United States Government Accountability Office

GAO

Report to Congressional Requesters

June 2008

HOMELAND SECURITY

First Responders' Ability to Detect and Model Hazardous Releases in Urban Areas Is Significantly Limited

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Highlights

Highlights of GAO-08-180, a report to congressional requesters

Why GAO Did This Study

First responders are responsible for responding to terrorist-related and accidental releases of CBRN materials in urban areas. Two primary tools for identifying agents released and their dispersion and effect are equipment to detect and identify CBRN agents in the environment and plume models to track the dispersion of airborne releases of these agents. GAO reports on the limitations of the CBRN detection equipment, its performance standards and capabilities testing, plume models available for tracking urban dispersion of CBRN materials, and information for determining how exposure to CBRN materials affects urban populations. To assess the limitations of CBRN detection equipment and urban plume modeling for first responders' use, GAO met with and obtained data from agency officials and first responders in three states.

What GAO Recommends

The Secretary of Homeland Security should (1) reach agreement with agencies on who will have the mission and responsibility to develop, certify, and independently test first responders' equipment for detecting hazardous material releases; (2) ensure testing and validation of manufacturers' claims about CBRN detection equipment's sensitivity and specificity; (3) refine IMAAC's procedures for addressing contradictory modeling predictions in CBRN events; (4) with IMAAC, work with the federal plume modeling community to accelerate R&D on model deficiencies in urban areas and improve federal modeling and assessment capabilities.

www.gao.gov/cgi-bin/getrpt? GAO-08-180.
To view the full product, including scope and methodology, click on the link above.
For more information, contact Nancy Kingsbury at 202-512-2700.

June 2008

HOMELAND SECURITY

First Responders' Ability to Detect and Model Hazardous Releases in Urban Areas Is Significantly Limited

What GAO Found

While the Department of Homeland Security (DHS) and other agencies have taken steps to improve homeland defense, local first responders still do not have tools to accurately identify right away what, when, where, and how much chemical, biological, radiological, or nuclear (CBRN) materials are released in U.S. urban areas, accidentally or by terrorists. Equipment local first responders use to detect radiological and nuclear material cannot predict the dispersion of these materials in the atmosphere. No agency has the mission to develop, certify, and test equipment first responders can use for detecting radiological materials in the atmosphere. According to DHS, chemical detectors are marginally able to detect an immediately dangerous concentration of chemical warfare agents. Handheld detection devices for biological agents are not reliable or effective. DHS's BioWatch program monitors air samples for biothreat agents in selected U.S. cities but does not provide first responders with real-time detection capability. Under the BioWatch system, a threat agent is identified within several hours to more than 1 day after it is released, and how much material is released cannot be determined.

DHS has adopted few standards for CBRN detection equipment and has no independent testing program to validate whether it can detect CBRN agents at the specific sensitivities manufacturers claim. DHS has a mission to develop, test, and certify first responders' CB detection equipment, but its testing and certification cover equipment DHS develops, not what first responders buy.

Interagency studies show that federal agencies' models to track the atmospheric release of CBRN materials have major limitations in urban areas. DHS's national TOPOFF exercises have demonstrated first responders' confusion over competing plume models' contradictory results. The Interagency Modeling and Atmospheric Assessment Center (IMAAC), created to coordinate modeling predictions, lacks procedures to resolve contradictory predictions.

Top Officials Exercises 1–4, 2000–2007

Exercise	Date	Place	Type of agent release simulated
1	May 20–24, 2000	Portsmouth, N.H.	Mustard gas
		Denver, Colo.	Pneumonic plague
		Washington, D.C.	Radiological dispersion device
2	May 12–16, 2003	Chicago, Ill.	Pneumonic plague
		Seattle, Wash.	Radiological dispersion device
3	April 4–8, 2005	New London, Conn.	Mustard gas
		New Jersey	Pneumonic plague
4	October 15–20, 2007	Guam	Radiological dispersion device
		Phoenix, Ariz.	Radiological dispersion device
		Portland, Ore.	Radiological dispersion device

Source: DHS.

Evaluations and field testing of plume models developed for urban areas show variable predictions in urban environments. They are limited in obtaining accurate data on the characteristics and rate of CBRN material released.

Data on population density, land use, and complex terrain are critical to first responders, but data on the effects of exposure to CBRN materials on urban populations have significant gaps. Scientific research is lacking on how low-level exposure to CBRN material affects civilian populations, especially elderly persons, children, and people whose immune systems are compromised.

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Abbreviations

AEGL	acute exposure guideline level
ALOHA	Areal Locations of Hazardous Atmospheres
ASTM	American Society for Testing and Materials
CAMEO	Computer-Aided Management of Emergency Operations
CB	chemical and biological
CBRN	chemical, biological, radiological, nuclear
CDC	Centers for Disease Control and Prevention
CFD	computational fluid dynamics
DHS	Department of Homeland Security
DNDO	Domestic Nuclear Detection Office
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DTRA	Defense Threat Reduction Agency
ECBC	Edgewood Chemical Biological Center
EPA	Environmental Protection Agency
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FRMAC	Federal Radiological Monitoring and Assessment Center
hazmat	hazardous materials
HHA	handheld immunoassay
HPAC	Hazard Prediction and Assessment Capability
HSC	Homeland Security Council
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory

IAB	InterAgency Board for Equipment Standardization and Interoperability
IDA	Institute for Defense Analyses
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IMS	ion mobility spectrometer
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LODI	Lagrangian Operational Dispersion Integrator
NARAC	National Atmospheric Release Advisory Center
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OLES	Office of Law Enforcement Standards
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
QUIC	Quick Urban and Industrial Complex
ppb	parts per billion
ppm	parts per million
RASCAL	Radiological Assessment System for Consequence Analysis
RKB	Responder Knowledge Base
SAVER	System Assessment and Validation for Emergency Responders
SAW	surface acoustic wave
SCIPUFF	Second-order Closure Integrated Puff
SHSP	State Homeland Security Program
S&T	Science and Technology
TIC	toxic industrial chemical
TIM	toxic industrial material
TOPOFF	Top Officials
UASI	Urban Areas Security Initiative
UDM	Urban Dispersion Model

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Congressional Requesters

A terrorist act involving the use of a chemical, biological, radiological, or nuclear (CBRN) agent or weapon presents an array of complex issues to state and local responders. The responders, who may include firefighters, emergency medical service personnel, and hazardous materials technicians, must identify the agent or weapon so that they can rapidly decontaminate victims and apply appropriate medical treatments. They must also determine whether the agent has spread beyond the incident site and what actions should be taken to protect other people.

Since at least 2001, it has been recognized that CBRN materials might be released by a terrorist act when letters laced with anthrax were sent through the mail to two U.S. senators and members of the media.[1] The letters led to the first cases of anthrax disease related to bioterrorism in the United States. In all, 22 persons contracted anthrax disease and 5 died in four states and Washington, D.C. The anthrax attack highlighted the nation's vulnerability. In 2002, the Congress enacted legislation to create the Department of Homeland Security (DHS), merging 22 separate agencies, with the primary mission of protecting the United States against conventional and unconventional attacks. In addition, the Homeland Security Council (HSC), in coordination with DHS and other federal agencies, identified nine possible scenarios involving the release of CBRN materials in urban areas.[2] In one scenario, for example, terrorists release sarin in three city office buildings. In this scenario, it is estimated that 6,000 people are killed and economic damages amount to $300 million.

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[1] Anthrax in this report reflects common terminology. Technically, the word refers only to the disease caused by *Bacillus anthracis*, not the bacterium or its spores.

[2] The Homeland Security Council is intended to ensure the coordination of all activities related to homeland security by executive departments and agencies and to promote the effective development and implementation of all homeland security policies. See also "Organization and Operation of the Homeland Security Council," Homeland Security Presidential Directive–1, The White House, Washington, D.C., Oct. 29, 2001.

Typically, the first to show up in emergency situations like these are local first responders.[3] Local first responders are responsible for identifying the nature of an emergency. In order to respond to a CBRN event, first responders need timely and accurate information about the type and quantity of agents released, where and when they were released, and how far contamination is likely to spread. Also critical for first responders is information on the potential effects on civilian populations from exposure to concentrations of CBRN materials.

In incidents caused by airborne CBRN releases, first responders' two primary tools are (1) detection equipment to identify CBRN materials released into the atmosphere and (2) information from plume models that track airborne dispersion of CBRN materials and define the area of contamination.[4] In this report, we focus on the limitations of these tools for first responders. Detection devices identify and confirm in real time the chemical or particle stimuli by triggering signals or alarms when certain sensitivity and specificity parameters are detected. With respect to equipment first responders purchase with DHS grant funds, DHS is required to establish and implement procedures for developing and adopting standards for such equipment to ensure that it meets a minimum level of performance, functionality, adequacy, durability, sustainability, and interoperability. Information from plume models is intended to help inform first responders—from analyses of the models' mathematical and computer equations and incorporation of field data—on the extent of a contaminated area. A comprehensive model takes into account the material released, local topography, and meteorological data, such as temperature, humidity, wind velocity, and other weather conditions, and continually refines predictions with field data.

In response to your request, we addressed the following questions: (1) What are the limitations of detection equipment currently available for first responders' use in identifying CBRN materials released in the

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[3] Individuals responsible for protecting and preserving life, property, evidence, and the environment in the early stages of a terrorist attack, natural disaster, or other large-scale emergency are known as first responders or emergency response providers. They include "Federal, State, and local governmental and nongovernmental emergency public safety, fire, law enforcement, emergency response, and emergency medical (including hospital emergency facilities), and related personnel, agencies, and authorities." See 6 U.S. Code §101(6).

[4] While we use CBRN for convenience, we do describe, later in the report, differences in the behavior and effects of these materials when they are released into the atmosphere.

atmosphere? (2) What has DHS done with regard to developing and adopting performance standards for CBRN detection equipment and testing this equipment to verify its performance? (3) What are the limitations of plume models first responders can use to track the dispersion of an airborne release of CBRN materials, including toxic industrial chemicals (TIC) and toxic industrial materials (TIM), in an urban environment? and (4) What information is available to first responders for determining the effects of exposure to CBRN materials on populations in urban areas?

To assess the limitations of CBRN detection equipment available for first responders' use, we interviewed federal program officials from the Science and Technology (S&T) directorate of DHS and its Homeland Security Advanced Research Projects Agency, from the Department of Defense (DOD) Defense Threat Reduction Agency (DTRA) and Joint Program Executive Office for Chemical and Biological Defense, and from the Department of Energy's (DOE) Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Oak Ridge National Laboratory (ORNL). We reviewed DHS, DOD, and DOE detection programs in place and being developed, as well as these agencies' studies on CBRN detection systems. We attended conferences and workshops on CBRN detection technologies.

To obtain information on detection equipment standards and the testing of CBRN detection equipment for first responders, we met with program officials from DHS's Responder Knowledge Base (RKB) and the Department of Commerce's (DOC) National Institute of Standards and Technology's (NIST) Office of Law Enforcement Standards (OLES). We also interviewed local responders in Connecticut, New Jersey, and Washington regarding their acquisition of CBRN detection equipment. We chose these states because of their participation in DHS-sponsored Top Officials (TOPOFF) national counterterrorism exercises. In addition, we interviewed members of the InterAgency Board for Equipment Standardization and Interoperability (IAB). IAB, made up of local, state, and federal first responders, is designed to establish and coordinate local, state, and federal standardization, interoperability, compatibility, and responder health and safety to prepare for, train and respond to, mitigate, and recover from any CBRN incident.

To assess the limitations of plume models, we interviewed modeling experts from DHS, DOD, DOE national laboratories, the National Oceanic and Atmospheric Administration (NOAA), and the Office of the Federal Coordinator for Meteorological Service and Supporting Research (OFCM) in DOC. We interviewed operations staff of the Interagency Modeling and Atmospheric Assessment Center (IMAAC) at LLNL. We also interviewed local responders in Connecticut, New Jersey, and Washington regarding the use of plume models during the TOPOFF 2 and TOPOFF 3 exercises.

We reviewed documentation on the various plume models and reports and studies evaluating models available for tracking CBRN releases in urban environments and studies identifying future needs and priorities for modeling homeland security threats. We attended several conferences and users' workshops sponsored by the American Meteorological Society, DOD, OFCM, and George Mason University, where modeling capabilities were evaluated. We also reviewed DHS internal reports on lessons learned from the use of modeling during TOPOFF national exercises.

To identify the information first responders have for determining the effects of exposure to CBRN materials on heterogeneous civilian populations, we reviewed agency documentation and studies on urban land use and population density. We also reviewed documentation on acute exposure guideline levels published by the Environmental Protection Agency (EPA) and other organizations. In addition, we reviewed studies on human toxicity estimates by the U.S. Army and DOE national laboratories. (More detail on our scope and methodology is in appendix I.)

We conducted our review from July 2004 to January 2008 in accordance with generally accepted government auditing standards.

Results in Brief

More than 6 years after the events of September 11, 2001, local first responders do not have tools that can accurately and quickly identify the release of CBRN material in an urban environment. While DHS and other agencies have undertaken initiatives to improve first responders' tools, these tools have many limitations for identifying CBRN materials released in urban environments, the extent of their dispersion, and their effect on urban populations. While equipment first responders use for the detection of radiological and nuclear materials may be able to identify the presence of these materials, they cannot predict the dispersion of these materials in the atmosphere. No agency now has the mission to develop, certify, and test equipment first responders can use for detecting radiological materials in the atmosphere. Commercial chemical and biological detectors that are available cannot detect all agents and have varying sensitivity and specificity. According to DHS, current detectors are considered generally inadequate to provide information on the presence of chemical warfare agents at less than lethal but still potentially quite harmful levels—that is, at higher than permissible exposure levels. For suspected exposure to biological threat agents, commercially available detection devices, such as handheld immunoassays (HHA), are not always reliable, and evaluation studies show that the devices have not passed acceptable standards for effectiveness. BioWatch—DHS's nationwide environmental monitoring system—does not allow first responders to obtain immediate real-time information on potential biological pathogens released in the atmosphere. Under the current BioWatch system, identification and confirmation of biological warfare agents does not occur until several hours to more than 1 day after release of the agent, and the quantity of the agent released cannot be determined.

DHS has adopted very few performance standards for CBRN detection equipment. As of October 30, 2007, DHS had adopted 39 total standards for CBRN equipment but had adopted only 4 standards for radiation detection instruments targeted at the interdiction and prevention of smuggling radioactive material and none for chemical and biological (CB) detection equipment. The remaining standards address personal protective equipment such as respirators and protective clothing.

DHS officials told us that it has the mission to develop, independently test, and certify CB detection equipment for first responders' use. However, DHS officials stated that their mission to test and certify chemical and CB detection equipment is limited to equipment that DHS is developing for first responders; it does not extend to detection equipment first responders buy from manufacturers. DHS does not have an independent testing program to validate manufacturers' claims regarding detection equipment for first responders. Consequently, first responders are buying detection equipment that may or may not be effective.

A number of nonurban plume models, supported by various agencies such as DOD, DOE, EPA, and NOAA, are being used to track the atmospheric release of CBRN materials for operational real-time applications. However, interagency studies have concluded that these models have significant limitations for analyzing the dispersion of CBRN materials in urban settings. These models have not been adequately validated and are not designed for complex built-up urban environments. DHS's national TOPOFF 2 exercise in 2003 demonstrated that using several of these models and different model inputs can produce contradictory results, causing confusion among first responders. To overcome the confusion over the use of multiple models during TOPOFF 2, DHS created IMAAC in 2004. IMAAC was expected to serve as a single point for the coordination and dissemination of federal dispersion modeling and hazard prediction products during actual or potential CBRN incidents requiring federal coordination. However, the results from the TOPOFF 3 exercise conducted in 2005 showed that despite IMAAC, problems with coordinating modeling inputs and results continued. Exercise results from the TOPOFF 4 exercise, conducted in 2007, showed improvement in IMAAC's ability to minimize differences in plume modeling outputs and provide one source for consequence predictions. However, decision makers had difficulty interpreting the plume and consequence models predicting radiation dispersal.

In addition, federal agencies have developed urban plume models specifically for use in urban areas. Evaluation and testing of urban plume models DHS, DOD, and DOE conducted in several full-scale field experiments has shown an unpredictable range of uncertainty in urban plume models' analyses that will not give first responders ground truth—that is, the actual hazard area and the level and extent of contamination on the ground. Model evaluations and field studies have also shown that urban plume models cannot determine with certainty the source term from a CBRN release—that is, the characteristics of the material that was released and its rate of release—particularly for estimating the source term of the release of TICs from accidents or terrorist acts.

Significant gaps exist in information first responders have for determining the effects of exposure to CBRN materials on heterogeneous urban populations. Scientific research on the effects of low-level exposure to CBRN material on civilian populations is severely lacking, especially for vulnerable populations such as elderly people, children, and individuals with compromised immune systems. A dose that may not be lethal for a healthy young adult might be lethal for them. For example, in the 2001 anthrax attack, many postal workers exposed to high concentrations over a prolonged period did not develop the anthrax disease, while an elderly woman in Connecticut with a compromised immune system died, presumably from inhaling very few spores. Dose response parameters for the general population also do not exist for most chemical warfare agents believed to pose a threat to civilians. Data are needed on exposure and dose assessments to identify vulnerable populations and how to adjust individual and population post-event activities and behavior to reduce casualties. Information on population density, land use, and nearby complex terrain is especially critical.

We are making recommendations in this report to the Secretary of Homeland Security for executive action to address shortcomings in detection and modeling capabilities. Specifically, we recommend that the Secretary of Homeland Security (1) reach agreement with other agencies on which agency should have the mission and responsibility to develop, test, and certify detection equipment that first responders use to detect hazardous material releases in the atmosphere; (2) ensure that manufacturers' claims are independently tested and validated regarding whether their commercial off-the-shelf CBRN detection equipment can detect given hazardous material at specific sensitivities; (3) refine IMAAC's procedures by working with other federal, state, and local agencies to (a) develop common/joint IMAAC emergency response practices, including procedures for dealing with contradictory plume modeling information, (b) refine the concept of operations for chemical, biological, and radiological releases, and (c) delineate the type and scale of major CBRN incidents that would qualify for IMAAC assistance; and (4) in conjunction with IMAAC, work with the federal plume modeling community to accelerate research and development to address plume model deficiencies in urban areas and improve federal modeling and assessment capabilities. Such efforts should include improvements to meteorological information, plume models, and data sets to evaluate plume models.

We obtained general comments on a draft of this report from DHS and DOC (see apps. III and IV). DHS concurred with our recommendations but stated that GAO should consider other scenarios as alternative ways of looking at the present national capabilities for CBRN response and the current status of testing and certification of detection equipment. DHS stated that in one alternative scenario, first responders, in the event of a terrorist attack, will use a variety of prescreening tools, and they will be assisted immediately by state and federal agencies that will bring the best available state-of-the-art CBRN detection equipment.

In our report, we have considered scenarios in which first responders are on the scene before federal assets arrive, not knowing what hazardous materials (including CBRN agents) have been released, either accidentally or by terrorist acts. In these situations, it is the first responder who has to first determine what was released and what tools to use to make that determination before receiving assistance from state and federal agencies. As discussed in our report, by DHS's own assessments, these state-of-the-art tools have significant limitations.

In its general comments on our draft report, DOC stated it believed that even with the implementation of GAO recommendations aimed at improving IMAAC operations, the plume models would still have several limitations as a primary tool for tracking the release of CBRN materials in urban areas. To improve information available for emergency managers, DOC suggested offering a recommendation that DHS work with the federal plume modeling community to accelerate research and development to address plume model deficiencies in urban areas. Such efforts should include improvements to meteorological information, plume models, and data sets to evaluate plume models. We believe that DOC's recommendation has merit and have included it in our final report for DHS's consideration.

We received technical comments from DHS, DOD, DOE (LLNL), and NIST and we made changes to the report where appropriate. Technical comments we received from LLNL, in particular, proposed broadening the recommendation related to revising IMAAC standard operating procedures to deal with contradictory modeling inputs. IMAAC operations staff at LLNL believed that integrated procedures with other emergency response agencies are the key to clarifying plume modeling information. We agreed and have revised our recommendation accordingly.

Background

The National Strategy for Homeland Security characterizes terrorism as "any premeditated, unlawful act dangerous to human life or public welfare that is intended to intimidate or coerce civilian populations or governments."[5] This definition includes attacks involving CBRN materials. The National Strategy recognizes that the consequences of such an attack could be far more devastating than those the United States suffered on September 11: "a chemical, biological, radiological, or nuclear terrorist attack in the United States could cause large numbers of casualties, mass psychological disruption, contamination and significant economic damage, and could overwhelm local medical capabilities."[6]

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[5] The White House, Office of Homeland Security, *The National Strategy for Homeland Security* (Washington, D.C.: July 16, 2002), p. 2. www.whitehouse.gov/homeland/book.

[6] *The National Strategy for Homeland Security*, p. ix.

Government Responsibilities for Responding to CBRN Events

State and Local Responsibilities

State and local responders share in the responsibility for responding to CBRN events, but local first responders play the key role because they are the first to respond. The first line of defense in any terrorist attack on the United States is its first responder community—police officers, firefighters, emergency medical providers, public works personnel, and emergency management officials. Their role is to protect against, respond to, and assist in recovery from emergency events. Traditionally, first responders have been trained and equipped to arrive at the scene of a natural or accidental emergency and take immediate action.

Federal Responsibilities

If state and local resources and capabilities are overwhelmed, governors may request federal assistance. In his February 28, 2003, Homeland Security Presidential Directive/HSPD-5, the President designated the Secretary of Homeland Security the principal federal official responsible for domestic incident management. The directive empowered the Secretary to coordinate federal resources used to respond to or recover from terrorist attacks, major disasters, or other emergencies in specific cases.[7] The Secretary, in coordination with other federal departments and agencies, is to initiate actions to prepare for, respond to, and recover from such incidents. The directive also called for the Secretary to develop a National Response Plan to provide the framework for federal interaction with nonfederal entities.[8]

In addition, HSPD-8, issued on December 17, 2003, established policies to strengthen first responder preparedness for preventing and responding to threatened or actual domestic terrorist attacks.[9] Among other things, it

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[7] "Management of Domestic Incidents," Homeland Security Presidential Directive/HSPD–5, The White House, Washington, D.C., Feb. 28, 2003. http://www.whitehouse.gov/news/releases/2003/02/20030228-9.html.

[8] Effective March 22, 2008, DHS renamed the National Response Plan, calling it the National Response Framework.

[9] "National Preparedness," Homeland Security Presidential Directive/HSPD–8, The White House, Washington, D.C., Dec. 17, 2003. http://www.whitehouse.gov/news/releases/2003/12/20031217-6.html.

required DHS to provide assistance to state and local efforts, including planning, training, exercises, interoperability, and equipment acquisition for terrorist events. HSPD-8 also required DHS to coordinate with other federal agencies and state and local officials in establishing and implementing (1) procedures for developing and adopting first responder equipment standards and (2) plans to identify and address national first responder equipment research and development needs.

First Responders' Challenges in CBRN Events

First responders face difficult challenges when they arrive at the scene of an accidental or terrorist release of CBRN agents in an urban environment. Local police, fire, and emergency medical units would be the first on the scene, attempting to control the situation while requesting technical assistance, specialized units, and backup. County and local hazardous materials (hazmat) teams and bomb squads would be among the first units called to augment the first responders. A major terrorist act involving CBRN materials might cause significant casualties among the first responders. It is therefore critical that they be able to quickly identify, locate, characterize, and assess the potential effect of CBRN, explosive, or incendiary threats and communicate this information rapidly and effectively.

The primary challenge facing first responders is knowing how to identify and distinguish between CBRN releases. The first responders need to be able to communicate what was released, the quantity of the material released (and its purity, in the case of chemical agents), where it is going, who is at risk, and how to respond. Of ultimate interest are the human health and environmental effects, since exposure to CBRN materials can kill or seriously injure people through their physiological effects. A chemical agent attacks the organs of the human body so as to prevent them from functioning normally. The results are usually disabling and can even be fatal. However, DHS S&T officials said that for biological agents, there "will be no first responders" in the traditional sense of being present while the aerosol cloud is present, and so they are not preferentially exposed in the initial exposure. Follow-up investigation does pose additional risk to the first responders from contamination and reaerosolization, but they can be suitably protected by both personal protective equipment and antimicrobials.[10]

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[10] An antimicrobial is a substance that kills or inhibits the growth of microbes such as bacteria, fungi, or viruses.

The danger that TICs and TIMs will be released in urban areas from industrial and transportation accidents is also of concern. Approximately 800,000 shipments of hazardous materials such as liquid chlorine and ammonia travel daily throughout the United States by ground, rail, air, water, and pipeline. Many are explosive, flammable, toxic, and corrosive and can be extremely dangerous when improperly released. They are often transported over, through, and under densely populated areas, where a release could cause injury or death and significant environmental damage.

Both international and domestic accidents illustrate the potentially catastrophic effects of the release of TICs and TIMs. An accidental, large-scale hazardous release in Bhopal, India, in 1984, killed approximately 3,800 people and left thousands of people with permanent or partial disabilities.[11] More recently, on January 6, 2005, in Graniteville, South Carolina, a freight train pulling three chlorine tanker cars and a sodium hydroxide tanker car collided with a train parked on an industrial rail spur. Almost immediately, 11,500 gallons of chlorine gas released from the tankers caused 9 people to die, 8 from inhaling chlorine gas, and at least 529 to seek medical care for possible chlorine exposure. A visible cloud that spread initially in all directions led local emergency officials to issue a shelter-in-place order. South Carolina officials later declared a state of emergency, under which local authorities evacuated 5,453 residents within a mile's radius of the collision.

In contrast to chemical agents, biological agents can multiply in the human body, significantly increasing their effects. Many biological agents are highly virulent and toxic; they may have an incubation period so that their effects are not seen for hours to days. According to DHS, biological attacks that have the greatest potential for widespread catastrophic damage include, but are not limited to, aerosolized anthrax and smallpox.

When radioactive materials are incorporated and retained in the body, the tissues in which the materials are concentrated, or in some instances the whole body, can suffer significant radiation injury. Radiation from deposited radiological material is a significant cause of radiation exposures and potential casualties once the airborne plume has passed.

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[11] In the early hours of December 3, 1984, methyl isocyanate gas leaked from the Union Carbide plant in Bhopal, India.

(Appendix II lists chemical, biological, and radiological agents and their effects on human health.)

Planning scenarios DHS developed for use in federal, state, and local security preparedness illustrate the difficult challenges first responders face in CBRN events and the extent of potential injuries and fatalities. Nine of the 15 possible scenarios in table 1 involve the release of CBRN agents or toxic industrial materials in metropolitan areas.

Table 1: Fifteen Projected Homeland Security Threats and Their Consequences

			Consequence				
Threat	**Type**	**Projected event**	**Fatalities**	**Hospitalized**	**Evacuated**	**Economic Impact**	**Other**
Terrorist attack							
Chemical	Blister agent	A combination of blister agents is sprayed into a crowded football stadium	150	70,000	More than 100,000	$500 million	
	Chlorine tank explosion	Explosives release a large quantity of chlorine gas	17,500	100,000	550,000	No data	70,000 evacuated; site and waterway contamination
	Nerve agent	Sarin is sprayed into the ventilation system of three commercial buildings in a city	6,000	No data	Unknown number	$300 million	350 injuries downwind
	Toxic industrial chemicals	Grenades and explosive devices are used at petroleum facilities	350	1,000	Up to 700,000	No data	50% of facility damaged
Biological	Anthrax	A concealed device sprays anthrax spores in a city	13,000[a]	No data	No data	Billions	Extensive contamination
	Food contamination	Food in processing facilities is contaminated with anthrax	300	400	0	Millions	
	Foot and mouth disease	Livestock are infected at specific locations	0	0	0	Hundreds of millions	Huge loss of livestock
	Plague	Pneumonic plague is released in three areas of a large city	2,500	No data	0	Millions	7,000 injuries

			Consequence					
Threat	**Type**	**Projected event**	**Fatalities**	**Hospitalized**	**Evacuated**	**Economic Impact**	**Other**
Radiological	Dispersal device	Dirty bombs are detonated in three cities in regional proximity	180	No data	No data	Billions	20,000 detectible contaminations in each city
Nuclear	Detonated device	A 10-kiloton nuclear device is detonated in a large city	No data	No data	450,000 or more	Hundreds of billions	Up to 3,000 square miles contaminated
Explosive devices	Explosive devices to detonate bombs	A bomb is detonated in a sports arena, a suicide bomber attacks an underground public transportation concourse, and another attacks a parking facility	100	450	No data	No data	
Cyber	Internet	U.S. financial infrastructure and other Internet-related services are attacked	0	0	0	Millions	
Natural event							
Disease outbreak	Pandemic influenza	Natural outbreak begins in China and spreads to other countries	87,000	300,000	0	$70 billion to $160 billion	
Natural disaster	Major earthquake	A 7.2 magnitude earthquake occurs in a major metropolitan area	1,400	100,000	No data	Hundreds of billions	150,000 buildings destroyed
	Major hurricane	A category 5 hurricane strikes a major city	1,000	5,000	1 million	Billions	

Source: Congressional Research Service, *The National Preparedness System: Issues in the 109th Congress* (Washington, D.C.: 2005).

[a] Includes injuries.

Tools Used to Identify and Track CBRN Materials

First responders have two primary tools in CBRN events: (1) equipment to identify CBRN materials in the atmosphere and (2) information from plume models and field measurements that track the atmospheric dispersion of CBRN materials. Detection devices identify and confirm CBRN material stimuli by triggering signals or alarms when certain sensitivity and specificity parameters are detected.

The sensitivity, specificity, and selectivity of CB detection equipment are key performance characteristics. Biological detection equipment has to be sensitive enough to detect very small amounts of biological agents and also has to have a high degree of specificity in order to distinguish biological agents from harmless biological and nonbiological material in the environment. For chemical detectors, sensitivity is the lowest concentration at which a chemical agent can be detected. As with biological agents, the most challenging aspect of identifying chemical agents with a detector is its selectivity in extracting the agent of interest from other chemicals in the environment. The sensitivity, specificity, and selectivity of CB detection equipment also determine false positive or negative alarm rates. Detectors should have minimal false positive and false negative alarm rates.

Information from plume models is intended to help tell first responders—from analyses of the models' mathematical or computer equations or both—the extent of the contaminated area. In emergency response, plume models are used to provide early estimates of potentially contaminated areas and should be used in combination with data gathered from the field. Model results are used to guide field sampling, data from which, in turn, are used to update plume predictions in a cyclical process until the effects have been accurately characterized.

A comprehensive model takes into account the material released, local topography, and meteorological data, such as temperature, humidity, wind velocity, and other weather conditions. Plume modeling requires several accurate components:

- meteorological data (for example, temperature, humidity, barometric pressure, dew point, wind velocity and direction at varying altitudes, and other related measures of weather conditions);
- data from global weather models to simulate large-scale weather patterns and from regional and local weather models to simulate the weather in the area of the chemical agent release and throughout the area of dispersion;
- the source term, or the characteristics or properties of the material that was released and its rate of release (for example, its quantity and purity, vapor pressure, the temperature at which the material burns, particle size distribution, its persistence and toxicity, and height of release);
- temporal and geographical information (for example, transport and dispersion processes such as whether the agent was initially released during daylight hours, when it might rapidly disperse into the surface

air, or at night, when a different set of breakdown and dispersion characteristics would pertain, depending on terrain, and plume height, complex terrain, urban effects, and agent processes such as environmental degradation and decay and growth rates for radiological agents); and

- information on the potentially exposed populations, such as dose response (conversion of exposures into health effects), animals, crops, and other assets that may be affected by the agent's release.

CBRN Detection Equipment Has Significant Limitations for First Responders' Use

Current CBRN detection equipment has significant limitations for first responders' use in an event involving the release of CBRN materials in an urban environment. First, the detection equipment first responders now use for radiological and nuclear incidents cannot detect the dispersal of radiological contamination in the atmosphere. Second, according to DHS, chemical detection equipment is generally inadequate to provide information on the presence of chemical warfare agents at less than lethal but still potentially harmful levels. Third, for biological detection equipment, the handheld assays first responders use do not provide accurate information because of this equipment's high level of false positives. In addition, BioWatch, the nationwide environmental monitoring system, does not enable first responders to obtain immediate real-time information about the effects of biological pathogens released in the atmosphere.

Current Radiological and Nuclear Detection Equipment First Responders Use Cannot Detect the Dispersion of Releases in the Atmosphere

While equipment first responders use for detecting radiological and nuclear materials can detect the presence of significant amounts of these materials, they cannot predict their dispersion in the atmosphere. In addition, current handheld, compact devices such as dosimeters and pagers are not able to detect low energy beta radiation from some isotopes and are not capable of handling rugged and harsh environments. DHS's Domestic Nuclear Detection Office (DNDO) is responsible for acquiring and supporting the deployment of radiation detection equipment. However, this office has primarily emphasized developing and deploying radiation detection equipment to secure cargo container shipments at U.S. ports of entry to prevent smuggling radioactive material into the United States. DNDO's Chief of Staff told us that it does not consider its mission to include the development of radiological detection equipment for local first responders to use in identifying the release of radiological materials in the atmosphere. It does not evaluate radiological detection equipment for first responder use in consequence management.

We surveyed federal agencies involved with CBRN defense about their mission in relation to radiological detection equipment for first responders. DHS, DOD, DOE, EPA, NIST, and NOAA responded that they do not have specific missions to develop, independently test, and certify detection equipment for use by first responders in detecting radiological materials in the atmosphere. However, DOD and DOE program officials said that first responders can certainly use radiological detection equipment DOD and DOE develop for other missions. In addition, agencies such as DOE and EPA have some capability for tracking airborne radiological materials—a capability that first responders do not have. For example, we previously reported that DOE can deploy teams that use radiation monitoring equipment, including sensors mounted on aircraft and land vehicles, to detect and measure radiation contamination levels and provide information to state and local officials on what areas need to be evacuated.[12] EPA also has its RadNet system for airborne radiation monitoring.[13]

Current Chemical Detection Equipment First Responders Use Cannot Detect Harmful Concentrations

According to DHS S&T's CB Division, significant investments have been made toward the detection of chemical agents, largely led by DOD investments, followed up by investments in the private sector to exploit the marketplace. As a result, a number of options are available for detecting these materials as vapor and liquids. However, according to DHS S&T, current detectors can be used for rapid warning of chemicals (warfare agents and TICs) as vapor but are considered generally inadequate to provide information on the presence of chemical warfare agents at less than lethal but still potentially quite harmful levels—that is, higher than permissible exposure levels. DHS S&T acknowledged that improvements are needed to meet sensitivities necessary for real-time protection of the population and for eliminating a tendency for high false-alarm rates. Improvements are also needed in the selectivity of most common chemical detector platforms. Anecdotal information led DHS S&T to make the following general observations with regard to currently available detectors and their ranking for performance for first responders' use:

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[12] GAO, *Combating Nuclear Terrorism: Federal Efforts to Respond to Nuclear and Radiological Threats and to Protect Emergency Response Capabilities Could Be Strengthened*, GAO-06-1015 (Washington, D.C.: Sept. 21, 2006).

[13] RadNet is a national network of monitoring stations that regularly collect air, precipitation, drinking water, and milk samples for analysis of radioactivity.

- Mass spectrometer devices are the most sensitive chemical detectors but are significantly costly and least frequently used by first responders. These devices are also significantly heavier and larger, so that they are typically bench-top, laboratory devices and not robust handheld detectors that are more suitable for field deployment.

- Ion mobility spectrometers (IMS) and surface acoustic wave (SAW) devices are next in selectivity but encounter frequent false positive responses and are susceptible to interference by common materials such as cleaners, pesticides, paint fumes, fire-fighting foams, and combustion products. Hazmat teams and other responders use both types, and they are used in protecting occupants of buildings, transit systems, and the like.

However, DHS S&T has assessed the sensitivity of IMS and SAW for V and G nerve agents as being in the low parts per billion (ppb) range—approximately 2 ppb to 20 ppb—while the limit of detection is higher—at 200 ppb to 300 ppb—for blister agents such as mustard and lewisite. According to DHS S&T, these sensitivities would detect some agents at concentrations immediately dangerous to life and health but would not easily detect other agents such as VX at concentrations that are immediately dangerous to life and health. DHS S&T stated that first responders could use IMS, SAW, and similar devices to monitor a condition that is changing from dangerous to tolerable if the detectors were used to provide guidance on the use of personal protective equipment but cannot be used for rapid warning of dangerous conditions.

Photo-ionization, flame-ionization, and flame photometric detectors—according to DHS S&T, prone to false positive alarms—can be improved if chromatographic separation techniques are incorporated before analyte streams are presented. However, DHS S&T officials state that few current detectors first responders use have this technology.

DHS S&T officials stated that the limitations noted for detectors of chemical warfare agents (cost and size; propensity for false positive alarms) also apply to TICs, many of which can be detected by IMS and SAW devices commonly in use. DHS S&T stated that electrochemical cells (and a variety of slower responding detector tubes) are used to fill the gaps in detection presented by IMS and SAW devices and expand the number of TICs that can be detected. Detection sensitivity of the electrochemical cells can range from ppb to low parts per million (ppm) concentration ranges. In general terms, TICs can be detected at concentrations considerably less than immediately dangerous, ranging in times from seconds to a few minutes, depending on the detector. DHS officials stated that these observations are based on an examination of manufacturers' claims that in some cases have been independently tested and evaluated.

First Responders' Handheld Biological Detectors Are Ineffective

During the emergency response phase of a suspected exposure to a biological threat agent, the only tool most likely available to first responders would be HHAs. HHAs are small test strips that contain an antibody to a specific biological agent. The assays require a suspension of the suspect sample in a liquid supplied with the test assay. Applying the liquid suspension to the strip yields a result in approximately 15 minutes. A quality control test is built into all the strips to indicate whether the assay materials are working properly.

However, according to officials in DHS S&T, HHAs do not have the sensitivity to detect the atmospheric concentrations of agents that pose health risks without large volume air collectors. A 2002 memorandum from the White House Office of Science and Technology Policy (OSTP) recommended against first responders' using HHAs. It stated that

> "Recent scientific evaluation of these commercially available detection systems concludes that this equipment does not pass acceptable standards for effectiveness. Specifically, *Bacillus anthracis* detection thresholds for these devices are well above the minimum level that can infect personnel, and are not suitable for determining biological determinants of personnel, rooms, or pieces of equipment. Many devices have been shown to give a significant number of false positives, which could cause unnecessary medical interventions with its own risk."[14]

OSTP's recommendation was based on a joint evaluation study by the Centers for Disease Control and Prevention (CDC) and the Federal Bureau of Investigation (FBI). Manufacturers of HHAs have expressed concern regarding the study's methods, objectivity, and overall quality.

According to DHS S&T officials, since the 2002 OSTP guidance, DHS has sponsored the development of standards for HHA detection of *Bacillus anthracis* through AOAC International, AOAC testing of a number of

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[14] John H. Marburger III, Director, "Purchase of Anthrax Detection Technologies," Memorandum for Federal Mail Managers and First Responders to Federal Mail Centers, Executive Office of the President, Office of Science and Technology Policy, Washington, D.C., July 19, 2002.

HHAs, and the development and propagation of ASTM International (originally known as the American Society for Testing and Materials) standards for sampling of white powders.[15] ASTM International developed standard E2458, *Standard Practices for Bulk Sample Collection and Swab Sample Collection of Visible Powders Suspected of Being Biological Agents from Nonporous Surfaces*, published in 2006. This standard was developed by CDC, DHS, EPA, the FBI, and state and local hazmat specialists.

DHS S&T officials noted that a biological attack is likely to be covert, and since no visible signatures or odors are associated with a release and people do not immediately fall ill, there will be no indicators for a first responder to know there was an attack. First responders for biological events are not likely to appear on the scene until well after the primary release cloud has dispersed. Therefore, all characterization is likely to be after the atmospheric release cloud has passed. The hazards first responders will encounter are surface contamination and any possible reaerosolization. In that case, S&T officials stated, the information to characterize the affected region is likely to come from environmental sampling (for example, BioWatch, surface sampling, or native air collectors) coupled with plume modeling and, as disease progresses, epidemiological information.

BioWatch Does Not Provide First Responders Real-Time Detection of Biological Pathogens

BioWatch is a nationwide environmental monitoring system for selected biological pathogens but does not provide first responders real-time detection of them. Under the current BioWatch system, a threat agent is not identified until several hours to more than a day after the release of the agent, and the system does not determine how much material was released. DHS BioWatch officials said that the system gives a qualitative rather than quantitative assessment of the release of biological material.

BioWatch is funded and managed by DHS and coordinated with CDC and EPA. LANL and LLNL provide technical support. BioWatch was designed to detect the release of biological pathogens in the air through aerosol

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[15] AOAC International is an independent scientific association of analytical scientists with members throughout the world. AOAC provides validated methods, proficiency test samples, accreditation criteria, and scientific information to industry, government agencies, and academic institutions. See www.aoac.org.

collector units installed in several major U.S. cities. The units collect airborne particles on filters, which are transported to laboratories for analysis. Set up very quickly in early 2003, according to DHS BioWatch Program officials, more than 30 jurisdictions now participate in BioWatch. DHS spending for the BioWatch program during fiscal years 2005 to 2007 was about $236 million.[16]

The BioWatch network of sampling units collects aerosol samples daily (fig. 1). Each aerosol collector has a single filter that traps aerosol particles. Couriers collect the air filters every 24 hours and deliver them to state or local public health laboratories, where they are tested for the presence of the genetic material of six specific biothreat pathogens. The BioWatch Laboratory assay, however, cannot differentiate between infectious and noninfectious agents (that is, live or dead germs).

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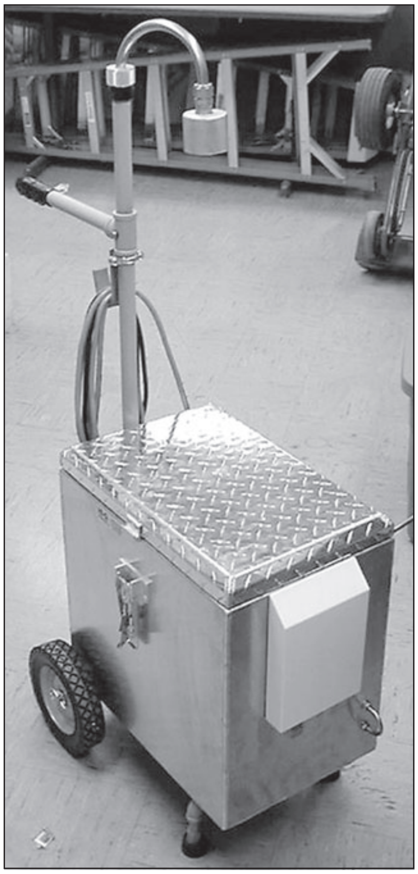
[16] DHS BioWatch officials provided cost data on the following program categories: Management, Oversight, and Program Control; Laboratory Operations; Field Operations; Studies and Analyses; National Security Special Events; New Technology Development and Transition, and Public Health Support-Outreach and ReachBack.

Figure 1: A BioWatch Aerosol Collector



Source: DHS.

First responders cannot use BioWatch to immediately determine an adequate response. While BioWatch is a detect-to-treat system designed to detect a biological attack in advance of symptoms arising within a population, it cannot help first responders make immediate medical intervention decisions. BioWatch is not intended to detect a release while it is in progress. It is intended to detect a release as soon after an event as practical and before the onset of symptoms so as to speed the delivery of medical countermeasures. DHS officials stated that BioWatch was not intended as a tool for first responders. A confirmed laboratory test result from a BioWatch sample, known as a “BioWatch Actionable Result,” is a data point used by the local Director of Public Health and BioWatch Advisory Committee to determine if the result has public health significance and, if it does, what actions are necessary to address a potential problem. If a response is necessary, the local jurisdiction’s

Incident Management System is used to determine the nature and logistics of the response. First responders may or may not be deployed.

The current BioWatch system can detect an aerosol attack with specific threat agents within several hours to more than 1 day after the release of the agents. This period of time includes the sample collection cycle of 24 hours, transportation to public health laboratories, and laboratory analysis to identify and confirm the agents used. According to DHS BioWatch officials, in general, symptoms would not develop until days to weeks after an attack.

However, experts have emphasized the importance of "real-time detection" of biological agents as an element of an effective biological detection system.[17] The system should rapidly recognize the release of likely biological agents before the onset of clinical illness. Without the benefit of real-time biological detection, a terrorist biological attack cannot be detected until the clinical analysis of the initial outbreak of patients' demonstrating symptoms and early fatalities. This delayed detection will allow disease to progress rapidly within the population and grow to potentially epidemic proportions. Real-time detection enables first responders to take action to limit the number of people exposed to the agent, allowing time to warn others before they are exposed and reduce the number of infections. Real time has been defined as 30 seconds or less from the time potential material reaches the device until an alarm is triggered.[18]

DHS officials stated that public health officials in the jurisdictions where BioWatch collectors are located can and plan to use BioWatch information immediately to make decisions about responses. They noted that a wide range of decisions is possible and that a specific course of action depends on such factors such as current intelligence about threats, the type of agents detected, the amount detected, the number of BioWatch collectors affected, and information from medical surveillance systems. BioWatch is moving toward next-generation technology, which will provide autonomous collection and detection and better time resolution than current BioWatch collector units.

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[17] Laszlo Retfalvi and others, "The Challenges of Effective Biological Agent Detection in Homeland Security Applications" (paper, 8th International Symposium on Protection against Chemical and Biological Warfare Agents, June 2004).

[18] Retfalvi, p. 7.

CBRN Detection Equipment Has Few Performance Standards and Is Not Independently Tested to Validate Manufacturers' Claims

First responders are hampered by the slow development of CBRN equipment detection standards. The CBRN detection equipment that first responders and other DHS grantees buy with DHS grant funds must comply with equipment performance standards adopted by DHS. However, DHS has adopted very few standards for this equipment, and the adoption of accepted standards has lagged behind the pace at which new products enter the market. In addition, according to our survey of federal agencies, DHS has the primary mission to develop, independently test, and certify CB detection equipment for first responders' use. However, DHS does not independently test and validate whether commercially available CBRN detection equipment can detect specific agents at specific target sensitivities claimed by the manufacturers.

DHS Grant Funds Allow First Responders to Acquire CBRN Detection Equipment

DHS's grant funding to states allows first responders to purchase commercially available CBRN detection equipment. First responders may use DHS's major grant funding under the State Homeland Security Program (SHSP) and Urban Areas Security Initiative (UASI) to buy equipment from the 21 categories on DHS's authorized equipment list. Detection equipment, category 7, is available for CBRN detection. For biological detection, for example, this includes field assay kits, protein test kits, DNA and RNA tools, and biological sampling kits, but descriptions and features, models and manufacturers, and operating considerations are not identified.

In the states we visited, we obtained information on detection equipment bought with DHS grant funds in 2003–2005. For example, in Seattle and the state of Washington, state agencies, hazmat teams, and local fire departments in 11 counties acquired CBRN detection equipment with about $3.2 million of SHSP and UASI grant funds in 2004–2005. Seattle alone purchased CBRN detection equipment, mostly chemical detection equipment, at a cost of about $500,000, primarily with UASI grants. According to the Assistant Chief of the Seattle Fire Department, about 20 to 26 hazmat teams served nine counties, varying widely in composition and equipment, with small populations and rural teams not having the capabilities of those in urban areas. Connecticut spent about $1.8 million in DHS grants for CBRN detection equipment in 2003–2005.

DHS Has Adopted Few Performance Standards for CBRN Detection Equipment

The purpose of standards for equipment is to ensure that equipment meets a minimum level of performance, functionality, adequacy, durability, sustainability, and interoperability. Adopting uniform standards for equipment helps first responders in procuring and using equipment that is safe, effective, and compatible. DHS works with a number of federal agencies and private organizations in developing standards for CBRN detection equipment, including NIST and IAB.[19] DHS's Standards Subject Area Working Groups and these organizations work, in turn, with standards development organizations such as ASTM and the National Fire Protection Association.

DHS's S&T directorate is the focal point for adopting CBRN detection equipment standards. According to a 2006 DHS Office of Inspector General report on DHS's adoption of equipment standards, S&T can adopt standards that apply to equipment first responders purchase with DHS grant funds, but it cannot develop mandatory standards for equipment because it has no authority to regulate the first responder community.[20] In addition, DHS S&T has no regulatory authority to compel first responders to purchase equipment not purchased with federal funds that conforms to S&T adopted standards or to order manufacturers not to sell equipment that does not meet these standards. NIST's OLES identifies needed performance standards and obtains input from others, such as IAB.[21]

As of October 30, 2007, DHS had adopted 39 total standards, but only 4 of them were for CBRN detection equipment. In February 2004, it adopted 4 standards for radiation and nuclear detection equipment. These standards address first responders' priorities for personal radiation detection and devices for detecting, interdicting, and preventing the transport of radioactive material rather than the detection of the atmospheric spread of radiation materials. Table 2 shows standards DHS adopted for radiation and nuclear detection equipment.

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[19] IAB is a users' working group of responders from the federal government, various local and state governments, and private organizations. It is designed to establish and coordinate local, state, and federal standardization, interoperability, compatibility, and responder health and safety to prepare for, train, respond to, mitigate, and recover from incidents by identifying requirements for an all-hazards incident response, with a special emphasis on CBRNE issues (E representing explosives).

[20] DHS, Office of Inspector General, *Review of DHS' Progress in Adopting and Enforcing Equipment Standards for First Responders*, OIG-06-30 (Washington, D.C.: March 2006).

[21] OLES also serves as IAB's executive agent for implementing and administering first responder equipment standards. IAB has developed a strategic plan to identify, adopt, modify, and develop a common suite of first responder equipment standards.

Table 2: DHS's Radiation and Nuclear Detection Equipment Standards

Standard	Requirement	Function
Performance criteria for alarming personal radiation detectors for homeland security	Design and performance criteria and testing methods for evaluating performance	Pocket-sized instruments carried on the body to detect the presence and magnitude of radiation
Radiation detection instrumentation for homeland security	Design and performance criteria, test and calibration requirements, and operating instruction requirements	Portable radiation detection instruments to detect photon-emitting radioactive substances for detection, interdiction, and hazard assessment
Performance criteria for handheld instruments for detecting and identifying radionuclides	Test procedures and radiation response requirements and electrical, mechanical, and environmental requirements	Instruments to detect and identify radionuclides, gamma dose rate measurement, and indication of neutron radiation
Evaluation and performance of radiation detection portal monitors for use in homeland security	Testing and evaluation criteria	Radiation detection portal monitors to detect and interdict radioactive materials that could be used for nuclear weapons or radiological dispersal devices

Source: DHS.

However, DHS has not adopted any standards for CB detection equipment.[22] The remaining standards address personal protective equipment such as respirators and protective clothing. NIST officials told us that it generally takes 3 to 5 years for an equipment standard to achieve full consensus from the network of users, manufacturers, and standards development organizations before final publication. DHS, however, noted that standards for radiation detection equipment and powder sampling were developed in 12 to 18 months.

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[22] A new standard for chemical warfare vapor detectors that DHS has not yet adopted—ASTM E2411-07, Standard Specification for Chemical Warfare Vapor Detector—would establish minimum performance requirements to detect, identify, and quantify the amount of chemical agent vapor in a threat environment. The instrument would be able to simultaneously detect multiple threat agents at or below levels that are immediately dangerous to life or health. The standard requires detection at the first level of EPA's acute exposure guidelines or lower.

DHS Has the Primary Mission to Develop, Independently Test, and Certify First Responders' Chemical and Biological Detection Equipment

We surveyed major federal agencies involved with CBRN defense about their missions to develop, independently test, and certify CBR detection equipment for first responders' use. To certify CBR detection equipment is to guarantee a piece of equipment as meeting a standard or performance criterion into the future. Certification must be based on testing against standards. According to DHS, certification is the attestation that equipment has been tested against standards using approved testing protocols by an accredited test facility. Table 3 shows agency responses to our survey, in which we found that only DHS indicated it has the missions to develop, independently test, and certify CB detection equipment for first responders' use.

Table 3: Agency Missions to Develop, Independently Test, and Certify CBR Detection Equipment for First Responders' Use

	Develop			Independently test			Certify		
Agency	**C**	**B**	**R**	**C**	**B**	**R**	**C**	**B**	**R**
DHS	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
DOD	No	No	No	No	No	No	No	No	No
DOE	No	No	No	No	No	No	No	No	No
EPA	No	No	No	No	No	No	No	No	No

Source: GAO.

According to DHS, DHS's components, principally the Federal Emergency Management Agency (FEMA) and the Office of Health Affairs, in conjunction with IAB, identify first responders' needs for CB detection equipment. However, DHS officials stated that their mission to test and certify CB detection equipment is limited to equipment that DHS is developing for first responders; it does not extend to detection equipment they purchase from commercial manufacturers.

DHS Is Not Independently Testing Manufacturers' Claims about CBRN Detection Equipment

DHS does not independently test and validate whether commercially available CBRN detection equipment can detect specific agents at specific target sensitivities claimed by the manufacturers. Although manufacturers may test equipment in a controlled laboratory environment using simulants, live agent testing and field testing by independent authorities provides the best indication of performance and reliability.

DHS S&T acknowledged that it does not have a testing program to independently test the performance, reliability, and accuracy of commercial CBRN detection equipment and determine whether specific, currently available detectors can detect at specific target sensitivities. No organized DHS evaluation and qualification program now guides and informs first responders on their purchases of chemical, biological, and radiological detection equipment. DHS relies on manufacturers' claims and anecdotal information in the open literature; it has not routinely tested or verified manufacturers' claims regarding equipment's ability to detect hazardous material at specific sensitivities.

DHS stated that test data may be found for some systems examined under its earlier Domestic Preparedness Program or other agency programs such as EPA's Environmental Technologies Verification Program.[23] However, we have not independently evaluated what, if any, CBRN technologies they have evaluated. Moreover, the testing is often at the anecdotal level since few copies of a given detector model are tested in these programs. DHS further stated that because the manufacturers' claims and, where available, limited testing data for different models of the detector systems are quite varied, compiling data at a reasonable confidence level would require a substantial current market survey.

DHS S&T officials said that manufacturers have asked DHS to establish a process for validating biodetection equipment. One official said that first responders are purchasing biodetection equipment that is "junk" because there are no standards and testing programs. Local and state first responders we interviewed also said that they often test and validate manufacturers' claims on their own. For example, Washington State Radiation Protection officials said that in one instance they tested one brand of new digital dosimeters they were planning to purchase against those they already used. They found that the brand tested consistently read only 40 percent of what their current dosimeters and instruments read.

DHS has two programs in place to provide first responders with information about CBRN detection equipment. One program, DHS's System Assessment and Validation for Emergency Responders (SAVER) program, assesses various commercial systems that emergency responders and DHS identify as instrumental in their ability to perform their jobs. The

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[23] According to EPA, its Environmental Technology Verification Program develops testing protocols and verifies the performance of innovative technologies that have the potential to improve the protection of human health and the environment. The goal of the program is to provide credible performance data for commercial-ready environmental technologies to speed their implementation for the benefit of purchasers, vendors, and the public.

assessments are performed through focus groups of first responders who are asked for their views on the effectiveness of a given technology based on a set of criteria.[24] The criteria address the equipment's capability, usability, affordability, maintainability, and deployability. However, DHS officials acknowledged that SAVER neither conducts independent scientific testing to determine the extent to which the equipment can detect actual chemical warfare agents nor tests or verifies manufacturers' claims regarding the equipment's ability to detect given hazardous material at specific sensitivities. As of October 2007, SAVER had conducted assessments of IMS chemical detectors, multisensor meter chemical detectors, photo-ionization and flame-ionization detectors, radiation pagers, and radiation survey meters, but it had not tested or verified manufacturers' claims regarding commercial off-the-shelf CBRN detection equipment's ability to detect given hazardous material at specific sensitivities. We have not independently evaluated the SAVER assessments.

The other information source for first responders is DHS's RKB, a Web-based information service for the emergency responder community. RKB is a one-stop resource that links equipment-related information such as product descriptions, standards, operational suitability testing, and third-party certifications. As of October 2007, it included 1,127 certifications for equipment on DHS's authorized equipment list and 268 reports of operational suitability testing of CBRN equipment by such organizations as the U.S. Army's Edgewood Chemical Biological Center (ECBC).[25]

Information available to first responders on CBRN detection equipment sensitivities comes largely from vendors' claims, either directly from a vendor or through vendor-maintained specification sheets on the RKB, reference guides NIST has developed, and reference guides ECBC has developed. The information in the guides is based on literature searches and market surveys and includes manufacturers' statements on product

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[24] The SAVER program is also supported by other organizations, including DHS's Center for Domestic Preparedness; DOE's Nevada Test Site; the Science Applications International Corporation; the Technical Support Working Group; the U.S. Army Soldier Systems Center, Natick, Massachusetts; and the U.S. Space and Naval Warfare Systems Center, Charleston, South Carolina.

[25] DOD has also established the Non-Standard Equipment Review Panel that evaluates commercial off-the-shelf chemical and biological defense equipment DOD purchases for consequence management. The DOD panel has established partnerships with DHS's RKB and SAVER programs to share information and leverage existing resources.

capabilities. However, the guides do not contain any testing data that would validate the manufacturers' claims. The guides, recently incorporated on DHS's SAVER Web site, also have not kept pace with emerging technology. They include the 2007 ECBC biological detector market survey, the 2005 NIST biological agent detection equipment guide, and the 2005 NIST chemical agent detection equipment selection guide.

Plume Models for Analyzing Urban Dispersion of CBRN Agents Have Limited Capabilities

Federal agencies such as DHS, DOD, DOE, and EPA have developed several nonurban plume models for tracking the atmospheric release of CBRN materials. Interagency studies, however, have concluded that these models have major limitations for accurately predicting the path of plumes and the extent of contamination in urban environments. Current models commonly used in emergency response do not have the resolution to model complex urban environments, where buildings and other structures affect wind flow and the structure and intensity of atmospheric turbulence. DHS's national TOPOFF exercises have also demonstrated that the use of several competing models, using different meteorological data and exercise artificiality, can produce contradictory results, causing confusion among first responders.

Evaluations and field testing show that urban plume models federal agencies have developed specifically for tracking the release of CBRN materials in urban areas have some of the same limitations as the older models used for emergency response. The new models show much variability in their predictions, and obtaining accurate source term data on the release of TICs is also a problem.

Nonurban Plume Models Have Limitations for Emergency Response to CBRN Events in Urban Environments

When using information from nonurban plume models in CBRN events, first responders may have to choose from the multiple models that various agencies support for tracking the release of CBRN materials. Several federal agencies operate modeling systems, including DHS, DOD, DOE, EPA, NOAA, and the Nuclear Regulatory Commission. U.S. interagency studies, however, have concluded that these models have major limitations. For example, according to OFCM, in the Department of Commerce, most of the more than 140 documented modeling systems used for regulatory, research and development, and emergency operations purposes, and for calculating the effects of harmful CBRN materials, are limited in their ability to accurately predict the path of a plume and the extent of contamination in urban environments. Table 4 shows examples of models that federal agencies and first responders have developed and used to predict the path of the plume for multiple CBRN materials.

Table 4: Six CBRN Models Federal Agencies and First Responders Use

Agent modeled	Model	Agency
Chemical, biological, radiological, nuclear	• HPAC: Hazard Prediction and Assessment Capability • SCIPUFF: Second-order Closure Integrated Puff	Defense Threat Reduction Agency
	LODI: Lagrangian Operational Dispersion Integrator	• Department of Energy • Lawrence Livermore National Laboratory/National Atmospheric Release Advisory Center
Chemical	• ALOHA: Areal Locations of Hazardous Atmospheres • CAMEO: Computer-Aided Management of Emergency Operations	• Environmental Protection Agency • National Oceanic and Atmospheric Administration
	HYSPLIT: Hybrid Singe-Particle Lagrangian Integrated Trajectory	National Oceanic and Atmospheric Administration
Radiological	HOTSPOT	• Department of Energy • Lawrence Livermore National Laboratory
Radiological, nuclear	RASCAL: Radiological Assessment System for Consequence Analysis	Nuclear Regulatory Commission

Source: OFCM.

OFCM provides the coordinating structure for federal agencies involved in modeling and has established interagency forums and working groups that have developed studies evaluating models available to address homeland security threats. In an August 2002 study, OFCM and other agencies evaluated 29 modeling systems used operationally by either first responders or federal agencies.[26] The study concluded that (1) few models had been tested or validated for homeland security applications; (2) their ability to predict the dispersal of chemical, biological, or radiological agents through urban buildings, street canyons, and complex terrain was not well developed; and (3) they could provide only a rudimentary description of the nocturnal boundary layer and not the more complex turbulence resulting from complex buildings, terrain, and shorelines.[27]

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[26] OFCM, *Atmospheric Modeling of Releases from Weapons of Mass Destruction: Response by Federal Agencies in Support of Homeland Security* (Silver Spring, Maryland: Aug. 1, 2002).

[27] The atmosphere near Earth's surface, called the boundary layer, is influenced by temperature, turbulence, air flow, and the like. It consists of a very turbulent mixed layer, a less turbulent residual layer, and a nocturnal, stable, sporadically turbulent boundary layer. Winds in the nocturnal boundary layer often accelerate at night.

According to DOD officials, many of these models were not developed for emergency response. For example, DOD developed HPAC as a model for counterproliferation purposes, but first responders also use it.[28] In addition, DOD officials said that some of the deficiencies OFCM noted have been somewhat addressed with the development of urban plume models. (We discuss urban plume models later in the report.)

A 2003 National Research Council (NRC) study on modeling capabilities reached essentially the same conclusions, stating that plume models in operational use by various government agencies were not well designed for complex natural topographies or built-up urban environments and that, likewise, the effects of urban surfaces were not well accounted for in most models.[29] No one model had all the features deemed critical—(1) confidence estimates for the predicted dosages, (2) accommodation of urban and complex topography, (3) short execution time for the response phase, and (4) accurate if slower times for preparedness and recovery. Both fast execution response models and slower, more accurate models needed further development and evaluation for operational use in urban settings, according to NRC.

In urban areas, buildings and street canyons separating them often cause winds that are almost random, making it exceedingly difficult for models to predict or even describe how CBRN materials are dispersed when released. Buildings create complex wind and turbulence patters in urban areas, including updrafts and downdrafts; channeling of winds down street canyons; and calm winds or “wake” regions, where toxic materials may be trapped and retained between buildings. Since most existing models have little or no building awareness, they could be misapplied in urban settings with fatal consequences. According to LLNL modeling experts, misinterpretation of modeling results is a key issue facing first responders. Many users assume that models are more accurate than warranted, because of the impression left by model predictions showing that individual buildings may actually not be accurately predicting fine-scale

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[28] Counterproliferation is the full range of military preparations and activities to reduce, and protect against, the threat posed by chemical, biological, and nuclear weapons and their associated delivery means.

[29] NRC, *Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases: Implications for Homeland Security* (Washington, D.C.: National Academies Press, 2003), p. 4.

features, like the location of hot spots and plume arrival and departure times.

Obtaining information on the source term, or the characteristics of CBRN materials released, is also a problem with current models, especially in complex urban environments. When modeling is used in an emergency, characterizing the source term and local transport is typically the greatest source of uncertainty. First responders' key questions are, What was released, when, where, and how much? Locating the source and determining its strength based on downwind concentration measurements is complicated by the presence of buildings that can divert flow in unexpected directions. Answers may not be available or may be based on uncertain and incomplete data that cannot be confirmed. For example, evidence of the release of a biological agent may not be known for days or weeks, when the population begins to show symptoms of exposure, becomes ill, and is hospitalized.

Information from four basic categories of models is available to first responders today:

1. Gaussian plume or puff models, widely used since the 1940s, can be run quickly and easily by nonspecialists. They typically use only a single constant wind velocity and stability class to characterize turbulence diffusion. They can be reasonably reliable over short ranges in situations involving homogeneous conditions and simple flows, such as unidirectional steady state flow over relatively flat terrain. The CAMEO/ALOHA model is a Gaussian plume model that has been widely distributed to first responders.

2. Lagrangian models (puff and particle) provide more detailed resolution of boundary layer processes and dispersion. Puff models represent plumes by a sequence of puffs, each of which is transported at a wind speed and direction determined by the winds at its center of mass. Lagrangian particle models use Monte Carlo methods to simulate the dispersion of fluid marker particles.[30] These models can capture plume arrival and departure times and peak concentrations. Examples of

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[30] A Monte Carlo method is a computational algorithm that relies on repeated random sampling to compute its results. Monte Carlo methods are often used when simulating physical and mathematical systems.

models in this category include HPAC (puff model), HYSPLIT and LODI (particle models).

3. Computational fluid dynamics (CFD) are first principles physics models that simulate the complex flow patterns created in urban areas by large buildings and street canyons. CFD models provide the highest fidelity transport and diffusion simulations but are computationally expensive compared to Gaussian or Lagrangian models. They can take hours or days to run on a large computer. However, CFD models can capture plume arrival and departure times and peak concentrations.

4. Empirical urban models are derived from wind tunnel and field experiment data. These models incorporate urban effects by explicitly resolving buildings. Such models are not considered as accurate as CFD models because of their empirical basis, particularly for the highest temporal and spatial resolutions and near-source regions. They need to be carefully validated. Examples include the Urban Dispersion Model and the Quick Urban and Industrial Complex dispersion modeling system.

For example, EPA and NOAA developed the CAMEO/ALOHA model specifically for first responders' use. Widely used by state and local first responders, it originated as an aid in modeling the release of TICs but has evolved over the years into a tool for a broad range of response and planning. CAMEO is a system of software applications used to plan for and respond to chemical emergencies and includes a database with specific emergency response information for over 6,000 chemicals. ALOHA can plot a gas plume's geographic spread on a map. It employs an air dispersion model that allows the user to estimate the downwind dispersion of a chemical cloud based on the toxicological and physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release.

However, like any model, CAMEO/ALOHA cannot be more accurate than the information given to it to work with. Even with the best possible input values, CAMEO/ALOHA can be unreliable in certain situations, such as at low wind speeds, very stable atmospheric conditions, wind shifts and terrain steering effects, and concentration patchiness, particularly near the spill source of a release. CAMEO/ALOHA does not account for the effects of byproducts from fires, explosions, or chemical reactions; particulates; chemical mixtures; terrain; and hazardous fragments. It does not make predictions for distances greater than 6.2 miles (10 kilometers) from the release point or for more than an hour after a release begins, because wind frequently shifts direction and changes speed.

TOPOFF 2 Revealed Weaknesses in Coordinating Plume Modeling Efforts

That using several competing models supported by different agencies can produce contradictory results and confuse first responders was highlighted during DHS's TOPOFF 2003 and 2005 exercises. The TOPOFF exercises are biennial, congressionally mandated, national counterterrorism exercises designed to identify vulnerabilities in the nation's domestic incident management capability. They test the plans, policies, procedures, systems, and facilities of federal, state, and local response organizations and their ability to respond to and manage scenarios depicting fictitious foreign terrorist organizations detonating or releasing simulated CBRN agents at various locations in the United States. One important aim is to identify any seams, gaps, and redundancy in responsibilities and actions in responding to the simulated attacks. DHS's after-action reports for each exercise showed continuing problems in the coordination of federal, state, and local response and in information sharing and analysis. The four TOPOFF exercises conducted 2000–07 are summarized in table 5.

Table 5: Top Officials Exercises 1–4, 2000–2007

TOPOFF	Date	Place	Attack type simulated
1	May 20–24, 2000	Portsmouth, N.H.	Chemical: mustard gas
		Denver, Colo.	Biological: pneumonic plague
		Washington, D.C.	Radiological: dispersion device
2	May 12–16, 2003	Chicago, Ill.	Biological: pneumonic plague
		Seattle, Wash.	Radiological: dirty bomb
3	April 4–8, 2005	New London, Conn.	Chemical: mustard gas
		New Jersey	Biological: pneumonic plague
4	October 15–20, 2007	Guam	Radiological: dirty bomb
		Phoenix, Ariz.	Radiological: dirty bomb
		Portland, Ore.	Radiological: dirty bomb

Source: DHS.

TOPOFF 2, 3, and 4 used plume models. In TOPOFF 2, on May 12–16, 2003, federal, state, local, and Canadian responders, leaders, and other authorities reacted to a fictitious foreign terrorist organization's detonation of a simulated radiological dispersal device, or dirty bomb, in

Seattle.[31] It showed the federal government's inability to coordinate and properly use atmospheric transport and dispersion models. According to DHS internal reports, critical data collection and coordination challenges significantly affected the response to the attack in Seattle and the ability to get timely, consistent, and valid information to top officials.

During the exercise, different federal, state, and local agencies and jurisdictions used different plume models to generate predictions, which led to confusion and frustration among the top officials. Seattle and Washington state officials told us that federal agencies provided modeling results not based on the preplanned series of scenario events exercise planners had established. They said that some of the data used to create the differing models had been made up in order to drive a federal agency's objectives for the exercise and bore no relationship to data that responders gathered at the scene.

For example, Seattle City Emergency Management officials from the fire and police departments said that the city was operating on readings it received from the Federal Radiological Monitoring and Assessment Center (FRMAC) while the state modeled a larger area for the plume.[32] Washington state officials also said that the deposition data received from field teams were not consistent with the National Atmospheric Release Advisory Center's (NARAC) plume modeling predictions.[33] NARAC modeling experts, however, stated that NARAC provided plume model predictions and worked with FRMAC to update model predictions as data became available. NARAC plumes were later found to be consistent with the ground truth used in the exercise. They attributed the disparity of data from the field to plume modeling predictions to exercise artificiality and

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[31] NRC defines "dirty bomb" as a weapon not of mass destruction but, rather, of "mass disruption," combining a conventional explosive, such as dynamite, with radioactive material that, "depending on the scenario . . . could create fear and panic, contaminate property, and require potentially costly cleanup." See "Fact Sheet on Dirty Bombs," U.S. Nuclear Regulatory Commission, Washington, D.C. http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/dirty-bombs.html.

[32] The mission of FRMAC, part of DOE's National Nuclear Security Administration, is to coordinate and manage all federal radiological monitoring and assessment activities during major radiological emergencies within the United States in support of state, local, and tribal governments.

[33] The mission of NARAC, at LLNL, the DHS and DOE operational support and resource center for plume modeling, is to provide timely and credible assessment advisories to emergency managers for hazardous releases to the atmosphere in order to help minimize exposure of the populations at risk.

the improper generation and interpretation of simulated exercise data for state-deployed field teams.

Washington State Emergency Management officials stated that the "canned" weather patterns factored into the model conflicted with real-time weather reports. Running counter to typical norms, they went almost directly against the prevailing winds and "straight as an arrow" where the terrain would certainly have diverted their path. Confusion resulted from models being generated using different meteorological inputs. The resulting plume models were contradictory. NARAC/IMAAC modeling experts stated that the exercise called for the ground truth scenario to be based on the canned winds and that contradictory results were obtained by exercise players who did not use the ground truth scenario canned weather.[34] However, NOAA modeling experts said that the ability of the TOPOFF exercises to identify gaps in plume modeling was limited by the use of canned weather patterns. In a real situation, the models would be run with current weather data.

Further, in TOPOFF 2, coordination was lacking between state and local and federal plume modeling. For example, the Seattle Emergency Operations Center contacted NARAC after the explosion, as called for in the exercise scenario, to have it generate a prediction of where the plume would travel. NARAC's product (shown in fig. 2) was provided to the Seattle, King County, and Washington State emergency operations centers, as well as to FEMA and other federal agencies. However, the Washington State Department of Health also generated a plume prediction with a HOTSPOT modeling program, adding to the confusion. In addition, several federal agencies developed their own plume predictions to make internal assessments concerning assets that might be required. As a result, while Seattle, King County, Washington State, and federal officials all had access to NARAC plume modeling results, state and federal agencies still chose to use other available models for information from which to make their preliminary decisions.

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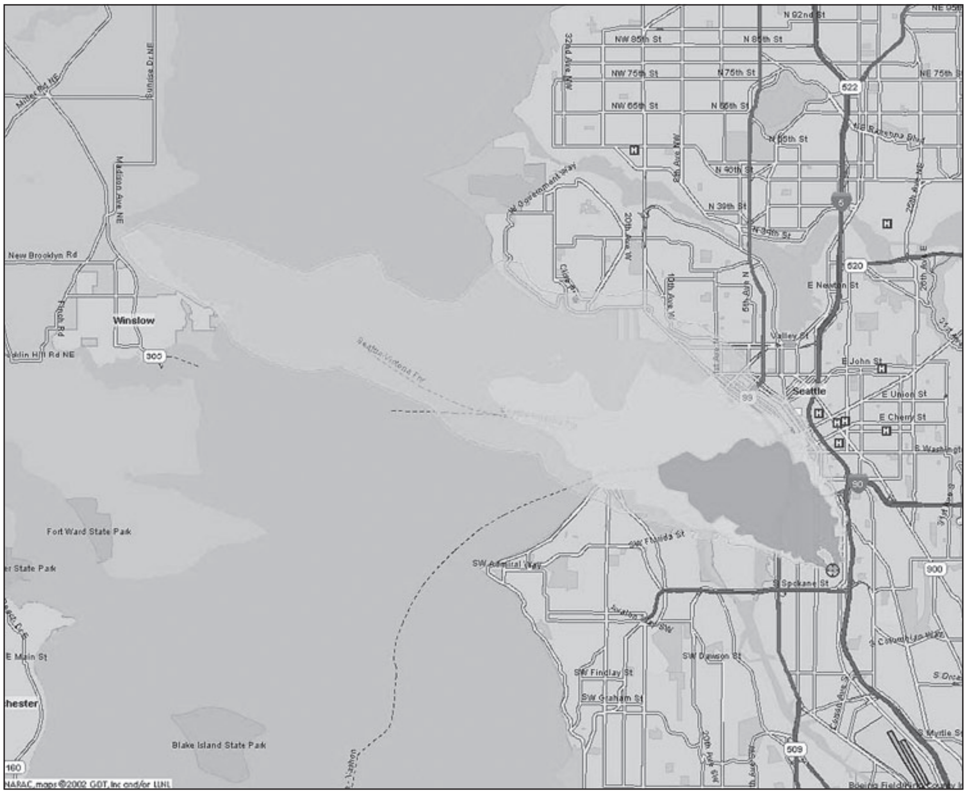
[34] Ground truth, as we indicated earlier, refers to information collected on location to verify modeling. It relates the model simulation to real features and materials on the ground.

Figure 2: NARAC's TOPOFF 2 Plume Prediction



Source: NARAC, LLNL.

The Creation of the Interagency Modeling and Atmospheric Assessment Center

The confusion over the use of multiple modeling tools in TOPOFF 2 led DHS to establish IMAAC in 2004 as an interagency center responsible for producing, coordinating, and disseminating predictions for airborne hazardous materials. NARAC is the designated interim provider of IMAAC products. According to NARAC and IMAAC program officials, IMAAC's goals are to provide one point of contact for decision makers, eliminate confusing and conflicting hazard predictions, and distribute "common operating picture" predictions to federal, state, and local agencies with key information such as plume hazard areas, expected health effects, protective action recommendations (such as for sheltering or evacuation), and the affected population. NARAC and IMAAC staffs are available 24 hours a day, 7 days a week, to provide support and detailed analyses to emergency responders.

IMAAC does not replace or supplant the atmospheric transport and dispersion modeling activities of other agencies whose modeling activities support their missions. However, IMAAC provides a single point for the coordination and dissemination of federal dispersion modeling and hazard prediction products that represent the federal position during actual or potential incidents requiring federal coordination. IMAAC aims to draw on and coordinate the best available capabilities of participating agencies. It entered into a memorandum of understanding with several agencies in December 2004, including DOD, DOE, EPA, and NOAA, on their roles and responsibilities for supporting and using IMAAC's analyses and products. According to NARAC and IMAAC operations staff, NARAC and IMAAC can provide an automated prediction for CBRN events within 5 to 15 minutes.

TOPOFF 3 Revealed Continuing Problems in Coordinating Plume Modeling Results

TOPOFF 3, conducted April 4 to April 8, 2005, simulated the release of mustard gas and a high-yield explosive in New London, Connecticut. Despite the creation of IMAAC and its mission to coordinate the best available modeling capabilities of federal agencies, TOPOFF 3 revealed continuing problems in coordinating the results of competing modeling outputs. Exercise results from DHS internal reports indicated that IMAAC did not appear to have adequate procedures for dealing with discrepancies or contradictions in inputs or modeling requests from various agencies. Although numerous modeling analyses and predictions were continually refined and confirmed as evidence and field measurements were collected, conflicting and misleading data other agencies submitted on the source of attack and hazard areas resulted in confusion.

According to NARAC and IMAAC operations officials, however, IMAAC was continuously in contact with state and local responders to resolve discrepancies in modeling inputs and requests and to correct misinformation. IMAAC provided its first modeling analysis 49 minutes after it was notified of a truck bomb explosion near a large public gathering in New London, Connecticut. The modeling prediction had estimated that a 55-gallon drum of mustard agent could be released in a small explosion involving a small truck and that the public could suffer serious health effects. Connecticut officials said that initial modeling was done when the hazmat teams arrived at the explosion site; NARAC and IMAAC were contacted after 30 minutes, and the hazmat team gave NARAC input. The NARAC modeling analysis was reviewed, but information received from the FBI resulted in tweaks to the model.

A second IMAAC modeling analysis more than 2 hours after the explosion determined that the truck explosion had not caused the observed blister agent effects. Instead, reports of a small aircraft flying over the New London City Pier area had led IMAAC to develop another analysis that concluded that only an airplane's release could have caused the casualties. In fact, about 2 hours before the truck explosion, a small aircraft had flown over the New London City Pier, releasing mustard in a gaseous form over the area. IMAAC operations officials stated that they determined that the bomb could not have caused the mustard gas casualties based on (1) information that exposure victims were reporting at the time of the explosion and (2) its own analysis that the size of the truck bomb explosion would have destroyed virtually all chemicals that might have been associated with the bomb.

Five hours after the explosion, IMAAC developed a third modeling analysis, based on the small aircraft's dumping the mustard agent, estimating that the public gathering at the pier would develop significant skin blistering, consistent with the casualty reports. IMAAC refined this prediction, based on field data received from state and local responders, and a fourth modeling analysis 10 hours after the explosion predicted significant skin exposures and some inhalation effects.

NARAC and IMAAC officials stated that IMAAC continuously informed users that its analyses showed that the plane, and not the bomb, was the only source of contamination consistent with available data but was unable to correct other agencies' misperceptions. Several other agencies insisted that the source of the blister agent was the truck bomb. IMAAC continued during the next day to receive contradictory requests for products that did not incorporate dispersion from an airplane. The Connecticut Department of Environmental Protection requested an updated model run, based on a ground release, and DHS's S&T instructed IMAAC to produce model runs that did not include the airplane. The Connecticut Joint Field Office also sought plume products that assumed either an air or a ground release but not both. In addition, considerable misleading information came from the field, according to IMAAC operations, as additional field measurements were collected. This misinformation resulted from state officials' claim that the FBI had determined that the plane contained no chemicals. However, with additional field data, IMAAC conducted another modeling analysis that confirmed that a release from the aircraft was the only plausible source. On the third day, IMAAC, with the full set of 158 field measurements, again confirmed that the airplane's release was the source.

According to Connecticut officials, contradictory data and analysis caused confusion regarding the hazard area and whether to shelter the population in place or evacuate. They stated that they received definitive analyses from IMAAC that would allow people to evacuate their premises. While weather forecasts indicated that rainfall would wash away any mustard gas on the ground, EPA disagreed, interpreting its own data as showing more contamination on the ground. EPA could not, however, explain the origin of these data, and NARAC and IMAAC had no knowledge of them. The issue was finally resolved by deciding not to use the EPA data.

Exercise results from DHS internal reports concluded that IMAAC did not appear to have adequate procedures for dealing with discrepancies or contradictions in inputs or modeling requests from various agencies. Among the recommendations made were that IMAAC (1) clarify processes for receiving and reviewing other modeling products, (2) establish a protocol for other modeling agencies to distribute to their consumers on the purpose of IMAAC's product and guidelines for redistribution, and (3) develop procedures on how IMAAC should handle discrepancies in data inputs or product requests.

IMAAC officials do not concur with the exercise findings and conclusions regarding the effectiveness of its federal plume modeling coordination during the exercise. They state that significant progress was demonstrated during TOPOFF 3 in coordinating federal plume modeling despite the fact that TOPOFF 3 was conducted in April 2005, less than a year after IMAAC's creation and the interagency agreement on its roles. They further state that IMAAC successfully coordinated the federal plume modeling to federal, state, and local agencies. There were no "dueling federal plume models with inconsistent results," as were observed during TOPOFF 2. However, the exercise did demonstrate a need for procedures for dealing with conflicting modeling requests for various agencies. IMAAC officials state that its procedures now call for an IMAAC Operations Coordinator to coordinate modeling requests and tasking.

IMAAC officials said that they were unable to obtain a copy of the internal DHS report on exercise results from TOPOFF 3 and were not given an opportunity to provide input and review and correct the contents of the report. An official in FEMA's National Exercise Division said that TOPOFF 3 had an established process for obtaining comments from each of the participating agencies and from participants within DHS. However, the official could not explain why IMAAC was not given a copy of the report and a chance to provide comments.

An IMAAC Technical Working Group developed the first version of its standard operating procedures in December 2005. However, it described a generalized concept of operations that does not specify procedures for coordinating modeling inputs from other agencies or procedures for CBRN incidents. The initial procedures identified as a key issue the need to clarify the type and scale of what would constitute a major CBRN incident that qualifies for IMAAC assistance. The procedures described the various levels of engagement and notification for activation of IMAAC but did not define the type and scale of what constitutes an incident qualifying for IMAAC assistance.

IMAAC's director said that the use of plume modeling during TOPOFF 2 and 3 primarily showed the lack of coordination among the participants on how to use technology. State and local responders are not required to use IMAAC plots, and IMAAC does not become the single federal point for coordinating and disseminating federal dispersion modeling and hazard prediction products until a significant CBRN event is declared. Agreement must be obtained from all federal agencies before a coordinated response can be implemented.

- Although officials from DHS's S&T stated that the concept of operations and specific procedures for CBRN incidents were to be completed by the end of 2006, IMAAC's standard operating procedures have not yet been revised to (1) develop common/joint IMAAC emergency response practices with federal, state, and local agencies for dealing with contradictory plume modeling information from other agencies during a CBRN event; (2) refine the concept of operations for chemical, biological, and radiological releases; and (3) delineate the type and scale of major CBRN incidents that would qualify for IMAAC assistance.

The issue of how a significant CBRN incident is to be defined was clarified in the 2006 National Response Plan Notice of Change, and the new IMAAC activation language has been changed to support "incidents requiring federal coordination." NARAC and IMAAC officials noted that while these procedures are important, they would not have affected the confusing field information in TOPOFF 3. In addition, operating procedures were meant to cover only the interim period, until the permanent configuration of IMAAC has been determined.

TOPOFF 4 Shows Improvements in Coordinating Plume Modeling but Difficulties in Interpreting Results

TOPOFF 4 was conducted October 15–19, 2007, and used a radiological dispersal device scenario that included coordinated attacks in Guam, Portland, Oregon, and Phoenix, Arizona. On April 10, 2008, FEMA released its initial analysis and impressions of the exercise in an “After Action Quick Look Report.” Regarding plume modeling conducted during the exercise, the report stated that IMAAC provided consequence predictions and that there were no “dueling plume models,” as was observed during TOPOFF 2. According to the report, the processes established after TOPOFF 2 to minimize differences in plume modeling outputs and provide one source for consequence predictions appeared to be effective. IMAAC models were requested and used in all venues and decision makers appeared to understand that the model was only a prediction and would be periodically upgraded as actual data were collected and analyzed.

However, the report noted that while most federal, state, and local agencies were familiar with IMAAC and its responsibility for producing consequence predictions, they had difficulty interpreting the plume and consequence models predicting radiation dispersal. Local decision makers had to rely on state and local subject matter experts during the first 24 to 48 hours of the response for immediate protective action recommendations. The report stated that it proved to be a challenge to get that expertise to key state and local decision makers during the exercise.

The Chief of the Exercise Division at DHS stated that a better format was needed for decision makers, such as governors and mayors without scientific backgrounds, to use to interpret model predictions and communicate these predictions to the public.

Urban Plume Models Give Variable Predictions

Model evaluations and field testing show that plume models federal agencies have developed specifically for tracking the release of CBRN materials in urban areas have some of the same limitations as the older models used for emergency response. Few models have been sufficiently validated against meaningful urban tests, and these models are not yet used regularly in emergency response applications. The urban models show much variability in their predictions, and obtaining accurate source term data is also a problem. Three such models are the Urban Dispersion

Model (UDM), Quick Urban and Industrial Complex (QUIC) dispersion modeling system, and CT-Analyst.[35]

UDM, a component of the DTRA HPAC modeling suite shown in table 4, is a Gaussian puff model designed to calculate the flow of dispersion around obstacles in an urban environment. According to modeling experts, Gaussian models are fast (less than a second), but their precision is poor. DTRA entered into a cooperative agreement in fiscal year 2000 with the United Kingdom's Defence Science and Technology Laboratory and Defence Research and Development Canada to develop UDM. The program's objective was to enhance HPAC models in an urban domain.

In fiscal year 2000, the UDM program's first year, it developed an initial urban modeling capability; it implemented a special version of HPAC in fiscal year 2001, added three new urban modeling components and conducted two dispersion experiments in fiscal year 2002, conducted the largest urban dispersion experiment in history in collaboration with DHS and performed independent verification and validation of the urban modules in fiscal year 2003, and included operational urban capabilities in fiscal year 2004.[36] UDM combines the standard HPAC developed for rural environments with urban canopy wind and turbulence profiles, urban dispersion models, and an urban flow model. It was used at the 2001 U.S. presidential inauguration, 2002 Salt Lake Winter Olympics, 2004 Democratic and Republican conventions in Boston and New York City, and other high-profile events.

UDM was subjected to a validation and verification program that compared model predictions against a comprehensive selection of measurements drawn from a database of field experiment trials. It was compared with three different field trials covering ranges from tens of meters to kilometers. Model predictions showed a typical error of greater

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[35] Other urban plume models include the FEM3MP, a CFD urban model developed by LLNL; CFD-Urban, developed by CFD Research Corporation; FLUENT-EPA, a commercial model adapted by EPA; and FLACS/FEFLO–Urban. However, these CFD models are too slow to be used for real-time emergency response.

[36] The goal of verification and validation is a model that can accurately predict the performance of the real-world system that it represents, or to predict the difference in performance between two scenarios or two model configurations. DOD Instruction 5000.61 describes the requirements and procedures for the verification, validation, and accreditation of DOD models and simulations. See "DOD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)," DOD Instruction 5000.61, Under Secretary of Defense (Acquisition, Technology, and Logistics), May 13, 2003.

than 50 percent of the mean, and more than 54 percent of the predictions were within a factor of 2.[37] However, the field trials also showed a trend toward underprediction at close-in distances and overprediction at greater distances from the source. The model was found to overestimate plume width with increasing distance and, as a result, to underestimate plume concentration.

The QUIC dispersion modeling system produces a three-dimensional wind field around buildings, accounts for building-induced turbulence, and contains a graphic user interface for setup, running, and visualization. QUIC has been applied to neighborhood problems in Chicago, New York City, Salt Lake City, and Washington, D.C. QUIC has medium speed (1 to 10 minutes) and fair accuracy, according to modeling experts.

The Naval Research Laboratory and other groups have developed models, like CT-Analyst, that use CFD for fast-response applications. According to LLNL modeling experts, CFD models provide the highest fidelity simulations of the transport and diffusion of hazardous materials but are computationally more expensive and slow to operate. They can capture transient phenomena, such as plume arrival and departure times and peak concentrations. Accurate knowledge of peak concentrations is critical for determining the effect of many chemical releases, for which the health effects depend on instantaneous or short-term peak exposures rather than time-integrated dose. CFD models can predict the variation of concentrations over small (1-second) time scales and over small grid volumes (about 1 cubic meter).

Evaluations and field testing have shown an unpredictable range of uncertainty in urban dispersion models' analyses.[38] A series of urban field

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[37] D. R. Brook and others, "Validation of the Urban Dispersion Model (UDM)," *International Journal of Environment and Pollution* 20, nos. 1–2 (May 10, 2004): 11–21.

[38] A model evaluation usually has three main components: (1) an assessment of the model's physics, (2) an operational performance evaluation with field data, and (3) operational testing against real-world events. The physics is assessed from a scientific review and comparison of the model with data from intensive field experiments, as well as numeric and laboratory simulations. Data in the operational evaluation can be from intensive experiments or routine monitoring networks. Operational testing evaluates the usability, efficiency, consistency, and robustness of models for operational conditions. A central issue is how well models can be evaluated in the presence of a large natural variability in concentration from atmospheric turbulence. According to modeling experts, two major limitations of many model evaluations and field experiments are a lack of information on the vertical distribution of concentration and the random variability or inherent uncertainty in concentration.

experiments have been sponsored by a number of agencies since 2000. In October 2000, DOE sponsored a meteorological and tracer field study of the urban environment and its effect on atmospheric dispersion. Called Urban 2000, the study included seven intensive nightlong operation periods in which extensive meteorological measurements were made and tracer gases of sulfur hexafluoride and perfluorocarbon were released and tracked across Salt Lake City.[39] Led by DOE and several DOE National Laboratories, the study covered distances from the source ranging from 10 meters to 6 kilometers. DTRA, U.S. Army Dugway Proving Ground, and NOAA also participated.

In one evaluation of six urban dispersion models using the Salt Lake City field data, it was found that while the six models did a good job of determining the observed concentrations and source term, there were indications of slight underpredictions or overpredictions for some models and some distances.[40] The urban HPAC model slightly overpredicted at most distances; another evaluation of HPAC found consistent mean overpredictions of about 50 percent.[41] For HPAC model predictions of the lateral distance scale of concentration distribution, HPAC predicted within a factor of 2 only about 50 percent of the time.[42]

In another 2003 evaluation, conducted by the Institute for Defense Analyses (IDA), it was found that, in general, urban HPAC overpredicted

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[39] Sulfur hexafluoride and perfluorocarbon are stable, colorless, odorless gases used extensively and safely since the mid-1960s as atmospheric tracers. At the low concentrations used for atmospheric studies, sulfur hexafluoride tracer gas has no known environmental effect or health risk. It is easily detected, easily handled, and relatively inexpensive.

[40] Steven Hanna and others, "Use of Urban 2000 Field Data to Determine Whether There Are Significant Differences between the Performance Measures of Several Urban Dispersion Models" (paper, Fifth Conference on Urban Environment, American Meteorological Society, Vancouver, British Columbis, August 2004).

[41] Joseph C. Chang and others, "Use of Salt Lake City URBAN 2000 Field Data to Evaluate the Urban Hazard Prediction Assessment Capability (HPAC) Dispersion Model, "*Journal of Applied Meteorology* 44, no. 4 (2005): 485–501.

[42] NARAC modeling experts state that model predictions within a factor of 2, approximately 50 percent of the time, if proper input and boundary condition data is available, is an acceptable level of accuracy. However, they acknowledge that the inaccuracy of model inputs is often the primary limitation on how well the models perform.

the observed concentrations and dosages of URBAN 2000.[43] Of 20 model configurations examined (four model types each considered with five weather input options), 19 led to overpredictions of the total observed concentration or dosage. The IDA study concluded that the general overprediction of the URBAN 2000 observations by the Urban HPAC suite is a relatively robust conclusion. HPAC predictions of 30-minute average concentrations or the 2-hour dosage were plagued, in general, by substantial overpredicitons. Model predictive performance was also degraded at the longer downwind distances.

An evaluation of QUIC found that the model predicted concentrations within a factor of 2 of the measurements 50 percent of the time.[44] According to LANL modeling experts, QUIC performed reasonably well, slightly underestimating the decay of the concentrations at large distances from the source. However, it also significantly underpredicted lower concentrations at large distances downwind.

A field study called Joint Urban 2003 and sponsored by DHS, DOE, and DTRA was conducted in Oklahoma City in July 2003. Its objectives were similar to those of URBAN 2000. The study included a series of experiments to determine how air flows through the urban area both day and night and to learn about the concentrations in the air of sulfur hexafluoride and perfluorocarbon.

A 2006 IDA study that used the Joint Urban 2003 data to assess the Urban HPAC capabilities found significant differences in model performance, depending on time of day. Daytime performance was better than nighttime for meteorology inputs but with a large day-night discrepancy.[45] The urban subcomponents of the HPAC model, the urban canopy, urban dispersion model, and urban wind field module all tended to underpredict at day and

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[43] Steve Warner, Nathan Platt, and James F. Heagy, "Comparisons of Transport and Dispersion Model Predictions of the URBAN 2000 Field Experiment," *Journal of Applied Meteorology* 43:6 (June 2004): 829–46.

[44] Akshay Gowardhan and others, "Evaluation of QUIC Urban Dispersion Model Using the Salt Lake City URBAN 2000 Tracer Experiment Data—IOP 10" (paper, 6th American Meteorological Society Symposium on the Urban Environment and the 14th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Atlanta, Georgia, February 2006).

[45] Jeffry Urban and others, "Assessment of HPAC Urban Capabilities Using Joint Urban 2003 Field Trial Data" (paper, 10th Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling, Fairfax, Virginia, August 2006).

overpredict at night. A 2007 IDA study confirmed that there was a substantial difference in the performance of Urban HPAC as a function of day and night.[46] For all meteorology inputs IDA used, daytime releases tended to be underpredicted and nighttime releases tended to be overpredicted.

LANL found that QUIC model predictions of Joint Urban 2003 tracer releases underestimated concentrations up to a factor of 10. An LLNL assessment of the performance of CFD models that also used data from Joint Urban 2003 found that CFD models did not capture the effects of turbulence and winds caused by nocturnal low-level jets—that is, winds during the night at altitudes of 400 meters above ground. Turbulence generated by these low-level jets can induce mixing that reaches the surface, thereby influencing the dispersion of hazardous materials.

The New York City Urban Dispersion Program conducted field studies in March 2005 and August 2005 that evaluated seasonal variations in the New York City area. The aim was to learn about the movement of contaminants in and around the city and into and within buildings and to improve and validate computer models that simulate the atmospheric movement of contaminants in urban areas. Inert perfluorocarbon and sulfur hexafluoride were released to track air movement. More than 200 samplers collected tracer samples at more than 30 locations.

Results from the New York City field experiments found that first responders should always use wind directions measured at the tops of tall buildings for making approach and evacuation decisions and that ready availability of building-top winds is essential. According to NOAA modeling experts, however, such data are not always routinely available. NARAC modeling experts also said that wind speeds will not necessarily reflect the complex flows that occur at ground and building levels, where the wind may be moving in completely different directions. In addition, the experiment found that first responders should be aware that

- hazardous clouds may be encountered one to two blocks upwind from a known or suspected release site,

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[46] IDA, *Comparisons of Transport and Dispersion Model Predictions of the Joint Urban 2003 Field Experiment* (Alexandria, Virginia: 2007).

- the roofs of nearby tall buildings for street-level releases should not be considered safe havens because of the rapid vertical dispersion around buildings, and
- wind sensors should not be automatically located with CBRN detectors and winds should not be measured adjacent to CBRN detectors in street canyons in order to interpret the direction or extent of a release location.

According to modeling experts, urban modeling systems require additional field evaluation. NOAA's modeling experts have noted that even after several field studies and evaluations have been conducted, very limited data are available to evaluate models under varying urban and meteorological conditions and to lead the improved simulations of difficult situations such as light winds and at the interface with the environment of buildings, subways, and the like. They believe that additional tracer studies should be conducted to address these issues. LLNL modeling experts stated that funding is not sufficient to make use of all the data generated by field studies in order to improve understanding of key urban processes, evaluate model performance, and build improved urban models.

Urban Plume Models Have Limitations for Estimating the Source Term of Toxic Industrial Chemical Releases

According to unclassified assessments, the most likely type of toxic chemical attack on the United States would involve dual-use chemicals from industrial sources. The 13 highest-priority TICs are inhalation toxics that are shipped in large quantities; the most dangerous are those with low boiling points that are transported as pressurized liquids. According to modeling experts, the highest-priority TICs from the perspective of rail or truck transport are ammonia, chlorine, and sulfur dioxide. They are stored and shipped as pressurized liquefied gases, have low boiling points, and result in dense two-phase (gas and liquid) clouds. Recent rail accidents have shown that these chemicals, released as a dense, two-phase cloud of gas and small but visible aerosol drops, would spread initially in all directions and follow terrain slopes. Modeling experts believe that this area needs improvement in source emissions models.

Source emissions formulas and models included in comprehensive, widely used models such as HPAC have been extensively reviewed. A study for the Defense Advanced Research Projects Agency, for example, indicated that while HPAC provides some source emissions algorithms for industrial chemical release scenarios, many emissions scenarios remain difficult to model.[47] It is difficult to model emissions scenarios such as the quick release of pressurized liquid ammonia or chlorine from a rail car or tanker truck, the plume from a burning pool, the geometry and physical and chemical characteristics of a boiling liquid expanding vapor explosion or an intentional explosion, and any release in complex terrain. The 2007 version of HPAC does not consider two-phase releases. In addition, sufficient field data for most real scenarios do not exist because it is too dangerous to carry out a full-size experiment such as the release of the total contents of a rail car carrying chlorine or the explosion of a large propane storage tank.[48] Available source emissions algorithms are based on theory and on small-scale field and laboratory experiments.

LANL, the developer of QUIC, has been working to enhance QUIC's ability to address dense gas two-phase releases in the midst of buildings. LANL has also been enhancing QUIC's ability to deal with other issues that arise with chemical, biological, and radiological releases in cities: multiple-particle size releases and their deposition characteristics on building surfaces, the buoyant rise of particles after an explosive release of material, and the influence of building-induced winds on buoyant rise and dispersion. DHS and DTRA are also investigating critical data and physics gaps for chemical source term models that need to be solved in order to develop appropriate source term models. In addition, NARAC is improving the capability of its CFD urban model, FEM3MP, to combine complex source terms, dense gas effects, chemical reactions, and building-scale effects.

DOD's development of the Joint Effects Model relies on the ability to extract and derive key information on CBRN source term from available CBRN and meteorological sensors and to use this information to predict the CBRN downwind hazard. According to DTRA, the Joint Effects Model will provide the military with a single validated ability to predict and track CBRN and TIC effects, as well as estimates of the source location and source term and the ability to make refined dispersion calculations. It was scheduled for full operation by fiscal year 2009, and the second increment

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[47] Hanna Consultants, *Source Term Estimation Methods for Releases of Hazardous Chemicals to the Atmosphere Due to Accidental and Terrorist Incidents at Industrial Facilities and during Transportation* (Kennebunkport, Maine: 2005).

[48] DOE operates the Nonproliferation Test and Evaluation Complex at the Nevada test site, which can conduct open air testing of toxic hazardous materials and biological simulants.

of JEM, scheduled to be operational by fiscal year 2011, will include the ability to predict hazard areas and effects for urban areas.

Data Gaps on How CBRN Releases Affect Urban Populations Are Significant

Urban plume models rely, as we have shown, on a wide range of data, but the difficult challenges in modeling the transport and dispersion of CBRN materials in complex urban settings have shown significant gaps in the data on how CBRN releases would affect urban populations. First, exposure rates the population would experience in an urban environment would be affected by the physical environment and where people work and live. Existing urban databases, however, have significant gaps in both quantity and quality of information on land use and complex urban terrain; knowledge as to where critical populations are located is also needed to focus predictions. Second, scientific research on the health effects of low-level exposure to CBRN material on civilian populations is lacking, especially for vulnerable populations at risk.

Urban Databases Have Significant Gaps

Urban land use type—residential, commercial, industrial—is used in meteorological models to assign building structure and composition parameters and other surface characteristics to the underlying terrain. Mesoscale meteorological models and many atmospheric plume models do not have the spatial resolution to simulate the fluid dynamics near and around buildings and other urban land features. Urban canopy parameters have been developed to allow plume models to simulate the effects of buildings and urban land features on plume transport and dispersion, wind speed and direction, and turbulent mixing.

Accurate urban land use definition is therefore an important component in modeling efforts. The ability to conduct modeling in urban areas, however, is typically limited to the use of a single or simplistic set of land use categories that do not provide explicit information on the effect of buildings and surfaces on the flow and transport of hazardous substances in the air. Determining the structure and composition of urban areas has resulted in the development of large datasets of high-resolution urban features for many of the nation's largest cities. The National Building Statistics Database, for example, contains data for 17 U.S. cities at a 250-meter grid cell resolution. This database contains mean building heights and other such statistics. It also contains high-rise district footprints for 46 of the most populous cities. In addition, the National Geospatial-Intelligence Agency and the U.S. Geological Survey have created a database of urban building footprints and heights in various cities.

Several efforts have been made to improve urban databases for urban plume modeling, such as creating a database for day and night populations. Geographic information that includes population density data is essential for a fast, effective first response to disasters and is the common thread in all planning, response, and recovery activities. Using geographic information systems and remote sensing, ORNL developed LandScan, a global population distribution model, database, and tool from census and other spatial data. LandScan is a collection of the best available census counts for each U.S. county and four key indicators of population distribution—land cover, roads, slope, and nighttime lights. Census tracts are divided into 1-kilometer grid cells, and each cell is evaluated for the likelihood of its being populated on the basis of the four indicators. The total population for each tract is then allocated to each cell, weighted to the calculated likelihood of being populated. ORNL's LandScan 2006 developed a high-resolution daytime population database.

According to DTRA, DOD efforts have added the number and quality of city databases available to 75 cities in the continental United States, with new ones added periodically. DTRA officials stated that enhancements in the UDM suite of urban domain characterizers have significantly improved the overall urban transport and dispersion modeling capability.

According to NOAA weather experts, the standard national meteorological observing network does not provide sufficient spatial resolution to resolve local conditions that influence urban plumes. While a number of "mesonets" provide meteorological observations with relatively high spatial resolution over a limited domain, the quality of data from them varies significantly, according to NOAA officials.[49] They stated that to provide reliable data for plume predictions, mesonet design should be considered, the quality of data from relevant mesonets should be characterized, and appropriate data screening and transformation approaches should be developed. Research is required to determine how best to incorporate urban mesonet data into plume models.

Establishing Urban test beds has been proposed as a way to provide critical data to improve urban plume modeling. An Urban test bed is a multifunctional infrastructure of atmospheric instruments that provide continuous, multiyear measurement and archival environmental data

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[49] A mesonet is a network of automated weather stations designed to observe mesoscale meteorological phenomena.

across a metropolitan area and through the atmospheric boundary layer. An Urban test bed would be used to support improvements in a range of activities from scientific research to user applications. In a September 2004 study, OFCM and other agencies recommended the implementation of multiple Urban test beds.[50] Urban test beds would provide (1) long term, continuous, high-resolution, meteorological observations of the urban domain and (2) long-term measurement and archiving of measurement data on atmospheric processes and modeling in urban environments. NOAA has implemented a dispersion measurement test bed called DCNet in Washington, D.C., to provide dispersion computations for planning and possible response.

According to LLNL modeling experts, a major issue has been how to provide cost-effective access to building, land use, population, and other geographic databases as well as local meteorological data, establish common formats for databases, and enforce quality assurance standards.

Data Are Insufficient on How Exposure to CBRN Materials Affects Health

Significant gaps exist in first responders' information for determining the effects of exposure to CBRN materials on heterogeneous urban populations. Scientific research on the effects of low-level exposure to CBRN material on civilian populations is severely lacking, especially for vulnerable populations such as elderly people, children, and individuals with compromised immune systems. A dose that may not be lethal for a healthy young adult might be lethal for such persons. For example, in the 2001 anthrax attack, many postal workers exposed to high concentrations over a prolonged period did not develop anthrax disease, while an elderly woman in Connecticut with a compromised immune system died, presumably from inhaling very few spores. Data are needed on exposure and dose assessments to identify vulnerable populations and how to adjust individual and population postevent activities and behavior to reduce numbers of casualties.

Knowing health effects from exposure to chemical agents depends on a hierarchy of EPA-published chemical exposure limits and chemical dose-response relationships as used in modeling. EPA has assigned three acute exposure guideline levels (AEGL) to TICs that could represent dangerous inhalation exposure from releases to air by accident or terrorist action.

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[50] OFCM, *Federal Research and Development Needs and Priorities for Atmospheric Transport and Diffusion Modeling* (Silver Spring, Maryland: September 2004).

AEGLs are threshold exposure limits for the general public and apply to emergency exposure periods ranging from 10 minutes to 8 hours. They are intended to help protect most people in the general population, including those who might be particularly susceptible to the deleterious effects of chemical substances, and are expressed as an airborne concentration in parts per million or milligrams per cubic meter. However, dose response parameters for the general population do not exist for most CB warfare agents believed to pose a threat to civilians. For radiological exposures, DHS and EPA provide Protective Action Guidelines that identify the radiation levels at which state and local officials should take various actions to protect human health during an accident.

At AEGL-1, the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. The effects are not disabling and are transient and reversible when exposure ceases. At AEGL-2, the experience could be irreversible or could consist of other serious, long-lasting adverse health effects or an impaired ability to escape. At AEGL-3, the experience would be life-threatening or fatal.

For chemicals for which AEGLs have not been established, the Emergency Response Planning Guidelines of the American Industrial Hygiene Association are used. If neither EPA nor the Association has established a value for a chemical, then DOE’s temporary emergency exposure limits are used.

AEGLs and other estimates attempt to describe the lower end of the dose response curve for particular chemical agents. Dose response parameters for the general population do not exist for most CB warfare agents believed to pose a threat to civilians. LLNL modeling experts stated that for chemical weapon and biological agents, they determine health effects levels from literature reviews. Toxicity estimates for the general population are required for hazard prediction models. Data are needed on exposure and dose assessments to identify populations at risk from primary or secondary contact and how to adjust individual and population postevent activities and behavior to reduce casualties. According to the Armed Forces Medical Intelligence Center, 50 percent lethal concentrations and dosages are unknown for most chemicals, and detailed information on high-volume chemicals and processes is not widely available.[51]

Little scientific research has been done on the effects of low-level exposure to CBRN material on civilian populations, especially vulnerable populations at risk. ECBC has the task of providing human chemical warfare agent toxicity estimates for the general population, together with supporting analyses. According to ECBC studies, most of the available toxicological data underlying human toxicity estimates for chemical warfare agents were generated in support of chemical weapons development for offensive battlefield deployment against military personnel, who at the time of the studies were nearly all male. Thus, the available human data represent a very limited segment of the population—relatively young, fit male soldiers. Using military values for civilian scenarios would therefore result in the underestimation of civilian casualties and the overall threat to civilian populations from potential or actual releases. ECBC has been developing mathematical models to estimate general population toxicity values from previously established military values. For example, figure 3 shows dose response curves for the fraction of a healthy military population and of the general population that would be killed by a 2-minute exposure to sarin.

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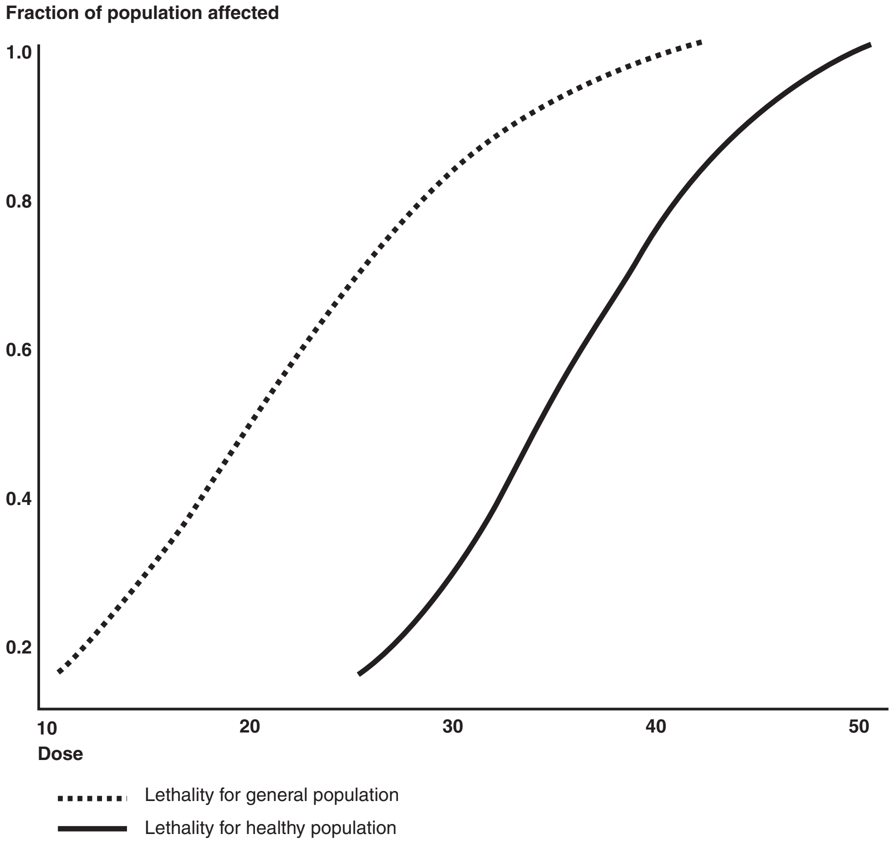
[51] Lethal concentration is the concentration of a chemical in the air that would kill 50 percent of a group of test animals. Lethal dosage is the dosage that kills 50 percent of the animals tested.

Figure 3: Dose Response for Healthy and General Population Exposures to Sarin



Source: LLNL, DOE.

Conclusions

Despite several initiatives and investments DHS and other agencies have undertaken since 2001, first responders do not have effective tools to respond to events involving the release of CBRN materials in urban areas. Detection systems are limited in their ability to provide the timely and accurate information first responders need about the release of CBRN materials in urban areas to make decisions on expected health effects and protective action—for example, sheltering and evacuation. Existing nonurban and urban plume models for emergency response to CBRN events have several limitations as a primary tool for tracking the release of CBRN materials in urban areas and for making decisions about handling them. National TOPOFF exercises have also shown the problems and confusion that could occur to first responders' responses to CBRN events from disparate modeling inputs and results. In addition, more data are needed about the effects of hazardous materials in built-up urban environments. Continued improvements are needed in urban building and population databases and for understanding the health effects from concentrations of hazardous substances, especially on vulnerable populations, so that first responders are properly prepared for addressing airborne releases of harmful materials in urban areas.

Led by DHS, ongoing federal efforts have attempted to improve the capabilities of detection systems and models so that first responders can accurately identify CBRN materials released in urban environments, the extent of their dispersion, and their effect on urban populations. For detection equipment, one shortcoming that should be addressed is the lack of emphasis on the development of detection equipment that first responders can use to detect radiological materials in the atmosphere. DHS has recognized the threat of a terrorist attack involving the explosion of radiological dispersal devices—or dirty bombs—and has used this as a scenario in TOPOFF exercises. However, DHS's development of radiation detection equipment has largely focused on the interdiction of radioactive material rather than on detecting the release of radioactive material into the atmosphere in urban areas. We found that agencies such as DHS, DOD, EPA, NIST, and NOAA do not have missions to develop, independently test, and certify equipment for detecting radiological materials in the atmosphere.

Another shortcoming is the lack of a formal DHS system to independently test and validate the performance, reliability, and accuracy of CBRN detection equipment that first responders acquire. While DHS indicated it has missions to develop, independently test, and certify CB detection equipment for first responders' use, its testing and certification are limited to equipment DHS is developing and does not extend to equipment developed by commercial manufacturers. As we have noted, DHS has no evaluation and qualification program that guides and informs first responders on the veracity of manufacturers' claims about the performance of their CBRN detection systems. DHS has no control over what manufacturers can sell to first responders and cannot order first responders not to purchase a certain piece of equipment, unless purchased with federal funds. A formalized process needs to be established for the evaluation and validation of manufacturers' claims regarding commercial biodetection equipment.

While existing urban plume models have several limitations as a primary tool for tracking the release of CBRN materials in urban areas, the TOPOFF exercises demonstrated the larger problem of confusion among first responders about the timing, value, and limitations of plume models and other analyses following a CBRN event. At best, models can give a close approximation and can help inform a decision maker on the probable plume. The TOPOFF exercises demonstrated that plume model results developed without the incorporation of field data are only estimates that should be used for guidance but are not an accurate rendition of the actual situation facing first responders. Plume models are most effectively used to provide early estimates of potentially contaminated areas in combination with data gathered from the field. These data, in turn, are used to update plume model predictions.

The major weakness of these models is that any real source release is nearly always more complicated than the simple scenarios studied in the field and wind tunnel experiments they are based on. Real sources tend to vary in time and space and to occur when the atmosphere is variable or rapidly changing. A small change in wind direction or height of release can result in a different or a more or less populated area being affected. During the TOPOFF exercises, first responders and decision makers used plume model predictions as real-time information on which to base decisions.

In addition, the TOPOFF 2 and 3 exercises demonstrated that while IMAAC is designated the focal point for coordinating and disseminating modeling products, it does not have adequate procedures to deal with discrepancies or contradictions from competing models from various agencies. DHS's preliminary assessment of the TOPOFF 4 exercise found improvement in IMAAC's coordination of federal plume modeling to minimize differences in model outputs and provide one source for consequence predictions. However, IMAAC Operations officials said the key to "deconflicting" plume modeling information is to have procedures that are coordinated and integrated with those of first responders and other local emergency response agencies. IMAAC also does not have a concept of operations or specific procedures for significant CBRN incidents. A key issue is the need to clarify the type and scale of what major incident could constitute a potentially significant CBRN event and qualify for IMAAC assistance.

Recommendations for Executive Action

We recommend that the Secretary of Homeland Security

- reach agreement with DOD, DOE, EPA, and other agencies involved with developing, testing, and certifying CBRN detection equipment on which agency should have the missions and responsibilities to develop, independently test, and certify detection equipment that first responders can use to detect hazardous material releases in the atmosphere;

- ensure that manufacturers' claims are independently tested and validated regarding whether their commercial off-the-shelf CBRN detection equipment can detect given hazardous material at specific sensitivities;
- refine IMAAC's procedures by working with other federal, state, and local agencies to (1) develop common/joint IMAAC emergency response practices, including procedures for dealing with contradictory plume modeling information from other agencies during a CBRN event; (2) refine the concept of operations for chemical, biological, and radiological releases; and (3) delineate the type and scale of major CBRN incidents that would qualify for IMAAC assistance; and
- in conjunction with IMAAC, work with the federal plume modeling community to accelerate research and development to address plume model deficiencies in urban areas and improve federal modeling and assessment capabilities. Such efforts should include improvements to meteorological information, plume models, and data sets to evaluate plume models.

Agency Comments and Our Evaluation

We obtained written comments on a draft of this report from DHS and the Department of Commerce. DHS concurred with our recommendations but stated that GAO should consider other scenarios as alternative ways of looking at the present national capabilities for CBRN response and the current status of testing and certifying detection equipment. DHS stated that in one alternative scenario, first responders, in the event of a terrorist attack, will use a variety of prescreening tools, and they will be assisted immediately by state and federal agencies that will bring the best available state-of-the-art CBRN detection equipment.

In our report, we have considered scenarios in which first responders are on the scene before federal assets arrive, not knowing what hazardous materials (including CBRN agents) have been released, either accidentally or by terrorist acts. In these situations, it is the first responder who has to first determine what was released and what tools to use to make that determination before receiving assistance from state and federal agencies.

By DHS's own assessments, these state-of-the-art CBRN detection tools have significant limitations. DHS acknowledged that first responders do not now have any equipment that can detect the dispersion of radiological and nuclear materials in the atmosphere. DHS's S&T Directorate assessed that while current detectors can be used for rapid warning of chemicals in the vapor phase, they are generally considered inadequate to provide information on the presence of chemical threat agents at less than lethal but still potentially harmful levels. According to DHS's S&T, HHAs, the tool that first responders would use to detect biological threat agents, do not have the sensitivity to detect the atmospheric concentrations of agents that pose health risks. Moreover, the detection of biological agent aerosols and particulates through the current BioWatch sample collection and laboratory analysis process is time-consuming and labor intensive, with final confirmation occurring long after initial exposure.

With respect to testing and validation of commercial CBRN detection equipment available for first responder use, DHS stated that there is no legislative requirement that such equipment for homeland security applications meet performance standards. DHS also believes that it will never be feasible for the federal government to fund testing of all commercial detectors without first assessing their potential merits for detection of CBRN agents because of the very large number of hazardous CBRN agents and the expense of testing detectors against these agents.

While there is no legislative requirement that CBRN detection equipment for homeland security meet performance requirements, we noted in our report that DHS does require that commercial detection equipment first responders purchase with DHS grant funds comply with equipment performance standards adopted by DHS. However, DHS has adopted few performance standards for CBRN detection equipment. Without such standards, first responders may purchase detection equipment that does not detect harmful levels or whose performance varies. Without standards, there would be no way to ensure the reliability of the equipment's detection capabilities.

As we indicated in our report, DHS had adopted only four standards for radiation and nuclear detection equipment as of October 30, 2007. DHS acknowledged that current testing is mainly limited to DHS and DOD CBRN detection systems under development, and it has no process to validate the performance of commercial CBRN detection equipment. However, we are not recommending that DHS test all available commercial detection equipment. We are recommending that DHS independently test and evaluate detection equipment first responders purchase using DHS grant funds. (DHS's comments appear in appendix III.)

In DOC's general comments on our draft report, DOC stated that it believed that even with the implementation of our recommendations aimed at improving IMAAC operations, the plume models will still have several limitations as a primary tool for tracking the release of CBRN materials in urban areas. To improve information available for emergency managers, DOC suggested offering a recommendation that DHS work with the federal plume modeling community to accelerate research and development to address plume model deficiencies in urban areas. Such efforts should include improvements to meteorological information, plume models, and data sets to evaluate plume models. DOC acknowledged that these improvements would be likely to take several years, but work should be initiated while IMAAC is instituting improvements.

We believe that DOC's recommendation has merit and have included it in our final report for DHS's consideration.

DOC also stated that it believed that IMAAC should be working to improve federal modeling and assessment capabilities and to enhance the national scientific capability through cooperation among the federal agencies for incidents of national significance. IMAAC and the atmospheric transport and diffusion community should support OFCM in developing a joint model development and evaluation strategy.

We also agree that IMAAC should continue to improve federal modeling and assessment capabilities with OFCM and other federal agencies involved with modeling terrorist-related or accidental releases of CBRN materials in urban areas. This is included in our recommendation. In technical comments on our draft report, IMAAC operations staff at LLNL stressed that improvements to plume modeling information and predictions are best achieved by establishing trusted working relationships with federal, state, and local agency operations centers and deployed assets.

DOC also stated that the inference in our report that IMAAC will be providing a single dispersion solution is misleading. IMAAC, as a federal entity, provides a recommendation to the local incident commander and the commander decides what information to use. This stems from the basis that all events are local in nature. DOC stated that it believed that the report should also highlight the need to promote an aggressive program of educating first responder and local incident commanders in the use of dispersion models.

We clarified our discussion in the report about the role of IMAAC in order to remove any inference that it was expected to provide a single dispersion solution. We noted in our draft report that IMAAC does not replace or supplant the atmospheric transport and dispersion modeling activities of other agencies whose modeling activities support their missions. IMAAC provides a single point for the coordination and dissemination of federal dispersion modeling and hazard prediction products that represent the federal position during actual or potential incidents requiring federal coordination. We also noted in our conclusions that TOPOFF exercise results demonstrated the larger problem of the confusion among first responders' awareness about the timing, value, and limitations of plume models and other analyses following a CBRN event. We agree that an aggressive program for educating first responders on the use of dispersion models is needed.

DOC also commented on our discussion about the confusion from the models produced during the TOPOFF 2 exercise. DOC noted that the confusion resulted from models being generated using different meteorological inputs—real weather versus "canned" weather. We noted in our draft report that one major cause for the confusion was the use of different meteorological inputs in the modeling conducted during TOPOFF 2. (DOC's comments appear in app. IV.)

We also received technical comments from DHS and DOC, from DOD, and from DOE (LLNL), and we made changes to the report where appropriate. Technical comments we received from LLNL, in particular, proposed broadening the recommendation related to revising IMAAC standard operating procedures to deal with contradictory modeling inputs. IMAAC operations staff at LLNL believed that integrating procedures with other emergency response agencies are the key to clarifying plume modeling information. They stated that their experience has shown that refining IMAAC's standard operating procedures is relatively ineffective unless this is coordinated with the development of joint operating procedures with other agencies, leading to the incorporation of IMAAC into these agencies' standard operations. We agreed and have revised our recommendation accordingly.

We are sending copies of this report to the Secretaries of Commerce, Defense, Energy, and Homeland Security and others who are interested. We will also provide copies to others on request. In addition, the report will be available at no charge on GAO's Web site at http://www.gao.gov.

If you or your staff have any questions regarding this report, please call me at (202) 512-2700. Key contributors to this assignment were Sushil Sharma, Assistant Director, Jason Fong, Timothy Carr, and Penny Pickett. James J. Tuite III, a consultant to GAO during our engagement, provided technical expertise.

Nancy R. Kingsbury

Nancy R. Kingsbury, Managing Director
Applied Research and Methods

List of Requesters

The Honorable Robert C. Byrd
Chairman
Committee on Appropriations
United States Senate

The Honorable Joseph I. Lieberman
Chairman
Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable Susan M. Collins
Ranking Member
Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable John D. Dingell, Jr.
Chairman
Committee on Energy and Commerce
House of Representatives

The Honorable David E. Price
Chairman
Subcommittee on Homeland Security
Committee on Appropriations
House of Representatives

The Honorable Bart T. Stupak
Chairman
Subcommittee on Oversight and Investigations
Committee on Energy and Commerce
House of Representatives

The Honorable Christopher Shays
Ranking Member
Subcommittee on National Security and Foreign Affairs
Committee on Oversight and Government Reform
House of Representatives

Appendix I: Scope and Methodology

To assess the capabilities and limitations of chemical, biological, radiological, and nuclear (CBRN) detection equipment, we interviewed federal program officials from the (1) Science and Technology directorate of the Department of Homeland Security (DHS) and its Homeland Security Advanced Research Projects Agency; (2) the Defense Threat Reduction Agency and the Joint Program Executive Office for Chemical and Biological Defense in the Department of Defense (DOD); and (3) the Department of Energy's (DOE) Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory, and Oak Ridge National Laboratory.

We also met with program officials from DHS's Responder Knowledge Base (RKB) and the Department of Commerce's (DOC) National Institute of Standards and Technology's Office of Law Enforcement Standards (OLES) to obtain information on equipment standards and the testing of CBRN detection equipment. We reviewed DHS, DOD, and DOE detection programs in place and being developed, as well as these agencies' studies on CBRN detection systems. We attended conferences and workshops on CBRN detection technologies.

To obtain information on detection equipment standards and the testing of CBRN detection equipment for first responders, we met with program officials from DHS's RKB and OLES. We also interviewed local responders in Connecticut, New Jersey, and Washington on their acquisition of CBRN detection equipment. We chose these states because of their participation in DHS-sponsored Top Officials (TOPOFF) national counterterrorism exercises. In addition, we interviewed members of the InterAgency Board for Equipment Standardization and Interoperability (IAB). IAB, made up of local, state, and federal first responders, is designed to establish and coordinate local, state, and federal standardization; interoperability; compatibility; and responder health and safety to prepare for, train for and respond to, mitigate, and recover from any CBRN incident.

To assess the limitations of plume models, we interviewed modeling experts from DHS, DOD, DOE's national laboratories, DOC's National Oceanic and Atmospheric Administration, and the Office of the Federal Coordinator for Meteorological Service and Supporting Research (OFCM) in the Department of Commerce. We also interviewed operations staff of the Interagency Modeling and Atmospheric Assessment Center (IMAAC) at LLNL. IMAAC consolidates and integrates federal efforts to model the behavior of various airborne releases and is the source of hazards predictions during response and recovery. We also interviewed local responders in Connecticut, New Jersey, and Washington regarding the use of plume models during the TOPOFF 2 and TOPOFF 3 exercises.

We reviewed documentation on the various plume models and reports and studies evaluating models available for tracking CBRN releases in urban environments and studies identifying future needs and priorities for modeling homeland security threats. We attended several conferences and users' workshops sponsored by the American Meteorological Society, DOD, OFCM, and George Mason University, where modeling capabilities were evaluated. We also reviewed DHS internal reports on lessons learned from the use of modeling during the TOPOFF national exercises.

To determine what information first responders have for determining the effects of exposure to CBRN materials on heterogeneous civilian populations, we reviewed agency documentation and studies on urban land use and population density. We also reviewed documentation on acute exposure guideline levels published by the Environmental Protection Agency and other organizations. In addition, we reviewed studies on human toxicity estimates by the U.S. Army and DOE's national laboratories.

We conducted our review from July 2004 to January 2008 in accordance with generally accepted government auditing standards.

Appendix II: Chemical, Biological, and Radiological Agents

Table 6: Chemical Warfare Agents

Class	Signs and symptoms	Name and symbol	Persistence	Rate of action	Eye and skin toxicity
Blister	First irritates cells, then poisons them; conjunctivitis (pink eye); reddened skin, blisters; nasal irritation; inflammation of throat and lungs	Ethyldichloroarsine (ED)	Moderate	Immediate irritation; delayed blistering	Vapor harmful on long exposure; liquid blisters
		Lewisite (L)	Days; rapid hydrolysis with humidity	Rapid	Severe eye damage; skin less so
		Methyldichloroarsine (MD)	Low	Rapid	Eye damage possible; blisters
		Mustard (H, HD)	Very high; days to weeks	Delayed hours to days	Eyes very susceptible; skin less so
		Nitrogen mustard (HN-1, -2, -3)	HN-1, -3, very high, days to weeks; HN-2, moderate	HN-1, -2, delayed 12 hours or more. HN-3, serious effects, same as HD; minor effects sooner	HN-1, eyes susceptible to low concentration, skin less so. HN-2, toxic to eyes; blisters skin. HN-3, eyes very susceptible; skin less so
		Phenyldichloroarsine (PD)	Low–moderate	Rapid	633 mg–min/m^3 produces eye damage; less toxic to skin
		Phosgene oxime (CX)	Low, 2 hours in soil	Immediate effects on contact	Powerful irritant to eyes and nose; liquid corrosive to skin
Blood	Skin cherry red or 30% cyanosis (bluish discoloration from lack of oxygen); gasping for air; seizures before death	Arsine (SA)	Low	2 hours to 11 days	None
		Cyanogen chloride (CK)	Evaporates rapidly and disperses	Very rapid	Low; tears and irritation
		Hydrogen cyanide (AC)	Extremely volatile; 1–2 days	Very rapid	Moderate
Nerve	Salivation, lacrimation (tearing), urination, defecation, gastric disturbances, vomiting	Cyclosarin (GF)	Moderate	Very rapid	Very high
		Sarin (GB)	Low; 1–2 days; evaporates with water	Very rapid	Very high
		Soman (GD)	Moderate; 1–2 days	Very rapid	Very high
		Tabun (GA)	Low; 1–2 days if heavy concentration	Very rapid	Very high
		VX	Very high; 1 week if heavy concentration; as volatile as oil	Rapid	Very high

Source: Analytic Services Inc., Central Intelligence Agency, and Edgewood Chemical Biological Center.

Table 7: Biological Warfare Agents

Agent	Possible means of delivery	Time	Symptoms	Lethality	Stability
Bacterium					
Anthrax	Aerosol	Incubation 1–5 days; symptoms in 2–3 days	Fever, malaise, fatigue, cough, and mild chest discomfort, followed by severe respiratory distress	3–5 days; shock and death 24–36 hours after symptoms	Spores are highly stable
Brucellosis	Aerosol, expected to mimic a natural disease	Rate of action usually 6–60 days	Chills, sweats, headache, fatigue, joint and muscle pain, and anorexia	Weeks to months	Organisms are stable for several weeks in wet soil and food
Cholera	Sabotaged food and water supply; aerosol	Sudden onset after 1–5 days incubation	Initial vomiting and abdominal distention, with little or no fever or abdominal pain, followed rapidly by diarrhea	One or more weeks; low with treatment; high without treatment	Unstable in aerosols and pure water; more stable in polluted water
Plague	Contaminated fleas, causing bubonic type, or aerosol, causing pneumonic type	Rate of action 2–3 days; incubation 2–6 days bubonic, 3–4 days pneumonic	High fever, chills, headache, spitting up blood, and toxemia, progressing rapidly to shortness of breath and cyanosis (bluish coloration of skin and membranes)	Very high	Extremely stable but highly transmissible
Q fever	Dust cloud from a line or point source	Onset may be sudden	Chills, headache, weakness, malaise, and severe sweats	Very low	Stable
Tularemia	Aerosol	Rate of action 3–5 days; incubation 1–10 days	Fever, chills, headache, and malaise	2 weeks moderate	Not very stable
Typhoid	Sabotaged food and water supply	Rate of action 1–3 days; incubation 6–21 days	Sustained fever, severe headaches, and malaise	Moderate if untreated	Stable
Typhus	Contaminated lice or fleas	Rate of action 6–15 days; onset often sudden, terminating after about 2 weeks of fever	Headaches, chills, prostration, fever, and general pain	High	Not very stable
Toxin					
Botulinum	Sabotaged food and water supply; aerosol	Rate of action 12–72 hours; incubation hours to days	Blurred vision; photophobia; skeletal muscle paralysis and progressive weakness that may culminate abruptly in respiratory failure	High	Stable

Agent	Possible means of delivery	Time	Symptoms	Lethality	Stability
Ricin	Aerosol	Rate of action 6–72 hours	Rapid onset of nausea, vomiting, abdominal cramps, and severe diarrhea with vascular collapse	High	Stable
Virus					
Ebola	Aerosol; direct contact	Rate of action: sudden	Malaise, headache, vomiting, diarrhea	High: 7-16 days	Unstable
Marburg	Aerosol; direct contact	Rate of action 7–9 days	Malaise, headache, vomiting, diarrhea	High	Unstable
Smallpox	Airborne	Rate of action 2–4 days; incubation 7–17 days	Malaise, headache, vomiting, diarrhea, small blisters on skin, bleeding of skin and mucous membranes	High	Stable
Venezuelan equine encephalitis	Airborne	Sudden rate of action; incubation 1–5 days	Headache, fever, dizziness, drowsiness or stupor, tremors or convulsions, muscular incoordination	Low	Unstable
Yellow fever	Aerosol	Sudden rate of action; incubation 3–6 days	Malaise, headache, vomiting, diarrhea	High	Unstable

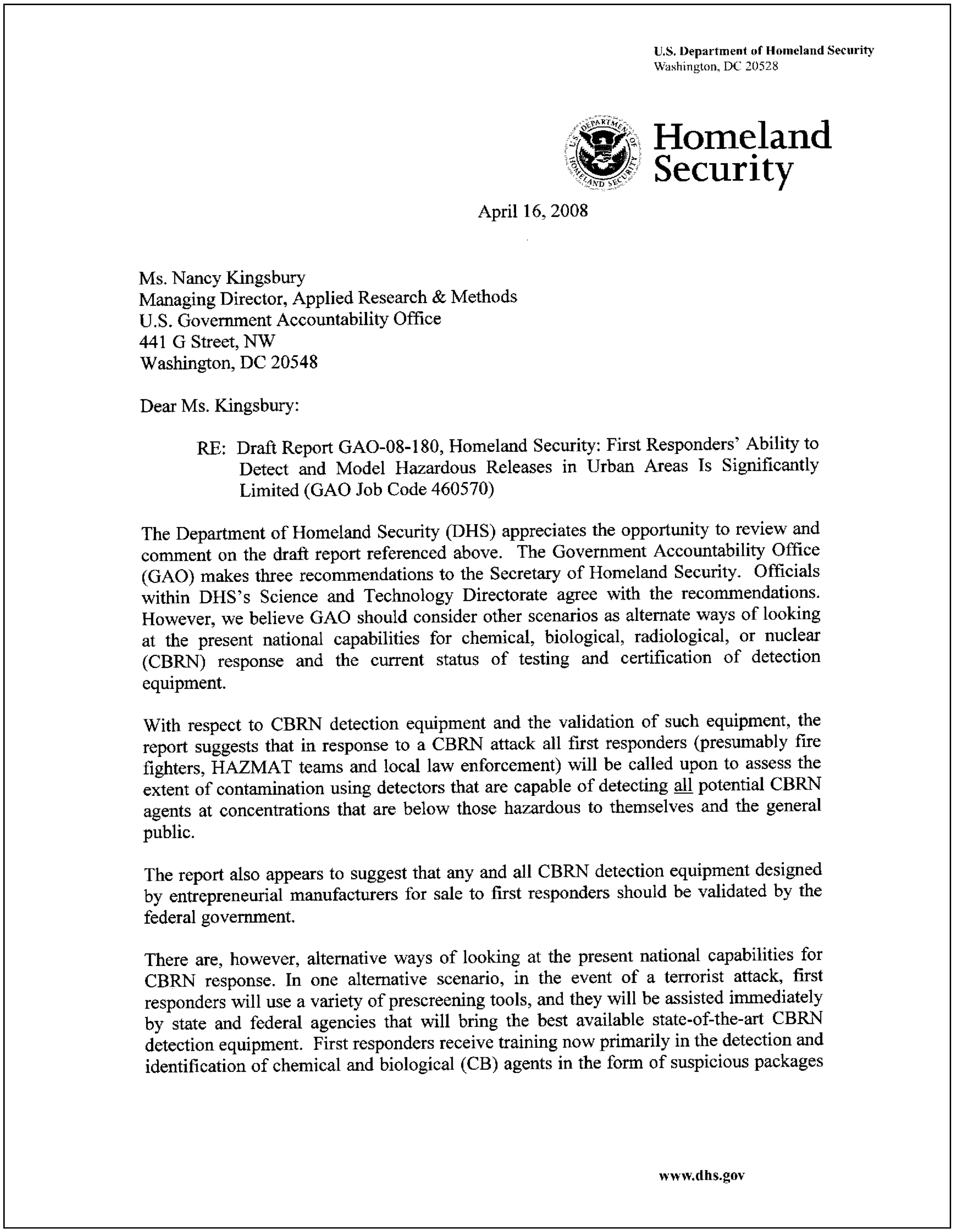
Source: Analytic Services Inc., Central Intelligence Agency, and Edgewood Chemical Biological Center.

Table 8: Radiological Warfare Agents

Radioactive isotope	Respiratory absorption and retention	Gastrointestinal absorption and retention	Skin wound absorption	Primary toxicity
Americium-241	75% absorbed; 10% retained	Minimal, usually insoluble	Rapid in first few days	Skeletal deposition; marrow suppression; hepatic deposition
Cesium-137	Completely absorbed; follows potassium	Completely absorbed; follows potassium	Completely absorbed; follows potassium	Renal excretion; beta and gamma emissions
Cobalt-60	High absorption; limited retention	Less than 5% absorption	Unknown	Gamma emitter
Iodine-131	High absorption; limited retention	High absorption; limited retention	High absorption; limited retention	Thyroid ablation carcinoma
Plutonium-238 and Plutonium-239	Limited absorption; high retention	Minimal, usually insoluble	Limited absorption; may form nodules	Local effects from retention in lung
Polonium 210	Moderate absorption; moderate retention	Minimal	Moderate absorption	Spleen, kidney
Strontium-90	Limited retention	Moderate absorption	Unknown	Bone, follows calcium
Uranium-235 and Uranium-238	High absorption; high retention	High absorption	High absorption; skin irritant	Renal, urinary excretion

Source: Armed Forces Radiobiology Research Institute, *Medical Management of Radiological Casualties Handbook*, 2nd ed. (Bethesda, Md.: April 2003), app. B.

Appendix III: Comments from the Department of Homeland Security



U.S. Department of Homeland Security
Washington, DC 20528

Homeland
Security

April 16, 2008

Ms. Nancy Kingsbury
Managing Director, Applied Research & Methods
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Ms. Kingsbury:

RE: Draft Report GAO-08-180, Homeland Security: First Responders' Ability to Detect and Model Hazardous Releases in Urban Areas Is Significantly Limited (GAO Job Code 460570)

The Department of Homeland Security (DHS) appreciates the opportunity to review and comment on the draft report referenced above. The Government Accountability Office (GAO) makes three recommendations to the Secretary of Homeland Security. Officials within DHS's Science and Technology Directorate agree with the recommendations. However, we believe GAO should consider other scenarios as alternate ways of looking at the present national capabilities for chemical, biological, radiological, or nuclear (CBRN) response and the current status of testing and certification of detection equipment.

With respect to CBRN detection equipment and the validation of such equipment, the report suggests that in response to a CBRN attack all first responders (presumably fire fighters, HAZMAT teams and local law enforcement) will be called upon to assess the extent of contamination using detectors that are capable of detecting all potential CBRN agents at concentrations that are below those hazardous to themselves and the general public.

The report also appears to suggest that any and all CBRN detection equipment designed by entrepreneurial manufacturers for sale to first responders should be validated by the federal government.

There are, however, alternative ways of looking at the present national capabilities for CBRN response. In one alternative scenario, in the event of a terrorist attack, first responders will use a variety of prescreening tools, and they will be assisted immediately by state and federal agencies that will bring the best available state-of-the-art CBRN detection equipment. First responders receive training now primarily in the detection and identification of chemical and biological (CB) agents in the form of suspicious packages

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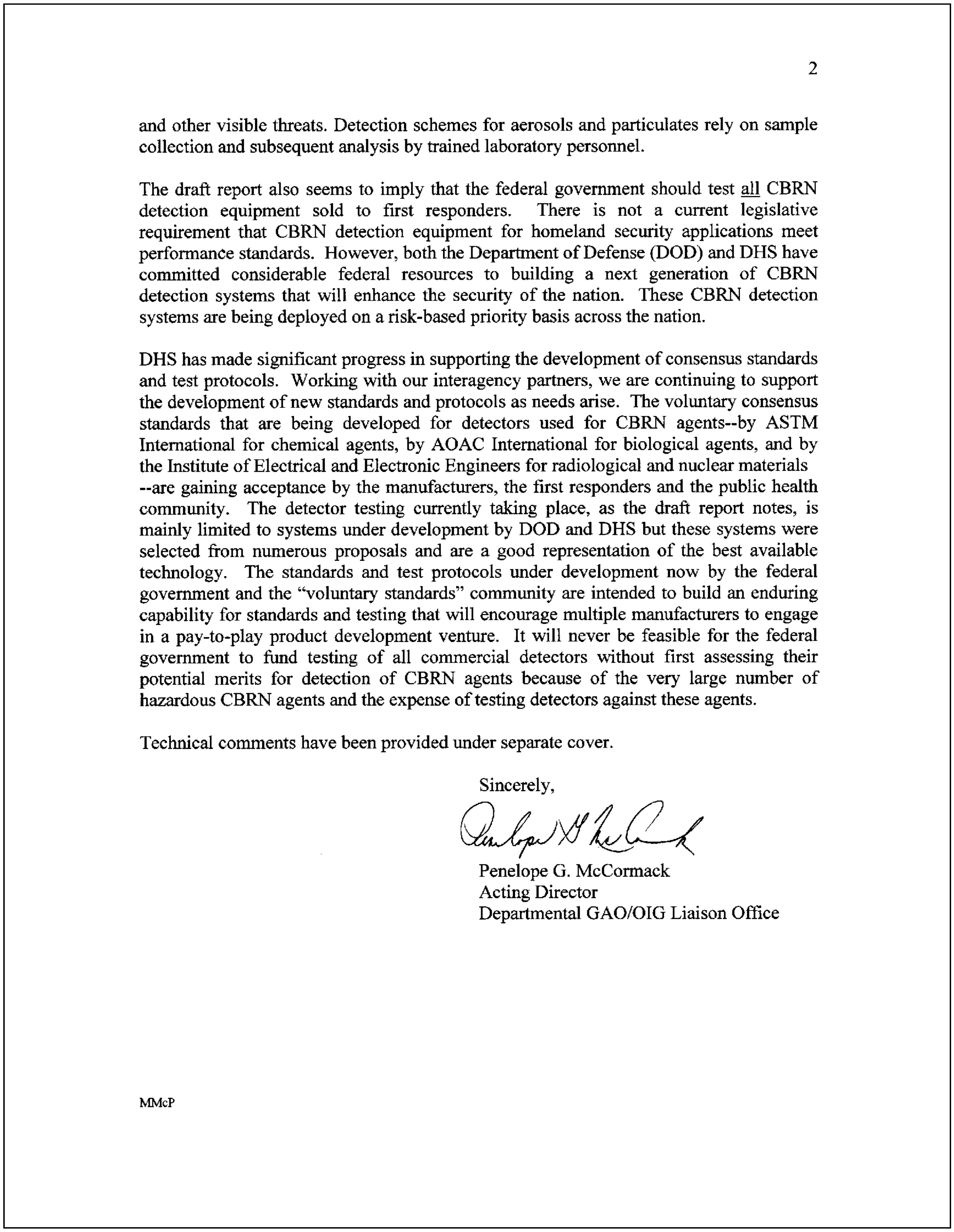


and other visible threats. Detection schemes for aerosols and particulates rely on sample collection and subsequent analysis by trained laboratory personnel.

The draft report also seems to imply that the federal government should test all CBRN detection equipment sold to first responders. There is not a current legislative requirement that CBRN detection equipment for homeland security applications meet performance standards. However, both the Department of Defense (DOD) and DHS have committed considerable federal resources to building a next generation of CBRN detection systems that will enhance the security of the nation. These CBRN detection systems are being deployed on a risk-based priority basis across the nation.

DHS has made significant progress in supporting the development of consensus standards and test protocols. Working with our interagency partners, we are continuing to support the development of new standards and protocols as needs arise. The voluntary consensus standards that are being developed for detectors used for CBRN agents--by ASTM International for chemical agents, by AOAC International for biological agents, and by the Institute of Electrical and Electronic Engineers for radiological and nuclear materials --are gaining acceptance by the manufacturers, the first responders and the public health community. The detector testing currently taking place, as the draft report notes, is mainly limited to systems under development by DOD and DHS but these systems were selected from numerous proposals and are a good representation of the best available technology. The standards and test protocols under development now by the federal government and the "voluntary standards" community are intended to build an enduring capability for standards and testing that will encourage multiple manufacturers to engage in a pay-to-play product development venture. It will never be feasible for the federal government to fund testing of all commercial detectors without first assessing their potential merits for detection of CBRN agents because of the very large number of hazardous CBRN agents and the expense of testing detectors against these agents.

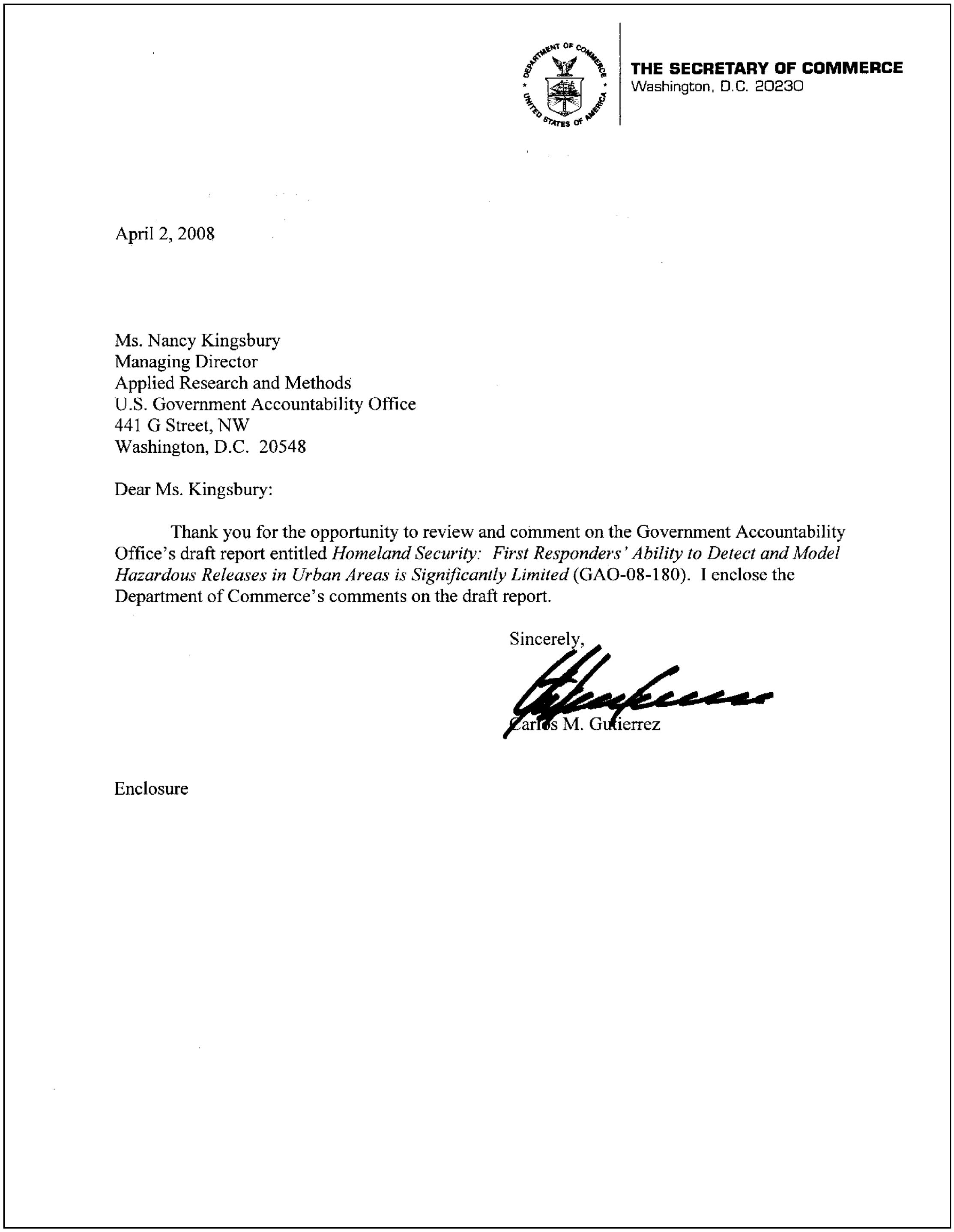
Technical comments have been provided under separate cover.

Sincerely,

Penelope G. McCormack
Acting Director
Departmental GAO/OIG Liaison Office

MMcP

Appendix IV: Comments from the Department of Commerce



THE SECRETARY OF COMMERCE
Washington, D.C. 20230

April 2, 2008

Ms. Nancy Kingsbury
Managing Director
Applied Research and Methods
U.S. Government Accountability Office
441 G Street, NW
Washington, D.C. 20548

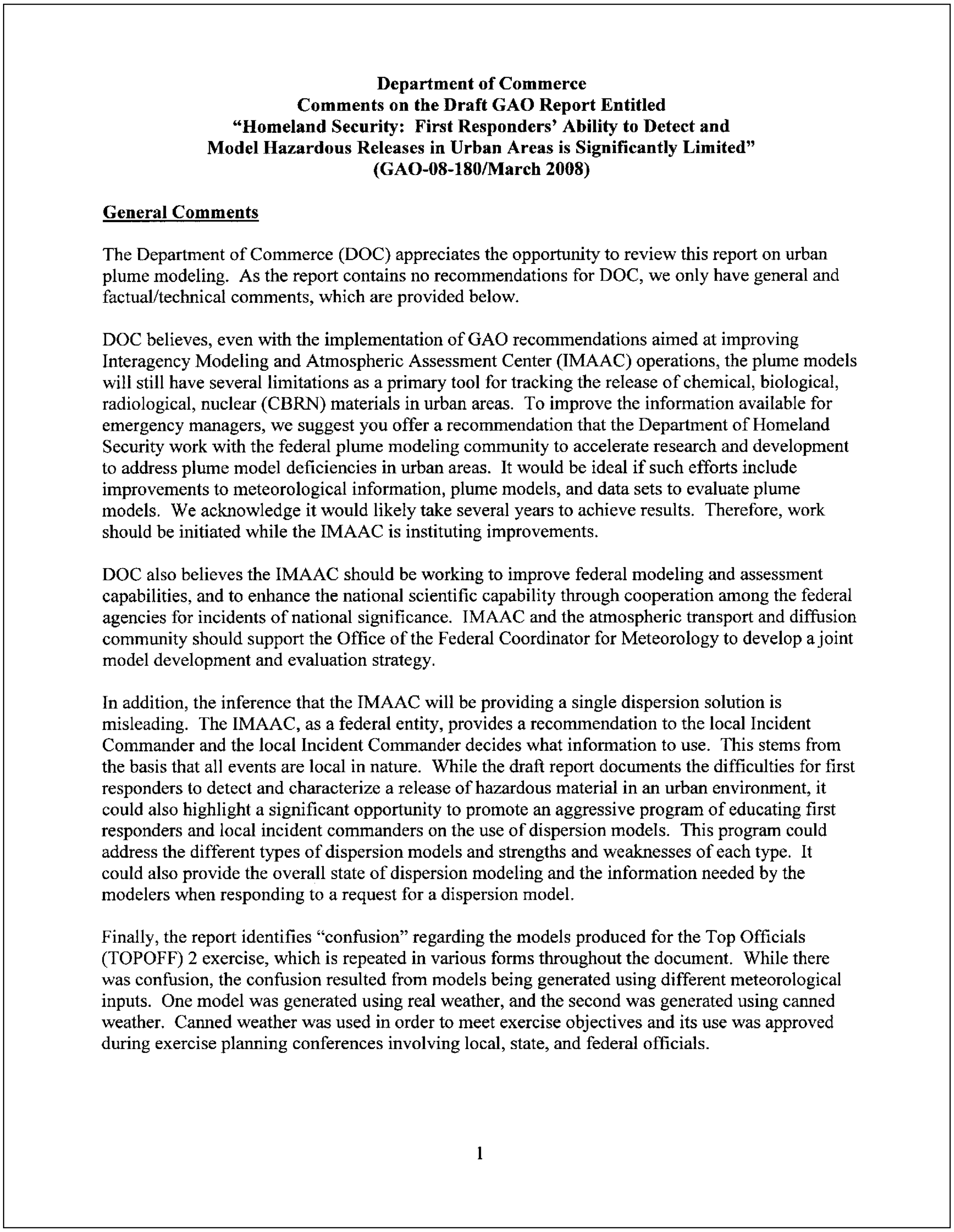
Dear Ms. Kingsbury:

Thank you for the opportunity to review and comment on the Government Accountability Office's draft report entitled *Homeland Security: First Responders' Ability to Detect and Model Hazardous Releases in Urban Areas is Significantly Limited* (GAO-08-180). I enclose the Department of Commerce's comments on the draft report.

Sincerely,

Carlos M. Gutierrez

Enclosure



Department of Commerce
Comments on the Draft GAO Report Entitled "Homeland Security: First Responders' Ability to Detect and Model Hazardous Releases in Urban Areas is Significantly Limited"
(GAO-08-180/March 2008)

General Comments

The Department of Commerce (DOC) appreciates the opportunity to review this report on urban plume modeling. As the report contains no recommendations for DOC, we only have general and factual/technical comments, which are provided below.

DOC believes, even with the implementation of GAO recommendations aimed at improving Interagency Modeling and Atmospheric Assessment Center (IMAAC) operations, the plume models will still have several limitations as a primary tool for tracking the release of chemical, biological, radiological, nuclear (CBRN) materials in urban areas. To improve the information available for emergency managers, we suggest you offer a recommendation that the Department of Homeland Security work with the federal plume modeling community to accelerate research and development to address plume model deficiencies in urban areas. It would be ideal if such efforts include improvements to meteorological information, plume models, and data sets to evaluate plume models. We acknowledge it would likely take several years to achieve results. Therefore, work should be initiated while the IMAAC is instituting improvements.

DOC also believes the IMAAC should be working to improve federal modeling and assessment capabilities, and to enhance the national scientific capability through cooperation among the federal agencies for incidents of national significance. IMAAC and the atmospheric transport and diffusion community should support the Office of the Federal Coordinator for Meteorology to develop a joint model development and evaluation strategy.

In addition, the inference that the IMAAC will be providing a single dispersion solution is misleading. The IMAAC, as a federal entity, provides a recommendation to the local Incident Commander and the local Incident Commander decides what information to use. This stems from the basis that all events are local in nature. While the draft report documents the difficulties for first responders to detect and characterize a release of hazardous material in an urban environment, it could also highlight a significant opportunity to promote an aggressive program of educating first responders and local incident commanders on the use of dispersion models. This program could address the different types of dispersion models and strengths and weaknesses of each type. It could also provide the overall state of dispersion modeling and the information needed by the modelers when responding to a request for a dispersion model.

Finally, the report identifies "confusion" regarding the models produced for the Top Officials (TOPOFF) 2 exercise, which is repeated in various forms throughout the document. While there was confusion, the confusion resulted from models being generated using different meteorological inputs. One model was generated using real weather, and the second was generated using canned weather. Canned weather was used in order to meet exercise objectives and its use was approved during exercise planning conferences involving local, state, and federal officials.

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