics (CFD) simulations of air-lock entry to support the development of an air-lock-specific SPM to be integrated into the overall SPM. An outcome of the air-lock SPM is a model for computational fluid (CF) transported versus time, which can be used as described above to predict the amount of agent transported into the air lock. The computational strategy is a large-eddy simulation, which attempts to capture the larger turbulent eddies generated by the external wind field and by personnel motion. The movement of people and doors is modeled using 3ds Max rendering software, which enables the construction of sequences of computer-aided design (CAD) objects representing different stages in a person's motion. These sequences are embedded into the computational domain using an immersed-boundary technique. This technique transfers the motion of the objects to the surrounding velocity field, which then drives transport of the agent material. Figure 2 shows a set of snapshots of an entry into an MPE equipped with a bump-through door. In all figures, surfaces representing vortex cores are colored by agent

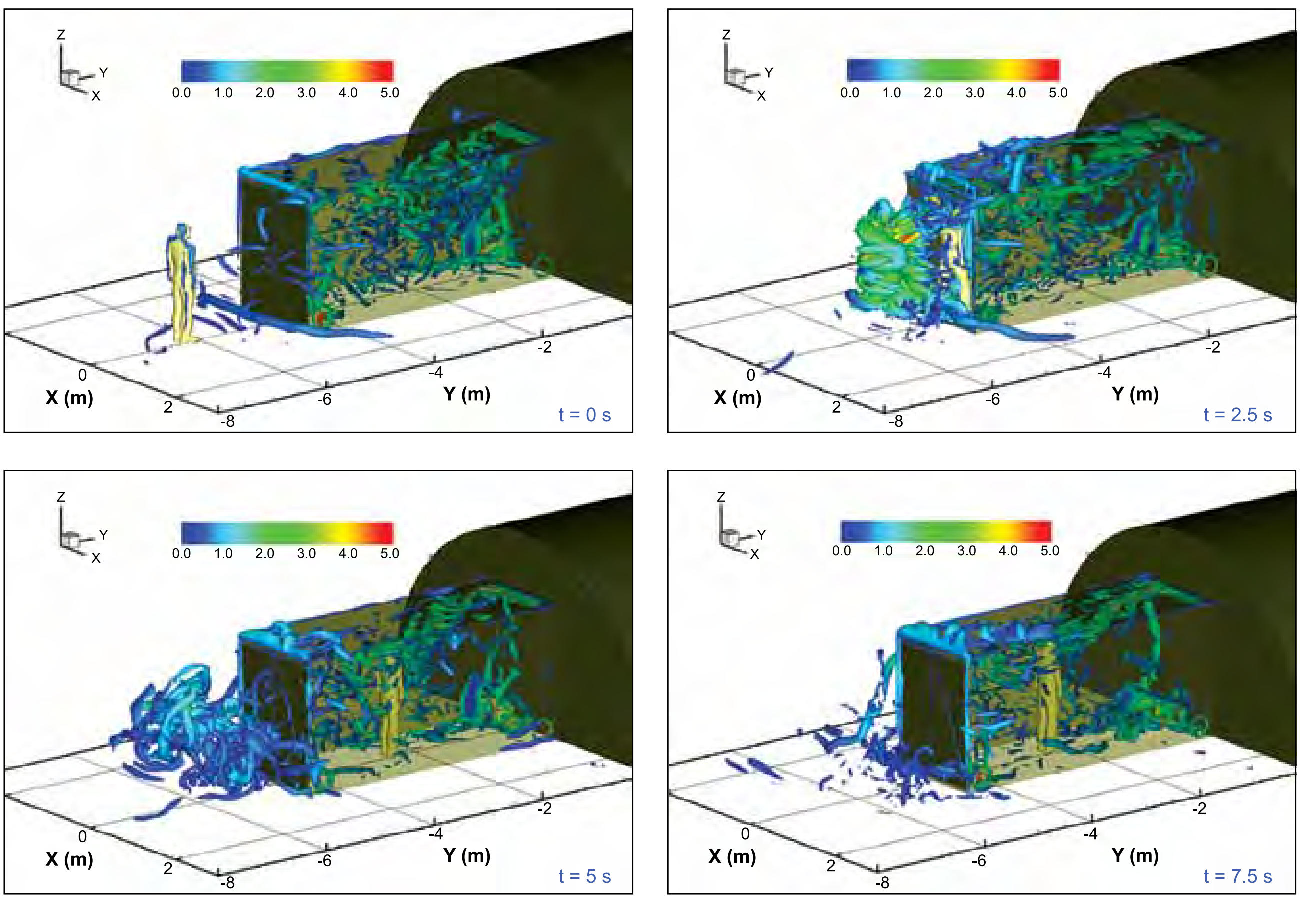


Figure 2. Snapshots of Vortex Cores (Colored by Agent Concentration) During a Simulated Entry Into an Air Lock

concentration, with red being high and blue being low. The top-right figure shows conditions just as the person enters. The release of overpressure forces a jet of air-lock gas outward and over the person. This response would naturally inhibit agent transport into the air lock, but the subsequent vacuum condition formed as the jet is released and the door closes counteracts this effect. The bottom snapshots show the decay of the initial jet and the reestablishment of the prevailing wind effect.

Simulations of this type have been performed for a sequence of trials generated by a Latin hypercube design-of-experiments (DOE) procedure developed at NSWCDD.[a] The trials vary the:

- Prevailing wind speed (0 to 5 m/s)
- Wind direction (0 to 180 degrees)
- Proximity of a person from the air lock (0 to 3 m)
- Walking speed (1 to 1.5 m/s)

The overpressure of the air lock is held fixed at 0.3 inches of water. Twenty-six individual simulations have been performed, with the initial stages of each simulation devoted to computing the air flow over the shelter (~45–60 s), and the last stages devoted to the entry event itself (~10 s). Figure 3a shows a plot of CF transported into the air lock versus time for the first 16 of these simulations. The general trend is toward an increase in CF transported for high wind speeds moving into the air-lock door. The fall in CF after its peak value is due to the closing of the air-lock door. A meta-modeling approach is employed to reduce the distributions shown in Figure 3a into a simpler form that correlates the response with the driving parameters of wind speed, wind direction, proximity, and walking speed. Figure 3b presents the data normalized by the maximum CF and by a time scale associated with the duration of the entry event. Also shown is a modified Gaussian fit to the normalized data. The modeling challenge is the regression of the parameters of the Gaussian fit (maximum CF, standard deviation) as functions of the driving parameters. A nonlinear regression analysis using SAS's JMP software has been used to determine the final form for the entry model.

Figure 4 shows model predictions (solid lines) versus computational data (symbols) for several trials not included in the initial set. These provide checkpoints for assessing the quality of the meta-model.

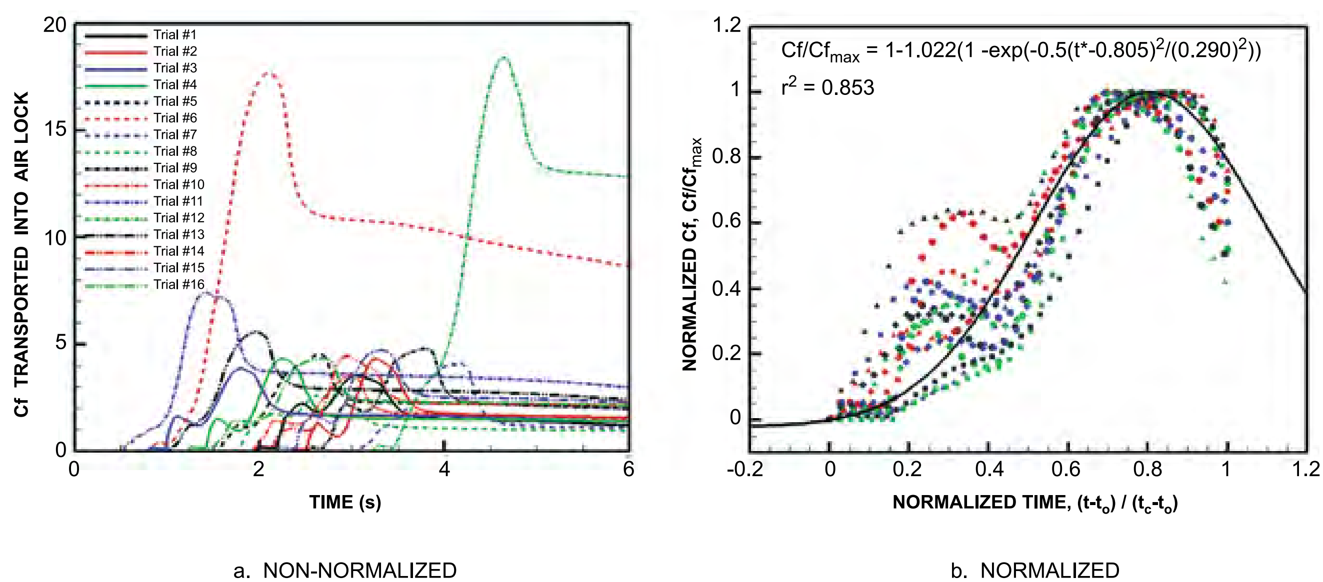


Figure 3. CF Transported Into Air Lock Versus Time

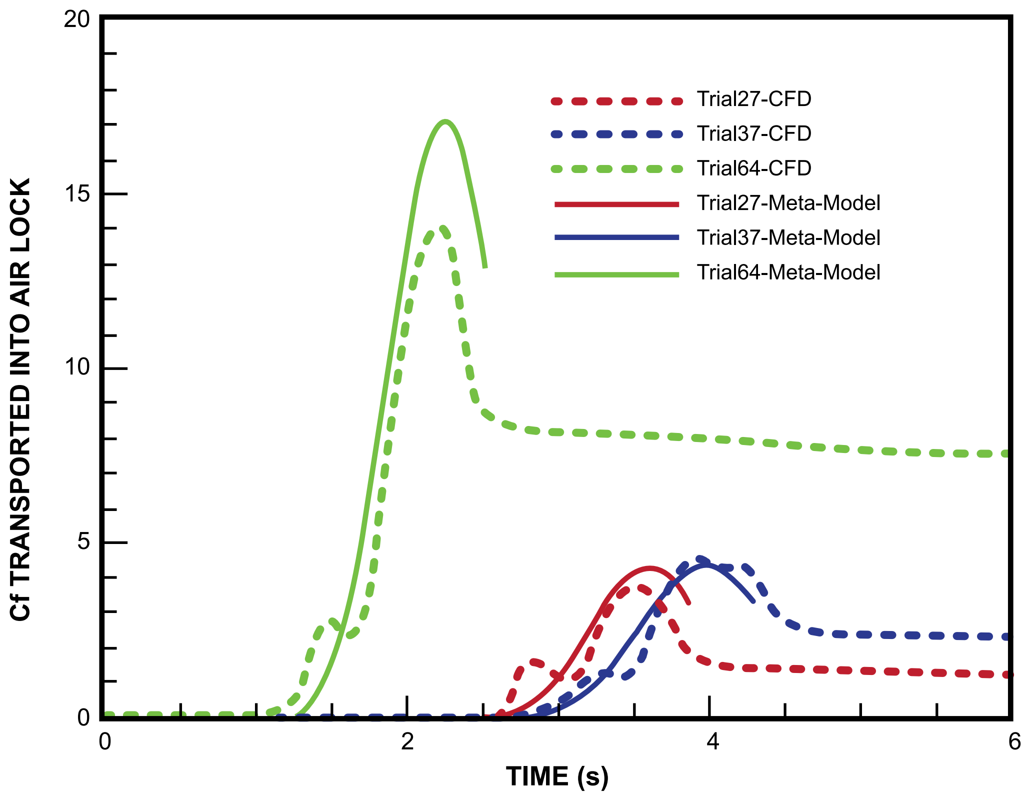


Figure 4. Meta-Model Predictions Versus Computational Data for CF Transported Into an Air Lock

This proof-of-concept exercise illustrates the potential of high-resolution CFD combined with metamodeling in developing a contaminant-transport model for air-lock personnel entry. The CF versus time distributions outputted are suitable for incorporation into zonal models such as CONTAM (multizone airflow and contaminant transport analysis software) from the National Institute of Standards and Technology (NIST) and, with refinement, may also be used to provide boundary conditions for coarse-grained CFD calculations of the flow within the air lock and TFA.[1] The techniques used in this exercise are now being applied to the actual JECP SPE and MPE air-lock configurations. The end product will ultimately help protect the warfighter from chemical and biological (CB) agents by improving the testing and evaluation process that is in place to help ensure that the best possible shelters are being produced.

Acknowledgments

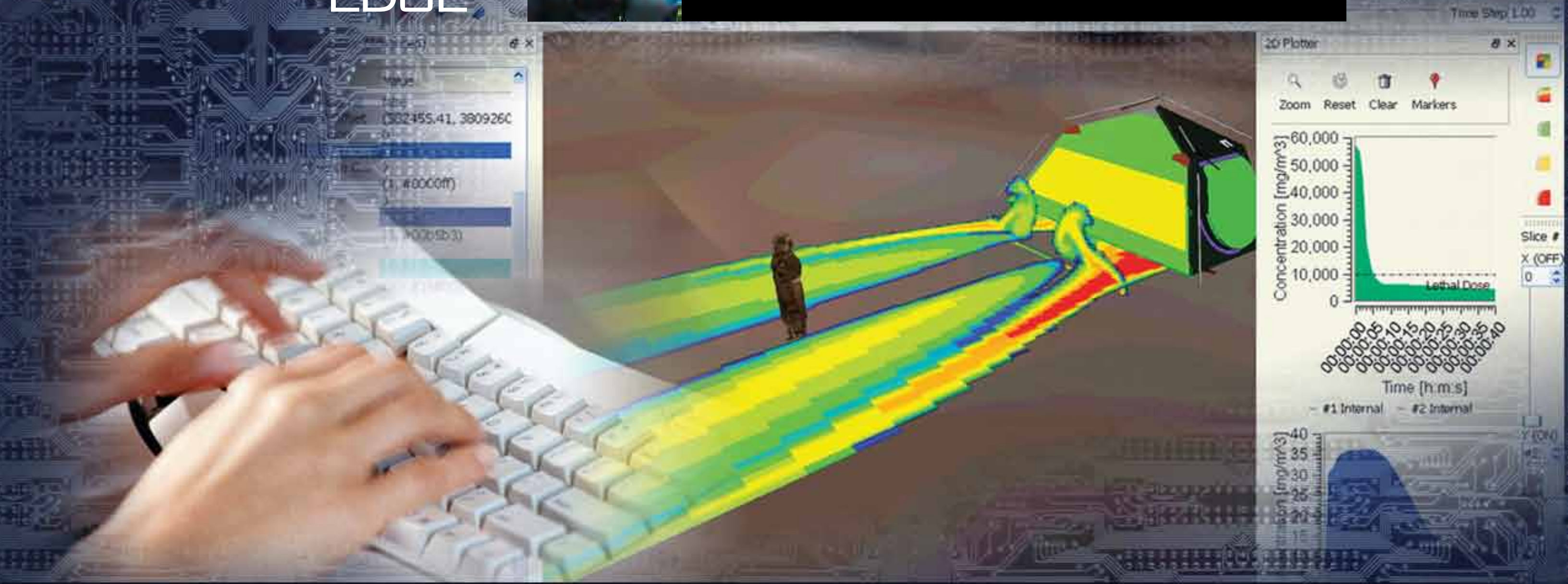
Jack Edwards, Jung-Il Choi, Jeffrey Eischen, and Nathan Obringer from North Carolina State University contributed to this article.

Endnote

a. Latin hypercube—a statistical method developed to generate a distribution of plausible collections of parameter values from a multidimensional distribution.

Reference

1. http://www.bfrl.nist.gov/IAQanalysis/CONTAM/overview/1.htm



The Next Generation of System Performance Model (SPM) for CBR Defense

By Gaurang R. Dävé and Michael O. Kelly

Overview

In developing a family of transportable shelter systems, the Joint Expeditionary Collective Protection (JECP) Program will provide collective protection to joint expeditionary forces and their assets. These shelter systems range from two-person passive filtration tents to large multiperson shelters that can be complexed together to provide active filtration and internal environmental conditioning. The objective of the JECP System Performance Model (SPM) is to model the collective protection performance of each JECP shelter and predict the level of exposure to chemical and biological (CB) agents experienced by personnel inside the toxic-free area (TFA). Exposure within the TFA can occur as a result of agent infiltration through barrier materials, air locks, closures, seams, filters, and from personnel entering or exiting the TFA. The SPM will provide a cost-effective method for predicting system collective protection performance while interacting within a complex environment, allowing users to create realistic operational scenarios. Also, the SPM will improve the test and evaluation (T&E) planning process by simulating results for testing environments that are otherwise too dangerous, complex, or expensive to physically test.

This article presents an overview of the challenges being addressed in JECP SPM software development, along with the technical solutions being applied to meet SPM requirements. The approach involves rigorous physics-based representations of most components or building blocks within the JECP system, along with empirical or semi-empirical representations for others. The fidelity of the representations will be commensurate with the level of detail that needs to be modeled for purposes of augmenting selected portions of the normal operational T&E (OT&E) process. The results of component and system analyses using computational fluid dynamics (CFD) models, along with the component and system testing conducted by the JECP program, will allow for the development of:

- Transfer functions for use in faster-running models
- Metadata models (empirical and/or physical) to allow more rapid system analysis during the JECP OT&E effort

Problem Statement

Given recent historic events and trends, the probability of a CB attack seems likely to increase. Consequently, protective measures must be taken to preserve the lives of warfighters in the field. In response to this threat, the JECP family of transportable shelter systems is being developed to provide protection against various types of CB attacks. However, it is critical to accurately assess the effectiveness of the protection provided in order to ensure that warfighters are safe from CB attacks.

The cost of physically testing the CB protection of the proposed shelters is very high. Thus, there is a strong desire to perform as much testing and evaluation as possible using modeling and simulation. This desire is in line with current acquisition strategies that specify modeling and simulation as a significant cost-saving tool.

The JECP SPM supplements the T&E strategy by providing a software construct (model test bed) that will enable testers to simulate operational environments for JECP applications across a range of battlefield conditions. The SPM will integrate several different data, component, and system modules (e.g., airflow mapping, breakthrough rate, and air filtration performance) with tactics, techniques, and procedures (TTPs), and simulated threats. Simulant data generated during T&E will provide a critical link between chamber performance data and field performance. The JECP SPM will relate test data to CB toxicological endpoints and provide output data to support operational system assessments.

The goal of the SPM effort is to design and implement a collection of modeling and simulation tools that can be used to accurately test and evaluate the various JECP shelters under a large number of conditions. The SPM software will allow one or more analysts to rapidly create and execute scenarios while specifying the conditions of a CB attack. Once a scenario has been executed, the SPM software will allow the user to view and analyze the resulting data in order to assess the level of performance for each shelter.

Challenges

The primary challenge facing SPM software development is ensuring the accuracy of the fluid flow and dispersion models. The chemical and physical properties required to accurately model the effects of a CB attack are far from trivial. Everything from weather conditions to the presence of trees and rough terrain must be considered to accurately predict the pressures and concentrations of harmful agents in and around the JECP shelters.

To meet the challenge of designing accurate models, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) enlisted the help of several experts in the field of CFD and dispersion. These scientists and engineers have the difficult task of researching and developing models that can accurately simulate the flow and dispersion of harmful agents from an external source into the JECP shelters. A depiction of modeled airflow over a shelter is shown in Figure 1.

To gain an appreciation for the complexity of this task, consider the number of instances for which various models must be developed:

- Modeling the initial release from a missile, rocket, sprayer, or other munition
- Modeling the flow, evaporation, and dispersion of contaminants over a variable terrain (This includes accounting for trees, buildings, rocks, and the deposition that may occur onto these surfaces.)
- Modeling the concentrations, pressures, temperatures, and accumulation of contaminants at the JECP shelter of interest
- Modeling the flow of contaminants through airlock doors and through airlock barrier materials
- Modeling the flow of contaminants through shelter doors and through shelter barrier materials
- Modeling the concentrations and flow profiles that result from personnel entering/exiting a shelter
- Modeling the flow and concentrations of contaminants within a shelter

As can be seen from the list above, there are several places in which physical and chemical models of varying types and complexities must be employed. Each model must provide a similar degree of accuracy to avoid passing high-precision, but low-accuracy results to downstream models. The SPM software provides the logic for connecting disparate models together and ensuring that they are invoked at the correct time with the appropriate set of inputs. This is no small task, since much of the modeling will likely require coordination of model inputs and outputs at every step. Factor in the need to model the effects of personnel entering and exiting a particular shelter, and the problem's complexity increases. The SPM must be capable of describing scenarios that have time-dependent properties. For example, a person's position changes during the scenario as a person moves toward and eventually into a particular shelter. Scenario dependencies may also affect the ingress of personnel into a shelter. For instance, if entrance

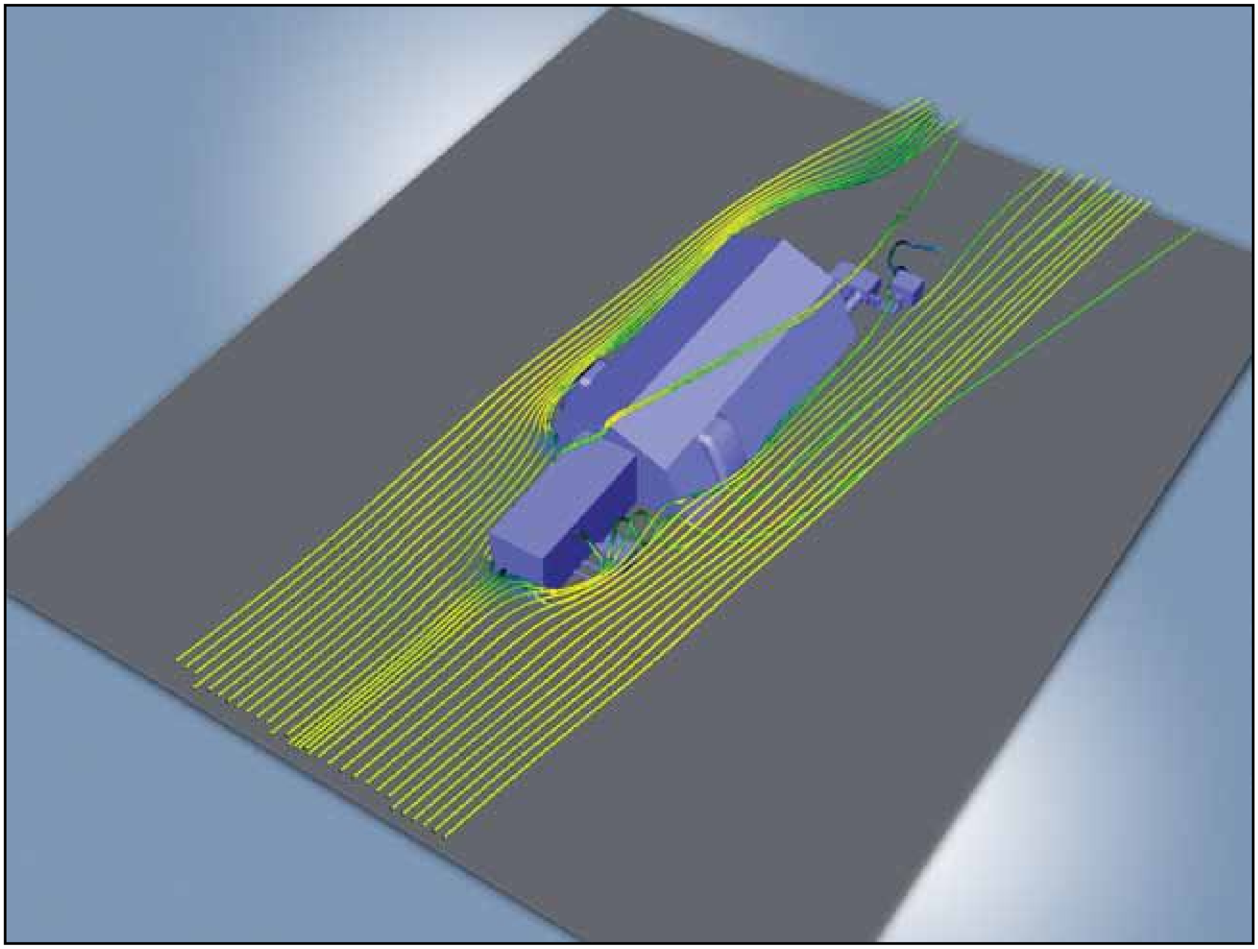


Figure 1. Airflow Over a Shelter

into the TFA is allowed only if airlock concentrations are below some threshold value, this may reduce the expected ingress rate of personnel (due to having to wait for concentrations to drop).

Another major challenge facing the development of SPM is the need for speedy performance. When it comes to CFD, the simulation run times are often on the order of hours, days, and sometimes even weeks. The lengthy run times typically associated with fluid flow modeling are not acceptable for the purposes of SPM; thus, performance-enhancing measures must be taken. Because of the large number of models (internal and external) that must be executed, and the required level of accuracy, the challenge of improving run times is very significant. There are algorithmic improvements that can be made, but the complexity of solving multiple, partial differential equations in three dimensions is difficult to reduce without sacrificing accuracy. Thus, the developers and engineers must try to find solutions that provide an acceptable degree of accuracy while drastically reducing computational run times.

Proposed Solution

As mentioned above, a major challenge facing the development of SPM is the lengthy run times typically associated with computation fluid dynamics (CFD) scenarios. Scenario execution times need to be on the order of a few minutes versus a few days in order to meet SPM usage requirements. To satisfy this requirement, the SPM team is exploring the use of "metamodels" as a means of maximizing performance without sacrificing accuracy. The term metamodel refers to a simple model that can be used to approximate a more complex model over a specific set of conditions. This approach is analogous to approximating a small section of a nonlinear function with a linear function. The objective is to design metamodels that closely match high-fidelity CFD results over the conditions required for SPM simulations. Once developed, these metamodels can be intelligently applied during SPM-scenario execution, such that execution time is minimized without losing a significant degree of accuracy.

From a software perspective, there are several "best practices" that can improve usability, maintainability, and flexibility. On the other hand, there are common mistakes that can all but ensure project failure despite the complexity of the problem domain. For the SPM development effort, the need to integrate several models that have evolving inputs, outputs, and requirements, and the desire for a flexible software approach is high. The SPM must be flexible enough to accommodate changing models and components as the details for each computational approach become known. There are several ways for achieving "flexibility" in software, but at an architectural level, the most common approach is to employ a "modular" approach. This modular approach refers to constructing several disjointed software components that, when loosely coupled, make up a useful application. The modular approach is not new and is commonly referred to in most programming languages.

The approach taken for SPM development leverages the open source NetBeans application platform. This approach allows for highly modular application development while making extensive reuse of mature software components. In developing any application that has a significant number of capabilities, there are typically a large number of "boilerplate" features that must be implemented in order to make the domain-specific capabilities accessible by the user. Many of these application components are taken for granted by most users (i.e., menus, drag and drop, cut/paste, undo/redo, open/save) but are very time-consuming to develop. The NetBeans platform provides a large portion of these common application capabilities as reusable components. This drastically reduces the development time required to implement a new application by allowing developers to focus primarily on the domain specific capabilities instead of the "boilerplate" code.

The NetBeans platform is an open-source framework that has been steadily maturing over the course of almost a decade. NetBeans is most commonly known as the host environment for the highly popular NetBeans integrated development environment (IDE) which, in many ways, outperforms commercial IDEs, such as Microsoft's Visual Studio. The platform provides a large set of reusable software components that allow for rapid development of highly modular applications. The workflow for developing applications that leverage the NetBeans platform is built into its IDE, which makes constructing new applications and modules very straightforward. Because of its flexibility and maturity, SPM developers chose to implement SPM capabilities on top of the NetBeans platform, which affords a great deal of flexibility that can easily accommodate changing requirements and data structures.

The various models and capabilities that need to be managed by SPM can be nicely encapsulated inside NetBeans modules. Each module has well-defined interfaces that govern which portions of the module's code are exposed to other modules. In addition, modules must specifically state dependencies on other application modules in order to access exposed classes. This ensures that all application dependencies can be quickly determined, thus providing better software maintainability.

General Interface

The user interface for SPM allows the user to arrange views in several different ways. There is a project view that resembles a "file explorer"-type widget. Users can navigate this project view to open files related to a project. Once located, files can be opened for viewing and editing. Encapsulating project components into individual "files" allows for greater scalability since only the portions of a project that are being viewed are loaded into memory. The JECP SPM Interface is shown in Figure 2.

Scenario Builder

SPM must be capable of modeling CB release scenarios under various conditions. The scenario builder allows users to drag and drop scenario components (e.g., shelters, air locks and personnel) onto a scenario canvas. Once added to the canvas, the user can set specific properties related to a particular object. In addition, time-dependent behavior can be described using a timeline. Once scenario properties have been specified, the scenario can be executed using the appropriate scenario executor.

Model Integration

Each model utilized by SPM is encapsulated in a module that can easily be added or removed from the application. Abstract services are defined to represent the models, which can then be implemented inside a module. The advantage is that the SPM execution logic does not need to be

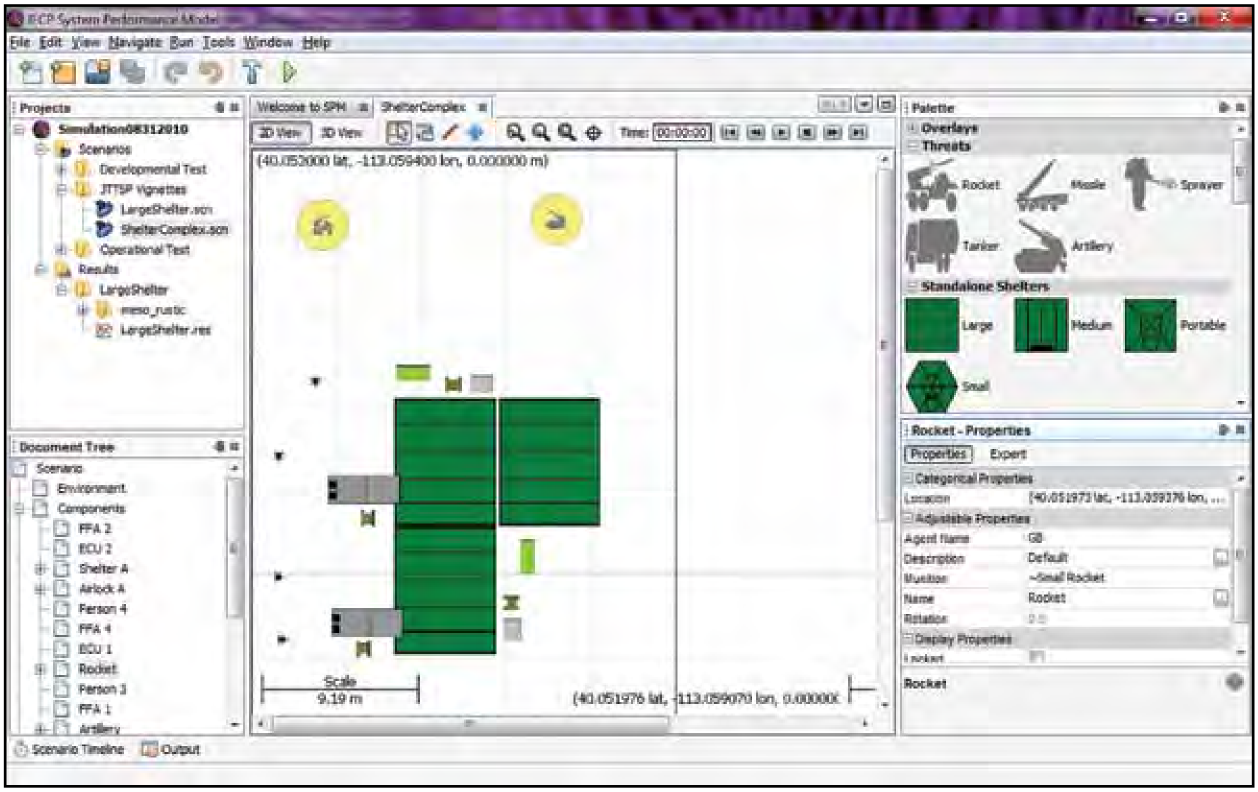


Figure 2. JECP SPM Interface

aware of the details of a particular module, except that it implements a particular interface. This allows models to be easily switched out as requirements evolve. It also allows capabilities to be added or removed without inadvertently affecting other portions of the application. The ability to add and remove capabilities without unwanted side effects is a huge plus when developing complex applications. In most circumstances, a full regression test is necessary to ensure that seemingly minor changes do not "break" the application. With the modular approach utilized by the NetBeans platform, dependencies can be traced easily, thus drastically reducing the time required for regression testing.

Results Visualization

During scenario execution, the models generate a large amount of result data. This data takes the form of flow fields, pressure profiles, and concentrations. Depending on the complexity and length of a scenario, the amount of result data can be several gigabytes. With such a large amount of data, sophisticated visualization tools are necessary to help analysts review and comprehend the results of a scenario. For this purpose, SPM utilizes the JECP SPM 3-D graphics package. This government off-the-shelf (GOTS) tool was developed by Lawrence Livermore National Laboratory (LLNL) and is capable of providing highly detailed visualizations of fluid flows and concentration profiles. In addition, the JMAT Visualization Package software allows analysts to "playback" a scenario in order to view how contaminants move externally and internally. This visualization, coupled with various reports and plots, allows the user to determine the overall performance of JECP shelters, air locks, and other components when faced with a variety of attacks, configurations, and environmental conditions. A depiction from the JMAT Visualization Package is shown in Figure 3.

Conclusion

The development of the JECP SPM is on course to meet the challenges of complexity, speed, and fidelity. The end product will ultimately help protect warfighters from CB agents by improving the T&E process currently in place to help ensure that the best possible shelters are produced.

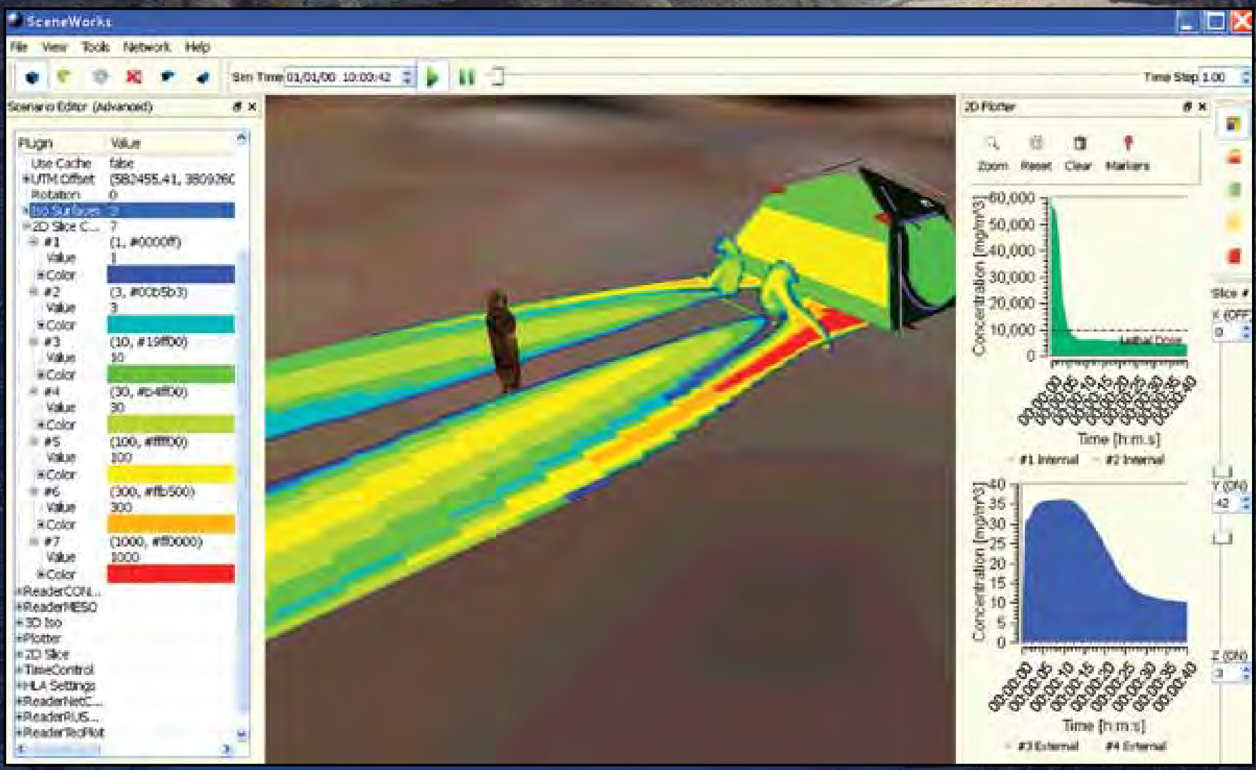


Figure 3. JMAT Visualization Package

Basic and Applied Science at NSWCDD Advances CBRD Capabilities

By Matthew J. Hornbaker and Richard C. Hodge

As a warfare center within the Naval Sea Systems Command (NAVSEA) Enterprise, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) works with other Navy laboratories to ensure that the technical challenges facing our warfighters are met with effective and affordable solutions. Scientists and engineers (S&Es) from NSWCDD design, develop, integrate, acquire, and test technologies and systems that our nation's warfighters rely on to meet current and future combat threats. NSWCDD's Chemical, Biological, and Radiological (CBR) Defense Division is responsible for providing disciplined systems engineering expertise for CBR research, development, test, and evaluation (RDT&E) modeling, integration, acquisition, and sustainment efforts to protect naval and joint forces afloat and ashore.

NSWCDD has a long history of leadership in chemical, biological, and radiological defense (CBRD) projects. During the Vietnam War, NSWCDD was named the lead Navy laboratory for chemical and biological warfare (confined to defensive countermeasures by Presidential directive). After the Vietnam War, the number of active CBRD projects waned until the use of chemical weapons by Saddam Hussein against Iraqi Kurds in the early 1980s brought renewed Navy interest.[1] Today, U.S. adversaries are constantly evolving their CBR methodologies and capabilities, necessitating continuous Navy research fundamental to the development of technologies and systems to counter or mitigate current and future CBR threats.

Although the structure of the CBR Defense Division at NSWCDD has changed several times throughout the years, maintaining a research component has always been a top priority for the organization's leadership. This commitment to basic and applied research programs is made with the understanding that the research ultimately enhances warfighter, fleet, and homeland defense CBRD capabilities. Today, NSWCDD has a robust CBRD research program providing a broad spectrum of support and technical solutions to many sponsors.

Laboratory Capabilities

In order to perform basic and applied scientific CBRD research, an organization must have personnel who have expertise in a variety of scientific and engineering disciplines. They need experience in CBR detection, decontamination, protection, or other specialty areas, as well as access to specialized laboratories and equipment. NSWCDD employs a diverse technical workforce, many with advanced academic credentials and security clearances, which enable them to perform CBRD research for the Navy. Research in the division is performed using in-house chemical, biological, and materials testing laboratories and equipment.

The CBR Defense Division's chemistry laboratories support RDT&E for characterization of new chemistries and materials for all product areas of CBRD. These laboratories are outfitted with a full suite of state-of-the-art analytical equipment commonly found in modern research institutions. Major focus areas for the chemistry laboratories include development of novel materials and formulations for hazard mitigation, spill cleanup, and advancement of detection technologies. A toxic chemistry laboratory provides hazard assessment and testing for high-hazard toxins, toxic industrial chemicals (TICS), and toxic industrial materials (TIMS). The Electrochemical Laboratory is set up to provide a test and evaluation (T&E) capability to determine accurate corrosion rates for multiple types of alloys, composites, and coatings. This technical capability provides input into paths forward in terms of fielding new CBRD products or in ship/vehicle design. The Materials Science Laboratory provides an additional capability used to judge the effects of the environment or CBRD products on military materials by mimicking the operational environment.

The Collective Protection System Laboratory, the Filtration Laboratory, and the CBR Filtration Evaluation and Support Facility are being used to evaluate components of the Collective Protection System (CPS), including filters, materials, and closures to identify limitations of currently fielded systems. Efforts are underway to develop advanced filters using engineered multicomponent systems that will improve TIC protection. Work in the Filtration Laboratory helps transition and field filtration systems to the warfighter that have been thoroughly and consistently evaluated against a full range of CBR threats. An engineer inside the CBR Filtration Evaluation and Support Facility demonstrating a filter change-out procedure is shown in Figure 1.

The CBR Defense Division hosts a number of biology laboratories operating at various biosafety levels. Biosafety level refers to the level of the biocontainment precautions, specified by the Centers for Disease Control and Prevention (CDC), required to isolate dangerous biological agents in a facility. Levels of containment range from the lowest biosafety level 1 to the highest at biosafety level 4. NSWCDD operates laboratories ranging from biosafety level 1 through biosafety level 3. These laboratories host programs that identify and develop new strategies for biological agent defense and validate the claims of commercial products for utility in neutralizing biological agents. The biology laboratories also support work that contributes directly to the understanding of low-dose exposures of various populations to biological agents.

The CBR Defense Division is responsible for various shipboard equipment and systems used for Navy radiological defense. The CPS, Countermeasure Washdown (CMWD) System, and Shipboard Personnel Decon Stations are three examples of shipboard systems that rely on the expertise of the CBR Defense Division researchers to ensure that radiation does not contaminate the inside of a ship. The Division has the appropriate permits in place

Figure 1. An engineer inside the CBR Filtration Evaluation and Support Facility demonstrates a filter change-out procedure.

for working with select radiological material associated with these and other systems. The Radiological Laboratory is used to conduct testing and repairs on fielded systems, which contain radiological sources as part of the detection system. The Aerosol Laboratory provides S&Es with the capability to sample and fully characterize fine solid particles or liquid droplets suspended in gases. Chemical or biological warfare agents can be deliberately or naturally masked by smoke, haze, or other means, making them more difficult to detect. S&Es working in the Aerosol Laboratory perform essential testing of detectors to ensure that chemical and biological threats are detected and that false alarms are minimized.

The CBR Defense Division also maintains an Imaging and Electron Microscopy Laboratory, where state-of-the-art optical and binocular microscopes equipped with both digital image and video capture systems are maintained. This laboratory also houses one of the world's most powerful scanning electron microscopes, providing researchers with the capability to evaluate material and generate images at the nanoscale. All of these systems are shared assets available for use by S&Es across the Division.

Potomac River Test Range (PRTR)

NSWCDD operates the PRTR, which is the Navy's only fully instrumented over-the-water littoral test range. The maritime environment provides unique challenges to CBRD due to factors such as corrosive effects of sea air, reflectivity of water, and temperature extremes impacting deployed equipment. To characterize and overcome these challenges, the CBR Defense Division utilizes the PRTR to test programs designed to rapidly and accurately detect and defend against chemical or biological agents. By testing equipment and systems under similar conditions those systems will see in the field, researchers are helping to ensure that deployed equipment will function as intended. An infrared (IR) sensor at the CBRD Facility overlooking the PRTR is shown in Figure 2. It is followed by a photograph of a meteorologist releasing a weather balloon prior to a test event in Figure 3.

Basic Research

Basic or fundamental research refers to research conducted to increase understanding of fundamental principles. Carried out at the bench level, this research consistently advances many areas of interest

Figure 2. View from the CBRD Facility overlooking the Potomac River Test Range (PRTR)—This IR sensor focuses on a very narrow frequency band to detect agents and simulants by their absorption of IR energy at "fingerprint" wavelengths.

Figure 3. A meteorologist releases a weather balloon prior to a test event—Weather data fed into high-resolution models is used for event prediction and for postevent analysis.

to the CBRD community. For example, through a unique collaboration between the Defense Threat Reduction Agency (DTRA) and the Environmental Protection Agency (EPA), traditional experimental techniques are being coupled with novel modeling techniques to gain a new understanding of the effects of low-dose exposure to biowarfare agents. Results are provided to warfighters, to the scientific community, and to Department of Defense (DoD) policy and decision makers to help them formulate strategies for risk assessment and for the mitigation of microbial pathogens. Spore characterization research is clarifying the extent to which environmental factors influence spore yield and viability. This research is being used to highlight the importance of spore preparation methods on efficacy testing. Standardization of spore preparation methods impacts the quality of data generated at laboratories across the DoD and allows for more direct comparison of results from different research groups. Surface chemistry research activities are leading to the development of advanced supergelators and superabsorbants, which enable small quantities of material to gel or capture large amounts of spilled chemicals for cleanup. Novel compounds prepared in NSWCDD's laboratories have achieved gelation or absorption of common chemicals at very low-weight ratios, in the range of one pound per one hundred pounds (or 1 percent by weight), which is like capturing 1 gallon of milk with 1 ounce of gellant. A researcher in the CBR Defense Division's Toxic Chemistry Laboratory is shown in Figure 4.

Applied Science

Applied science refers to research accessing, using, or leveraging the scientific communities' accumulated theories, knowledge, methods, and techniques for a specific purpose. NSWCDD's applied technology efforts are helping to safely and effectively remove and neutralize contaminants from personnel, equipment, vehicles, and the environment. NSWCDD's efforts also provide critical standards and methods to the testing community.

Applied research at NSWCDD led to the development of a fieldable decontamination formulation product and a number of patents and publications.

Figure 4. A Researcher Conducting Experiments in the CBR Defense Division's Toxic Chemistry Laboratory

Using a Navy-centric approach focused on fielding a solid or concentrated formulation, a decontamination formulation was developed that is both environmentally and logistically friendly. Material and chemical compatibility tests were performed on these formulations prior to procurement to ensure that they did not degrade the capability of the protective suits or equipment they were designed to decontaminate. Testing and the evaluation of hazards associated with decontamination formulations sometimes reveal incompatibilities between fielded materials and products being considered for fielding. NSWCDD scientists routinely perform this type of testing and provide data to program managers in support of milestone decisions in the acquisition process. Further characterization of identified incompatibilities allows the development of guidelines for proper storage, handling, and training in order to better ensure the safety of our warfighters.

Basic and Applied Science Value-Added

New threats and changing technology often create situations where new methods are needed or old methods become obsolete. Recently, standard methods for both biological and biotoxin decontamination testing and analysis methods were developed to ensure that the best available technology is used. These methods now represent the standard for conducting efficacy testing for all DoD laboratories. Quality-control samples produced by NSWCDD are utilized by customer laboratories for proficiency tests and validation of biological detection equipment. These samples are critical to biological defense analysis efforts and ensure that both military and civilian organizations monitoring the environment for release of biowarfare agents near population centers and key assets can do so with confidence.

The CBR Defense Division's multidisciplinary CBR experts perform work for a broad range of projects and provide critical subject matter expertise in support of multiple sponsors, including policy makers, program managers, partner Navy and DoD laboratories, and other government agencies. Subject matter expertise is critical for ensuring that effective CBRD systems are developed and that those systems are compatible with currently fielded technologies. Major sponsors for the organization include the DTRA, the EPA, the Defense

Advanced Research Projects Agency (DARPA), the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) and supporting Joint Program Managers (JPMs), the Department of Homeland Security (DHS), the Navy Treaty Implementation Office, and the Office of Naval Research.

The pursuit of basic and applied science enables researchers to discover and apply solutions important for all CBR Defense Division sponsors. Basic and applied science ultimately arms warfighters with technological advances that give U.S. forces the advantage where it matters most—on the battlefield.

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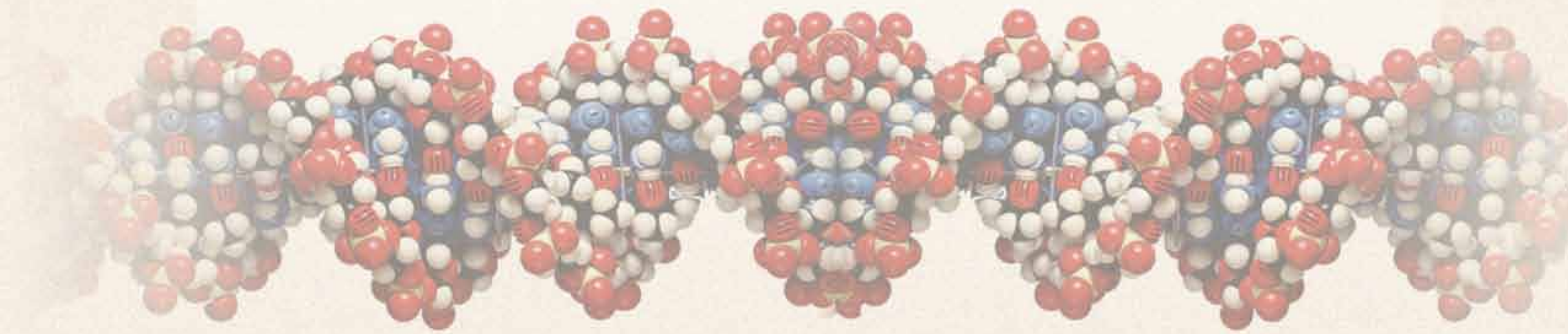

High-Containment Biological Laboratories

By Meredith Bondurant

In the field of biosafety, the primary objective is containment of potentially harmful biological agents. These agents may be pathogenic to humans, animals, or plants. Containment is accomplished with a combination of safe methods, facilities, and equipment that reduce the possibility of exposure of laboratory workers, other people, and the environment to potential biological hazards. Containment laboratories are described using four biosafety levels (BSLs).

BSLs range from BSL-1 laboratories, which have the most basic level of containment, to BSL-4 laboratories, which have the most robust containment. BSL-1 laboratories are acceptable for agents that are not usually associated with disease in healthy adults. BSL-1 laboratories rely primarily on standard microbial practices for containment. BSL-4 laboratories are equipped to contain the world's most dangerous biological agents. Agents handled in a BSL-4 are exotic agents that pose a high risk of life-threatening disease for which no vaccine or therapy is available. Containment is accomplished with a complex system that provides complete isolation of the agents through facility design; glove boxes; full-body, positive-pressure personnel suits; specialized ventilation; and waste management. BSL-2 and BSL-3 laboratories fall in between. BSL-2 laboratories are able to contain moderate-risk indigenous agents, while the BSL-3 is designed for work with indigenous or exotic agents with the potential for serious or potentially lethal infection.

Specific agents of concern are regulated by the Centers for Disease Control and Prevention (CDC) and the Animal and Plant Health Inspection Service (APHIS). The agents regulated by these organizations are referred to as "select agents." Select agents include *Bacillus anthracis* (causative agent of Anthrax), *Yersinia pestis* (causative agent of Plague), Ricin, and Ebola virus, to name a few. Laboratories that work with select agents may be BSL-2, -3, or -4 laboratories and must be registered with either the CDC or APHIS.

Laboratories that meet the criteria to operate as BSL–3 or BSL-4 are commonly referred to as high-containment laboratories. According to a 2009 Government Accountability Office (GAO) report on high-containment laboratories, in 2008 there were 279 entities registered with the CDC and APHIS to handle select agent(s) in 1,643 BSL-3 laboratories, and 5 entities registered to operate BSL-4 laboratories.[1] Of the 279 entities with registered BSL-3 laboratories, one of those entities resides within the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, which has met the regulatory requirements to manipulate select agents within its BSL-3 laboratory. NSWCDD conducts basic and applied research focusing on Navy-specific concerns of detection and decontamination of biological agents. A researcher is shown in a BSL-3 laboratory in Figure 1.

Operating a BSL-3 with a select agent requires an immense commitment of time, expertise, and resources. The U.S. Navy imposes physical and personnel security requirements above and beyond the CDC/APHIS regulations. Why does the Navy invest substantial resources in high-containment laboratories? The U.S. Navy's commitment to maintaining BSL-3 capability is a testament to the importance of these facilities and personnel necessary to keep warfighters safe. Maintaining BSL-3 capability is central to meeting operational needs in a biologically threatened environment and being prepared for the unknown. Simulant organisms have been identified that closely mimic virulent organisms and are much less hazardous. However, these organisms are not identical to virulent agents. In order to detect biological agents and destroy them, we must understand them and challenge them to various novel decontamination conditions. This can be accomplished only by working with virulent agent(s) in a secure, safe environment.

NSWCDD utilizes its BSL-3 for basic research in spore characterization, decontamination challenges, and modeling disease progression. For example, the bacterium, *Bacillus anthracis*, forms a spore that can remain dormant for many years. If that spore is better understood (i.e., characterized), vulnerabilities can be detected that could be exploited for more effective decontamination methods, and detection capabilities could be developed for specific spore qualities. Development of a decontamination method that is effective with a high degree of material compatibility is ideal. NSWCDD is able to test novel decontaminate methodologies on virulent agent(s) in its BSL-3. This is critical to fielding reliable decontamination solutions.

The value of maintaining BSL-3 capabilities cannot be understated. Responsible research is necessary to protect warfighters and the nation from biological attack. As such, the Navy recognizes the importance of understanding select agents and the value of BSL capabilities in the quest to discover detection and decontamination solutions. By following strict biosafety and security regulations, NSWCDD's basic and applied research is advancing the Navy's understanding of biological threats and its ability to counter them.

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Figure 1. BSL-3 Researcher at NSWCDD

Basic Research in Biology Facilitates the Development of Biodefense Products

By Tony Buhr and Derrell McPherson

Anthrax is a common name for one of the primary threats in biological warfare (BW). The disease has an important and well-known history compared to emerging diseases, such as severe acute respiratory syndrome (SARS) or hantavirus pulmonary syndrome (HPS). Anthrax is a natural disease of livestock, but it also affects humans. The historic knowledge of anthrax and its stability in the environment contributed to its development as a biological weapon. The aims of this article are to briefly describe the history of anthrax, *Bacillus anthracis* (the bacterium that causes anthrax), microbial relatives of *B. anthracis* that are critical for testing, and biodefense product development.

The Roman poet Virgil (70–19 BCE) wrote four works on agriculture, the third covering the topic of animal husbandry. In this volume, he gave a detailed account of a plague in the eastern Alps and described early attempts at decontamination:

> A terrible plague once sprang up there and raged on through the warmer part of autumn, not only destroying one flock of sheep after another, but killing animals of all kinds. Nor did the victims die an easy and uncomplicated death. After a burning fever had raged through an animal's veins and shriveled its flesh, the fluids again became abundant and virtually dissolved the bones… . The steaming ox falls before the heavy plow. Blood mixed with froth issues from his mouth as he groans his last… . His sturdy flanks waste away, a heavy stupor dulls his eyes, and his head sags near the earth. Of what use to him now is all his toil in the service to mankind? What profit has he gained by turning up the heavy soil with the plow?… .The pelts of diseased animals were useless, and neither water or fire could cleanse the taint from their flesh. The sheepmen could not shear the fleece, which was riddled with disease and corruption, nor did they dare even touch the rotting strands. If anyone wore garments made from tainted wool, his limbs were soon attacked by inflamed papules and foul exudates.[1]

In the 19th century, an anthrax epidemic destroyed approximately half of the sheep in Europe. From 1867 to 1870, more than 56,000 horses, cattle, and sheep, and 528 men perished in Russia. Inhalation anthrax became known in Victorian England as woolsorters' disease because of the frequency of infection in millworkers exposed to animal fibers contaminated with *B. anthracis* spores. Twenty-three cases of anthrax were recorded in the Bradford district of England, where the animal hair industry was concentrated, between November 1879 and September 1880.[2–4]

Historically, it was very difficult to deal with a disease such as anthrax because there was no rational understanding of the cause of the disease. For example, a primary treatment for anthrax was to simply avoid areas where the disease occurred. This was problematic since anthrax was a worldwide disease, and it was very persistent in the environment; some areas were known to be heavily infected for centuries. Treatment of anthrax changed during the 1800s with the advancement of scientific knowledge. Studies by Eloy Barthelemy, Aloys Pollender, Casimir Davaine, Robert Koch, John H. Bell, and Louis Pasteur in France, Germany, and England between 1823 and 1881, culminated in the demonstration that *B. anthracis* was the causal agent of anthrax disease. This knowledge was critical because the focus shifted to treatments and decontamination of *B. anthracis* rather than treatment of disease symptoms or avoiding regions known to have problems with anthrax. This knowledge also contributed to the development of anthrax vaccines and early industrial hygiene practices.[2–4]

During the 20th century, incidence of anthrax decreased significantly due to vaccination and improved animal husbandry, as well as the processing of animal products. Anthrax continued to represent a worldwide presence outside the United States, with an annual occurrence of 20,000–100,000 in the first half of the 20th century, and approximately 2,000 cases yearly during the second half.[2–4] Thus, knowledge of *B. anthracis* led to control of anthrax disease in developed countries. However, the stability of *B. anthracis* spores (spores are the dormant state of the bacterium, analogous to a plant seed) also made it a top candidate as a biological weapon for both state-sponsored programs and terrorists.

Today, safety, security, and costs constrain our ability to test virulent, disease-causing strains of

B. anthracis under many test conditions. Instead, biodefense testing frequently relies on relatives of *B. anthracis*. These relatives are often called simulants or surrogates. One traditional simulant has been *Bacillus atrophaeus* because it has not been confirmed to cause disease in livestock or humans.

One important role of biodefense testing is to accumulate and compare data about different strains and species in order to develop tests that accurately and safely represent the threat from a *B. anthracis* (anthrax) spore attack. Collections of different *Bacillus* strains have greatly increased over recent decades at a number of different laboratories. Data comparisons, particularly genetic information, also greatly increased in the past decade. One goal of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) is to study and characterize spore preparation methods and physical characteristics of select strains of *Bacillus* species.[5] These data help design experiments that will best reflect different scenarios for anthrax attacks. They also help prepare for postattack management.

Figure 1 shows electron microscope pictures of spores from four different species. The outside structure of the spore is called an exosporium. This structure exists on *B. anthracis*, *Bacillus cereus*, and *Bacillus thuringiensis* spores, but not on *B. atrophaeus* spores. The exosporium is a critical feature because it impacts spore hydrophobicity. The degree of hydrophobicity is related to spore stickiness, spore clumping, and spore suspension in different solutions. The traditional simulant has been *B. atrophaeus* spores, which do not contain the exosporium, do not clump, and are easy to suspend in water. *B. atrophaeus* spores are also prepared differently than *B. anthracis*. This suggests that *B. atrophaeus* may not be the best simulant for *B. anthracis*.

Selection of simulants and spore preparation methods can impact test results. For example, there are thousands of known strains of *Bacillus* scattered throughout the world, and there are thousands of differences among strains. There are also many similarities among different strains. Detection methods must be developed based on similarities and differences in order to distinguish *B. anthracis* from other species. Otherwise, detectors may send out false alarms, i.e., false information. This impacts resources in terms of responding to false alarms and the costs associated with such responses.

During the basic research process, multiple objectives are addressed in order to develop improved biodefense test methods, improve test reproducibility, decrease test time, and increase confidence in data and data analyses. Programmatic goals that are

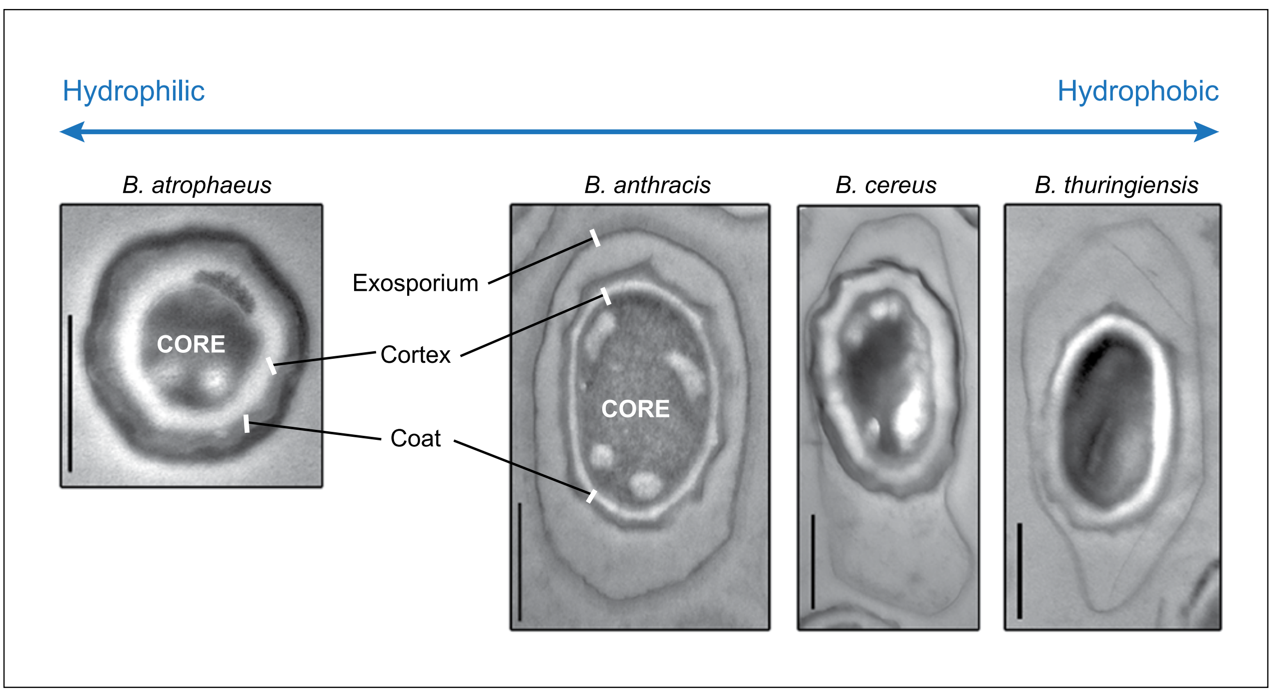

Figure 1. Transmission Electron Microscope Spores of Four Different Species—Size bars are 0.5 µm in size.

addressed include costs, performance, and schedule. Moreover, increased confidence in BW research data related to spore decontamination testing increases over time. Recent sporicidal (decontamination) testing at NSWCDD led to two decontamination technology transitions from Defense Threat Reduction Agency (DTRA) Science and Technology (S&T) to Joint Project Manager Decontamination (JPM-Decon): the transition of hot humid air for whole aircraft decontamination and electronically generated chlorine dioxide for general decontamination of rugged materials. NSWCDD's basic research, therefore, ultimately leads to improved protection for warfighters.

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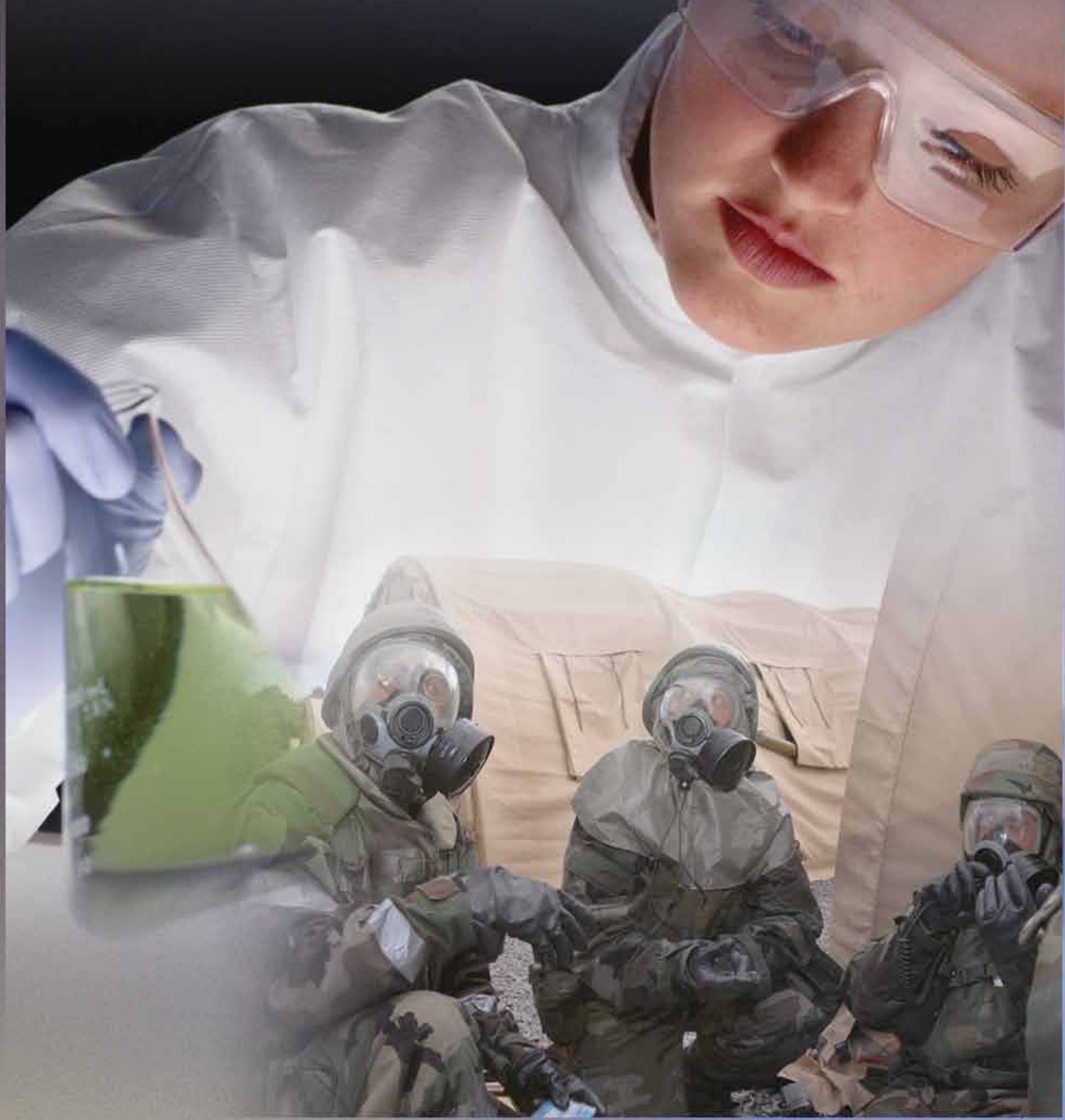

Biotoxin Research at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD)

By Elaine M. Strauss, Wynn Vo, and Linda C. Beck

The potential use of biotoxins as weapons against military and civilian targets constitutes an emerging threat to national security. Following the tragic terrorist attacks of September 2001 and the anthrax mailing attacks the following month, there has been heightened interest concerning the deliberate use of chemical and biological agents by terrorists. A recent report, *World at Risk—The Report of the Commission on the Prevention of WMD Proliferation and Terrorism*, submitted by Senators Bob Graham and Jim Talent in December, 2008 to then-President, George W. Bush, indicated that nuclear and biological weapons "... pose the greatest peril."[1] The severity of this threat was reiterated recently by Undersecretary of Defense for Policy Michele Flournoy, who said, "The risk of weapons of mass destruction falling into the hands of terrorists is the gravest threat facing the United States."[2] The extent of the concern about bioterror activity is highlighted in numerous papers, reports, and books published over the past decade. Examples are listed under the References subheading at the end of the article.[1–11]

Background on Biotoxins and Their Potential Threat

Biotoxins can be defined as biologically active compounds that are produced by living organisms. They can be grouped according to the organisms that produce them, including bacteria, fungi, plants, and dinoflagellates. Based on their chemical structure, it is also possible to divide biotoxins into protein and nonprotein categories. Toxins of biological origin generally reflect the following attributes:

- Are natural, although some biotoxins can be synthesized
- Can be produced in large-scale or small quantities
- Are nonvolatile
- Are more toxic than chemical agents, such as sarin, soman, and VX
- Have legitimate medical uses
- Are odorless and tasteless
- Are capable of producing diverse toxic effects
- Are highly dependent on the route of exposure
- Are effective immunogens

For state or non-state terrorists who lack the funding to acquire nuclear weapons, biotoxins, offer significant appeal for several reasons. First, biotoxins already have been produced for use as strategic and tactical weapons. Second, in general, the source organisms for many biotoxins are readily available worldwide. Third, the extraction and purification process for many biotoxins poses relatively few technical challenges, especially as compared to constructing a nuclear device. Lastly, biotoxins are endemic to much of the world and cause natural contaminations in food and water. Moreover, they may be easy to conceal.

Ricin and botulinum toxin represent two protein biotoxins that are of great interest as potential weapons of warfare and terrorism. Ricin is a protein produced by the castor oil plant, *Ricinus communis.* The seeds of the plant contain the highest concentration of the biotoxin and are used for castor oil production. As a result, ricin is one of the toxins that can be obtained very easily in large quantities. Each year, more than one million tons of castor beans are processed to produce castor oil, and ricin can easily be separated from the castor bean waste mash, which contains 5–10 percent of the toxin by weight. Toxicity results from ricin's ability to shut down protein synthesis, which leads to cell death. Further, ricin is stable and is toxic by ingestion, injection, or by inhalation. When considering its use as a weapon of mass destruction (WMD), the quantity of ricin required for 50 percent lethality over a 100-km^2 area is estimated to be much greater than *Bacillus anthracis.* However, it could be used to contaminate food or water supplies, which could incapacitate many and overwhelm healthcare facilities. Seeds from *Ricinus communis* are shown in Figure 1.

Also of grave concern is botulinum toxin, produced by the bacterium *Clostridium botulinum,* which has the distinction of being known as the most potent toxin. In contrast to ricin, which acts by inhibiting protein synthesis, botulinum toxin is a neurotoxin and acts by inhibiting the release of the neurotransmitter acetylcholine from the nerves, resulting in paralysis. There are seven antigenic types of botulinum toxin designated A to G, with types A, B, E, and F causing most human poisoning. Botulinum toxin could be delivered by contaminated food or water, but it is extremely toxic by inhalation, with estimates of 1–10 ng/kg of body mass as all that would be required for 50 percent lethality in humans. Recently, terrorism experts have raised the possibility that terrorist organizations could obtain significant quantities of botulinum toxin from the emerging black market for counterfeit "Botox" from counterfeit laboratories and networks in Russia, Eastern Europe, or China. "Botox" is the commercial name for botulinum toxin used in tiny amounts for legitimate medical purposes, including treating migraine headaches, facial tics and facial wrinkles.[11] The bacterium *Clostridium botulinum* is shown in Figure 2.

Figure 1. Seeds From *Ricinus communis*

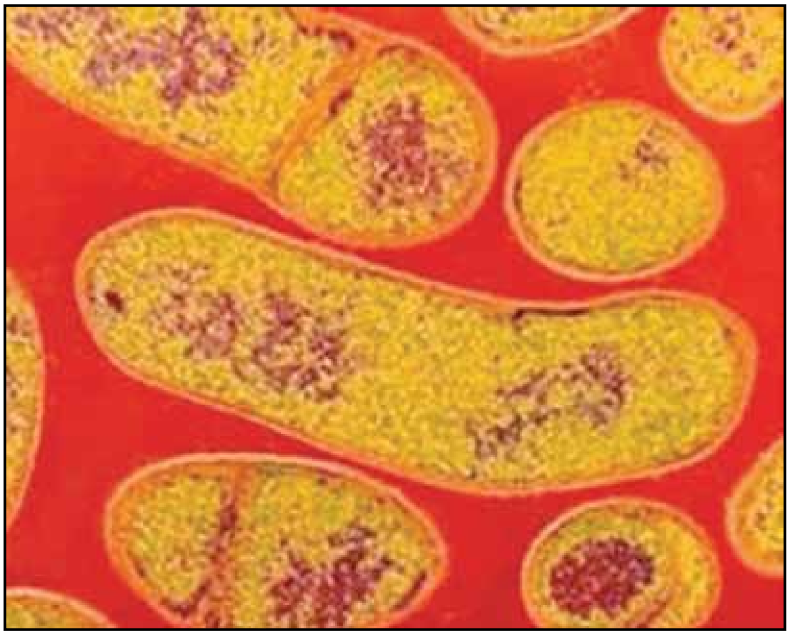

Figure 2. *Clostridium botulinum*

Biotoxin Research and Experimentation

Since the Herbert H. Bateman Chemical, Biological, and Radiological (CBR) Defense Center at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, was dedicated on 22 August 2002, one focus has been the analysis, detection, and decontamination of biotoxins. This CBR Defense Center houses chemical and biological laboratories, with Biosafety Levels 2 and 3 (BSL-2 and BSL-3) containment facilities, quality assurance and materials laboratories, collective protection and standoff detection laboratories, and high-performance computing capabilities.[a] Within this facility, the CBR Concepts and Experimentation Branch plans and executes research, development, test, and evaluation (RDT&E) projects directed toward an improved understanding of the nature of biotoxins and how to better detect and neutralize them. To facilitate these studies, the Toxin Testing Laboratory is outfitted with dual chemical fume hoods equipped with charcoal and high-efficiency particulate air (HEPA) filters, and equipment for high-pressure liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and electrochemiluminescence (ECL) analyzers. Prior to initiating projects with active biotoxins, all scientists and engineers undergo extensive safety and security training, and each project is rigorously reviewed for safety and treaty compliance. A scientist working in a toxin laboratory with a powered, air-purifying respirator is shown in Figure 3.

Utilizing this Navy CBR defense facility and specialized equipment, highly qualified scientists and engineers investigate biotoxin detection, decontamination, remediation, and consequence management. To illustrate the scope of the their efforts, projects have included:

- Developing methods for determining decontamination efficacy against biotoxins on military-relevant surfaces
- Investigating the effects of standard water treatments, including chemical oxidants, coagulants, heating, and boiling on biotoxins in water samples
- Analyzing recovery of bioagents, including biotoxins, from dry filter units (DFUs)

As part of the Joint Chemical, Biological, Radiological, and Nuclear (CBRN) Defense Concept, these biotoxin projects enabled collaborations with several military (Edgewood Chemical Biological Center, Naval Medical Research Center, Naval Research Laboratory, and U.S. Army Dugway Proving Ground) and nonmilitary agencies (Environmental Protection Agency and the Lincoln Laboratory, Massachusetts Institute of Technology (MIT)).

Protecting the Navy and Our Nation

John Michael McConnell, former Director of National Intelligence, stated in a speech in 2008 that, "One of our greatest concerns continues to be that a terrorist group or some other dangerous group might acquire and employ biological agents…to create casualties greater than September 11."[1] This

Figure 3. Scientist Working in a Toxin Laboratory With a Powered, Air-Purifying Respirator

concern was again confirmed by Michele Flournoy's more recent statement, "…The thing that keeps me awake at night is a nexus between terrorism and massive destruction."

The Navy and our nation must be prepared for these potential threats. Accordingly, scientists from NSWCDD are not only committed to biotoxin research, they are contributing significantly to the Navy's and our nation's ability to detect, protect, and decontaminate hazards from a biotoxin attack.

Endnote

a. Biosafety Level 2 (BSL-2) is appropriate for handling moderate-risk agents that cause human disease of varying severity by ingestion or through percutaneous or mucous membrane exposure. Biosafety Level 3 (BSL-3) is appropriate for agents with a known potential for aerosol transmission, for agents that may cause serious and potentially lethal infections, and for those that are indigenous or exotic in origin. Source: *Biosafety in Microbiological and Biomedical Laboratories*, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and the National Institutes of Health, Fifth Edition, 2007.

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Development of Novel Solutions for Decontaminating Warfare Agents

By Claire Wells and Chris Hodge

In the aftermath of a chemical or biological warfare agent attack, the inevitable question asked is, "How do we clean this up?" For chemical and biological experts and experienced naval personnel, the obvious answer is to use a decontamination solution, commonly called a decon. Decons currently in the field are based on oxidative chemistry employed in water-based systems. One example is the high-test hypochlorite (HTH) presently used by the Navy as its standard shipboard oxidizer for decontamination. HTH is more commonly known as a common active ingredient in swimming pool shock products. It is a reactive, corrosive, chlorinated chemical that severely corrodes metals and can cause serious damage to the eyes, skin, and respiratory tract. Because of its reactivity, oxidants like HTH are effective in neutralizing the threat from the warfare agents. However, for the same reason, they can also be harsh on materials, users, and the environment.

Decontamination Challenges

It is challenging to formulate a decon that is powerful enough to neutralize the agents but gentle enough to be compatible with common military materials. How do scientists and engineers balance the reactivity required for quick agent neutralization with the stability required to avoid destruction of the surface they are trying to clean? How can a decon meant to chemically react be stable enough to have a useful shelf and pot life? The challenges don't stop there. Scientists and engineers must also solvate hydrophobic (i.e., water-hating) chemical warfare agents and hydrophilic (i.e., water-loving) oxidizers into the decon solution at the same time, under the same conditions, so the neutralization reaction has a chance to occur in the first place. Anyone who has mixed olive oil and vinegar for their salad and wanted it to stay mixed understands the challenge. Even though solvents can help solvate the agents, their use would create additional environmental concerns and safety issues. To be most useful for the warfighter, a decon needs to be:

- Effective
- Compatible with common military materials
- Easy to use by a warfighter in protective gear
- A low logistical burden
- Nonhazardous to the user and the environment

To address these challenges, a diverse team of scientists and engineers from the Chemical, Biological, and Radiological (CBR) Defense Division of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), in Dahlgren, Virginia, conducts research and development efforts to design and test new decon formulations. In one such effort, scientists and engineers utilized microemulsions formulated from biodegradable surfactants in place of solvents to solvate the warfare agents. Microemulsions are typically mixtures of water, one or more surfactants, and an oil. In this case, the warfare agent serves as the oil.[1] A 2-D depiction of a microemulsion is shown in Figure 1.

Using a particular ratio of one surfactant slightly soluble in the oil phase and one surfactant slightly soluble in the aqueous phase, the researchers designed a microemulsion with high solubilization characteristics. The resulting water-based solution of surfactants formed a stable, single-phase solution without the use of harmful solvents.[1]

In addition to using microemulsions rather than organic solvents to solvate the chemical agents, the researchers utilized peroxygen compounds instead of harsh chlorinated oxidizers (e.g., HTH) to neutralize them. A wide range of peroxygen compounds was evaluated, from simple hydrogen peroxide to complex peracids. These nonchlorine-based peroxygen compounds were of interest because of their low environmental impact, their improved materials compatibility, and their relatively low toxicity. Particularly effective was peracetic acid, which has been shown to achieve 100 percent neutralization of all major chemical and biological agents, while avoiding production of toxic by-products.[1]

Discovering Decontamination Solutions

While improved safety and compatibility were important achievements of these efforts, seeking options to reduce the logistical footprint of the developing decon was also required. This was especially important for the Navy since shipboard storage space is limited. One way to achieve this is by identifying solid counterparts for the decon ingredients. The use of solid ingredients avoids the unnecessary storage and transportation of extra water and allows the decon to be mixed on demand. However, locating a solid source of peracetic acid proved particularly challenging. Typical systems generated the peracid *in situ* upon mixing in water. For example, peracetic acid can be generated from the reaction of hydrogen peroxide and tetraacetylethylenediamine (TAED).[1] This approach is feasible but offers limited success partially because of poor solubility and a slowed reaction rate. A milestone was reached when the Dahlgren research team identified and successfully tested a novel, solid source of peracetic acid developed for the commercial detergent industry. This compound—with the trade name PES-Solid—does not depend on *in situ* generation peracetic acid,

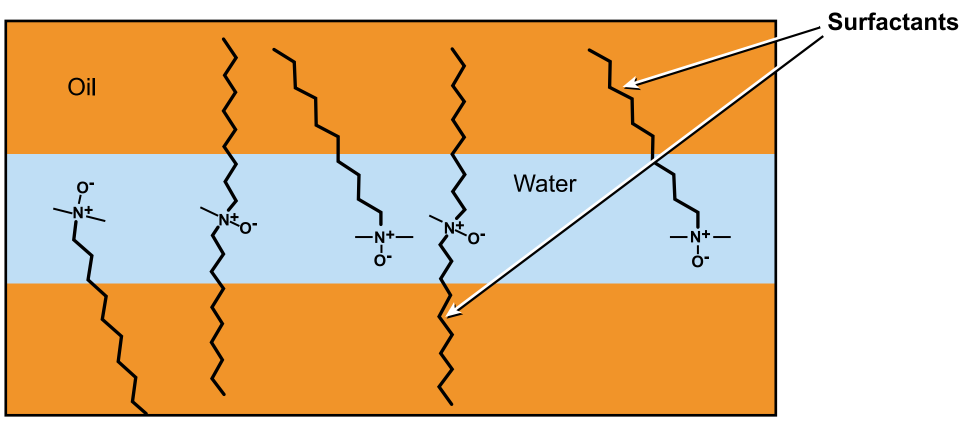

Figure 1. 2-D Depiction of a Microemulsion

but releases it immediately upon dissolution in water. This makes it available for agent neutralization much more rapidly than *in situ* methods.[1] In numerous testing efforts at NSWCDD, PES-Solid has shown promise against chemical and biological agents, as well as improved materials compatibility with military materials.[1–3] A representative structure of PES-Solid is shown in Figure 2. The exact structure remains unknown.

Current NSWCDD decontamination development efforts utilizing PES-Solid are focused on creating a product for the warfighter that is safe and user-friendly. In the course of efforts to mature the developed technology, formal collaboration with the solid oxidizer manufacturer will allow researchers to explore the optimization of the product for safe storage and transportation, as well as for ease of mixing. This will help to reduce the risk and workload of the operators in the field.

The journey to creating a safe and effective decon that meets the needs of the warfighter is challenging because many of the desirable attributes of a decon formulation conflict with one another. NSWCDD scientists and engineers continue to work with our Navy and joint partners to develop technologies that lead to more effective and safer decontamination methods.

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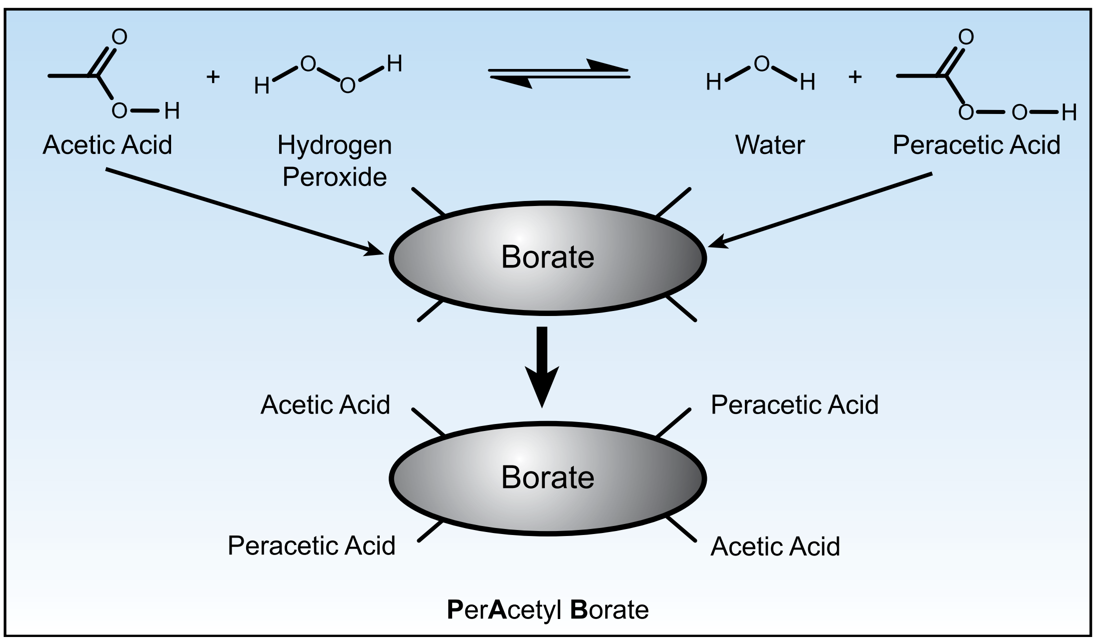


Figure 2. Representative Structure of PES-Solid


NDCTC

Soft Matter Makes Tough Technologies

By James R. Lee

The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, is home to the Chemical, Biological, and Radiological (CBR) Defense Division, where one of its primary goals is to develop technologies that will neutralize or contain chemical warfare agents (CWAs). This article communicates how soft-matter technologies are used to accomplish this goal.

What is soft matter? Soft matter refers to materials that are in-between crystalline solids and simple liquids. Examples include liquid crystals, gels, foams, and microemulsions. These materials are found in many common commercial products. Liquid crystals, for example, are found in liquid crystal displays (LCDs) in flat-screen televisions. Jello and shaving cream are examples of gels and foams. So how do soft-matter technologies like these help to neutralize and contain CWAs? This is where the last example, microemulsions, is really important. This article explains how microemulsions are the solution to one of the toughest problems in CWA cleanup and decontamination.

To begin, consider a problem that is specific to the decontamination of CWAs. Some CWAs—like the blistering agent distilled mustard—are soluble in oil; other CWAs—like the nerve agent sarin—are soluble in water. Most chemical compounds that neutralize CWAs are soluble only in water. It is common knowledge that water and oil don't mix, as illustrated in Figure 1, which shows motor oil and water in a glass. Even if shaken, the two liquids will separate. The oil remains on top since it has a lower density than water. This creates two problems:

1. How to get neutralizing agents, soluble in water, to react with oil-soluble CWAs
2. How to make a cleaning solution that will dissolve both oil- and water-soluble CWAs

Figure 1. Motor Oil and Water in a Glass

There is a way to make oil and water mix and solve both of the decontamination problems. Chemicals called surface active agents, commonly known as surfactants, are the key to the solution. A surfactant is a molecule that contains both hydrophilic (water-loving) and lipophilic (oil-loving) groups. Figure 2 shows a simple model of the surfactant octane-1-oxydiethylene glycol.

Chemical Structure of Octane-1-oxy-diethylene glycol
C = Carbon, H = Hydrogen, O = Oxygen

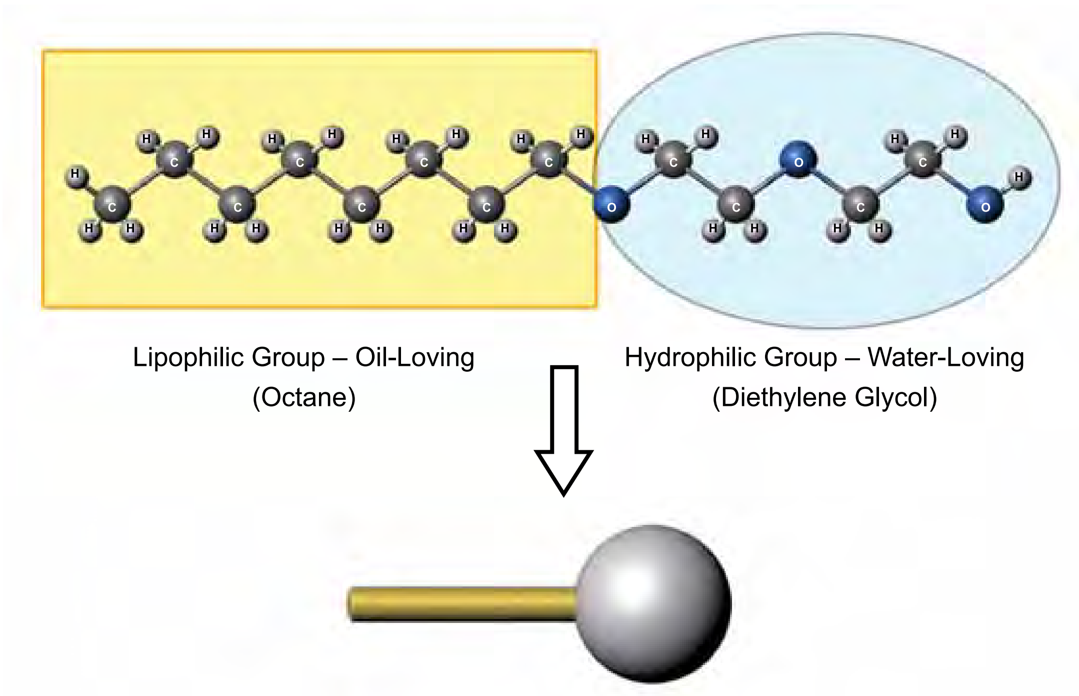


Figure 2. Simple Model of a Surfactant

particular case shown in Figure 4, the spherical micelles have the hydrophilic part of the surfactant on the surface of the sphere, and the hydrophobic part

Octane-1-oxydiethylene glycol is only one example of a surfactant; there are thousands of surfactants, if not more. They are actually very common. The phospholipids that make up the cell membranes in the human body are surfactants. Surfactants can also be found in all sorts of commercial products, including paints, detergents, shampoos, conditioners, cosmetics, inks, and insecticides, to name a few.

How do surfactants cause oil and water to mix? The dual nature of surfactant molecular structure causes these molecules to reside at the interface between a nonpolar solvent (like oil) and a polar solvent (like water). The hydrophilic group prefers to bond with water, and the lipophilic group prefers to bond with oil. A depiction of this interface is shown in Figure 3.

Surfactants don't just sit at the interface. They actually self-assemble into different micro- and nano-structures depending on their specific physical properties. One specific example, shown in Figure 4A, are small spheres called micelles. In the

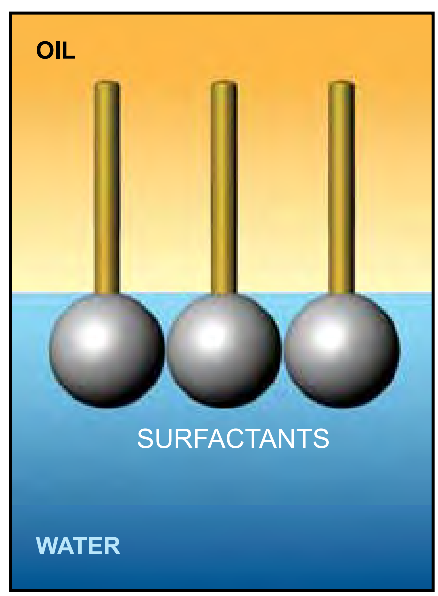


Figure 3. Surfactants reside at the oil and water interface. The hydrophilic group prefers to bond with water, and the lipophilic group prefers to bond with oil.

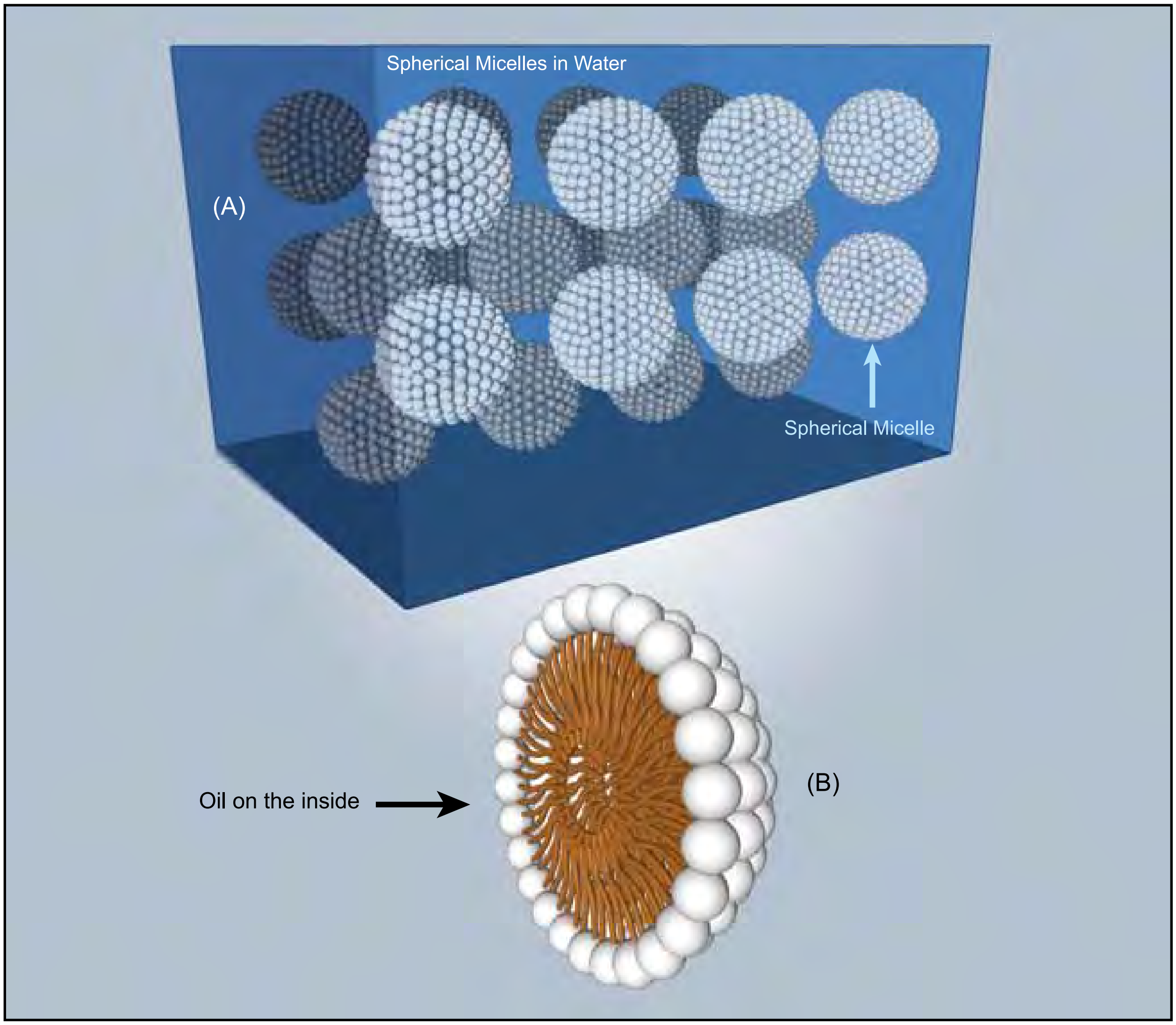


Figure 4. (A) Spherical Micelles in Water (B) Cross-Section of a Micelle—Micelles cause oil and water to mix by encapsulating oil droplets and carrying them into the water.

of the micelle on the interior of the sphere, depicted in Figure 4B. Therefore, the water is on the outside, and the oil is on the inside. This means that the spherical micelle encapsulates oil droplets and carries them into the water. This is how surfactants cause oil and water to mix.

It is important to note that when surfactants form structures where the domains are from 10 to 100 nanometers (the diameter of a micelle sphere), the solutions are referred to as a microemulsion. These nanostructures cannot be seen with the naked eye and do not scatter light, making microemulsions transparent. The really important fact about surfactant structures that are smaller than 100 nanometers is that they are stable. In other words, the oil, water, and surfactants in a microemulsion do not separate over time. Figure 5 shows how microemulsions are stable, transparent oil and water solutions where surfactants have formed nanostructures with 10–100 nanometer domains.

Microemulsions dissolve CWAs that are soluble in oil or in water because surfactants cause oil and water to mix. However, it is not clear how microemulsions allow neutralizing agents dissolved in water to interact with CWAs that are soluble only in oils. From the information presented, it would seem that a layer of surfactants would prevent these chemicals from coming into contact.

How do neutralizing agents interact with oil-soluble CWAs? Surfactant structures are not permanent structures floating in water or oil. They are highly dynamic, falling apart and reforming many times each second. This can be compared

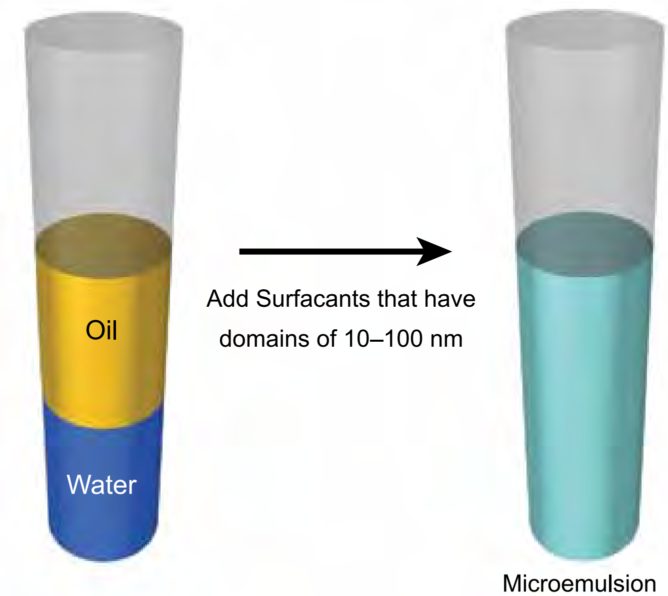
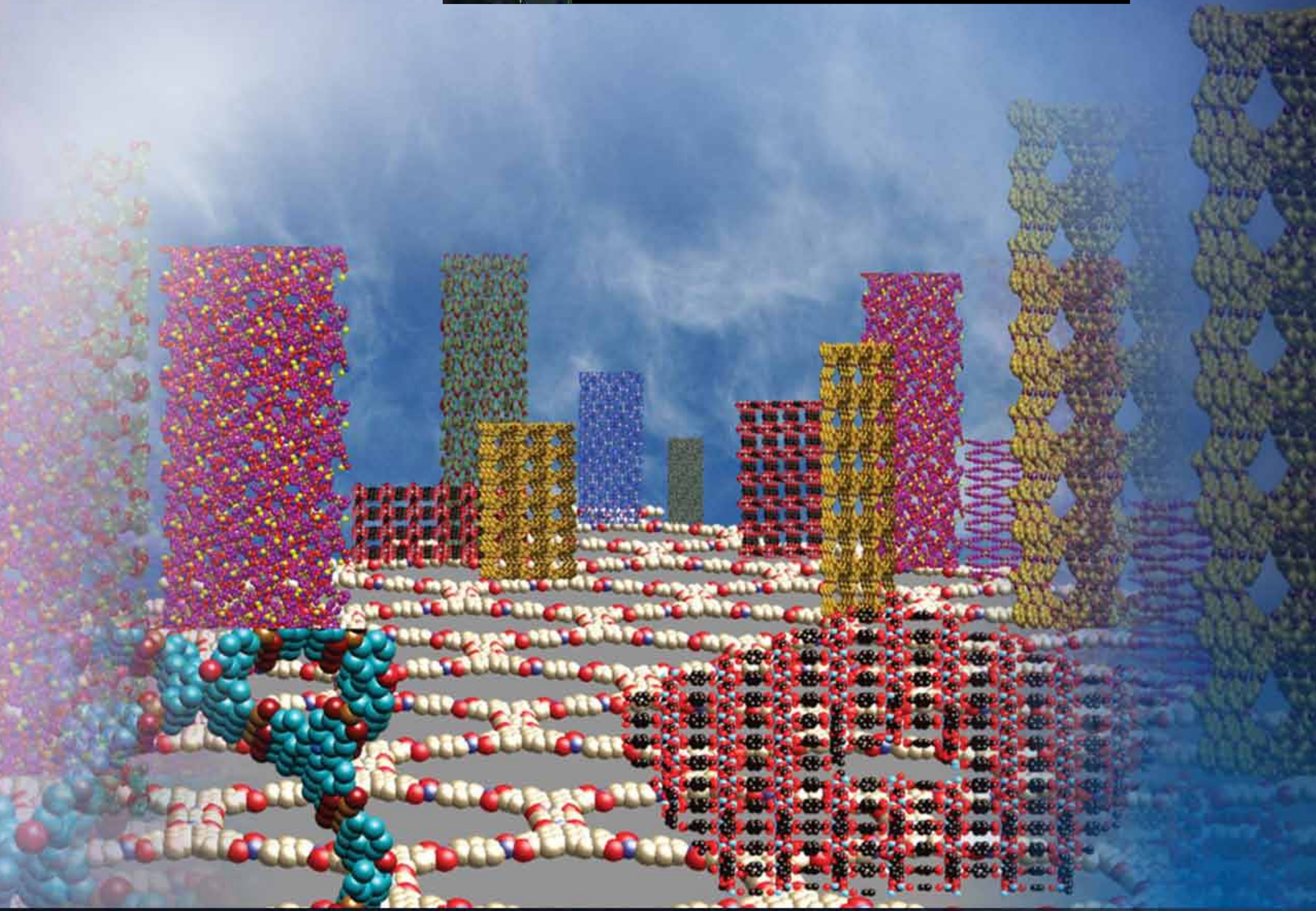


Figure 5. Illustration of a Microemulsion

to ballroom dancing, where each dancer changes partners as the dance moves along. The dance has structure but is always changing. This type of dynamics in microemulsions allows neutralizing agents to bump into CWAs in the oil phase, causing a reaction that neutralizes the agent.

Microemulsions provide an amazing capability, as they allow for the creation of a decontamination solution that soaks up and neutralizes a broad spectrum of CWAs. This one-size-fits-all approach saves storage capacity and money. Microemulsion-based decontamination solutions also have other advantageous properties. For example, these solutions are not considered to be corrosive and can be used at low temperatures; microemulsions can be designed to function below the freezing point of water. Furthermore, many of the components are already commercially available, making this approach very attractive. Microemulsion decontamination solutions have been developed at NSWCDD and are currently being evaluated for approval for use by the military. They are also in consideration for use by nonmilitary emergency personnel, such as first responders.



Molecular Construction: Novel Multifunctional Adsorbents for the Next-Generation CBR Protection Systems

By Joseph Hunt

Introduction

Construction involves the combination of artificial or natural components into a larger whole. There have been many advancements in the development of construction methods and building blocks used throughout history—from wooden log cabins to steel skyscrapers. This ability to manipulate and produce complex structures with specific designs, while common in the macroscale world of rivets and girders, has been, for the most part, unrealized in the microscale and nanoscale regimes of our world. Consequently, the ability to produce advanced functional materials displaying many different properties like conductivity and reactivity has been hindered by limitations in our materials science and engineering capabilities. Reticular chemistry is concerned with the design and controlled construction of nanoscale structures through the linking of molecular building blocks with strong bonds. More simply, this chemistry allows one to design and construct nanoscale materials with specific properties and structures with a great deal of control. The image on the previous page represents the idea of molecular construction by illustrating a city with buildings and roads constructed from various extended reticular materials using actual crystal structures. This powerful form of molecular construction could be used to build materials for any number of relevant technologies including organo-electronics, catalysts, or building materials, but this article will focus on the design and synthesis of advanced, functional materials for chemical, biological, and radiological (CBR) defense applications.

Fielded CBR Adsorbents

Current CBR technologies utilize porous materials that adsorb or trap a chemical weapon agent (CWA) and other toxic industrial chemical (TIC) threat molecules. Some of these adsorbents also contain reactive species that break down the threats after adsorption. Currently, activated carbon materials are used in filters to adsorb the CWA/TIC threats while metal salts impregnated into the pores chemically break down those threats. These carbon materials have random, disordered structures and allow very little control over the sizes and shapes of the pores or spaces in the materials. While these carbon materials adsorb some threat molecules very well, some TIC threats are not as strongly adsorbed and can pose protective challenges. Reticular chemistry is concerned with the connection of simple chemical building blocks into predictable structures using strong bonds to connect the building blocks. Reticular chemistry is well suited to improve on porous carbon materials because materials with the same or improved adsorptive properties could be produced. Reticular chemistry produces materials like metal organic frameworks (MOFs) in which organic building blocks are combined with metal salts to produce extended structures connected through robust bonds [1a–f] (Figure 1A) and covalent organic frameworks (COFs) in which the structures are formed by connecting the organic building blocks together without the metal ions [2a–g] (Figure 1B). These figures show how the simple organic building blocks on the left are connected together to make the extended interconnected structures on the right through chemical bonds. The advantages and benefits of using reticular materials to produce new CBR protection systems will be laid out in the rest of the article.

Nanoscale Design

One of the many advantages of MOF and COF systems is that the design of specific structures is possible. The principles of reticular chemistry involve simplifying organic molecules or metal complexes as simple geometric shapes with points of connectivity at the corners like those shown in Figure 2.[1a] The organic linker, shown as a simple line, is analogous to an I-beam or girder (Figure 2A, B, and D). The metal coordinates with linkers, forming the secondary building unit (SBU) with a specific shape similar to the joints found in construction (Figure 2C, E, and F). These struts and joints form an extended structure similar to the structural skeleton of a building (Figure 2G and H [3]). In past publications—such as the *Taxonomy of periodic nets and the design of materials* by Michael O'Keeffe—crystal structures of many different materials were analyzed, simplifying the molecules into simple geometric shapes. It was found that despite the wide range of materials in nature, only a small number of basic structures were present, and the structure of materials in nature could be predicted if the molecules were simplified into rigid shapes.[4] These principles have been further tested and proven in many MOF and COF publications that demonstrate the ability to predict the structures of materials before making them. Thus it is possible to truly design a material with a specific desirable structure through careful selection of the building blocks used. This is similar to the blueprints used in the fabrication of buildings, where the structure is planned out with specific joints and beams. This design is important for certain CBR applications where specific pore sizes or shapes may be needed to obtain maximum protection. Using reticular chemistry, the sizes and shapes of the pores in the material can be designed by changing

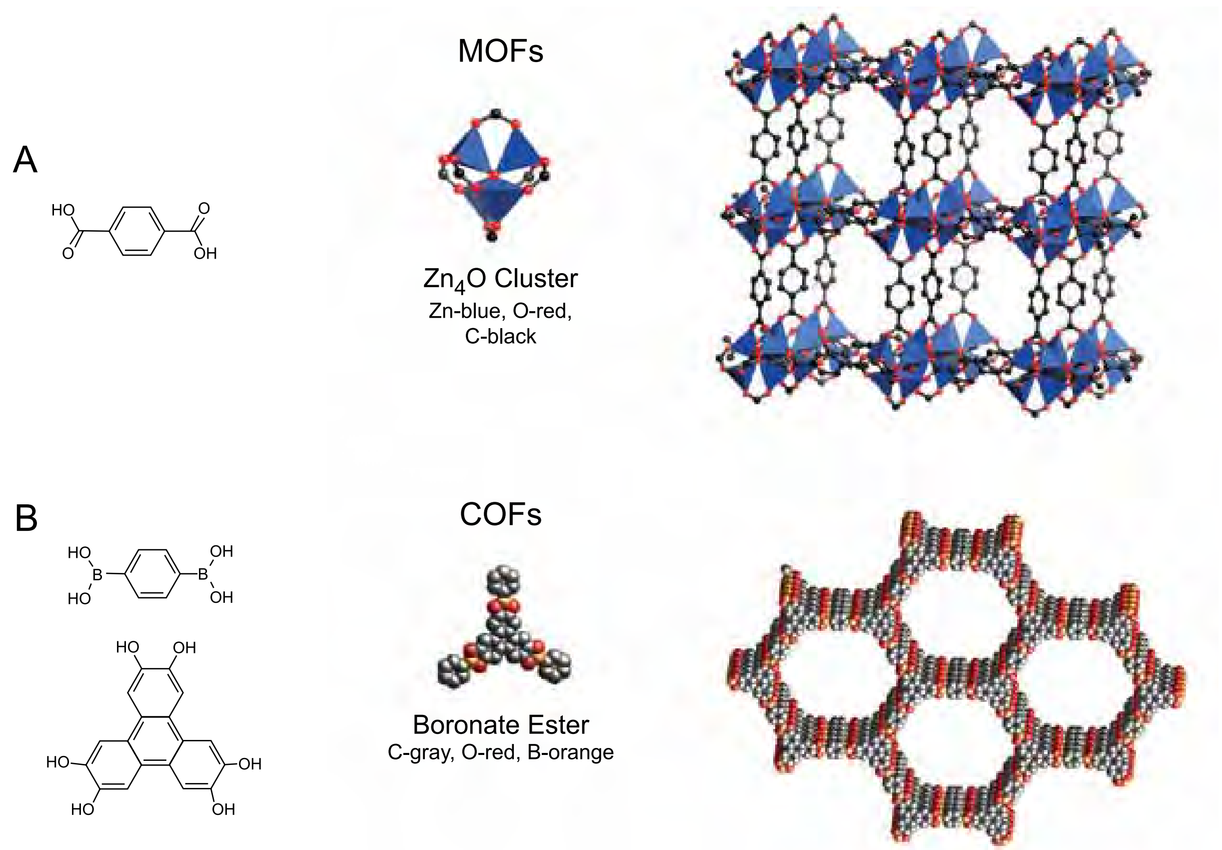


Figure 1. Synthesis of MOFs (A) and COFs (B) showing the formation of building units from organic linkers and metal ions and the extended structures formed from these building units.

the shapes and lengths of the building blocks used. This capability is not possible with current porous carbon materials, where there is very little control over the structures.

Functionalization Methods

Functionalization refers to the ability to change or add chemical groups to a molecule or polymer. The functionalization and variability of potential building blocks is another advantage for reticular materials. This is important because certain functional groups may bind or react with a desired CWA or TIC threat to give better protection. Using well-known chemical reactions (Figure 3a), virtually any organic molecule or metal could be incorporated into a MOF or COF material simply by producing a building block with desired functionality. These functional groups may improve adsorption, add reactive capabilities, or enhance the detection of specific CBR threats. The amazing thing about MOFs and COFs is that building blocks with these functionalities can be used to make the material without changing the overall structure.[5] This is similar to using girders made from different metals or changing the decorations in a building without changing the skeleton structure. This variability makes it possible to make materials with any functional group or structure desired. This is important to CBR applications because materials can be designed for specific threats where reactivity or increased sensitivity requires special materials. Using reticular chemistry, these threat-specific materials could be made without altering the basic adsorbent material structure and properties. This functionalization, however, does not always need to

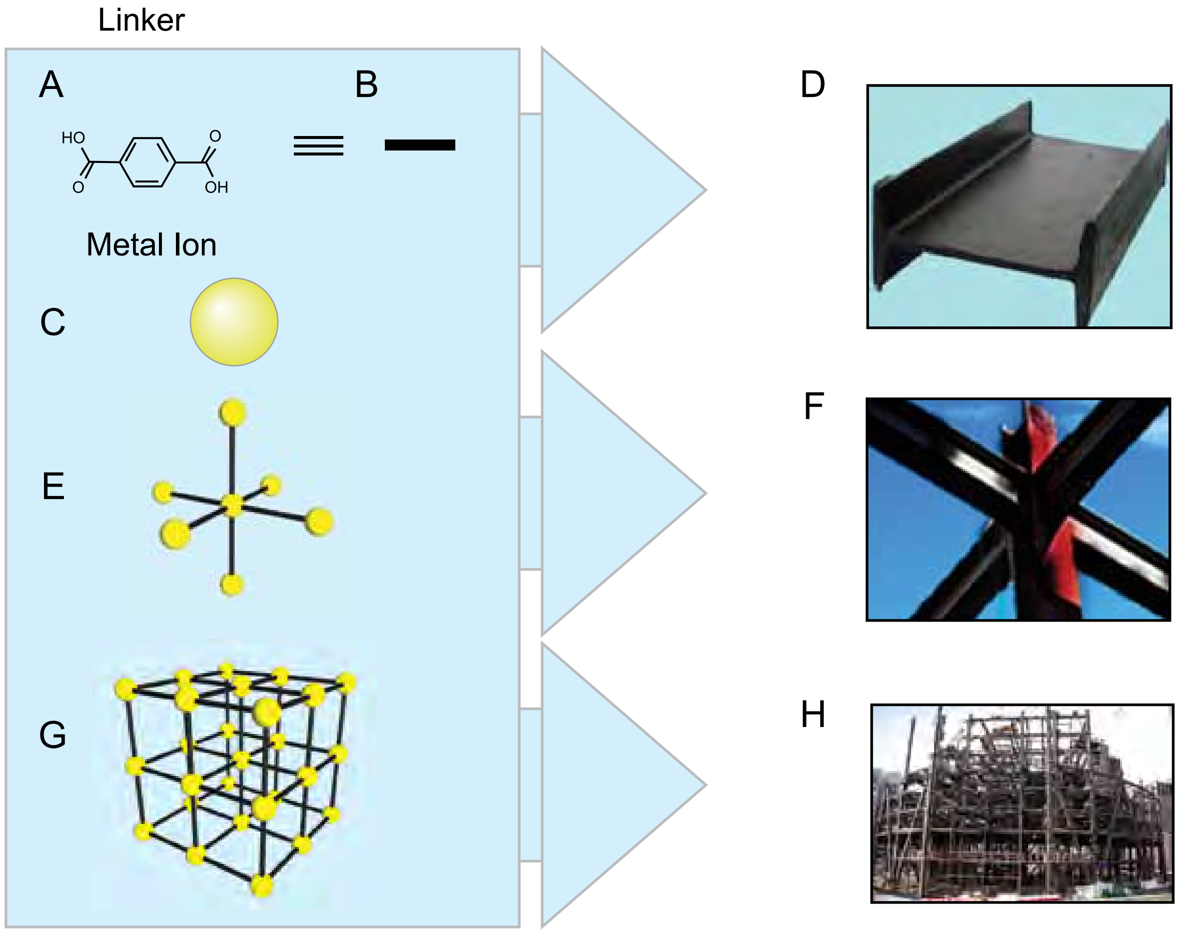


Figure 2. Organic linker (A), which is represented as a black line (B), is analogous to an I-beam or girder (D). When this linker is reacted with a metal ion (C), the octahedral building unit (E) is formed, which is similar to the joints (F) found in modern construction. The extended structure formed by the connection of linkers and metal ions (G) is analogous to the skeletal structure of a modern building (H).

be carried out on the building blocks before production of the adsorbent. Reticular chemistry has also demonstrated the ability to modify the structure after synthesis of the MOF or COF. This procedure, called postfunctionalization,[6a–e] utilizes known organic reactions to chemically change the side groups of the building blocks without destroying the extended structure (Figure 3B). Recent discoveries have added even more options to the modification of MOF and COF materials. Researchers have shown that the linkers in MOF materials can even be exchanged without losing the original extended structure.[7] This was demonstrated by starting with the MOF shown in Figure 3C and sequentially exchanging different functionalized building blocks in the structure, producing a material with many different side chains present.

Importance of Order

The fact that MOFs and COFs are produced as crystalline materials is another advantage for these materials. A crystalline material has an ordered structure where the arrangement and position of atoms repeats itself throughout the structure. Although crystalline structures are not necessary for adsorption and other applications, the ability to produce well-defined, ordered materials can be very useful. Crystalline MOFs and COFs have well-ordered pore structures that can be thoroughly characterized. This characterization can tell you where every atom in the structure is and reveal important information about reaction, adsorption properties, or sensing mechanisms in the material. This information could then be used to design better materials and predict their behavior and performance. Even though materials like porous carbons

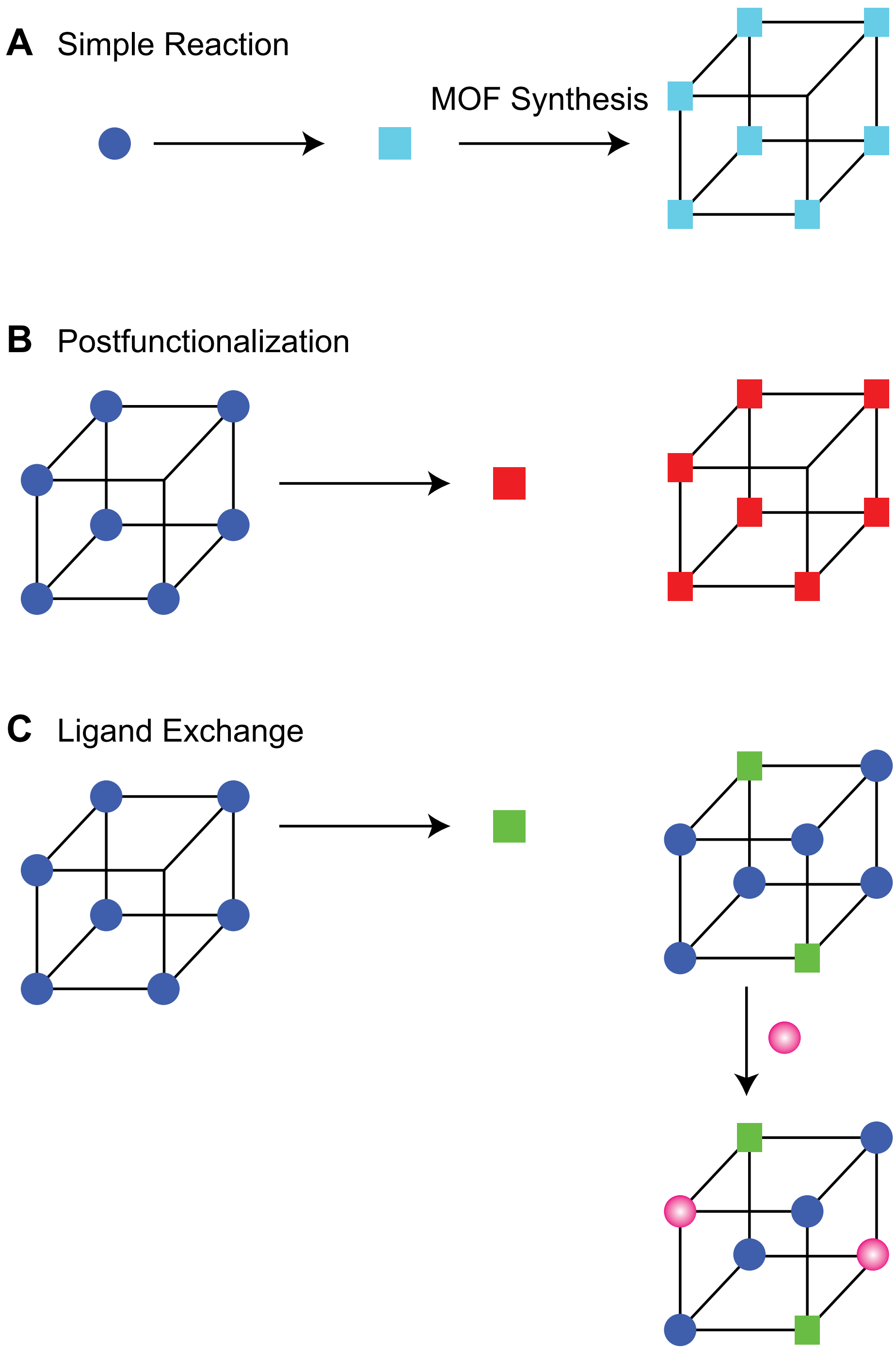


Figure 3. Various methods of MOF, COF functionalization: (A) Represents direct transformation of the building block followed by synthesis of the MOF or COF, (B) Postfunctionalization involves modification of the building blocks after synthesis of the extended structure, and (C) Ligand exchange involves sequential exchange of some of the building blocks in the structure after the MOF is synthesized.

have been used for the last 50–100 years, we still lack complete fundamental knowledge in terms of reaction mechanisms with CWA and TIC threats. This lack of fundamental knowledge hinders our understanding of many mechanisms important to CBR applications—including loss of reactivity in aged or fielded filters for collective protection systems (CPSs)—limiting our ability to effectively address shelf life and residual life issues.

Properties of MOFs and COFs

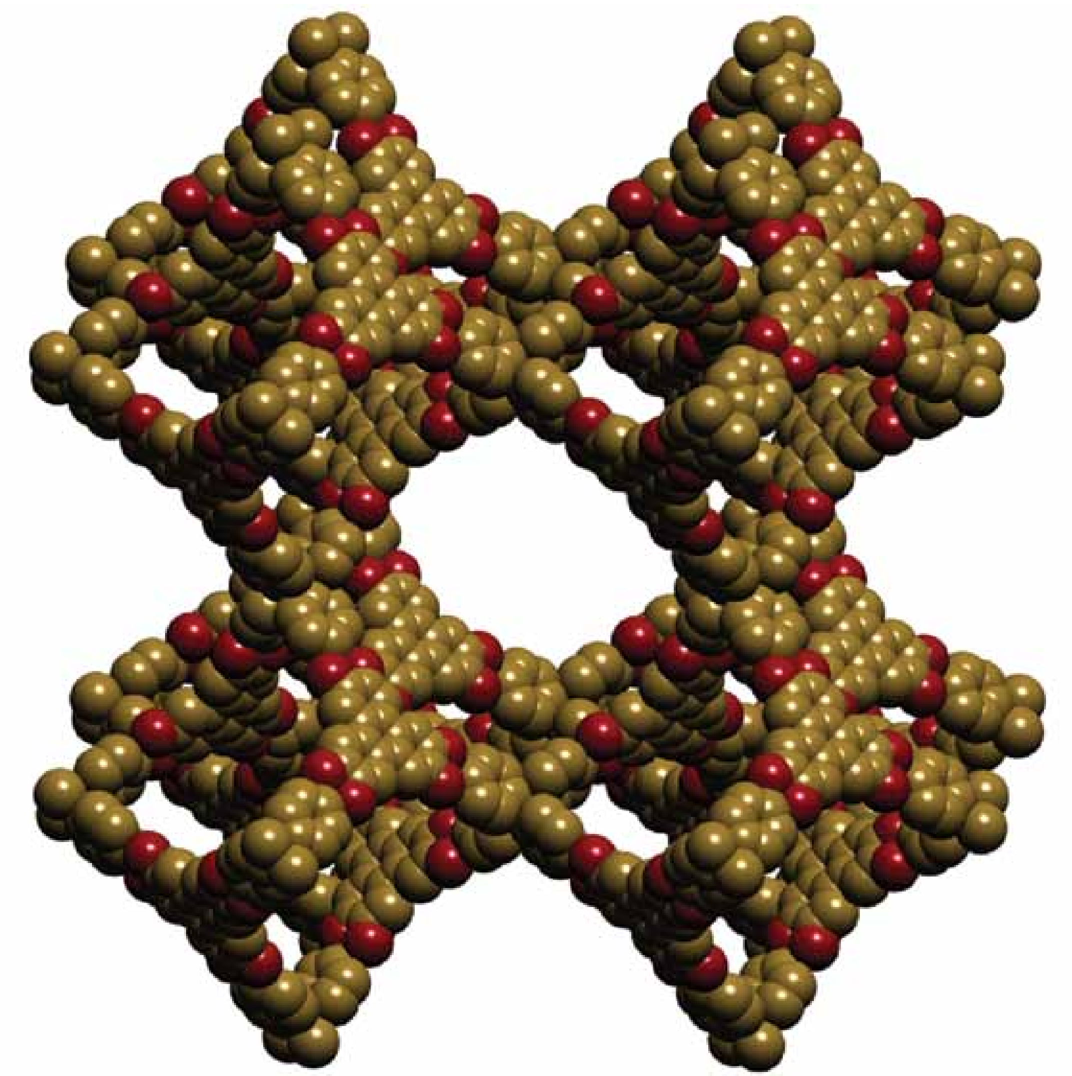
The advantages described above give MOF and COF materials certain properties that are superior to the currently fielded porous carbons. Most MOF and COF materials are extremely porous and, unlike porous carbons where the adsorption occurs in microporous branched channels, MOFs and COFs are completely open structures, allowing access to the pore structure from any direction. This is similar to a building with six entrances versus a building with only one entrance, allowing much more efficient access. Consequently, MOFs and COFs exhibit much higher surface areas than porous carbons because the open structure allows access to all the adsorption sites. This means that there is more area inside these MOF and COF materials for reacting with or adsorbing gas molecules. Due to the strong bonding in MOFs and COFs, these materials exhibit high thermal stabilities. Many MOFs and COFs have demonstrated very good chemical stability to water and even acids and bases. Most MOFs and COFs also have very low densities due to the large amounts of open space in the structures versus the volume of the structures. The author discovered COF-108—which has the lowest density known for a crystalline material (0.17 g cm^{-1})[2c] (Figure 4)—in 2007 during his doctoral work. The properties described above are common for most MOF and COF materials, but there are also material-dependent properties that are very important to consider when designing MOF and COF materials for CBR and other applications.

Future Applications of MOF and COF Materials

As mentioned before, any organic molecule or metal could potentially be incorporated into a MOF or COF. This includes molecules that are currently used in other applications like catalysis, electronics, detection, and others. The versatile nature of reticular chemistry or molecular construction towards enhancing warfighter capabilities is detailed in the following examples. Many organic molecules are used in electronic applications to conduct electricity or signals. A newly discovered 2-D COF was tested and found to conduct electricity and produce electricity from light.[8] These molecules could be used to construct MOFs or COFs that would be able to adsorb CBR threats and then signal through the conductivity that an attack is underway. The COF or MOF materials could even bind reactive species or incorporate reactive linkers in the synthesis so that a multifunctional material could be produced that would capture, detect, and destroy CWA and TIC threats. This technology would be useful for collective and individual protection equipment applications such as CP filters and masks. The materials could also be developed for protective clothing that would protect the warfighter, as well as signal him, his unit, and headquarters that the area is dangerous. Conducting MOFs or COFs could also be used to produce standoff/remote point detection technologies by supplying new detection materials with better sensitivity and selectivity. These sensing materials could be incorporated into remote CBR sensors that could be left around the perimeter of a ship or encampment to warn against attacks. Other MOF and COF materials could also be developed to capture solar energy or make more efficient batteries so that detection devices could be fielded longer with less necessary maintenance. These examples should demonstrate how new MOF and COF materials could be utilized in protecting warfighters on the ship, in battle, or in the field. There are additional areas of military interest in which MOFs and COFs could be applied—including armor, water filtration, gas storage, or organo-electronics—that are not discussed.

Current Research

Many of the concepts and applications discussed in this article are theoretical; however, there is research showing the effectiveness of MOF and COF materials towards CBR applications. One study tested a group of well-known MOFs against common TIC threats like ammonia and chlorine, and compared their performance to an activated carbon (BPL carbon).[9] The results showed that some of the MOFs were more effective than carbon materials towards some TIC threats. Some COF and MOF materials have been synthesized and characterized at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, and tested against TIC threats like ammonia and sulfur dioxide at the Edgewood Chemical and Biological Center (ECBC) to probe the structural features and characteristics most effective against TIC and CWA protection. The MOFs and COFs tested showed good potential to improve TIC threat



COF-108
Density 0.17 g cm^{-1}

Figure 4. COF-108 shown above exhibits the lowest density (0.17 g cm^{-1}) of any known crystalline material.

protection. NSWCDD scientists are also designing and researching new multifunctional MOF and COF materials with potential improvements in CBR protection capabilities against TIC threats.

Conclusion

Since the discovery of MOF materials in 1999, research has grown quickly, with thousands of new MOFs being reported every year. Research into COF materials has not been as extensive; however, COFs were discovered only in 2005. It is only in the last couple of years that concerted efforts were made to apply MOF and COF materials towards air purification and CBR applications. Despite the infancy of this field of chemistry, the potential for these materials is vast. Reticular chemistry truly represents molecular construction in the sense of synthesizing nanostructured materials in a controllable and reproducible manner. This article highlights the power of reticular chemistry to design and tailor adsorbents towards specific threats and applications. Given the amazing potential for MOF and COF materials, the molecular construction used to construct a city like the one shown on the first page of this article may not be so unrealistic after all.

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Investigating Natural Flavonoid Compounds as Potential Radioprotective Agents for the Warfighter

By Dena H. Kota and Linda C. Beck

Radiological threats are a potential area of terrorism that has not received much attention until recently. The U.S. Nuclear Regulatory Commission estimated that approximately one licensed source of radiation is lost every day of the year in the United States alone.[1] Moreover, there have been 700 incidents of illegal trafficking of radioactive materials worldwide, including 440 incidents in the United States, according to the International Atomic Energy Agency (IAEA).[2]

Radiological threats are usually found in the format of a dirty bomb, also known as a radiological dispersion device (RDD). RDDs are a combination of conventional explosives and radioactive material designed to scatter dangerous amounts of radioactive material, as well as shrapnel over a general area. Terrorist use of RDDs is considered far more likely than use of a nuclear device because they require very little technical knowledge to build and deploy compared to that of a nuclear device. RDDs also appeal to terrorists because certain radiological materials are used widely in medicine, agriculture, industry, and research, and are much more readily available compared to weapons-grade uranium or plutonium. Unlike a conventional terrorist bomb, the primary objective of an RDD is not to target warfighters or civilians directly with the explosion; rather, the explosion disperses radioactive material over a wide area in an attempt to create fear and disruption. The levels of radioactive material are usually sublethal; however, they can still result in long-term, harmful effects. The concept of an RDD is shown in Figure 1.

In 2005, the Radiological and Nuclear Threat Countermeasure Working Group established a priority list of research goals relevant to this rising area of concern. Their top two goals were:

1. To understand the mechanisms of radiation injury at the molecular, cellular, tissue, and organism levels as a basis for development of preventative, therapeutic, and diagnostic approaches
2. To develop new therapeutic agents that can be used to treat people who have been exposed to ionizing radiation (IR)

Just recently, the Department of Health and Human Services reiterated the importance of this effort in a report stating that:

> "…the understanding of the mechanisms of radiation damage, as well as organ system injury, damage repair, and inflammation, is necessary to develop optimal medical management and medical countermeasures."[3]

Scientists from the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), Dahlgren, Virginia, recently teamed with scientists from Virginia Commonwealth University in Richmond, Virginia, to examine the basic scientific principles behind the damage caused by IR, as well as novel solutions to mitigate these risks.

It is known that exposure to IR leads to the production of toxic free radicals and DNA damage in living cells. However, understanding the mechanisms behind this damage will allow researchers to

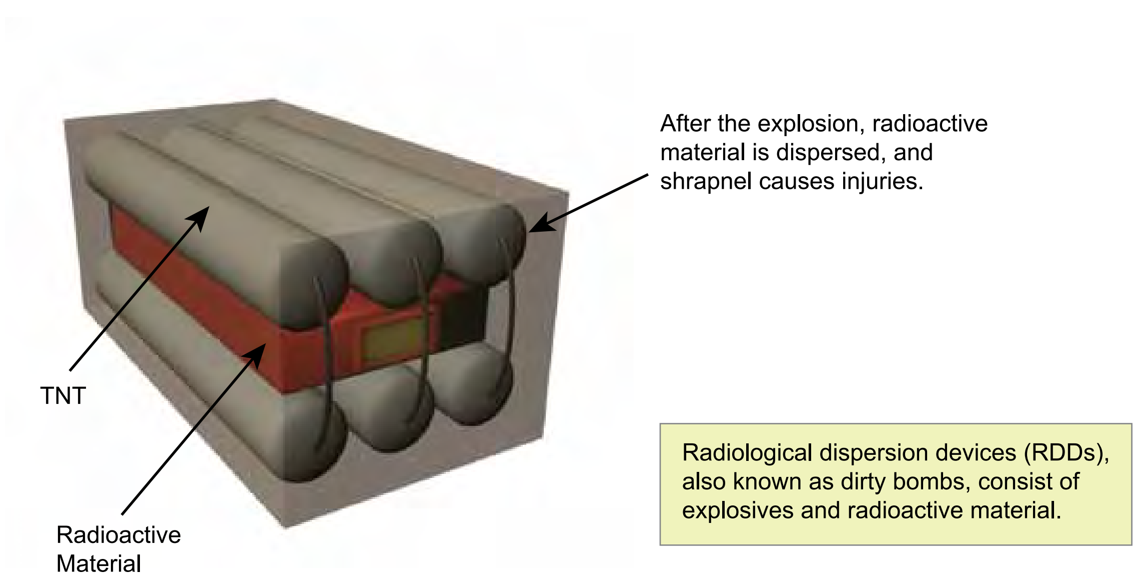


Figure 1. Radiological Dispersion Device (RDD) Concept

develop more efficient methods of protection and treatment against radiological attacks. Figure 2 depicts a strand of DNA being damaged by an outside source of radiation. When this occurs, it begins a cascade of signaling molecules that reaches various effectors in the cells of our bodies and results in certain responses. In some cases, the DNA is able to repair itself and continue with its normal function. At other times, this type of damage will lead to the arrest or inhibition of various cell cycle transitions, which ultimately results in the demise of the cell. It is also possible for this exposure to result in the generation of new genes and proteins, a process known as transcription, which can initiate a variety of cellular processes. Lastly, the cell can undergo a protective process of cell death, referred to as apoptosis, which prevents the damage from being passed on to future generations of cells.

One possible mitigation method under examination is the use of naturally occurring compounds known as flavonoids. Flavonoid compounds show promise as protective agents against IR-induced damage. One of the main functions of flavonoids is to act as an antioxidant to slow or prevent formation of free radicals and DNA damage following exposure to IR. These compounds are found ubiquitously throughout common foods in the human diet such as citrus fruit, red wine, dark chocolate, and tea. Due to their high availability, flavonoids represent an extremely cost-efficient method of protection.

While preliminary work with flavonoids has shown the potential to mitigate the harmful effects of radiation, specific information on effective doses and therapeutic mechanisms is still lacking. Dahlgren scientists have begun to explore these gaps in hopes of answering the types of basic research questions that will enable development of successful preventative and treatment options.

In initial studies, Dahlgren researchers examined the effect of quercetin (QN)—a flavonoid with strong antioxidant and anti-inflammatory effects—on cell survival following exposure to radiation. In primary human skin cells, quercetin dose dependently[a] increases the percentage of cell survival following exposure to radiation, suggesting a protective effect. Figure 3 shows skin cell survival

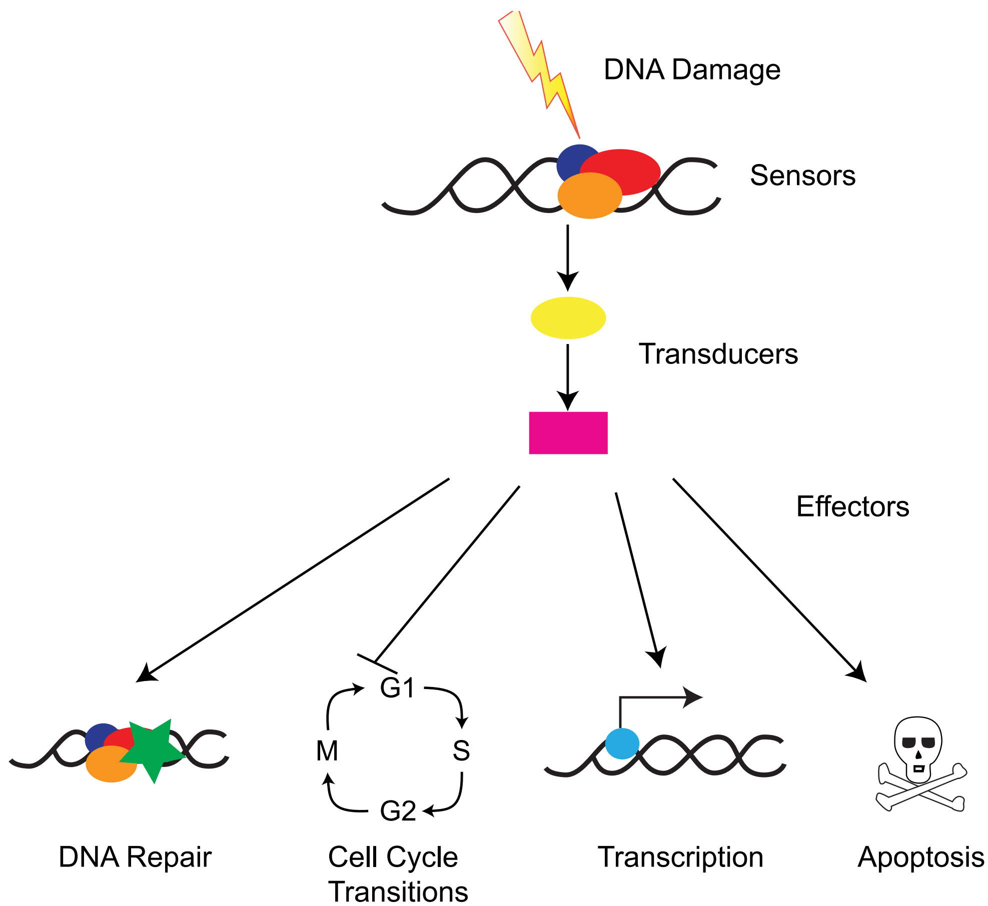
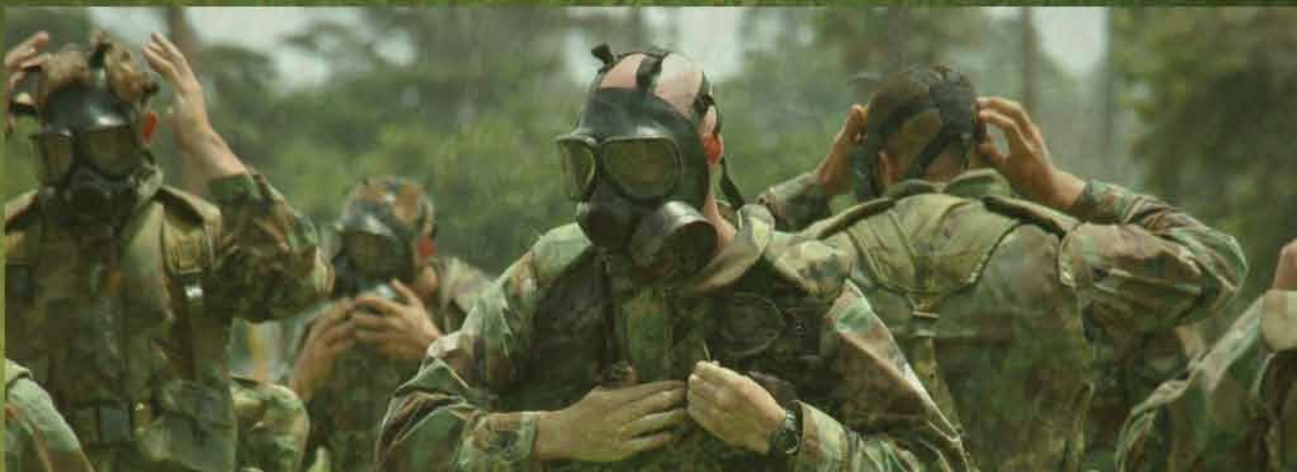


Figure 2. Possible Effects of DNA Damage Due to Ionizing Radiation (IR)



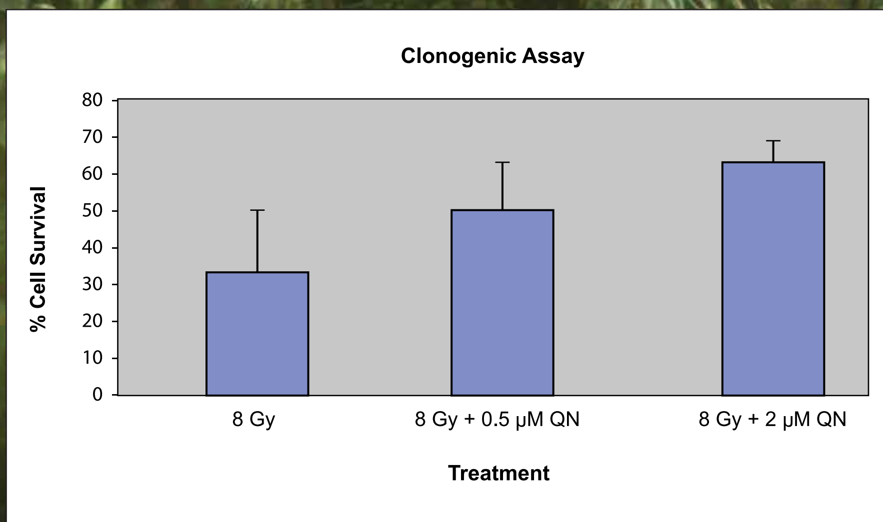


Figure 3. After exposure to 8 gray (Gy) of radiation, approximately 35 percent of human skin cells survived. Pretreating these cells with various concentrations of quercetin (QN) dose-dependently increased the amount of cell survival, suggesting that this flavonoid compound may have potential as a protective agent for both the warfighter and civilians.[b]

resulting from pretreatment with various concentrations of the flavonoid compound quercetin.

Scientists plan to complete studies testing a full range of IR doses and quercetin concentrations to fully understand the most effective way to counter radiological threats using natural sources. In addition, studies will be conducted to examine responses that are occurring at the cellular level so that these mechanisms can be targeted for therapeutic measures. Ultimately, it is hoped that this research will lead to the development of effective radioprotective agents that will keep warfighters safe from the effects of RDDs and other radiological threats.

Endnote

a. Dose-dependent refers to the effects of treatment with a drug or compound. If the effects change when the dose is changed, the effects are said to be dose-dependent, Centers for Disease Control and Prevention (CDC) Diethylstilbestrol (DES) Glossary, http://www.cdc.gov/des/consumers/resources/glossary.html#D

b. A clonogenic assay is a microbiology technique for studying the effectiveness of specific agents on the survival and proliferation of cells. It is frequently used in cancer research laboratories to determine the effect of drugs or radiation on proliferating tumor cells, as well as for titration of cell-killing particles (CKP) in virus stocks, http://en.wikipedia.org/wiki/Clonogenic_assay

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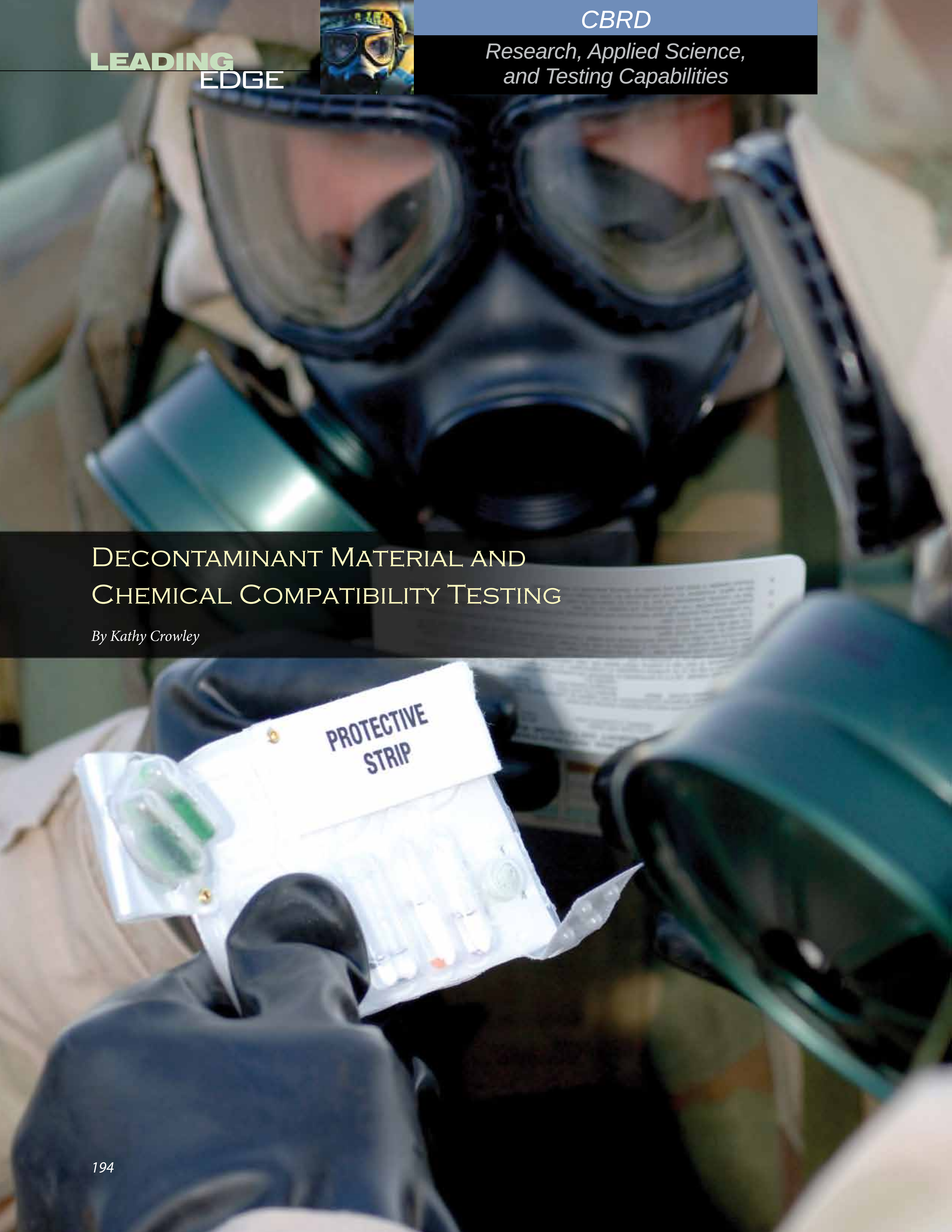


Decontaminant Material and Chemical Compatibility Testing

By Kathy Crowley

Imagine fighting terrorists in Afghanistan, or any other strange land for that matter, and being attacked with a chemical warfare agent . . . pretty scary. While many nations have agreed through treaties to eradicate the use of chemical, biological, and radiological (CBR) weapons, terrorists follow no such agreements. Fortunately, warfighters are equipped and trained to protect themselves if this happens.

The research arm of the Chemical, Biological, and Radiological (CBR) Defense Division at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in Dahlgren, Virginia, is the Concepts and Experimentation Branch. Scientists and engineers in this branch actively seek CBR defense solutions for the technical challenges and threats facing the Navy and the U.S. homeland. These skilled professionals are responsible for performing the basic and applied science supporting the research, development, testing, and evaluation of technologies necessary to defend against chemical, biological, and radiological weapons. This research enhances warfighter, fleet, and homeland CBR defensive capabilities and increases fleet readiness.

The Joint Program Manager for Decontamination (JPM-Decon), located in Stafford, Virginia, conducts testing and evaluation of decontaminants selected for acquisition programs to support subsequent fielding decisions. As part of these efforts, the NSWCDD Concepts and Experimentation Branch conducts testing to determine the compatibility of decontaminants selected by these programs with representative military materials; selected petroleum, oils, and lubricants (POL); and, where applicable, other currently fielded decontaminants. Testing by branch personnel provides a thorough assessment of the compatibility of the selected decontaminants. The testing also is designed to identify any destructive effects on materials, as well as potentially hazardous interactions with compounds commonly found in the operational environment.

The following hypothetical field scenarios demonstrate the need for decontaminant testing.

Hypothetical Field Scenario: Incompatible Decontaminant Solution

After possible exposure to a chemical warfare agent during mission operations, soldiers perform decontamination procedures before returning to base. After doing so, they stow their respirators in their mask storage containers until the next time they need them. Unfortunately, when the respirators are needed again, they cannot be used because the decontaminant destroyed the masks' lenses, hindering a warfighter's ability to complete mission operations. A personnel decontamination exercise is shown in Figure 1.

Figure 1. A respirator with a lens that impairs vision would hinder a warfighter's ability to complete mission operations.

For materials compatibility, the primary objective is to determine the extent of degradation of a material after decontamination procedures. Representative military materials include individual protection equipment (IPE) such as protective outer garments, respirators, gloves, and overboots. Military materials also include equipment such as weapons, tactical vehicles, etc., and the paints, metals, fabrics, and plastics that are used to make them. Prospective decontaminants need to be tested against these articles to ensure that the decontaminating process does not destroy the materials and that the equipment will perform as expected. Accordingly, following the decontamination process, IPE must still be able to protect against CBR events, weapons must still fire safely, and vehicles must still start and run as expected.

Hypothetical Field Scenario: Decontaminant Deadly–Gas Hazard

A vehicle had a small, undetected fuel leak during decontamination, and the fuel reacted with the decontaminant. When the two mixed, a toxic and potentially deadly gas formed, endangering personnel. Vehicle decontamination procedures are shown in Figure 2.

Selected POL are tested for incompatibility, with prospective decontaminants based on prescribed decontamination procedures developed to prevent accident or injury due to chemical reactivity. POL testing focuses on two primary issues:

1. Chemical incompatibility, resulting in hazardous increases in temperature or off-gassing when the decontaminant comes into contact with a POL
2. The potential interaction of the decontaminant with external or topical POL that could result in a loss of lubricating properties and increased maintenance requirements

Hypothetical Field Scenario: Decontaminant Fire Hazard

During decontamination operations, a quantity of personnel decontaminant reacts violently with a vehicle decontaminating solution when mixed in

Figure 2. An odorless, colorless, toxic gas created by decontaminant/fuel incompatibility could quickly overcome this soldier.

certain ratios. The two are incompatible, and the reaction starts a fire. A depiction of the reaction is shown in Figure 3.

Selected decontaminants are also tested against currently fielded decontaminants. For compatibility of any potential decontaminant with currently fielded decontaminants, the primary objective is to identify any hazards resulting from accidental or intentional mixing. Fire, large and rapid temperature increases, hazardous off-gassing, or profound physical changes help determine whether the risks of potentially hazardous consequences are worth the decontaminating potential of a newly deployed solution.

As these realistic field scenarios demonstrate, introducing new decontaminants without understanding the potential hazards involved can be dangerous. The efforts of JPM-Decon and NSWCDD's Concepts and Experimentation Branch ensure that warfighters are protected by the latest and most effective decontaminants and are made aware of potential hazards that can undermine their safety further ensuring that they can fight, win, and come home safely.

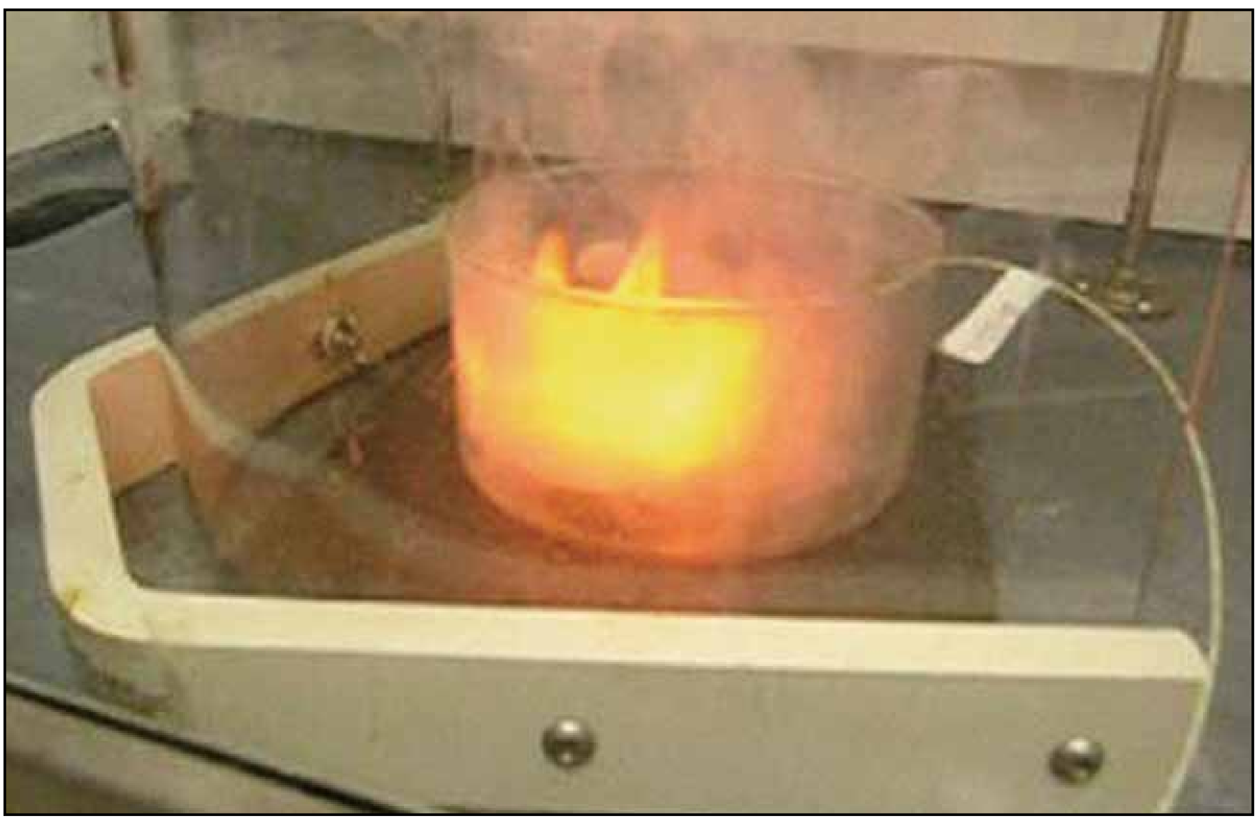
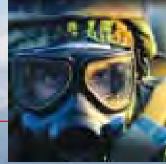


Figure 3. A potential personnel decontaminant reacts violently with a fielded decontaminant when mixed in certain ratios.



Testing is Key to Maintaining an Effective Navy Fighting Capability in a Contaminated Environment

By Tim Thomasson

Nowhere else on earth can you find such an assemblage of deadly firepower, intricate electronics, powerful propulsion systems, and numbers of highly trained personnel than on a U.S. Navy warship. Nor can you find a more challenging environment for testing the protective equipment designed to prevent chemical, biological, and radiological (CBR) threats or other toxic compounds from doing harm to these amazingly powerful vessels and their crews. The lives of the crew and the missions assigned to the Navy are too important to base the measures of effectiveness of the protective technologies on laboratory testing or engineering assessments. The equipment must be placed on ships and must be tested in realistic, measurable ways. Testing on ships, however, is both challenging and complex, and requires specialized expertise—expertise available thanks to scientists and engineers from the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), who have earned the title, Shipboard Testing Subject Matter Experts. The amphibious dock landing ship USS *Oak Hill* (LSD 51), which was recently used for shipboard testing, is shown at sea in Figure 1 and is followed by a photograph of U.S. Navy test personnel aboard USS *Oak Hill* in Figure 2.

Shipboard Testing

The Defense Acquisition Process employs a number of paths for equipment to follow during development, but for shipboard equipment, all end up needing some final test phase that places it on an appropriate vessel for testing and evaluation. Central to this evaluation process is subjecting the equipment to a realistic threat environment and measuring its performance. This is where the challenges of testing can actually exceed those of developing the new hardware.

What is so hard about CBR shipboard testing? For one thing, the testing often needs to be done at sea underway with all the other ship systems operating. Another challenge is the need for a realistic threat in order to evaluate the performance of the protective equipment. A ship cannot be attacked with an actual chemical or biological agent, or anything that would harm the ship, the crew, or the environment. Consequently, a safe

Figure 1. USS *Oak Hill* (LSD 51) (Official U.S Navy Photo Released)

Figure 2. U.S. Navy Test Personnel Aboard USS *Oak Hill* (U.S. Navy photo released)

way to simulate the hazardous CBR threat must be found (a safe substitute), and a means of delivering it must be developed.

Along with the challenges of simulating the attack, there is the requirement for instrumentation to measure how effective the attack was on the ship. It answers the question "How much hit the ship?" This measurement becomes the reference point for evaluating the performance of the protective technology with respect to whether the equipment will protect the ship and crew, enabling them to safely perform the mission. In Figure 3, a helicopter spraying a simulated agent is shown performing an area attack to determine if the shipboard detectors adequately detect the attack in time to protect the ship and crew.

NSWCDD has been conducting CBR shipboard testing for over 25 years and has assembled the world's best expertise in taking on these challenging tests. Their team includes in-house personnel, contractors, and joint participation from other service laboratories.

Testing is key to maintaining an effective Navy fighting capability in a contaminated environment. Testing ensures that our CBR systems work, that our Sailors are protected, and that our ships can continue to conduct their missions in spite of CBR attacks.

Figure 3. Helicopter Spraying Simulated Agent

NSWCDD's Chemical, Biological, and Radiological Defense (CBRD) Role – Past, Present, and Future

By Michael Purello, P.E.

In approximately 190 B.C., Hannibal of Carthage made history when, while helping the king of Bithynia, he had some earthen vessels filled with poisonous snakes, covered the pots, and set sail. As the Bithynians prepared for battle, they hurled the pots full of the poisonous snakes onto the decks of the enemy ships. The resulting confusion, fear, and chaos demonstrated the effects of a chemical or biological (CB) attack. This is perhaps the first recorded instance of a CB attack on a naval ship. Over 2,000 years later, the threat is still just as real—only much more sophisticated—and generates the need for a comprehensive Navy Chemical, Biological, and Radiological (CBR) defense program.

Introduction

A leader in the Navy CBR defense program, the CBR Defense Division of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) provides our warfighters with the tools and capabilities necessary to detect, protect, and if necessary, decontaminate the toxic residue resulting from a CBR attack. The CBR Defense Division has a full complement of capabilities to support the naval warfighter both on land and at sea, as well as throughout the Department of Defense (DoD) and Homeland Defense communities.

NSWCDD has a long history of supporting CBR defense initiatives. Tracing back to the earliest ordnance-based programs and moving ahead to today's full-spectrum CBR defense support, this article provides a broad-brush historical perspective of the

CBR work performed at NSWCDD in Dahlgren, Virginia, since the mid-1950s. It examines present products, capabilities, and fleet support services, and concludes with an exploration of the future on Navy CBR defense.

Historical Perspective

Beginning in August 1954, NSWCDD—then the Naval Proving Ground at Dahlgren, Virginia—conducted a variety of work in chemical warfare (CW) research and development programs. This initial work, which was performed for the Bureau of Ordnance, focused on the simulant-filled EX 23 (Mk 94) bombs and involved fit checks, assembly tests, environmental testing, and ballistic characterization. Having its roots as a naval gunnery range, it is not surprising that NSWCDD would be the recipient of this kind of work.

1960s–1980s

In the early 1960s, the CBR work performed at NSWCDD expanded from a solely chemical weapon focus to include CW defense. At this time, the Cold War was in full throttle, and there was a real and increasing concern of CW being used against the U.S. Navy. Once again, the Navy turned to NSWCDD to meet their needs for:

- Information to support commanding officer's decision-making capability in the event of a CW attack
- A centralization of the resources that were becoming available to help deal with a possible attack
- An understanding of the complexity of CW situations

As the Vietnam War progressed, the use of biological and chemical warfare (BW/CW) agents against U.S. forces emerged as a significant threat. To help address this threat, NSWCDD (known then as the Naval Weapons Laboratory) constructed a CB devices test chamber, which consisted of a full-scale mock-up of a shipboard magazine. In this chamber, personnel safely performed experiments and tests using toxic materials. Tests with CW agents, if required, were performed at the Dugway Proving Ground in Utah. Throughout the 1960s, the work performed at NSWCDD expanded to include:

- Toxicology research
- CB research, development, test, and evaluation
- CB detection
- CB decontamination

In 1969, National Security Decision Memorandum 35 ended offensive BW programs; however, defensive programs for both BW/CW threats were still very much needed. Because the Navy deemed the work that NSWCDD performed in this area so critical, it designated NSWCDD as the lead laboratory for BW/CW work in early 1970 and, when the Navy's Biological Laboratory facility in Oakland, California, was closed, some of its personnel were reassigned to NSWCDD.

While the U.S. production of CB weapons stopped in 1969, the CBR defense work continued to grow. In the 1970s and 1980s, NSWCDD continued working in CB safety, logistics, and operations planning, which included the logistics and safety of binary chemical weapons and increased research and development work in the area of chemical agent detection and decontamination. NSWCDD also received new work in the area of personal and collective protection, as Dahlgren engineers provided technical support in the development of the M98 Collective Protection System (CPS) filter for shipboard applications. The collective protection efforts led to the first CPS installation on a U.S. Navy ship with the backfit of CPS into USS *Belleau Wood* (LHA 3) in 1983 (shown in Figure 1).

International events would shape the future CBR efforts at NSWCDD. In the 1980s Iran-Iraq War, Iraq used chemical weapons against the Iranian army. Iraq began with the use of riot control agents and progressed to the use of blister and nerve agents. As the war was coming to a close, the Iraqi government used chemical weapons against their own people, killing thousands of Kurd civilians (see Figure 2).

During this time, it is believed that Iraqi scientists were also researching biological agents and nuclear weapons to add to their arsenal of mass destruction. As these events unfolded, the emphasis on chemical and biological defense (CBD) increased.

While the Iraqi government was intentionally using chemical weapons, in 1984, a tragic incident occurred that reminded us that not all CB threats are war- or terrorist-related. A Union Carbide industrial plant in Bhopal, India, released a toxic cloud of methyl isocyanate, which killed over 3,000 people and injured tens of thousands more. This incident demonstrated the need for our nation to be prepared for a chemical, biological, or radiological event whether it is the result of a terrorist activity, war, or an accident. Having the capability to protect the fleet from these kinds of scenarios was imperative.

Back home, an event was taking shape that would impact the CBR defense work being performed at NSWCDD. In March 1986, Rear Admiral J.B. Mooney, Jr., Chief of Naval Research (CNR),

Figure 1. USS *Belleau Wood* (LHA 3)

formalized in a letter to the Naval Surface Warfare Center (NSWC) what would quickly become what some called the "Panic of '86".[1] That short letter said:

> "Budget constraints have required that the Office of Naval Technology (ONT) reduce the scope of several of its programs beginning in FY86 and into the out years … . The Chemical and Biological Defense Program has not been identified in the Program Objective Memorandum (POM) 88 process as a high priority technology area by the Chief of Naval Operations (CNO) … . Hence, ONT intends to reduce the CBR effort starting in FY86, followed by 50 percent in FY87, with total phase-out by FY91."

Almost immediately, the CBR defense leadership sought new positions for the branch personnel that would be immediately affected and by July had identified placement for some of the individuals. In August, the Commander of NSWCDD advised the Commander, Naval Sea Systems Command (COMNAVSEASYSCOM) of his intent to eliminate the Center's involvement in CBR defense matters over the next several years.[2] Other Division personnel continued to look for and find positions across NSWCDD.

In August, the Undersecretary for Defense, Research, and Engineering—who had previously concurred with the Navy decision to reduce the ONT CBR defense budget—expressed his concerns to the Navy at the Department of the Navy (DON) Science and Technology (S&T) Investment Strategy Review. By September, the CNO had officially expressed his concern to the Space and Naval Warfare Systems Command (SPAWAR)

> … about the potential loss of the Navy's capabilities in this area, especially at a time when upgraded individual and collective protection measures are being developed and purchased for the fleet.

The Deputy Chief of Naval Operations (DCNO) for Surface Warfare went on to say, "I strongly

Figure 2. Chemical Weapons Killed Thousands of Kerds—Halabja, Iraq, March 1988

support the continuance of NAVSURFWPNCEN's role in CBR defense and request that you act expeditiously to prevent loss of core expertise."[3]

By December, CNR was having second thoughts and recommended that CNO (OP 098) consider additional coordination with the Office of the Secretary of Defense (OSD).[4] In February 1987, the CNO made it clear that the Navy needed to maintain a capability to support fleet needs, and SPAWAR was directed to develop a plan for a continuing program at NSWCDD.[5] The Division began hiring new personnel to replace the many valuable people who had left and reorganized to fulfill the earlier CNO mandate.

1990s

During Operation Desert Shield, it was feared that Iraq would once again use CB weapons, this time against U.S. and coalition forces. The use of CB weapons against ships was of particular concern to the Navy given the unique challenges associated with the sea environment. The Navy turned to NSWCDD as the Navy's leader in CBD to help prepare the Navy to operate in a maritime CB environment.

To determine how effectively the Iraqi army could contaminate our ships with attacks from their shore batteries, NSWCDD developed a computerized CW naval simulation model. This model—first called PLUME and later Vapor, Liquid, and Solid Tracking (VLSTRACK)—simulated the attacks and tracked the vapor, liquids, and solids from the munitions based on agent type and meteorological (e.g., temperature, humidity, wind direction, and speed) conditions. The ship's commanding officer could then use the output to determine where there would be a threat of contamination.

To address the threat of ships being contaminated by CW agents, NSWCDD aggressively fielded CBD equipment and trained deploying personnel. CPS was installed on ships heading to the Persian Gulf to allow Sailors in the protected areas to operate without wearing cumbersome protective clothing and masks. These areas also allowed a place for Sailors to remove their protective clothing to prevent excessive heat stress. NSWCDD provided special protective clothing, detection and monitoring equipment, and CB warfare training to deploying

units. In addition, they provided decontamination and casualty-handling training to fleet physicians and corpsmen.

To determine the threat to personnel once a ship was exposed to CW agents, NSWCDD conducted extensive research and testing to determine how long agents would remain on shipboard deck surfaces and how effectively the wash-down countermeasure system would remove the agents. The compilation of all this information under various environmental conditions led to the publication of the *Chemical Hazard Assessment Guide*, which was disseminated to the fleet to aid them in conducting risk assessments.

Fortunately, the Iraqis did not use any CB weapons against coalition forces; however, the lessons learned during Operation Desert Shield/Desert Storm would impact the management of CBD research, development, and acquisition. Based on some of the lessons learned, Congress passed Public Law 103-160 in 1994. This law mandated that the CBD efforts of all the Services be consolidated in a single program managed under OSD. While NSWCDD had collaborated across the Services prior to this, the implementation of the law formalized the means of collaboration. The Joint Service Materiel Development Group (JSMG) was established as the organization responsible for developing and acquiring CBD equipment for all the Services. Each Service had representatives in the JSMG. NSWCDD was selected to hold two of the key positions:

1. The Commodity Area Manager (CAM) for Collective Protection
2. The CAM for Battle Management, and Modeling and Simulation (M&S)

In addition to holding the CAM positions, NSWCDD represented the Navy on the joint Service acquisition programs and was selected to lead the ARTEMIS active standoff detection system program. The organization expanded to address the increase in workload, including new work in modeling, threat analysis, and decision aid development.

2000–2004

The collateral benefits of the collective protection were seen in the October 2000 terrorist attack on USS *Cole* (DDG 67) in the Port of Aden, Yemen. Seventeen of our Sailors were killed in this attack, and had it not been for the bravery and heroic deeds of the crew, the ship would most likely have sunk. Although not a CB attack, the CPS nevertheless performed as designed and continued to provide clean filtered air to the interior of the ship where the Sailors, who were fighting for their ship's survival, could receive respite from the noxious fumes and resultant hazardous contaminants.

The terrorist attacks in 2001 on the World Trade Center and the Pentagon, as well as the anthrax attacks, brought renewed focus on CBR defense. NSWCDD was once again called on to expeditiously address CBR defense shortfalls in the fleet. NSWCDD managed the procurement of CBR defense items across all commodities, including both medical and nonmedical items to ensure that our Sailors deploying to the Gulf were adequately prepared to defend themselves against a CBR attack. Dahlgren engineers were also called upon to support the newly formed Pentagon Force Protection Agency and helped design and install CBD systems throughout the Pentagon to ensure continuity of operations in the event of another attack. As part of this work, Dahlgren engineers and scientists were involved in a project that completely upgraded the Pentagon mailroom.

During the same time period, NSWCDD was also erecting a new facility to house the Center's CBR defense workforce. The Herbert H. Bateman Chemical Biological Defense Center was dedicated by Navy officials on 22 August 2002. This facility provided the organization with a state-of-the-art research and development facility to continue the research and development of new and novel technologies, methods, and equipment to protect our Sailors.

In 2003, the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) was established, replacing the JSMG organization. The Navy filled two of the original seven chartered Joint Program Manager (JPM) positions:

1. JPM for Collective Protection (JPM-ColPro)
2. JPM for Information Systems (JPM-IS)

NSWCDD was established as the office for the JPM-ColPro, while JPM-IS established its office at SPAWAR in San Diego, California. Because of the uniqueness of the naval and maritime environment, NSWCDD provides support to all the JPMs, as well as to JPEO-CBD headquarters.

2004–Present

In 2005, the Base Realignment and Closure (BRAC) commission recommended moving NSWCDD's CB research and development work to Edgewood Chemical Biological Center in Edgewood, Maryland (near the Aberdeen Proving Ground). This was a challenging time for the CBR Defense Division. Because most of the Division's employees were longtime Dahlgren area residents, with children in schools and involvement in the local communities, many of the employees looked for and got opportunities in other areas at Dahlgren (as many had done almost 20 years earlier with the "Panic of 86"). Before long, the Division had lost about 30 percent of its employees. The good news is that the BRAC decision was overturned, and the DoD decided to keep the capability at Dahlgren. This decision was primarily based on two factors. First, it was decided that the Navy was indeed unique, and due to the high quality and quantity of support that NSWCDD provides to the fleet, it was the right place to perform this work in support to the warfighter. Secondly, JPEO-CBD was intent on having an organization that was truly joint with representation from all Services, and NSWCDD was the recognized lead for Navy CBR defense.

Mission

Serve DoD and the nation as the Navy organization providing innovative, timely, and effective products, technical solutions, and expertise in chemical, biological, and radiological defense (CBRD)

The period of 2006 to the present has been a period of rebuilding and growth: rebuilding to replace the many high-quality individuals who left after the initial BRAC decision was made and growth to handle the new work that came from a variety of areas, as potential sponsors saw the value of not only the qualified people in the CBR Defense Division, but the technical strength of NSWCDD as well.

It was also during this time frame that NSWC, Crane, as part of its sunset strategy, decided to focus on only a few major areas and divest itself of other work. One of these divestitures was the In-Service Engineering Agent (ISEA) CB Detection work. NSWCDD is a research, development, test, and evaluation institution, and as such, the focus is not usually on the ISEA component. However, there were three reasons why this work eventually came to NSWCDD:

- First and foremost, the warfighter needed to have the work done.
- Second, the sponsor—the Naval Sea Systems Command's (NAVSEA's) SEA 05P14—saw NSWCDD as the place to send this work. This decision came after conducting a LEAN value stream analysis, several resultant rapid improvement events, and several "Just Do Its."
- Third, the decision was in sync with the Asymmetric Defense Systems Department and the CBR Defense Division's vision of making NSWCDD a Navy Center of Excellence for CBR defense.

The transition was not without its challenges, but with a supporting command, dedicated personnel, and the outstanding leadership at the branch and programmatic levels, the work for the fleet continued and thrived.

One of the main impacts to the Division is the increased focus on providing relevant and timely support to the Sailor at the waterfront. To improve support to the fleet, the CBR Defense Division established locations on the waterfront: first in Norfolk, Virginia, and then in San Diego, California. (More comprehensive coverage of NSWCDD's waterfront support can be found in this issue's Haymes article, "Sustaining the Navy's Chemical and Biological Detection Capability," and in the Lalonde and Roller article, "CBRD Waterfront Team Improves Fleet Readiness.") Suffice it to say that this focus on the fleet has been a huge success for the warfighter, as every Commanding Officer deploys with a complete knowledge of their CBR state of readiness, and fleet issues and concerns are fed back into research and development areas that can find fixes and improvements.

Present Products, Capabilities, and Fleet Support Services

The CBR Defense Division is a Navy organization supporting the NAVSEA technical warrant holder in SEA 05P14 and providing CBR defense products, services, and expertise to the Navy, the DoD, and the nation in the areas of collective protection, detection, decontamination, M&S, systems engineering, and S&T. The CBR Defense Division consists of over 175 talented government and contractor professionals with various education and experiential backgrounds, outstanding reputations at the national and international level, and a sense

Facilities

State-of-the-art laboratory and equipment housed in a new 54,000-ft^2 building.
Laboratories include:

- Biological Safety Level 1, 2, & 3,
- Quality Assurance
- Stand-Off Detection
- Collective Protection
- Modeling and Simulation
- Systems Engineering

Equipment includes:

- Optical Microscopes
- Scanning Electron Microscopes

of service and dedication. The Division collaborates with the other warfare centers performing CBR work as part of the seamless warfare enterprise.

Occupying a state-of-the-art research and development facility, the Division combines a strong systems engineering approach, technical competence, extensive experience, modern laboratories, and a continuous-improvement attitude, with extensive collaborative relationships with other Services, government, industry, and academia in order to deliver world-class, full-spectrum CBR defense solutions for the fleet, warfighters, key national assets, operational facilities, and military installations.

The Division's strong S&T base ensures that new ideas are continuously being created, and that the most promising ideas are being matured into affordable technologies that can be integrated into CBR defense solutions of the future. Division personnel brief their work at symposiums, conferences, and seminars, and learn about work being performed by other organizations. By staying on the leading edge of S&T, they can leverage the latest technologies to enhance the effectiveness and affordability of CBR defense solutions. See this issue's ***Research, Applied Science, and Testing Capabilities*** section for examples of the Division's ongoing S&T efforts.

With a presence in Norfolk and San Diego, the NSWCDD CBR defense waterfront support team maintains daily, direct contact with the fleet on both the East and West coasts. This direct and active connection with the fleet helps the warfighter and provides a wealth of valuable information for our scientists and engineers in the laboratory. This knowledge is immediately put to use as they work to create, develop, and provide updates and future solutions for our men and women in uniform. The Readiness Assist Visit (RAV) component of the waterfront support team—again, read details in Lalonde and Roller's "CBRD Waterfront Team Improves Fleet Readiness" article in this issue—ensures that our ships deploy at the highest state of CBRD readiness (see RAV Feedback Report summary slide in Figure 3).

The CBR Defense Division continues to be an integral member of the joint Service CBD community and supports key CBR defense initiatives. The Division's inherent understanding of what it takes to design and field CBR defense systems that will reliably operate in a maritime environment has helped ensure that the Navy gets the right products and services at the right time and at the right cost. The Division also uses this understanding to ensure that the joint Service programs adequately address Navy requirements in the design of new CBR defense equipment.

NSWCDD's CBR Defense Division collaborates with and supports other DoD agencies, such as the:

- Missile Defense Agency
- Defense Advanced Research Projects Agency
- Defense Threat Reduction Agency

NSWCDD's increasing national reputation in several areas of CBR defense has expanded the Division's support in the national needs areas through support of other federal government agencies, such as the Coast Guard and the Centers for Disease Control and Prevention. In addition, subject matter expertise is provided to local governments in support of Homeland Defense initiatives. For example, when the New York City Fire Department (NYFD) wanted to build a new fireboat that was prepared to deal with a CB threatened or contaminated environment, they came to NSWCDD for the CBR defense expertise. NYFD Fireboat *Three Forty Three* was recently commissioned and is fully prepared to deal with the CB threat.

Future of NSWCDD's Role in Naval CBR Defense

There will be many challenges and opportunities for the Division as the CBR defense threat continues to evolve. As such, NSWCDD will be required to address these evolving threats and ensure

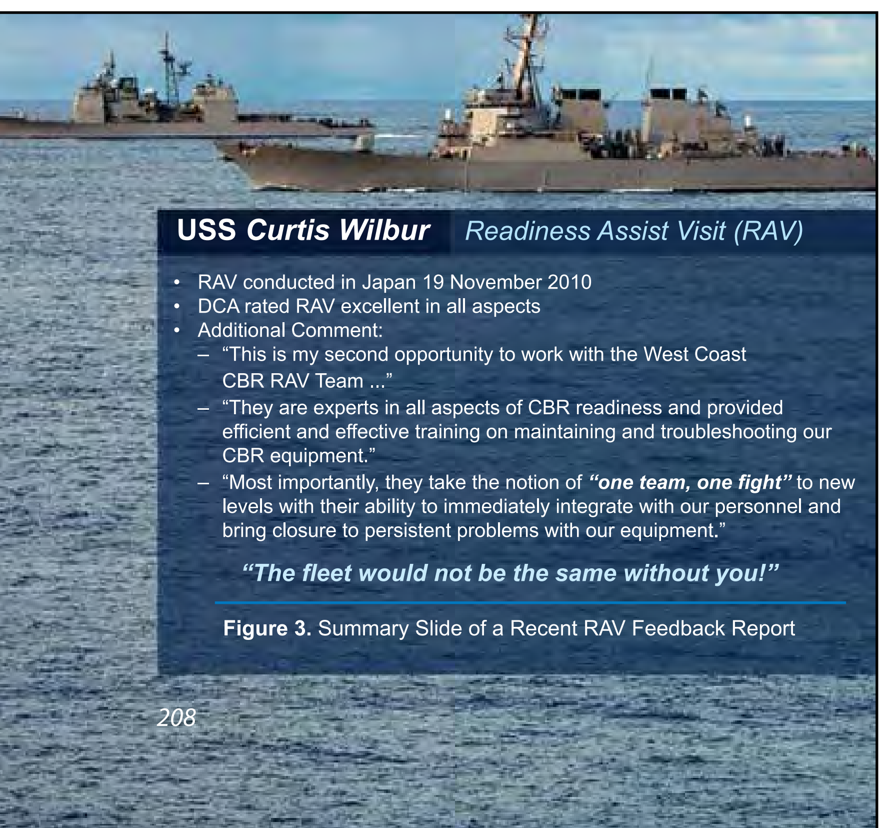


Figure 3. Summary Slide of a Recent RAV Feedback Report

Vision

Be the recognized leader in providing revolutionary concepts through fully integrated family of systems/system of systems solutions for chemical, biological, and radiological defense (CBRD)—in short, be the "voice" of the Navy for all matters pertaining to naval CBRD

that the Navy's unique considerations and needs are addressed and continuously met through demonstrating adaptability to change and responsiveness to the fleet, as well as by applying creativity and technical expertise. The CBR Defense Division is adapting to the changes that are ongoing with the JPEO-CBD reorganization in response to new direction coming from the White House. There is more focus on medical initiatives as evidenced by the new JPM Transformational Medical Technologies Initiative and the start of the Medical Countermeasures Initiative. The CBR Defense Division is aligning itself to support these efforts while remaining responsive to the fleet's current needs. For example, in March 2011, NSWCDD responded to fleet requests for support as Japanese nuclear power plants that were hit by a powerful tsunami were leaking radiation. The adaptability, responsiveness, creativity, and technical expertise of the naval CBR defense community will ensure that the Navy can be involved in cutting-edge products to support the fleet. Examples of these kinds of projects include:

- Integrated prediction models and warning systems to provide real-time warfighter decision support, prediction and tracking tools for CBR events, and a common operational picture for the warfighter that is integrated and seamless with other systems
- Improved decontamination with the creation of all-in-one decontamination products, decontamination of threat clouds, verification that decontamination has occurred, and selection of the right decontaminant for the agent or toxin used
- Better biological and chemical standoff detection capability that can operate effectively in the harsh maritime environment
- More capable filtration systems that are lighter and smaller, last longer, and are more effective than current filters
- Increased use of systems engineering principles and practices to ensure that CBR defense is properly integrated into complex naval systems
- Expanded roles and responsibilities for our waterfront support team
- Increased collaborative relationships with government, industry, and academia
- Pioneering S&T efforts geared towards providing highly adaptive solutions that are not only evolutionary, but revolutionary

Defense funding levels and expenditures have come under intense scrutiny. All Defense organizations are looking for ways to increase efficiencies. Fewer dollars for invention purposes demands more focus on innovation. The ability to look at how existing technologies can be used in a different way to solve a complex problem is how successful organizations will thrive in the next decade. This holds especially true in the area of CBR defense. Perhaps the next great "all-in-one" decontaminant already exists and needs only slight modification to be used on the battlefield or on board ship. Innovation, not invention, may supply the answers to some of our most vexing problems and challenges. As new technologies are introduced, NSWCDD will be expected to play an integral role in assuring that the technologies perform as promised and are integrated across multiple systems and platforms.

NSWCDD's CBR Defense Division is poised to address the future's challenges and ensure that our Sailors can fight, win, and survive in a CBR-threatened or -contaminated environment. Success will be measured by the state of the Navy's CBR defense readiness, the confidence that the Sailors have in our detection, M&S, protection and decontamination systems, and the ability to treat any CBR attack or accident as a nuisance rather than as an ordeal. The Division's expertise, facilities, and strong fleet interaction will ensure this success.

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2. NAVSURFWPNCEN Letter 3400 H301-DWC of 11 August 1986.
3. CNO Letter 3430 Ser 03/6U391055 dated 12 September 1986.
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5. CNO Letter 3430 Ser 03/7U390406 dated 2 February 1987.

World War I

World War II

Korea

Persian Gulf (May 28, 2005) – Sailors assigned to USS *Ashland* (LSD 48) inspect the sprinklers and valves of the chemical, biological, and radiological (CBR) wash down system on the ship's flight deck. USS *Ashland* is currently conducting Maritime Security Operations in the Northern Persian Gulf.

U.S. Navy photo by Photographer's Mate 1st Class Aaron Ansarov (Released)

LEADING EDGE April 2012

Vietnam

Iraq

Afghanistan

CBRD – Chemical, Biological, and Radiological Defense

The CBR threat is real. Chemical and biological weapons have been used in the past. Accordingly, we must guard against current and future use.

That's our mission—to keep our Navy prepared and safe and to provide warfighters with the tools, systems, and equipment needed to fight and win in a CBR threatened or contaminated environment.

Mike Purello
Head, CBR Defense Division
Naval Surface Warfare Center
Dahlgren Division

LEADING EDGE
April 2012

Fallen Warriors

Here we honor those who died while serving their country

NAVSEA
WARFARE CENTERS
DAHLGREN

NSWCDD/MP-11/1
Statement A: Approved for public release; PR Number 3414