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Modeling and Simulation of Hazardous Material Releases for Homeland Security Applications

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Comments or questions about this report may be e-mailed to: simresponse@cme.nist.gov.

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1. Purpose

Simulations of hazardous material releases attempt to model and evaluate the dispersion of various kinds of materials including chemical, biological, nuclear, and radiological agents into the atmosphere, HVAC systems within buildings and other enclosed spaces, watershed systems, and the soil. Releases may be accidental (e.g., a ruptured tank car from a train derailment), intentional (e.g., a terrorist attack), or natural (e.g., a wildfire or volcanic eruption). Examples of release sources include nuclear power plant accidents, leaks or spills from tanks or industrial plants, use of chemical and biological sprayers, fires, smokestack emissions, nuclear detonation clouds, and other explosive blasts. The goal of this document is to capture the current knowledge and information resources that can serve as a common baseline for researchers and developers of models and simulations of hazardous material releases for homeland security applications. This initial version of the document attempts to assemble relevant, publicly available information from a number of sources within U.S. Department of Homeland Security (DHS) and the modeling and simulation (M&S) communities.

This document is intended to help initiate the discussion of the current leading research, development, standards, and implementation issues within the hazardous material release M&S community. The document will be updated based on the input of domain experts across government, research, and commercial organizations. These experts will be invited to join together in a workshop to review and extend this document. The workshop will focus on simulation and modeling activities and needs that support analysis, planning, and training for the hazardous material release as well as the integration of those M&S applications with those developed by other sectors. Issues to be addressed within the scope of this workshop include the establishment of consensus on:

- identification of subject matter experts
- definition of customer and user needs
- system requirements specifications
- recommended/approved modeling techniques and approaches
- identification of data sources, reference data sets, formats, and standards
- identification of appropriate model evaluation and accreditation practices

The workshop will also help identify the current leading research, development, standards, and implementation issues. Such analysis by the workshop participants may be found to be relevant by future efforts for developing standards, conducting research and development, and enhancing implementation policies and procedures for homeland security applications of M&S to improve the protection of critical infrastructure systems.

This document provides a compendium of information that has been assembled that is relevant to the M&S of hazardous material releases (HMR). HMR, as defined by DHS, are introduced in Section 2. Section 3 provides a general background on methodologies, models, and simulations. An initial set of high level user and customer needs for M&S applications in the HMR domain is presented in Section 4. Section 5 translates the high level needs to a representative set of M&S system requirements (a more detailed specification is currently under development in a related effort). The existing HMR M&S resources and capabilities such as projects, tools, standards, and data sets that have been developed over the years to meet the needs and requirements are identified in Section 6. Section 7 presents a discussion of issues, concerns, and recommendations for advancing M&S for HMR emanating from a comparison of current resources and capabilities with the needs and requirements. Section 8 concludes the document while section 9 provides list of references used.

Three additional documents have been prepared as a part of this effort. The other documents address M&S for critical infrastructure and key resources (CIKR), incident management, and healthcare systems. To minimize redundancy between the documents, each document focuses on the M&S techniques that are most significant to the sectors mission and objectives. The CIKR document emphasizes modeling and simulation supporting analysis of systems (e.g., vulnerability, security), whereas the incident management document focuses more on training and exercises. The healthcare systems document addresses M&S for analysis, training, and exercises, but at a more detailed level than the previous two documents. The hazardous material release document focuses on the more physical aspects of M&S associated with explosions, fires, plumes, and the flow of hazardous materials in building ventilation systems, bodies of water, and the soil. The authors recognize that each of the sectors may employ all of the M&S techniques that have been identified in the other documents, but typically to a lesser extent.

The authors welcome identification of omissions as well as suggestions for improvements. Please contact the authors directly or submit comments or questions by e-mail to simresponse@cme.nist.gov.

2. Introduction to Hazardous Material Releases (HMR) and Associated DHS Guidance

Hazardous materials are substances which if released or misused can cause death, serious injury, long lasting health effects, and damage to structure and other properties as well as to the environment [GBRA 2010]. Hazardous materials may be in solid, liquid or gaseous form and may be explosive, flammable, combustible, corrosive, reactive, poisonous, biological or radioactive. These material have to be properly contained in storage, use and transport, else their chemical, physical and biological properties may pose a potential risk to life, health, the environment, and property. In a hazardous materials incident, solid, liquid and/or gaseous contaminants may be released from fixed or mobile containers. Hazardous material incidents can range from an accident on highway resulting in a chemical spill to contamination of groundwater by naturally occurring methane gas.

There are numerous incidents of hazardous material releases (HMR) in United States every year. The releases may be airborne, or spills and discharges that contaminate water bodies, vegetation, soil, and built up structures. The airborne hazards are also identified as hazardous fumes, noxious chemicals, or mysterious odors. The airborne hazards affect areas and people outdoors but they may permeate buildings and affect people indoors. The hazardous material releases lead to areas and buildings being evacuated in a majority of cases. However, depending on the hazard, release pattern, weather conditions, and a number of other factors, it may be advisable to stay indoors, i.e., shelter in place.

Majority of the HMR incidents are results of accidental releases of toxic industrial or agricultural chemicals [AFCESA 2001]. Occasionally they may be releases of biological or radiological materials. Majority of releases happen during the course of regular operations at fixed facilities [KCOEM 2011], that is, due to industrial accidents (e.g., fire or equipment malfunction at chemical plants). Other causes of releases are transportation accidents (e.g., tanker collisions, train derailments, etc.), malicious acts (e.g., vandalism, terrorist attacks), and natural disasters (e.g., earthquakes, hurricanes, etc). A recent example of HMR due to a natural disaster is the release of radioactive plumes from a nuclear power plant affected by earthquake and tsunami in Japan in March 2011.

The airborne HMR have drawn more attention due to their potential to negatively affect large areas. Some key parameters that are relevant to dispersion of atmospheric releases are the release location, release mechanism, agent chemical/material properties, weather conditions, and terrain and geography. M&S tools are important to analyze and predict the dispersion of such releases using inputs on these parameters based on reports, visual observations and sensors. The tools take into account the material released, the local topography, and meteorological and atmospheric data to determine the dispersion area and associated concentrations [NRC 2003, page 9]. The concentrations are then used to assess the risk to the population, environment and property in the affected areas. Incident management personnel use the results of these types of models and simulations to predict the impact of releases, allocate resources, and plan response operations, among other uses.

Management of large HMR incidents should be done following the template in the National Incident Management System (NIMS) [DHS 2008a] developed by U.S. Department of Homeland Security under the authority granted by the Homeland Security Presidential Directive (HSPD)-5, Management of Domestic Incidents. NIMS provides a national template for federal, state, tribal, and local governments, nongovernmental organizations (NGOs), and the private sector to work together to prevent, protect against, respond to, recover from and mitigate the effects of incidents, regardless of cause, size, location, or complexity. It integrates best practices into a comprehensive framework for use nationwide by emergency management/response personnel. The HMR incident management should also utilize the National Response Framework (NRF) [DHS 2008b] that builds upon NIMS and describes additional specific Federal roles and structures for incidents in which Federal resources are involved. NIMS, together with NRF and other documents, provides the structure needed to coordinate, integrate, and synchronize activities derived from various relevant statutes, national strategies, and Presidential directives to create a unified national approach to implementing the incident management mission (see Figure 1).

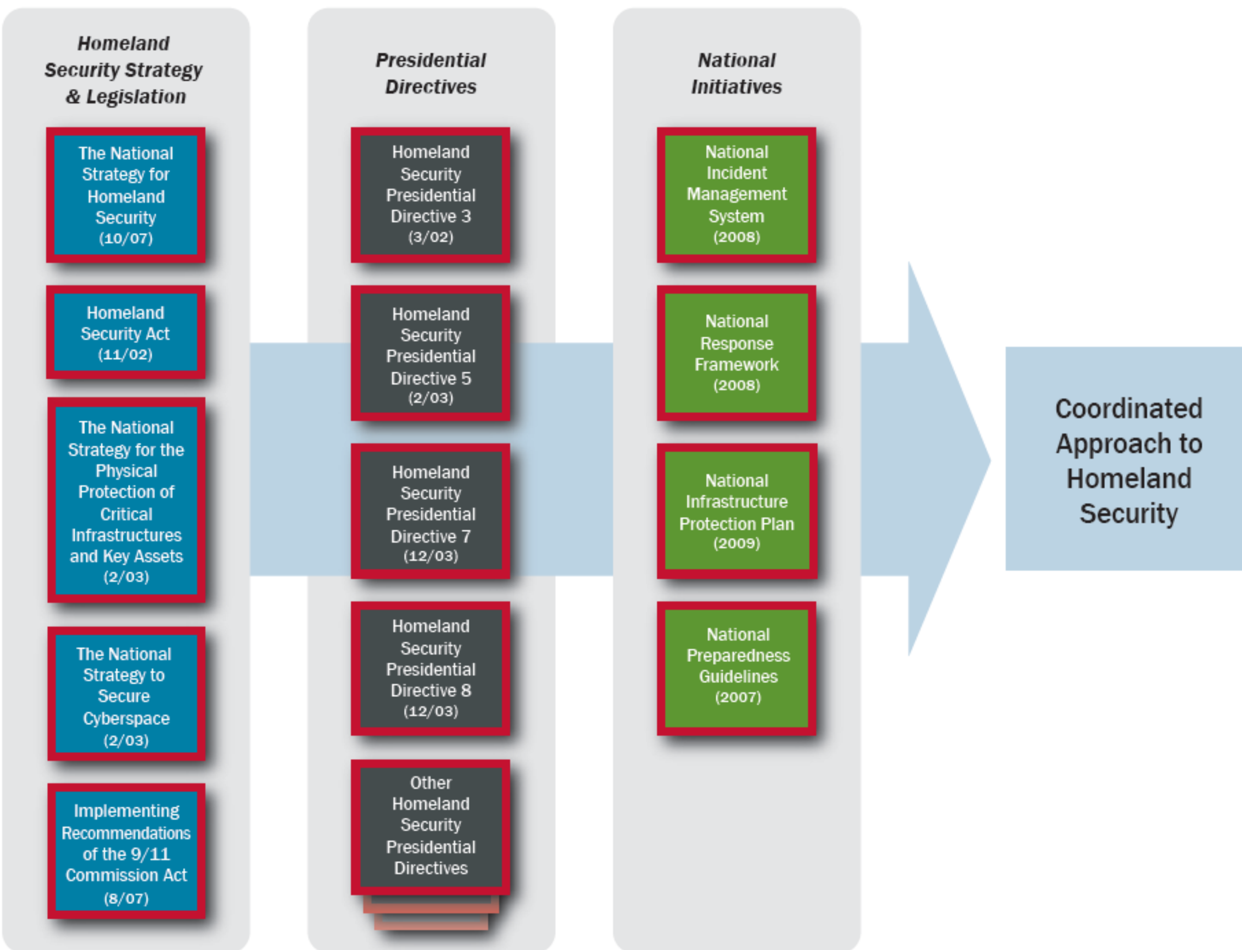

Figure 1: National Framework for Homeland Security (from [DHS 2009])

HMR is one of hazards included in the all-hazard context that NIMS addresses. NIMS identifies a specific resource category, hazardous material response, for national resource typing to facilitate resource management for HMR incidents. It also calls for utilizing personnel with special skills for HMR incidents in the unified command. Similarly, it calls for the planning section to include a distinct Technical Unit to coordinate and manage large volumes of environmental samples or analytical data from multiple sources in the context of certain complex incidents, particularly those involving biological, chemical, or radiological hazards. Technical specialists assigned to the Environmental Unit may include a scientific support coordinator as well as technicians proficient in response technologies, weather forecast, resources at risk, sampling, cleanup assessment, and disposal.

The NRF includes 15 emergency support functions (ESFs) to align categories of resources and provide strategic objectives for their use. The ESFs are called up as needed by the Federal Emergency Management Agency (FEMA) to coordinate response support from across the federal government and NGOs. The ESF#10 is devoted to oil and hazardous material response and provides federal support in response to an actual or potential discharge and/or uncontrolled release of oil or hazardous materials when activated. The ESF describes the role of different federal agencies in responding to HMR incidents. It calls for use of the Interagency Modeling and Atmospheric Assessment Center (IMAAC) under U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) when needed for operational weather data and forecasts tailored to support the response.

The NRF also provides Incident Annexes that describe the concept of operations to address specific contingency or hazard situations. There are two annexes relevant to HMR, biological and nuclear/radiological incident annexes. The nuclear/radiological incident annex identifies Department of Energy's National Atmospheric Release Advisory Center (NARAC) as a key resource that may be activated. NARAC provides a computer-based emergency preparedness and response predictive modeling capability. NARAC utilizes M&S to provide real-time computer predictions of the atmospheric transport of material from radioactive releases and of the downwind effects on health and safety. The annex also calls for IMAAC to generate the single and interagency coordinated Federal prediction of atmospheric dispersions and their consequences. IMAAC and NARAC functions are currently served by a single unit based at the Lawrence Livermore National Laboratory in Livermore, California. In addition, Department of Commerce responsibilities in the annex include providing atmospheric transport and dispersion (plume) modeling assessment and forecasts to the coordinating agency when IMAAC is not activated, and maintaining and further developing the HYSPLIT transport and dispersion model.

3. Perspectives on Methodologies, Models, and Simulations

Concise Oxford Dictionary of Current English, 1996, defines Methodology as "a body of *methods* used in a particular activity." Methodology is principles of method, and such principles can be used to study and inform problem solving and decision-making. [Checkland 2000] describes a useful model linking methodology and the user of a methodology to problem solving:

> *'A problem-solving situation with three elements:*
> - *A user of methodology (this assumes that the user is familiar with the methodology)*
> - *Methodology as documented*
> - *Situation as perceived by the user*
>
> *Relationship and interactions between the three elements are encapsulated in the LUMAS model (Learning, User of methodology, Methodology formally described, Actual approach adopted, and real world problem Situation) shown in figure 2. A simple example narrative for the diagram may be: A user, U, appreciating a methodology, M, as a coherent set of principles and perceiving a problem situation, S, asks, "what can I do?" The User then tailors from M a specific*

approach, A, judged to be appropriate for S, and uses it in an attempt to improve the situation. This generates learning, L, which may change the user, U or the methodology, M.

A methodology is, then, a logical framework that not only brings forth learning for an individual, but does so in a consistent and systemic manner so learnings can be shared and passed on.'

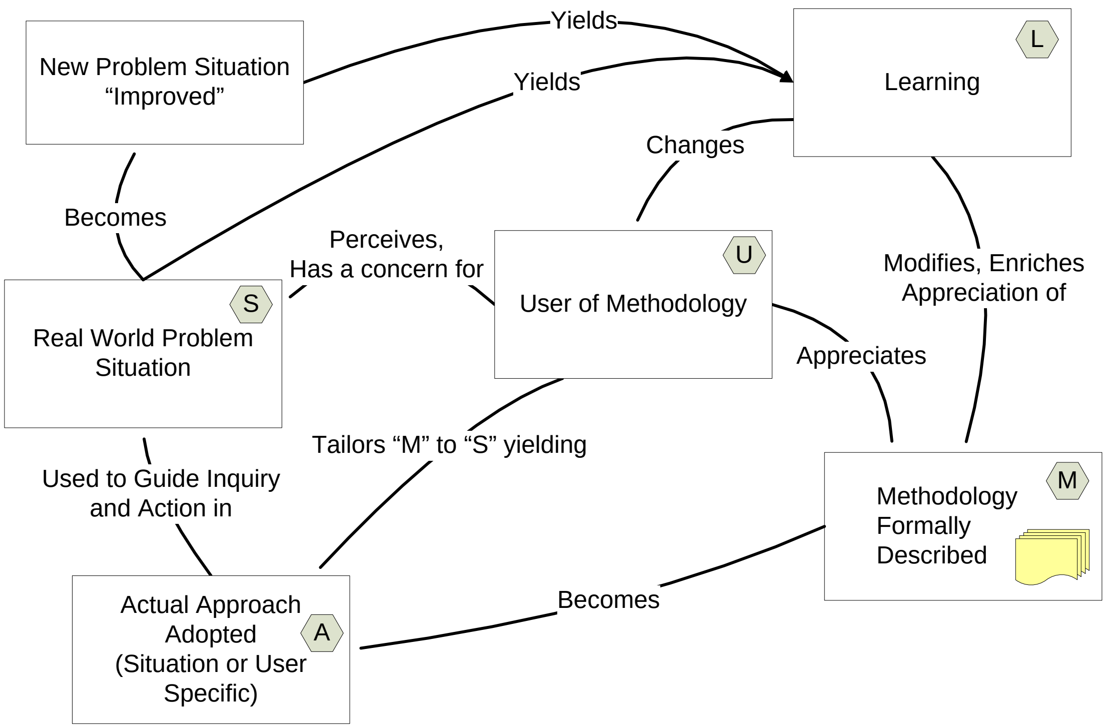

Figure 2: The LUMAS Model (from [Checkland 2000])

Another perspective on methodology comes from the International Council on Systems Engineering (INCOSE) where methodology is defined as "a collection of <u>related</u> processes, methods and tools" [INCOSE 2008]. This is based on definitions from [Martin 1996]:

'Methodology can be differentiated from other related concepts using the following definitions from [Martin 1996]:

- *A Process (P) is a logical sequence of tasks performed to achieve a particular objective. A process defines "WHAT" is to be done, without specifying "HOW" each task is performed. The structure of a process provides several levels of aggregation to allow analysis and definition to be done at various levels of detail to support different decision-making needs.*
- *A Method (M) consists of techniques for performing a task, in other words, it defines the "HOW" of each task. (In this context, the words: "method," "technique," "practice," and "procedure" are often used interchangeably.) At any level, process tasks are performed using methods. However, each method is also a process itself, with a sequence of tasks to be performed for that particular method. In other words, the "HOW" at one level of abstraction becomes the "WHAT" at the next lower level.*
- *A Tool (T) is an instrument that, when applied to a particular method, can enhance the efficiency of the task; provided it is applied properly and by somebody with proper skills and training. The purpose of a tool should be to facilitate the accomplishment of the "HOWs." In a broader sense, a tool enhances the "WHAT" and the "HOW." Most tools used to support*

systems engineering are computer- or software-based, and are also known as Computer Aided Engineering (CAE) tools.

Closely associated with methodology is an Environment (E) that consists of the surroundings, the external objects, conditions, or factors that influence the actions of an object, individual person or group [Martin 1996]. These conditions can be social, cultural, personal, physical, organizational, or functional. The purpose of a project environment should be to integrate and support the use of the tools and methods used on that project. An environment thus enables (or disables) the "WHAT" and the "HOW".'

The interrelationship of processes, methods, tools, and environments is graphically represented in Figure 3.

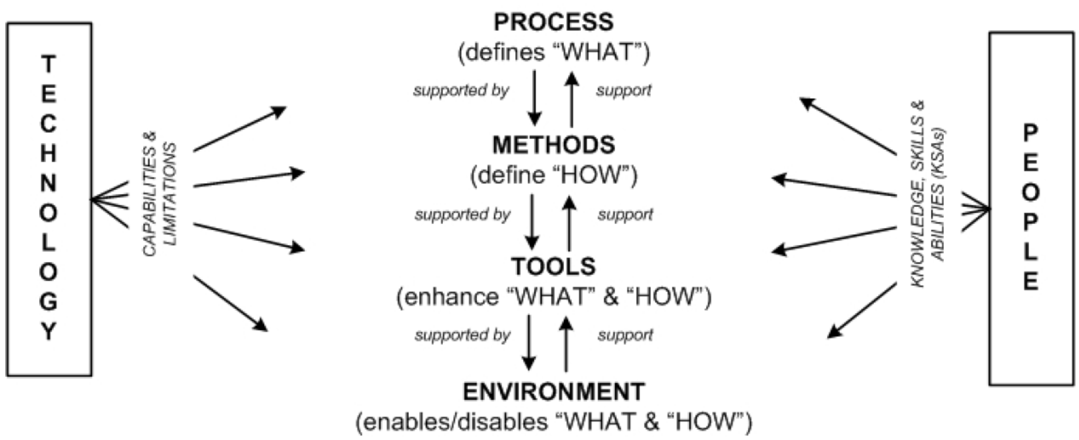

Figure 3: The Process, Methods, Tools, Environments Elements, and Effects of Technology and People (from [INCOSE 2008])

"Model" and "simulation" can be defined or classified in many ways. For example, the DHS Lexicon [DHS 2010] includes the following definitions:

- *Model*: approximation, representation, or idealization of selected aspects of the structure, behavior, operation, or other characteristics of a real-world process, concept, or system.

- *Simulation*: model that behaves or operates like a given process, concept, or system when provided a set of controlled inputs.

In addition, Department of Defense glossary [DoD 2010] provides the following definition.

- *Modeling & Simulation*: Modeling and Simulation (M&S): The discipline that comprises the development and/or use of models and simulations. M&S is highly dependent upon Information Technology as defined in DoD Directive 4630.05, Interoperability and Supportability of Information Technology (IT) and National Security Systems (NSS), May 5, 2004.

  a. The use of models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably, but simulations generally execute models over time, space, events, or other processes.

The focus of this document is on computer models and simulations – computer implemented physical, mathematical, process, phenomenological or other types of models. One perspective on the way in which computer models and simulations support methodology is modeled in Figure 4 (M in the LUMAS Model).

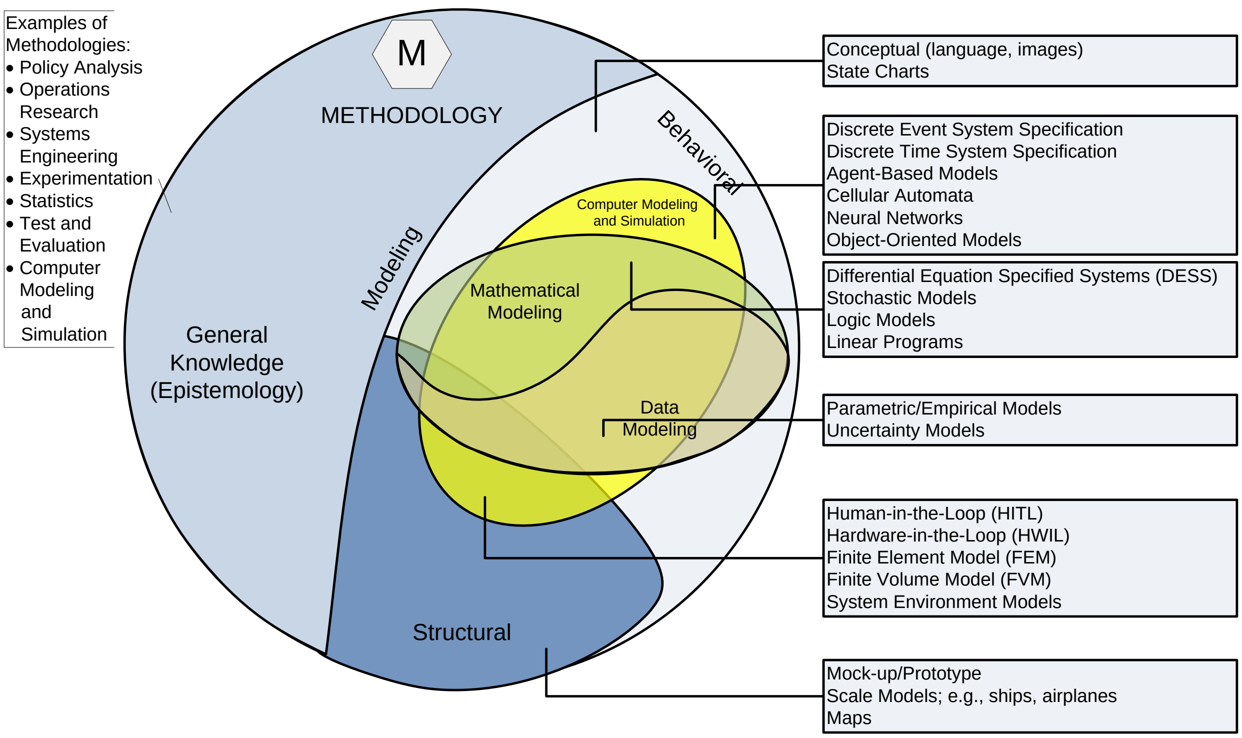

Figure 4: Modeling in methodology

Models can broadly be divided into structural and behavior representations of systems, which could include mathematical or empirical modeling. Each of these types of models can be implemented using computer models for simulation and used to study questions of interest about a particular system. Various examples of model types are shown. This list of model types is not complete or exhaustive, but is meant to show typical applications of M&S that support methodologies such as operations research, systems engineering, experimentation, or other types of analysis.

Although M&S capabilities are tools in many different methodologies, M&S using computers is itself a methodology with supporting processes, methods and tools. Figure 5 illustrates a simplified, generic process for development of computational M&S capabilities to address a non-trivial engineering or scientific problem from the perspective of an M&S developer. The process shown in Figure 5 also maps to the LUMAS model as shown in the figure. This process is also applicable to simpler problems where trivial steps may be combined. Also, the M&S developer may be the problem solver and consumer of the M&S results such as an engineer addressing a systems design question or a program manager doing a "what if' analysis to assess the risk to a program.

The first step in the process includes the model or code developer (U) developing a clear understanding of what problem situation (S) the consumer of the M&S results is trying to address. A conceptual model of the system or problem serves as a framework in developing and implementing the appropriate computer modeling capability (A) using the M&S methodology (M) to address the question at hand. With a clear conceptual model in mind, developers have a number of choices to make in generating results:

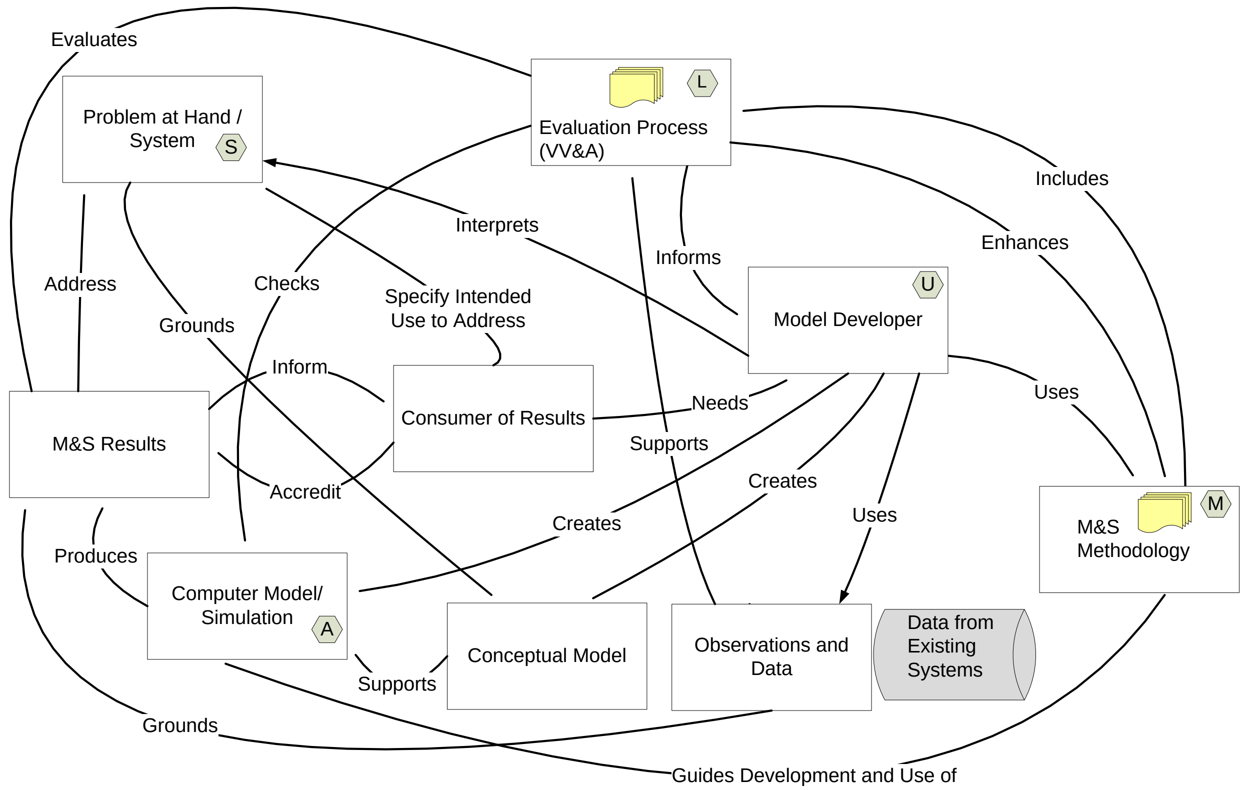

Figure 5: Computer Modeling and Simulation – Developer's Perspective

- What data, knowledge, theories, or models are available or applicable to address the problem at hand?
- Is the data, knowledge, or understanding sufficient in both quality and quantity to address the problem at hand, or will additional data or observations be required to support development?
- What is the risk of using erroneous results, e.g., will these results be the only input to a decision, or will other sources of information be available to support decision making?
- How can the conceptual model be expressed mathematically or physically?
- What boundary and initial condition should be used?
- What modeling paradigm or approach would be most appropriate to implement the analysis?
- Given the developers' experience, what particular codes or capabilities would be most suitable for implementing the model, considering software, hardware, and other constraints and limitations?
- Given the code or computer capability has been developed, have any mistakes or errors been made in completing this or in entering the data?
- Given there are no mistakes or errors found in developing the capability or entering the data, are the results realistic, and do they make sense?
- What approach should be used to ensure that the results are correct?
- How do uncertainties and approximations affect the computational results?
- Given that everything else is correct, are the results suitable to address the problem at hand?
- How should the results and associated uncertainty be present for use in decision making?

M&S capabilities are used to model only selected aspects of a system and the models are implemented in a computing environment; therefore, the models need to be critically evaluated to ensure that the results are credible for their specific intended use, and this is typically done using an evaluation process (L) which is included in the M&S methodology (M) and informs the model developer (U) of the quality of the M&S capability and results in addressing the problem at hand (S).

Evaluation of M&S capabilities and results should take into account the many factors that affect the quality of the results including the level of understanding or knowledge of the issues being addressed and the experience level of model developers. Several organizations have developed processes and guidelines to address the credibility of M&S capabilities. For example, DoD has a process for documentation, evaluation, and certification of M&S results known as Verification, Validation and Accreditation (VV&A) that is defined in a recommended practice guide [DoD 2006]. The DoD process is implemented in policy, which develops a common understanding of the major steps in the VV&A process defined as below [DoD 2009]:

- *Verification.* The process of determining that a model implementation and its associated data accurately represents the developer's conceptual description and specifications.
- *Validation.* The process of determining the degree to which a model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.
- *Accreditation.* The official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose.

All M&S capabilities should complete verification and validation (V&V). M&S capabilities used as the primary input to critical decision making, e.g., on cost, schedule, or performance of the system, should be formally accredited to certify that the results are credible for their intended use. Analysts and decision-makers need to be aware of these sorts of issues when presented with computational modeling and simulation results.

[Balci 1998] developed a taxonomy and describes the use of different methods to evaluate M&S capabilities and results based on software testing approaches. Figure 6 identifies these verification, validation, and testing methods or techniques which can be used to support an evaluation process such as VV&A.

In addition to the use of recommended practices for conceptual modeling and ensuring model credibility, model developers should employ recommended practices for a number of other aspects. [Jain 2011] recommends best practices for modeling, simulation, and analysis for homeland security applications for the following aspects:

1. conceptual modeling
2. innovative approaches
3. software engineering
4. model confidence/ verification, validation and accreditation (VV&A)
5. use of standards
6. interoperability
7. execution performance
8. user friendliness and accessibility

Figure 6: Taxonomy of Verification, Validation, and Testing Techniques (from [Balci 1998])

4. Needs Analysis Overview

Emergency planners, first responders, and training personnel need simulations to support exercises, drills, emergencies, tests, alerts, real world incidents, and planning for national security events. When a hazardous atmospheric release occurs officials want to know – *What is the hazard? Where is it going? Who is at risk? How do we respond?* Simulation results may be used to help officials to:

a) Provide real-time access and automated reach-back to plume modeling capabilities with the incorporation of real-time weather data.
b) Establish situational awareness of current/forecast plume transport direction and hazard areas.

c) Support contingency planning, damage assessment, development of response strategies, and consequence management as well as the development of protective action guides/recommendations to deal with the short and long term health and other adverse effects of a hazardous release.
d) Estimate potential damages, casualties, illnesses, fatalities.
e) Estimate emergency assistance requirements.
f) Project areas where buildings, land, agricultural crops, bodies of water, and other man-made or natural resources are or will be contaminated.
g) Select locations for incident command sites, decontamination facilities, sheltering, and evacuation areas.
h) Determine emergency response and health services facilities impacted by the release.
i) Make shelter-in-place, evacuation, and personal protective equipment use decisions.
j) Identify safe approach and evacuation routes.
k) Guide field measurement and aerial sampling teams.
l) Determine radiological monitoring requirements.
m) Estimate the source amounts and locations of unknown releases.
n) Obtain information for communications with the public to allay concerns.
o) Support post-event analysis for exercises and actual incidents.

Both forward and reverse simulations are needed. Forward simulations predict the spread of a cloud of materials from a known release. Reverse simulations may be used to predict probable source locations and quantities of agent released based on sensor data. The source location, weather, quantity and types of chemicals involved may affect the dispersion of materials.

Inputs to simulation models may include the characteristics of the agent released, release mechanism used, the location of release point, terrain and structures around the release point, and weather conditions. Inputs may alternately be based on the sensor readings over time in the area of interest indicating the presence of an agent and the direction(s) of the spreading plume.

Outputs may include time profile of the plume, affected areas and populations, and the exposure profile for the population in the region affected by the plume over time.

5. Requirements Specifications

This section provides a high level list of requirements for hazardous material release model implementations. Requirement specifications are categorized into five major areas:

- Functional requirements (Section 5.1)
- Data requirements (Section 5.2)
- User interface requirements (Section 5.3)
- Performance requirements (Section 5.4)
- Verification, validation, and accreditation requirements (Section 5.5)

A specific system implementation may contain only a subset of these requirements as determined by program management and/or the customers and users.

5.1. Functional Requirements

This section identifies functions that may be included in hazardous material release models and simulations.

a) Predict the initial direction, travel, and dispersion of a plume over time from a single or multiple sources taking into account the type of source, material/chemical properties, release location, weather conditions, terrain, urban areas, and other man-made structures.
b) Predict the concentration of the chemical or biological agent within the plume and flow through drainage areas over time.
c) Estimate deposition and contamination levels for air, water, ground, and building surfaces.
d) Identify exposed population and predict exposure levels over time.
e) Identify the time when the sensors placed in the area of interest will be triggered following the release of the plume.
f) Provide for reverse simulations to estimate unknown source amounts, probable release locations, and support event reconstruction.
g) Provide capabilities to refine simulations based on field measurements and other sensor data.
h) Support a number of different established problems, models, representations, and techniques including chemical, biological, radiological, nuclear, and explosives (CBRNE) source characterizations, Gaussian-plumes, dense gas dispersion physics, boundary layer meteorology, atmospheric turbulence, urban flow and dispersion, high altitude dispersion, time integrated dosages, inverse modeling and event reconstruction.
i) Automate the utilization of sensor field measurements to estimate source terms and optimize predictions.
j) Couple sensor data and simulations via Bayesian inference, stochastic sampling, and optimization methods.
k) Perform backwards analyses to determine probabilistic distribution of unknown source characteristics.
l) Generate optimal and probabilistic forward plume model predictions.
m) Use Markov chain sampling to determine probabilistic source locations based on sensor readings, Green's function methodology (heat conduction and diffusion), fate and transport models.
n) Provide source characterization models for explosive dispersal devices that predict airborne fractions and particle-size distribution.
o) Provide fast-running empirical urban models and high-resolution building-scale computational fluid dynamics models use finite element modeling (FEM) techniques.
p) Support vector and raster representations of geography, buildings, and other structures.
q) Support a range of different grid resolutions, e.g., 30 meter, 100 meter, 1 kilometer, 10 kilometer.
r) Model indoor exposure levels due to the effects of building leakiness, i.e., outdoor plume air concentration versus corresponding indoor air concentration.
s) Support the integration and/or distributed execution of interrelated models including dispersion, weather, exposure and hazard effects, watershed flows.
t) Support various release mechanisms including explosions, fires, volcanic eruptions, gas cylinders, sprayers, manual methods, tank ruptures, and building collapses.
u) Support micro and meso-scale forecasts (10 km).
v) Model radiation effects including fallout, wet deposition hotspots, ground shine, cloud shine, and inhalation doses.
w) Identify regions where the exposed population will experience life threatening, serious long-lasting, or notable discomfort effects.

5.2. Data Requirements

This section identifies input and output data types that may be supported for hazardous material release models and simulations.

a) Meteorological data: observed and forecast weather conditions that may affect a plume including wind speed, direction, and precipitation

b) Plume release mechanisms and their attributes: explosions, fires, compressed gas cylinders, tank ruptures, and manual release of powders
c) Specifications of characteristics of an explosive release: detonation point, explosive source characteristics (particle size distribution and spatial distribution of mass from surface to several hundred meters above ground)
d) Hazardous agent characteristics including form (gas, liquid, or powder), chemical properties, particle size and weight distributions, cohesion, and lethality
e) Specification of the incident area including location of source, terrain, and buildings
f) Demographics data – population location, density, and attributes by time of day

5.3. User Interface Requirements

This section identifies user interface capabilities that may be supported for hazardous material release models and simulations.

a) Provide capabilities to configure simulation runs with specific release incident parameters, weather conditions, and geographic regions.
b) Provide a capability for modifying of key release parameters including location of source, agent characteristics, and location of sensors.
c) Generate graphical views of plume dispersion over a 2D or 3D representation of area of interest.
d) Provide user control mechanisms that effect rapid execution/playback of simulation runs to move forward and back to desired points in time.
e) Use various representation schemes to display release effects including chemical concentration, radiation intensity, toxicity, lethality, and exposure levels, e.g., colors, shading, contour lines.
f) Provide interfaces to generate still image and video files that can be used to transfer results for viewing or playback using other software tools.

5.4. Performance Requirements

This section identifies possible performance considerations for hazardous material release models and simulations.

a) Support fast running local models that generate predictions in 5-15 minutes.
b) Provide for updates from real time meteorological databases and observations.
c) Share model predictions with other software applications, e.g., incident management applications.

5.5. Verification, Validation, and Accreditation Requirements

This section identifies approaches that may be used to verify, validate, and/or accredit hazardous material release models and simulations.

a) Use the release and monitoring of harmless/inert tracer chemicals to validate models.
b) Use of validated dispersion models as component modules in other systems.
c) Validate new models by comparison of model predictions against historical release data.

6. Identification of M&S Resources

This section identifies existing M&S resources that support HMR response and are possibly relevant to meeting some of the needs and requirements presented in sections 4 and 5. Resources that primarily support other M&S areas or domains, e.g., critical infrastructure, are not included. Topics addressed include:

- Projects, facilities and capabilities (Section 6.1)
- Simulation models and tools (Section 6.2)
- Relevant standards and Guidelines (Section 6.3)
- Data sources (Section 6.4)

6.1. Projects, Facilities and Capabilities

This section identifies projects, facilities, and other capabilities that currently exist that are working on modeling and simulation of hazardous material releases.

National Atmospheric Release Advisory Center (NARAC) – provides tools and services to the Federal Government that map the probable spread of hazardous material accidentally or intentionally released into the atmosphere. NARAC provides atmospheric plume predictions in time for an emergency manager to decide if taking protective action is necessary to protect the health and safety of people in affected areas. Located at the U.S. Department of Energy's Lawrence Livermore National Laboratory, NARAC is a national support and resource center for planning, real-time assessment, emergency response, and detailed studies of incidents involving a wide variety of hazards, including nuclear, radiological, chemical, biological, and natural emissions [NARAC 2010a].

BioWatch Indoor Reachback Center (BIRC), Sandia National Laboratory – BIRC's role is to provide scientific modeling support to decision-makers responding to a public release of a biohazard agent. BIRC is prepared to deliver information to decision-makers (typically, the emergency response personnel at high-traffic transportation facilities) within two hours of notification of a biohazard release. The information includes important issues such the size and location of the release and recommendations as to where sampling efforts should be focused. BIRC can also offer insight into whether the release is merely environmental in nature, or intentional, for example a terrorist attack. BIRC is part of the Department of Homeland Security's BioWatch program, an early warning system designed to rapidly detect trace amounts of biological materials at various public facilities across the United States. BioWatch assists public health experts to determine the presence and geographic extent of a biological agent release, allowing federal, state, and local officials to more quickly determine emergency response, medical care, and consequence management needs [Sandia 2008].

Federal Radiological Monitoring and Assessment Center (FRMAC)- FRMAC is one of the emergency response resources, or assets, administered by NNSA. The Federal government maintains an extensive response capability for radiological monitoring and assessment. In the unlikely event of a major radiological incident, the full resources of the U.S. government will be coordinated to support state, local, and tribal governments. The FRMAC mission 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 through the Lead Federal Agency [NNSA 2010].

Environmental Protection Agency (EPA) National Exposure Research Lab (NERL) – located in Research Triangle Park, North Carolina, provides scientific understanding, information and assessment tools to reduce and quantify the uncertainty in the Agency's exposure and risk assessments for all environmental stressors [EPA 2010a]. The Atmospheric Modeling and Analysis Division provides numerical and physical modeling support to the homeland security mission in protecting against the environmental and health effects of terrorist acts. This involves numerical modeling complemented by physical modeling in the Division's wind tunnel. For example, a 1:600 scale model of lower Manhattan was built and the dispersion of material from the collapse of the World Trade Center towers was studied under various meteorological conditions. Also, dispersion of airborne material around the Pentagon was simulated in the wind tunnel.

Indoor Environment Department Facilities and Instrumentation, Lawrence Berkeley National Laboratory – The department has a number of facilities for indoor environment research under controlled conditions. The Stainless Steel Environmental Chamber is designed for investigations of emissions of pollutants from indoor sources under very low background pollutant conditions and other related research. The Dual Chamber Facility is constructed of conventional indoor materials to more closely simulate rooms in a building, e.g., with painted wallboard. The Indoor Dispersion Experimental Facility is equipped for studies of air and pollution transport and dispersion in large indoor spaces, and evaluation of computational fluid dynamics simulations using advanced experimental techniques. Ventilation Research Laboratories are used to develop and evaluate tracer gas analytical methods, to calibrate tracer gas instrumentation, and to assemble gas samplers and other instruments. The duct research laboratory is for research on building duct systems with respect to energy losses and indoor air quality [LBNL 2010a].

Joint Ambient Breeze Tunnel (JABT), West Desert Test Center, Dugway Proving Grounds, U.S. Army - The tunnel can be used for physically testing the behavior of different challenge materials, interferents, and obscurants. The facility is 530 ft long, 42 ft. wide and 58 ft high and rests on a 15-cm (6-in) thick, steel-reinforced concrete pad. An inner movable ceiling provides flexibility in size and allows the operator to tailor challenges enabling prudent use of chemical and biological agent stimulants. Sensors are strategically located in areas where they will not interfere with cloud movement or standoff detector line of sight. Referee/control and monitoring instruments are housed in the test control room annex near the middle of the JABT. Variable-speed blowers move the cloud through the test section at speeds ranging from 0.2 to 6.0 meters per second (0.4 to 12 mph). Clouds may be as long as 100 meters (328 ft) while moving through the test section at the desired concentration [DPG 2010].

Wind Engineering and Fluids Laboratory (WEFL), Colorado State University – The lab focuses on determination and mitigation of wind effects on buildings and structures, dispersion of pollutants, and experiments using boundary-layer wind tunnels. The core of the WEFL is three large boundary-layer wind tunnels. Research is carried out in cooperation with faculty and students from various departments at Colorado State University and other institutions in the U.S. and abroad. Staff of the WEFL also is involved in wind engineering service. Facilities and technical personnel are available to researchers and practitioners not affiliated with the WEFL [ColoState 2008].

Radiation Safety Information Computational Center (RSICC), Oak Ridge National Laboratory – The RSICC is a Department of Energy Specialized Information Analysis Center (SIAC) authorized to collect, analyze, maintain, and distribute computer software and data sets in the areas of radiation transport and safety [ORNL 2010a]. RSICC staff tests each code before its release, documents and resolves difficulties or problem areas, and assists users with their questions. Problems and issues that are unresolved will be made available to code developers to promote the improvements in new code releases. RSICC maintains a database of issues and fixes for code installation, verification, and use. New versions of codes sent to customers are 'recycled' to RSICC for further dissemination, thereby increasing the value-added of codes in a cost efficient manner.

Research Applications Laboratory (RAL), National Center for Atmospheric Research (NCAR) – National Security Applications Program at RAL has grown to include a combination of DOD, foreign, and private–

industry projects. RAL's objective is to improve meteorological support of homeland security needs through the use of new capabilities in high–resolution mesoscale modeling, short–term thunderstorm prediction, multi–dimensional integrated displays, numerical weather prediction and fine–scale regional and global climatology prediction. New technologies are in operational use at U.S. Army Test and Evaluation Command's (ATEC's) ranges and are being implemented in Washington, DC at the Pentagon, originally sponsored by the Defense Advanced Research Projects Agency (DARPA) and later adopted by the Pentagon Force Protection Agency (PFPA). The projects involving modeling plumes of hazardous materials include: sensor data fusion, Salt Lake City Olympics, Urban Shield, Joint Urban 2003, and bioaerosol study [UCAR 2010].

6.2. Simulations, Models and Tools

A large number of dispersion modeling tools exist across a number of federal agencies, universities, research organizations, and commercial companies. A survey [Mazzola 1995] in the mid-90s listed 94 such tools while another survey [OFCM 2010a] in the late 90s listed 63 of them. This section lists some of the better-known tools as indicated by Internet searches. The tools are arranged alphabetically based on their acronyms.

Tool Acronym	Brief Description
A2C	A2C integrates mesoscale modeling and computational fluid dynamics modeling (CFD) into a single model. It can be used to model: airflows over complex terrain, airflows around buildings with diurnal variations of weather conditions, recirculation flow, separation streamline, and reattachment points on a building, and transport and diffusion of airborne particles and pollutants [YSASoft 2010].
ADAM	Air Force Dispersion Assessment Model (ADAM) is a modified box and Gaussian dispersion model which incorporates thermodynamics, chemistry, heat transfer, aerosol loading, and dense gas effects. Release scenarios include continuous and instantaneous area and point, pressurized and unpressurized, and liquid/vapor/two-phased options [EPA 2010c].
ADMS-Fire	ADMS-Fire is a model of dispersion and deposition from fires. It uses the ADMS (Atmospheric Dispersion Modeling System) dispersion model coupled with a fire source model to predict dispersion and deposition of contaminants. The types of incidents modeled by ADMS-Fire are tire and other scrap fires on open sites. The contaminants of concern are those that could potentially have a food safety impact, namely PAHs, dioxins/furans and heavy metals. It can calculate the dispersion and deposition of these or any other contaminants for which emission data are available [CERC 2010].
ADMSSTAR	ADMSSTAR is a model for the analysis of Short-Term Accidental Releases based on the ADMS methodology, developed specifically to estimate air concentration and deposition rate for radiological or chemical emissions to the atmosphere. It can be used either in situations where the source details are known or it can perform a back calculation and estimate the source strength based on sample data. ADMSSTAR may be linked with ESRI's ArcGIS (Geographical Information System) and used to display contours of concentration and/or deposition overlaid on a map of the area where the incident occurred [CERC 2010].
AFTOX	AFTOX is a Gaussian dispersion model that will handle continuous or instantaneous liquid, gas, elevated or surface releases from point or area sources. Output consists of concentration contour plots, concentration at a specified location, and maximum concentration at a given elevation and time [EPA 2010c].
ALOHA	Areal Locations of Hazardous Atmospheres (ALOHA) is an atmospheric dispersion model used for evaluating releases of hazardous chemical vapors. ALOHA allows the user to estimate the downwind dispersion of a chemical cloud based on the toxicological/physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release. It is part of EPA's Computer-Aided Management of Emergency Operations (CAMEO) suite of tools [EPA 2010b].
AMET	The Atmospheric Model Evaluation Tool (AMET) was developed to aid in the evaluation of meteorological and air quality simulations [EPA 2010a]. AMET utilizes an open source relational database program and an open source statistical program to store and analyze model predictions against observations. AMET is currently script based, and includes numerous scripts for performing common analysis such as scatter plots, box plots, spatial and time series plots, and output of many different statistics. AMET is available for download from the Community Modeling and Analysis

	System website [CMAS 2010].
ASPEN	The Assessment System for Population Exposure Nationwide (ASPEN) consists of a dispersion and a mapping module. The dispersion module is a Gaussian formulation based on ISCST3 for estimating ambient annual average concentrations at a set of fixed receptors within the vicinity of the emission source. The mapping module produces a concentration at each census tract. Input data needed are emissions data, meteorological data and census tract data [EPA 2010c].
BERT	The Bio-agent Event Reconstruction Tool (BERT) is used to estimate the magnitude and extent of an airborne biological release based on measurements from wind sensors and biological agent sensors distributed around a city. BERT is used to find potential release areas and eliminate others, and if possible to put upper and lower limits on the amount of material that could have been released. The tool can then be used to predict the potential downwind hazard areas, to compute the total number of persons at risk, and to locate hospitals, school, police stations, fire stations and other infrastructure that might be impacted by the release [Zajic 2010].
BioDAC	BioDAC (an abbreviation for the Weapons of Mass Destruction Decision Analysis Center [WMD-DAC] Biological Defense Application) is a component of the WMD-DAC suite of simulation components. BioDAC is used to simulate the release of biological agents and evaluate the efficacy of a large set of response strategies. Three primary roles exist in a BioDAC simulation—Public Health Official (PHO), Navy Official (NO), and Analyst. BioDAC is designed for use in simulator-based exercises involving officials from various interested military and governmental agencies [Linebarger 2007].
BROOM	Building Restoration Operations Optimization Model (BROOM) is a handheld, software-based restoration and decontamination tool that contains building maps and other information to simplify tracking and sample collection in a contaminated area. Surface sampling results transmitted to Sandia's BIRC (see section 6.1) can be input into BROOM, an approach that leads to more accurate contamination maps and more certain predictions [Sandia 2008].
CFAST	The Consolidated Model of Fire and Smoke Transport, CFAST, is a computer program that fire investigators, safety officials, engineers, architects and builders can use to simulate the impact of past or potential fires and smoke in a specific building environment. CFAST is a two-zone fire model used to calculate the evolving distribution of smoke, fire gases, and temperature throughout compartments of a building during a fire. These can range from very small containment vessels, on the order of 1 m^3 to large spaces on the order of 1000 m^3. A visualization program, Smokeview (SMV), is available to display the output of CFAST simulations [NIST 2009].
COAMPS	The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) can be used for short-term numerical weather prediction for various regions. The atmospheric portion of COAMPS represents a complete three-dimensional data assimilation system comprised of data quality control, analysis, initialization, and forecast model components. Features include a globally relocatable grid, user-defined grid resolutions and dimensions, nested grids, an option for idealized or real-time

	simulations, and code that allows for portability between mainframes and workstations. Model applications include dust forecast, cloud and fog forecast, land-surface and urban effects, and chemical/biological agent transport and dispersion [NRL 2010a].
COMIS	Conjunction Of Multizone Infiltration Specialists (COMIS) models the air flow and contaminant distributions in buildings. The program can simulate several key components influencing air flow: cracks, ducts, duct fittings, fans, flow controllers, vertical large openings (windows and/or doors), kitchen hoods, passive stacks, and “user-defined components.” COMIS allows the user to define schedules describing changes in the indoor temperature distribution, fan operation, pollutant concentration in the zones, pollutant sources and sinks, opening of windows and doors, and the weather data. The flexible time step implemented in COMIS enables the modeling of events independent of the frequency with which the weather data are provided [LBNL 2010b].
COMIS Integrated Models	COMIS has been integrated with outdoor and other indoor modeling tools and techniques [LBNL 2010c]. These include: • Residential models in NARAC – Combines NARAC’s models for outdoor plumes with “box” model of houses to predict indoor-outdoor exchange. • COMIS in HPAC – Combines HPAC for outdoor plumes with COMIS to determine indoor exposure to outdoor plumes. • Building Interior and Exfiltration (BINEX) – includes two models for building airflow, COMIS ported by LBNL to HPAC, and an interior model from Science Applications International Corporation (SAIC). • CFD in COMIS – combines COMIS with a Computational Fluid Dynamics (CFD) capability to study exposure in large, poorly mixed spaces such as auditoriums or conference halls.
CONTAM	CONTAM is a multi-zone indoor air quality and ventilation analysis computer program designed to help determine airflows, contaminant concentrations, and personal exposure. Predicted contaminant concentrations can also be used to estimate personal exposure based on occupancy patterns in the building being studied. Exposure estimates can be compared for different assumptions of ventilation rates and source strengths [NIST 2008].
CT-Analyst	The Contaminant Transport Analyst, or CT-Analyst is an instant-response software tool developed at the Naval Research Laboratory that can help cities respond quickly and efficiently to the release of a chemical, biological, or radioactive threat. It combines detailed 3D modeling of the city with an understanding of how airflow carries contaminants through its streets and provides first responders with the information they need to make effective decisions [NRL 2010b].
EPIcode	The Emergency Prediction Information code is a commercially available computer code for modeling routine or accidental releases of hazardous chemicals to the environment. It is reported to be routinely used for NEPA calculations within the Department of Energy system, as well as emergency response centers. It is a commercial product from Homann Associates, Inc. [EPIcode 2010].

FDS	Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires. A visualization program, Smokeview (SMV), is available to display the output of FDS simulations [NIST 2010].
FEM3MP	FEM3MP is a finite element model based massively parallel code that generates accurate predictions of wind fields and dispersed concentrations. It has been developed at Lawrence Livermore National Laboratory (LLNL) over the past two decades. It has both Reynolds Averaged Navier-Stokes (RANS) and Large Eddy Simulation (LES) turbulence models. The code has been extensively tested against data obtained from wind-tunnel and field experiments, such as Urban 2000 in Salt Lake City, Utah, and Joint Urban 2003 in Oklahoma City [LLNL 2001].
FLUENT	FLUENT is a computation fluid dynamics (CFD) tool that has been used for gas dispersion analysis and hazard assessments. It uses an unstructured grid to represent complex shapes together with Large Eddy Simulation (LES) and Detached Eddy Simulation (DES) turbulence models. It is a commercial tool available through ANSYS [ANSYS 2010].
GASTAR	GASTAR is a dense gas dispersion model suited to modeling accident and emergency response scenarios or investigating site safety involving releases of flammable and/or toxic materials from a variety of industrial accidents such as cryogenic spills, catastrophic tank failure, pipe fractures, and multi-phase jets. It is used for risk assessment, land-use planning, emergency response planning, and management and training [CERC 2010].
HOTSPOT	HOTSPOT is a fast-running local-scale steady-state Gaussian plume model for radiological releases developed at LLNL. This model is fast and simple, requiring a minimum amount of input data. It can provide initial predictions of the time-integrated effect (such as dosage from the entire plume passage). It can be used to make initial protective action recommendations, using conservative assumptions, before advanced model results are available [NARAC 2010c].
HPAC	Hazard Prediction and Assessment Capability (HPAC) automated software system provides the means to accurately predict the effects of hazardous material released into the atmosphere and its impact on civilian and military populations. It can model chemical, biological, radiological, and nuclear agents. It has been developed under the sponsorship of the Defense Threat Reduction Agency [ODATSD 2010].
HYSPLIT	Hybrid Singe-Particle Lagrangian Integrated Trajectory models dispersion of chemical agents. It is a complete system for computing simple air parcel trajectories to complex dispersion and deposition simulations. The model’s default configuration assumes a puff distribution in the horizontal and particle dispersion in the vertical direction. It was developed by National Oceanic and Atmospheric Administration [NOAA 2010a].
LODI	Lagrangian Operational Dispersion Integrator, LODI, is an atmospheric dispersion model developed for operational emergency response within the U.S. Department of Energy’s National Atmospheric Release Advisory Center (NARAC). It solves the 3-D

	advection diffusion equation using a Lagrangian stochastic, Monte Carlo method which calculates possible trajectories of fluid "particles" in a turbulent flow [Leone 2001].
LSMS	LSMS (Liquid Spill Modelling System) is a tool for calculating the spreading and vaporization of a liquid pool. Liquids such as liquefied natural gas (LNG), liquefied petroleum gas (LPG) and others are routinely stored at low temperatures and on their release to the atmosphere they boil or evaporate depending on their temperature relative to the ambient air. As the liquid spreads, the size of the liquid pool changes and the vaporization rate alters accordingly and such information is essential for calculating the subsequent dispersion of the cold vapor [CERC 2010].
JEM	Joint Effects Model (JEM) is being developed by DTRA and will provide the military with a single validated ability to predict and track CBRN and toxic industrial chemicals (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 of JEM, scheduled to be operational by fiscal year 2011, will include the ability to predict hazard areas and effects for urban areas [Smith 2005].
OBODM	OBODM is intended for use in evaluating the potential air quality impacts of the open burning and detonation (OB/OD) of obsolete munitions and solid propellants. OBODM uses cloud/plume rise dispersion, and deposition algorithms taken from existing models for instantaneous and quasi-continuous sources to predict the downwind transport and dispersion of pollutants released by OB/OD operations [EPA 2010c].
QUIC	Quick Urban and Industrial Complex (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. [LANL 2010].
RASCAL	Radiological Assessment System for Consequence Analysis (RASCAL) was developed for use by U.S. Nuclear Regulatory Commission (NRC) staff who respond to power reactor accidents and other radiological emergencies. RASCAL 3.0.5 (December 2006 release with December 2008 updates), is the latest version available. It evaluates releases from nuclear power plants, spent fuel storage pools and casks, fuel cycle facilities, and radioactive material handling facilities. RASCAL can be used by response personnel to conduct an independent evaluation of dose and consequence projections and for training and drills [ORNL 2010b].
RUSTIC/MESO	RUSTIC/MESO is a coupled fast-CFD/Lagrangian transport and dispersion model for predicting airborne and deposited hazards in urban environments. The modeling system consists of a fast running urban wind flow code, Realistic Urban Spread and Transport of Intrusive Contaminants (RUSTIC), that is coupled with a Lagrangian particle advection and diffusion code (MESO – Mesoscale Atmospheric Transport and Diffusion Code). The design of both codes is such that the computational speed can be moderated with input parameters that determine the degree of accuracy and/or quickness of the solution [Roney 2010].

SCIPUFF	Second-order Closure Integrated PUFF Model (SCIPUFF) is a Lagrangian puff dispersion model that uses a collection of Gaussian puffs to predict three-dimensional, time-dependent pollutant concentrations. In addition to the average concentration value, SCIPUFF provides a prediction of the statistical variance in the concentration field resulting from the random fluctuations in the wind field [EPA 2010c].
Turbo FRMAC	Turbo Federal Radiological Monitoring and Assessment Center (Turbo FRMAC (TF)) software automates the calculations described in volumes 1-3 of The Federal Manual for Assessing Environmental Data During a Radiological Emergency. This software automates the process of assessing radiological data during a Federal Radiological Emergency. The manual upon which the software is based is unclassified and freely available on the Internet. TF takes values generated by field samples or computer dispersion models and assesses the data in a way which is meaningful to a decision maker at a radiological emergency; such as, do radiation values exceed city, state, or federal limits; should the crops be destroyed or can they be utilized; do residents need to be evacuated, sheltered in place, or should another action be taken [OSTI 2010].
UDM	Urban Dispersion Model is a component of the DTRA HPAC modeling suite. It is a Gaussian puff model designed to calculate the flow of dispersion around obstacles in an urban environment. 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 [Neuman 2006].
VERDI	VERDI is a Java program for visualizing meteorology, emissions, and air quality modeling data. With options for overlaying GIS Shapefiles and observational data onto model output, VERDI offers a range of options for viewing atmospheric modeling data. VERDI scripting provides a powerful interface for automating the production of graphics for analyzing the data [CMAS 2010].
VLSTRACK	The VLSTRACK Computer Model, version 1.6, provides approximate downwind hazard predictions for a wide range of chemical and biological agents and munitions of military interest. Output can be obtained either as a cumulative hazard from the time of the attack or as a periodic hazard for each time period. The model also features variable meteorology, allowing for interfacing the attack with a meteorological forecast; this feature is very important for biological and secondary evaporation computations. A vertical wind profile meteorology forecast can also be used for high-altitude releases [OFCM 2010c].
WRF	Weather Research and Forecasting (WRF) model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers [WRF 2010].

6.3. Relevant Standards and Guidelines

This section identifies standards and guidelines that are potentially relevant to the development of hazardous material release models and simulations. The standards and guidelines may include mechanisms and formats for the interchange of data, data storage, generation of information displays, integration of systems, and/or conceptualization and design of hazardous material release models and simulations. Subsection 1 includes the standards that are specific to hazardous material release domain. The following subsections list standards that are common across the homeland security applications of M&S and focus on conceptual modeling, distributed simulation, geographical information system (GIS), and communications respectively.

6.3.1 Domain Specific Standards

Standard Title	Overview
After a Terrorist Bombing: Health and Safety Information for the General Public	**Description:** Federal, state, and local officials are working together to help people who have been affected by the blast and will provide updated information as soon as they learn more. This document contains "Immediately after the event" and "Hours or days after the event" [CDC 2010a]. **Standard type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Air Quality – Exchange of Data	**Description:** A general air quality data format for direct data import and condensed air quality data format for file exchange [ANSI 2010]. **Standard Type:** ISO 7168-1:1999; ISO 7168-2:1999 **Organization:** International Organization for Standardization (ISO), and American National Standards Institute (ANSI) **Classification:** Domain-specific Integration Interfaces
Airborne instrumentation for measurement of terrestrial gamma radiation	**Description:** Applies to airborne radiation detection systems used in geologic mapping, in regional and local prospecting for uranium mineralization and for locating and monitoring man-made changes in environmental radioactivity [IEC 2010]. **Standard type:** IEC 61134 Ed. 1.0 b:1992 **Organization:** International Electrotechnical Commission (IEC) **Classification:** Operational Guidelines
American National Standard for Training Requirements for Homeland Security Purposes Using Radiation Detection Instrumentation for Interdiction and Prevention	**Description:** This standard describes training requirements for U.S. Homeland Security purposes using radiation detection instrumentation for interdiction and prevention [ANSI 2010]. **Standard Type:** ANSI N42.37-2006 **Organization:** American National Standards Institute (ANSI) **Classification:** Operational Guidelines
Binary Universal Form for Data Representation of Meteorological Data (BUFR)	**Description:** Format specifications for representing meteorological, non-grid-point data (alphanumeric text) [ANSI 2010].

	Standard Type: FM94 BUFR; FM 94-IX EXT. BUFR **Organization:** World Meteorological Organization (WMO) and American National Standards Institute (ANSI) **Classification:** Domain-specific Integration Interfaces
Casualty Management After Detonation of a Nuclear Weapon in an Urban Area	**Description:** Immediate actions for first responders when a nuclear weapon has been detonated in an urban area. This document contains recommended immediate actions for police officers, firefighters, and emergency medical technicians who may be faced with the detonation of a nuclear weapon in a populated area [CDC 2010b]. **Standard Type:** N/A **Organization:** the Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Communicating in the First Hours for Anthrax: Short and Extended Messages	**Description:** Public health officials can use these short and extended messages during the first hours after a suspected anthrax emergency. The short messages include essential information to help minimize the immediate risk to the public from an attack. The extended messages also include general information that can be used as a resource for officials in developing messages tailored to a specific situation [CDC 2010c]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Digital Weather Markup Language (DWML)	**Description:** An XML-based language for retrieving data from the NWS digital forecast database [NWS 2010a]. **Standard Type:** Government specification **Organization:** National Weather Service (NWS) **Classification:** Domain-specific Integration Interfaces
Emergency Response Cards	**Description:** Detailed tables describing the necessary PPE & actions for different types of exposure to each agent [CDC 2010d]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
ESRI Shapefile Technical Description	**Description:** A geospatial vector data format for geographic information systems software [ESRI 2010]. **Standard Type:** Industry specification **Organization:** Environmental Systems Research Institute (ESRI) **Classification:** Document formats

Facts About the Laboratory Response Network	**Description:** Description of the network of labs that respond to biological & chemical terrorism. In 1999, the Centers for Disease Control and Prevention (CDC) established the Laboratory Response Network (LRN). The LRN's purpose is to run a network of labs that can respond to biological and chemical terrorism, and other public health emergencies. The LRN has grown since its inception. It now includes state and local public health, veterinary, military, and international labs. This fact sheet provides a brief description of the LRN, and how it works [CDC 2010e]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Fire Protection Guide to Hazardous Materials	**Description:** A guide on how to safely store and handle chemicals and respond to emergencies quickly and effectively. This resource provides three comprehensive indexes so the users can access information by chemical name, synonym, or CAS number. You'll have information about the full range of chemicals, plus National Fire Protection Association (NFPA) 30 or Occupational Safety and Health Administration (OSHA) classifications for flammable and combustible liquids [NFPA 2010]. **Standard Type:** 2001 Edition **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Flexible Image Transport System (FITS)	**Description:** A data format designed to provide a means for convenient exchange of astronomical data between installations whose standard internal formats and hardware differ. It is used for the transport, analysis, and archival storage of scientific data sets [NASA 2010a]. **Standard Type:** Government specification **Organization:** National Aeronautics and Space Administration (NASA) **Classification:** Document formats
Guidance Documentation – Dispersion Modeling of Toxic Pollutants in Urban Areas	**Description:** Guidance related to air pollution and air quality management [EPA 2010d]. **Standard Type:** EPA-454/R-99-021 **Organization:** Environmental Protection Agency (EPA) **Classification:** Operational guidelines
Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks	**Description:** This document identifies actions that a building owner or manager can implement without undue delay to enhance occupant protection from an airborne chemical, biological, or radiological attack [CDC 2010f]. **Standard Type:** N/A

	Organization: The National Institute for Occupational Safety & Health (NIOSH), The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Guidance on the Application of Refined Dispersion Models to Hazardous/Toxic Air Pollutant Releases	**Description:** Guidance related to air pollution and air quality management [EPA 2010e]. **Standard Type:** EPA-454/R-93-002 **Organization:** Environmental Protection Agency (EPA) **Classification:** Operational guidelines
Guidance on the Development, Evaluation, and Application of Environmental Models	**Description:** The U.S. Environmental Protection Agency (EPA) uses a wide range of models (http://www.epa.gov/osp/crem/library/whitman.PDF) to make informed decisions that support its mission of protecting human health and safeguarding the natural environment – air, water, and land – upon which life depends. This guidance provides recommendations for the effective development, evaluation, and use of models in environmental decision making once an environmental issue has been identified. This guidance recommends best practices to help determine when a model, despite its uncertainties, can be appropriately used to inform a decision [EPA 2009]. **Standard Type:** EPA/100/K-09/003 **Organization:** U. S. Environmental Protection Agency (EPA) **Classification:** Operational Guidelines
Guide for Fire and Explosion Investigations	**Description:** The Guide for Fire and Explosion Investigations is designed to assist individuals who are charged with the responsibility of investigating and analyzing fire and explosion incidents and rendering opinions as to the origin, cause, responsibility, or prevention of such incidents [NFPA 2010]. **Standard Type:** NFPA 921-2008 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Guide for the selection of Personal Protective Equipment for Emergency First Responders	**Description:** A guidance intended to be useful to the emergency first responder community in the selection of personal protective equipment (PPE) [NCJRS 2010]. **Standard Type:** National Institute of Justice (NIJ) Guide 102-00 **Organization:** National Institute of Justice **Classification:** Operational guidelines
Hazardous Substances Emergency Events Surveillance (HSEES)	**Description:** Collects & analyzes info about acute releases of hazardous substances that need to be cleaned up or neutralized according to federal, state, or local law, as well as threatened releases that result in a public health action such as an evacuation. The Hazardous Substances Emergency Events

	Surveillance (HSEES) system was established by the Agency for Toxic Substances and Disease Registry (ATSDR) to collect and analyze information about acute releases of hazardous substances and threatened releases that result in a public health action such as an evacuation. The goal of HSEES is to reduce the morbidity (injury) and mortality (death) that result from hazardous substances events, which are experienced by first responders, employees, and the general public [CDC 2010g]. **Standard Type:** N/A **Organization:** The Agency for Toxic Substances and Disease Registry (ATSDR) **Classification:** Operational Guidelines
Hierarchical Data Format-Earth Observing System (HDF-EOS)	**Description:** HDF is a format for prescribing standard data products that are derived from EOS missions [NSIDC 2010]. **Standard Type:** Government specification **Organization:** National Aeronautics and Space Administration (NASA) **Classification:** Domain-specific Integration Interfaces
Interim Recommendations for Firefighters & Other First Responders for the Selection & Use of Protective Clothing & Respirators Against Biological Agents	**Description:** The approach to any potentially hazardous atmosphere, including biological hazards, must be made with a plan that includes an assessment of hazard and exposure potential, respiratory protection needs, entry conditions, exit routes, and decontamination strategies. Any plan involving a biological hazard should be based on relevant infectious disease or biological safety recommendations by the Centers for Disease Control and Prevention (CDC) and other expert bodies including emergency first responders, law enforcement, and public health officials. The need for decontamination and for treatment of all first responders with antibiotics or other medications should be decided in consultation with local public health authorities. This INTERIM STATEMENT is based on current understanding of the potential threats and existing recommendations issued for biological aerosols [CDC 2010h]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Long Term Structure of the IAEA (International Atomic Energy Agency) Safety Standards and Current Status	**Description:** The long-term set of Safety Standards includes unified Safety Fundamentals (SF1), General Safety Requirements (GSR) in seven parts applicable to all facilities and activities with a graded approach, and complemented by a set of six facilities and activities Specific Safety Requirements (SSRs). The Safety Requirements are implemented through a set of general and specific safety guides [IAEA 2010]. **Standard Type:** N/A **Organization:** International Atomic Energy Agency (IAEA) **Classification:** Operational guidelines

Managing Hazardous Material Incidents (MHMI)	**Description:** The MHMI series is a three volume set (with a video) comprised of recommendations for on-scene (pre-hospital), and hospital medical management of patients exposed during a hazardous materials incident [CDC 2010p]. **Standard Type:** N/A **Organization:** The Agency for Toxic Substances and Disease Registry (ATSDR) **Classification:** Operational guidelines
Medical Management Guidelines for Chemical Agents	**Description:** The document provides a list of chemical medical management guidelines for Ammonia, Arsine (SA), Benzene, Chlorine (CL), Cyanide, Cyanogen chloride (CK), Ethylene glycol, Hydrogen cyanide (AC), Lewisite (L, L-1, L-2, L-3), Mustard gas (H), Nitrogen mustard (HN-1, HN-2, HN-3), Phosgene (CG), Phosphine, Potassium cyanide (KCN), Sarin (GB), and Sodium cyanide (NaCN), etc. [CDC 2010i]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Medical Management Guidelines for Unidentified Chemicals	**Description:** Basic victim management recommendations to follow when the chemical is not known [CDC 2010i]. **Standard Type:** N/A **Organization:** The Agency for Toxic Substances and Disease Registry (ATSDR) **Classification:** Operational Guidelines
NARSTO Data Exchange Standard (DES) format	**Description:** A data exchange format for evaluation, analyses, and sharing NARSTO data including air chemistry, meteorological, and related atmospheric data, and metadata [ORNL 2010c]. **Standard Type:** Industry specification **Organization:** NARSTO (formerly North American Research Strategy for Tropospheric Ozone) **Classification:** Domain-specific Integration Interfaces
National Ambient Air Quality Standards (NAAQS)	**Description:** There are two types of national air quality standards: Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings [EPA 2010f]. **Standard Type:** Government Specification **Organization:** Environmental Protection Agency (EPA) **Classification:** Operational guidelines
NFPA Standard Classifications for Incident Reporting and Fire	**Description:** A specification that provides a common language and definitions to define and describe pre-incident

Protection Data	environments, fire and other emergency incidents, post-incident damage assessments, and fire service data [NFPA 2010]. **Standard Type:** NFPA-901 **Organization:** National Fire Protection Association (NFPA) **Classification:** Domain-specific Integration Interfaces
NIOSH Pocket Guide to Chemical Hazards (NIOSH)	**Description:** The NIOSH Pocket Guide to Chemical Hazards (NPG) is intended as a source of general industrial hygiene information on several hundred chemicals/classes for workers, employers, and occupational health professionals. The NPG does not contain an analysis of all pertinent data, rather it presents key information and data in abbreviated or tabular form for chemicals or substance groupings (e.g., cyanides, fluorides, manganese compounds) that are found in the work environment. The information found in the NPG should help users recognize and control occupational chemical hazards [CDC 2010j]. **Standard Type:** N/A **Organization:** The National Institute for Occupational Safety & Health(NIOSH) **Classification:** Operational Guidelines
Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners	**Description:** Population monitoring is the process of identifying, screening, and monitoring people for exposure to radiation or contamination from radioactive materials. This planners' guide presents an introduction to population monitoring in radiation emergencies for public health officials and emergency preparedness planners at the state and local levels. It describes how to plan for population monitoring and provides practical suggestions to address the many challenges it presents when a large population is potentially impacted [CDC 2010k]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Public Health Response to Biological & Chemical Terrorism: Interim Planning Guidance for State Public Health Officials	**Description:** This Planning Guidance is designed to help state public health officials determine the roles of their departments in response to biological and chemical terrorism and to understand the emergency response roles of local health departments and the emergency management system. The Planning Guidance also can be used to help state health departments coordinate their efforts with the many agencies and organizations at all levels of government that ultimately would respond to a biological or chemical terrorism event [CDC 2010l]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines

Recognition of Illness Associated with the Intentional Release of a Biologic Agent	**Description:** Provides guidance for healthcare providers & public health personnel about recognizing illnesses or patterns of illness that might be associated with intentional release of biologic agents [CDC 2010m]. **Standard Type:** MMWR 2001 **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Roundtable on Population Monitoring Following a Nuclear/Radiological Incident	**Description:** Recommendations & comments from participants in CDC's roundtable (Jan. 11-12, 2005) on challenges associated with monitoring people affected by a nuclear or radiological incident [CDC 2010n]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Sheltering in Place during a Radiation Emergency	**Description:** This action is called "sheltering in place." Because many radioactive materials rapidly decay and dissipate, staying in your home for a short time may protect you from exposure to radiation. The walls of your home may block much of the harmful radiation. Taking a few simple precautions can help you reduce your exposure to radiation. The Centers for Disease Control and Prevention has prepared this fact sheet to help you protect yourself and your family and to help you prepare a safe and well-stocked shelter [CDC 2010o]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents	**Description:** It identifies the minimum levels of competence required by responders to emergencies involving hazardous materials/weapons of mass destruction (WMD). The 2008 edition has been re-titled and completely rewritten (with major chapter reorganization) to apply to ALL first responders, regardless of response discipline, who may respond to the emergency phase of such incidents. It is based on the operational philosophies that emergency responders should be trained to perform their expected tasks, and that a responder cannot safely and effectively respond to a terrorism or criminal scenario involving hazmat/WMD if they don't first understand basic hazardous materials response [NFPA 2010]. **Standard type:** NFPA 472-2008 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines

Standard for Competencies for Emergency Medical Services (EMS) Personnel Responding to Hazardous Materials/Weapons of Mass Destruction Incidents	**Description:** Expanded coverage in the 2008 NFPA 473 includes qualifications for EMS responders to terrorism incidents that involve hazardous materials. NFPA 473: Standard for Competencies for EMS Personnel Responding to Hazardous Materials/Weapons of Mass Destruction Incidents identifies the levels of competence required of emergency medical services (EMS) personnel who respond to hazardous materials incidents. It specifically covers the requirements for Basic Life Support (BLS) and Advanced Life Support (ALS) personnel in the pre-hospital setting. The 2008 edition of NFPA 473 has been re-titled and completely rewritten to address the hazards that emergency medical services (EMS) personnel encounter from hazardous materials/weapons of mass destruction. New definitions and technical information have been added. The requirements in the 2008 edition will enhance the safety and protection of response personnel and all components of the EMS system [NFPA 2010]. **Standard type:** NFPA 473-2008 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Standard Guide for Application of Engineering Controls to Facilitate Use or Redevelopment of Chemical-Affected Properties	**Description:** This guide presents general considerations for application of engineering controls to facilitate continued use or redevelopment of properties containing chemical-affected soil, groundwater, or other environmental media, due either to chemical releases or naturally-occurring conditions [ASTM 2010]. **Standard type:** E2435 – 05 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Assessing the Hazard of a Material to Aquatic Organisms and Their Uses	**Description:** This guide describes a stepwise process for using information concerning the biological, chemical, physical, and toxicological properties of a material to identify adverse effects likely to occur to aquatic organisms and their uses as a result of release of the material to the environment [ASTM 2010]. **Standard type:** E1023 – 84(2007) **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Assessing the Health Hazard of Pesticides to Applicators and Others with Potential Exposure	**Description:** This guide covers a stepwise process for using information concerning biological, chemical, physical, and toxicological properties of a pesticide or other chemical(s), or of a formulation to identify adverse effects that may occur to pesticide applicators or others with potential exposure [ASTM 2010]. **Standard type:** E1429 – 91(2004) **Organization:** ASTM International **Classification:** Operational Guideline

Standard Guide for Chemical Fate in Site-Specific Sediment/Water Microcosms	**Description:** This guide provides procedures and criteria for the development and use of sediment/water microcosms for laboratory evaluations of the fate of chemical substances in the environment [ASTM 2010]. **Standard type:** E1624 – 94(2008) **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Collecting Treatment Process Design Data at a Contaminated Site-A Site Contaminated With Chemicals of Interest	**Description:** This guide lists the physical and chemical treatment processes design data needed to evaluate, select, and design treatment processes for remediation of contaminated sites [ASTM 2010]. **Standard type:** D7294 – 06 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Containment of Hazardous Material Spills by Emergency Response Personnel	**Description:** This guide describes methods to contain the spread of hazardous materials that have been discharged into the environment [ASTM 2010]. **Standard type:** F1127 – 07 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Health and Safety Training of Oil Spill Responders in the United States	**Description:** This guide establishes minimum health and safety training standards for three types of oil spill responders: Type A, first responders who are responsible for initial containment and cleanup; Type B, longer-term shoreline cleanup personnel; and Type C, other necessary support personnel who have minimal contact with the contamination [ASTM 2010]. **Standard type:** F1656 – 01 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for In-Situ Burning of Oil in Ships or Other Vessels	**Description:** This guide covers the use of in-situ burning directly in ships and other vessels. This guide is not applicable to in-situ burning of oil on sea or land [ASTM 2010]. **Standard type:** F2533 – 07 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for In-Situ Burning of Oil Spills on Water: Environmental and Operational Considerations	**Description:** This guide covers the use of in-situ burning to assist in the control of oil spills on water. This guide is not applicable to in-situ burning of oil on land. **Standard type:** F1788 – 08 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites	**Description:** This is a guide to risk-based corrective action (RBCA), which is a consistent decision-making process for the assessment and response to a petroleum release, based on the

	protection of human health and the environment [ASTM 2010]. **Standard type:** E1739 – 95(2002) **Organization:** ASTM International **Classification:** Operational Guideline
Standard on Protective Ensembles for First Responders to CBRN Terrorism Incidents	**Description:** It establishes the minimum requirements for the design, performance, testing, documentation, and certification of protective ensembles and ensemble elements for protection of emergency first responder personnel from chemicals, biological agents, and radiological particulate (CBRN) terrorism agents [NFPA 2010]. **Standard type:** NFPA 1994-2007 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies	**Description:** It provides requirements for the highest level of protection for emergency responders to hazardous materials incidents where an unknown threat, a vapor threat, or a chemical or biological terrorism WMD threat is present or expected. Criteria address design, performance, certification, and documentation requirements [NFPA 2010]. **Standard Type:** NFPA 1991-2005 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Standard Practice for Determination of Hydrolysis Rate Constants of Organic Chemicals in Aqueous Solutions	**Description:** This practice describes specific procedures for obtaining solution hydrolysis rate constants and half-lives of organic chemicals that may enter the aquatic environment [ASTM 2010]. **Standard type:** E895 – 89(2008) **Organization:** ASTM International **Classification:** Operational Guideline
Standard Practice for Radiological Emergency Response	**Description:** This practice provides decision-making considerations for response to incidents that involve radioactive materials. It provides information and guidance for what to include in response planning, and what activities to conduct during a response. The scope of this standard does not explicitly consider response to improvised nuclear devices (INDs) or nuclear power plant accidents. It does not expressly address emergency response to contamination of food or water supplies. This practice applies to those emergency response agencies that have a role in the response to a radiological incident, excluding an IND incident. It should be used in emergency services response such as law enforcement, fire department, and emergency medical response actions. This practice assumes that implementation begins with the recognition of a radiological incident and ends when emergency response actions cease or the

	response is assumed by specialized regional, state, or federal response teams [ASTM 2010]. **Standard type:** ASTM E2601-08 **Organization:** ASTM International **Classification:** Operational Guidelines
Topologically Integrated Geographic Encoding and Referencing /Geography Markup Language (TIGER/GML)	**Description:** A specification for encoding geographic features in XML [OGC 2010c]. **Standard Type:** Industry specification **Organization:** The Open Geo-spatial Consortium, Inc (OGC) **Classification:** Domain-specific Integration Interfaces
Vector Product Format (VPF)	**Description:** A format, structure, and organization for large geographic databases that are based on a geo-relational data model and are intended for direct use [MIL 2010]. **Standard Type:** MIL-STD-2407 **Organization:** National Geospatial-Intelligence Agency **Classification:** General purpose Integration Interfaces

6.3.2 Conceptual Modeling Standards

Standard Title	Overview
Discrete Event System Specification (DEVS)	**Description:** DEVS is a systems-theoretic approach to modeling. More specifically, it is state-centered formalism. A system consists of interconnected subsystems. A subsystem is a system. Leaf systems (atomic DEVSes) are state machines. DEVS can be viewed as a framework unifying a number of other formalisms in a consistent, systems theoretic, state centered fashion [DEVS 2011]. **Standard Type:** Specification **Organization:** Simulation Interoperability Standards Organization (SISO); Society for Modeling and Computer Simulation International (SCS) **Classification:** Domain-specific integration interface
Systems Modeling Language (SysML)	**Description:** SysML is a general purpose modeling language for systems engineering applications. It is a dialect of UML, the industry standard for modeling software-intensive systems. It supports the specification, analysis, design, verification and validation of a broad range of systems and systems-of-systems. These systems may include hardware, software, information, processes, personnel, and facilities [OMG 2011]. **Standard Type:** SysML 1.2 **Organization:** Object Management Group, Inc. (OMG) **Classification:** Document format

Unified Modeling Language (UML)	**Description:** A graphical language for visualizing, specifying, constructing and documenting the artifacts of a software-intensive system. The UML offers a standard way to write a system's blueprints, including conceptual things such as business processes and system functions, as well as concrete things such as programming language statements, database schemas, and reusable software components [ANSI 2011c]. **Standard Type:** UML 2.0, UML 2.1.1; UML 2.1.2; UML 2.2; UML 2.3; ISO/IEC 19501:2004 **Organization:** ISO; ANSI; Object Management Group, Inc. (OMG) **Classification:** Document format

6.3.3 Distributed Simulation Standards

Standard Title	Overview
Distributed Interactive Simulation	**Description:** Distributed Interactive Simulation (DIS) is a government/industry initiative to define an infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual worlds for the simulation of highly interactive activities. A series of IEEE standards to support information exchange between simulation applications participating in the DIS environment are defined. IEEE Std 1278.1 defines the format and semantics of data messages, also known as Protocol Data Units (PDUs), that are exchanged between simulation applications and simulation management. IEEE Std 1278.2 defines the communication services required to support the message exchange described in IEEE Std 1278.1. IEEE 1278-3 provides guidelines for establishing a DIS exercise, managing the exercise, and providing proper feedback. IEEE 1278-4 establishes guidelines for the verification, validation, and accreditation (VV&A) of Distributed Interactive Simulation (DIS) exercises [IHS 2011a]. **Standard Type:** IEEE 1278-1993, IEEE 1278.1-1995, IEEE 1278.1A-1998, IEEE-1278.2-1995, IEEE 1278.3-1996, IEEE 1278.4-1997 **Organization:** IEEE; IHS, Inc. **Classification:** Domain-specific integration interface
Extensible Modeling and Simulation Framework (XMSF)	**Description:** The Extensible Modeling and Simulation Framework (XMSF) is defined as a set of Web-based technologies and services, applied within an extensible framework, that enables a new generation of modeling & simulation (M&S) applications to emerge, develop and interoperate [DODCCRP 2011]. XMSF provides a framework which allows both Department of Defense (DoD) and non-DoD Modeling and Simulation (M&S) projects to take advantage of Web-based technologies.

	Standard Type: XMSF 1.0 **Organization:** Naval Postgraduate School MOVES Institute; George Mason University NetLab; Science Applications International Corporation; Old Dominion University **Classification:** Domain-specific integration interface
High Level Architecture (HLA)	**Description:** This standard defines the HLA, its components, and the rules that outline the responsibilities of HLA federates and federations to ensure a consistent implementation [IEEE 2011c]. **Standard Type:** IEEE 1516-2000, IEEE 1516.1-2000, 1516.2-2000, ANSI/IEEE 1516.3-2003; IEEE 1516.4-2007 **Organization:** IEEE/Simulation Interoperability Standards Organization (SISO); ANSI **Classification:** Domain-specific integration interface

6.3.4 Selected Geographic Information System (GIS) Standards

Standard Title	Overview
CityGML – Exchange and Storage of Virtual 3D City Models	**Description:** A standard for the representation, storage, and exchange of virtual 3D city and landscape models. CityGML is implemented as an application schema of the Geography Markup Language version 3.1.1. It is based on a rich, general purpose information model in additional to geometry and appearance information. For specific domain areas, CityGML also provides an extension mechanism to enrich the data with identifiable features under preservation of semantic interoperability [OGC 2011a]. **Standard Type:** OGC 06-057r1; ISO TC211 **Organization:** Open Geospatial Consortium, Inc. (OGC) **Classification:** Domain-specific integration interface
American National Standard for Information Technology – Geographical Information Systems – Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE)	**Description:** This standard provides a means to model and categorize real-world geographic phenomena of interest to the Facilities, Infrastructure, and Environment (FIE) Domain(s) into a set of geographic data that can be represented in a spatial database and presented to a user in digital form. This SDSFIE standard is intended to provide the enterprise spatial database schema to support multiple FIE applications. This National Standard is applicable to the federal, state, county, and city agencies; private companies; and any other organizations that perform AM & FM functions for facilities and other types of infrastructure (such as roads, waterways, utility systems, etc,) and/or perform environmental compliance, restoration, and/or pollution prevention activities [ANSI 2011a]. **Standard Type:** ANSI INCITS 353-2006 **Organization:** American National Standards Institute (ANSI);

	International Committee for Information Technology Standards (INCITS) **Classification:** Domain-specific integration interface
Content Standard for Digital Geospatial Metadata (CSDGM)	**Description:** The standard is often referred to as the FGDC Metadata Standard. The objectives of the standard are to provide a common set of terminology and definitions for the documentation of digital geospatial data. The standard establishes the names of data elements and compound elements (groups of data elements) to be used for these purposes, the definitions of these compound elements and data elements, and information about the values that are to be provided for the data elements [FGDC 2011a]. **Standard Type:** FGDC-STD-001-1998; FGDC-STD-001.1-1999; FGDC-STD-001.2-2001 **Organization:** Federal Geographic Data Committee (FGDC) **Classification:** Domain-specific integration interface
Content Standard for Digital Geospatial Metadata (CSDGM) – Extensions for Remote Sensing Metadata	**Description:** The standard of Extensions for Remote Sensing Metadata standard provides a common terminology and set of definitions for documenting geospatial data obtained from remote sensing, within the framework of the FGDC Content Standard for Digital Geospatial Metadata (CSDGM) standard. The extensions provide a means to use standard FGDC content to describe geospatial data derived from remote sensing measurements. This standard is intended to support the collection and processing of geospatial metadata for data derived from remote sensing. It is intended to be used by all levels of government and the private sector [FGDC 2011b]. **Standard Type:** FGDC-STD-012-2002 **Organization:** The Federal Geographic Data Committee (FGDC) **Classification:** Domain-specific integration interface
GeoAPI SWG Standard	**Description:** The GeoAPI Standard Working Group (SWG) aims to create the GeoAPI 3.0 Standard, which will define a set of Java language interfaces along with an associated test suite, to provide a standardized, programming language level realization of some core Open Geospatial Consortium (OGC) specifications. These interfaces will facilitate the creation of accurate, coherent, interoperable, and verifiable implementations of those OGC standards [GEOAPI 2011]. **Standard Type:** OGC GeoAPI 3.0 SWG **Organization:** OGC **Classification:** Domain-specific integration interface
Geographic Information – Encoding	**Description:** The standard specifies the requirements for defining encoding rules to be used for interchange of geographic data within the ISO 19100 series of International Standards [ISO 2011b].

	Standard Type: ISO 19118:2005 **Organization:** ISO **Classification:** Domain-specific integration interface
Geographic Information – Location-based services – Multimodal Routing and Navigation	**Description:** The standard specifies the data types and their associated operations for the implementation of multimodal location-based services for routing and navigation. It is designed to specify web services that may be made available to wireless devices through web-resident proxy applications, but is not limited to that environment [ISO 2011b]. **Standard Type:** ISO 19134:2007 **Organization:** ISO **Classification:** Domain-specific integration interface
Geographic Information – Location-based Services – Tracking and Navigation	**Description:** ISO 19133:2005 describes the data types, and operations associated with those types, for the implementation of tracking and navigation services. It is designed to specify web services that can be made available to wireless devices through web-resident proxy applications, but is not restricted to that environment [ISO 2011b]. **Standard Type:** ISO 19133:2005 **Organization:** ISO **Classification:** Domain-specific integration interface
Geographic Information – Portrayal	**Description:** The standard defines a schema describing the portrayal of geographic information in a form understandable by humans. It includes the methodology for describing symbols and mapping of the schema to an application schema. It does not include standardization of cartographic symbols, and their geometric and functional description [ISO 2011b]. **Standard Type:** ISO 19117:2005 **Organization:** ISO **Classification:** Domain-specific integration interface
Geographic Information – Procedures for Item Registration	**Description:** ISO 19135:2005 specifies procedures to be followed in establishing, maintaining and publishing registers of unique, unambiguous and permanent identifiers, and meanings that are assigned to items of geographic information. In order to accomplish this purpose, ISO 19135:2005 specifies elements of information that are necessary to provide identification and meaning to the registered items and to manage the registration of these items [ISO 2011b]. **Standard Type:** INCITS/ISO/IEC 19135-2005 **Organization:** ISO; International Committee for Information Technology Standards (INCITS); International Electrotechnical Commission (IEC) **Classification:** Domain-specific integration interface
Geographic Information – Schema for Moving Features	**Description:** The standard defines a method to describe the geometry of a feature that moves as a rigid body [ISO 2011b].

	Standard Type: ISO 19141:2008 **Organization:** ISO **Classification:** Domain-specific integration interface
Geographic Information – Services	**Description:** ISO 19119:2005 identifies and defines the architecture patterns for service interfaces used for geographic information, defines its relationship to the Open Systems Environment model, and presents geographic services taxonomy and a list of example geographic services placed in the services taxonomy. It also prescribes how to create a platform-neutral service specification, how to derive conformant platform-specific service specifications, and provides guidelines for the selection and specification of geographic services from both platform-neutral and platform-specific perspectives [ISO 2011b]. **Standard Type:** INCITS/ISO 19119-2005 **Organization:** ISO; International Committee for Information Technology Standards (INCITS) **Classification:** Domain-specific integration interface
Geographic Information – Simple Feature Access	**Description:** ISO 19125-1:2004 establishes a common architecture for geographic information and defines terms to use within the architecture. It also standardizes names and geometric definitions for Types for Geometry. INCITS/ISO 19125-2-2004 specifies an Structured Query Language (SQL) schema that supports storage, retrieval, query and update of simple geospatial feature collections via the SQL Call Level Interface (SQL/CLI) and establishes an architecture for the implementation of feature tables. INCITS/ISO 19125-2-2004 defines terms to use within the architecture of geographic information and defines a simple feature profile of ISO 19107. In addition, this part of ISO 19125:2004 describes a set of SQL Geometry Types together with SQL functions on those types. The Geometry Types and Functions described represent a profile of ISO 13249-3. INCITS/ISO 19125-2-2004 standardizes the names and geometric definitions of the SQL Types for Geometry and the names, signatures and geometric definitions of the SQL Functions for Geometry [ISO 2011b]. **Standard Type :** INCITS/ISO 19125-1-2004 ; INCITS/ISO 19125-2-2004 **Organization:** ISO; International Committee for Information Technology Standards (INCITS) **Classification:** Domain-specific integration interface
Geographic Information Framework Data Standard	**Description:** The standard establishes common data requirements for the exchange of National Spatial Data Infrastructure (NSDI) framework data [FGDC 2011c]. **Standard Type:** FGDC-STD-014.0-2008; FGDC-STD-014.1-2008; FGDC-STD-014.2-2008; FGDC-STD-014.3-2008; FGDC-STD-014.4-2008; FGDC-STD-014.5-2008; FGDC-STD-014.6-2008; FGDC-STD-014.7-2008; FGDC-STD-014.7b-

	2008; FGDC-STD-014.7c-2008; FGDC-STD-014.7d-2008; FGDC-STD-014.7e-2008 **Organization:** Federal Geographic Data Committee (FGDC) **Classification:** Domain-specific integration interface
GeoTIFF	**Description:** GeoTIFF is a metadata format, which provides geographic information to associate with the image data. GeoTIFF implements the geographic metadata formally, using compliant Tagged Image File (TIFF 6.0) tags and structures. "GeoTIFF" refers to TIFF files, which have geographic (or cartographic) data embedded as tags within the TIFF file. The geographic data can then be used to position the image in the correct location and geometry on the screen of a geographic information display [GEOTIFF 2011]. **Standard Type:** GeoTIFF/Revision 1.0 **Organization:** geotiff.osgeo.org **Classification :** Document format
Governmental Unit and Other Geographic Area Boundaries	**Description:** A specification for establishing of content requirements for the collection and interchange of Government units and legal entity boundary data and for facilitating the maintenance and use of that information [FGDC 2010]. **Standard Type:** FGDC-STD-014.5-2008 **Organization:** Federal Geographic Data Committee (FGDC) **Classification:** Domain-specific Integration Interfaces
GRIdded Binary (GRIB)	**Description:** Format specifications for representing meteorological, gridded-point data [WMO 2010a]. **Standard Type:** FM 92-IX Ext. GRIB; FM 92-VIII EXT. GRIB **Organization:** World Meteorological Organization (WMO) **Classification:** Domain-specific Integration Interfaces
Homeland Security Mapping Standard – Point Symbology for Emergency Management	**Description:** The primary purpose of this standard is to establish a common set of symbols for use by mapmakers in support of emergency managers and first responders. It will allow users to rapidly interpret map data and to be able to disseminate consistent, usable information. This American National Standard is applicable to all organizations that create maps or otherwise display features for the Emergency Management or First Responder communities. It is limited at this time to support portrayal of point features that relate to the emergency management and hazard mapping disciplines [ANSI 2011b]. **Standard Type:** ANSI INCITS 415-2006 **Organization:** American National Standards Institute (ANSI); International Committee for Information Technology Standards (INCITS) **Classification:** Domain-specific integration interface

OpenGIS Implementation Specification for Geographic Information – Simple Feature Access	**Description:** The OpenGIS Simple Features Interface Standard (SFS) provides a well-defined and common way for applications to store and access feature data in relational or object-relational databases, so that the data can be used to support other applications through a common feature model, data store and information access interface. OpenGIS Simple Features are geospatial features described using vector data elements such as points, lines, and polygons [OGC 2011c]. **Standard Type:** OGC 06-103r4 Version 1.2.1, OGC 05-126 **Organization:** Open Geospatial Consortium, Inc (OGC) **Classification:** Domain-specific integration interface
Spatial Data Transfer Standard (SDTS)	**Description:** The Spatial Data Transfer Standard (SDTS) base specification (Parts 1, 2 and 3) describes the underlying conceptual model and the detailed specifications for the content, structure, and format for exchange of spatial data. Additional parts (4, 5, 6 and potentially others) are added as profiles, each of which defines specific rules and formats for applying SDTS for the exchange of particular types of data [FGDC 2011d] **Standard Type:** FGDC-STD-002.1; FGDC-STD-002.5; FGDC-STD-002.6; FGDC-STD-002.7-2000 **Organization:** Federal Geographic Data Committee (FGDC) **Classification:** Domain-specific integration interface
Standard for a U.S. National Grid (USNG)	**Description:** A standard is used to define the U.S. National Grid and supports Universal Transverse Mercator (UTM) coordinates, Military Grid Reference System (MGRS) grids, and the specific grid presentation requirements. It is used for acquisition/production of printed map and acquisition of location service appliances with printed map products [FGDC 2011e] **Standard Type:** FGDC-STD-011-2001 **Organization:** Federal Geographic Data Committee (FGDC) **Classification:** Domain-specific integration interface

6.3.5 Selected Communication Standards

Standard Title	Overview
Common Alerting Protocol (CAP)	**Description:** The Common Alerting Protocol (CAP) is a simple, flexible data interchange format for collecting and distributing "all-hazard" safety notifications and emergency warnings over information networks and public alerting systems. In Web-services applications, CAP provides a lightweight standard for exchanging urgent notifications. CAP can also be used in data-broadcast applications and over legacy data networks. CAP is fully compatible with the existing national broadcast Emergency Alert System (EAS) [OASIS 2011a]. It is an XML-related data interchange standard for alerting and event notification

	applications. The standard supports two functions: a standalone protocol and a payload for Emergency Data Exchange Language (EDXL) messages. **Standard Type:** CAP-V1.1 **Organization:** Organization for the Advancement of Structured Information Standards (OASIS) **Classification:** Domain-specific integration interface
Common Incident Management Message Sets for use by Emergency Management Centers	**Description:** This standard is the Base Standard for a family of related standards that address the intercommunication needs of emergency management centers and other types of centers engaged in transportation incident management [IEEE 2010]. **Standard Type:** IEEE 1512-2000, IEEE 1512.1, IEEE 1512.2, IEEE 1512.3 **Organization:** Institute of Electrical and Electronics Engineers (IEEE) **Classification:** Document Format
Emergency Data Exchange Language (EDXL)	**Description:** Several organizations are collaborating on the design and development of a suite of specifications under the name "Emergency Data Exchange Language (EDXL)" [OASIS 2011b]. EDXL is an integrated framework for a wide range of emergency data exchange standards to support operations, logistics, planning, and finance. **Standard Type:** EXDL Distribution Element, V. 1.0 (EDXL-DE-V1.0); EDXL Resource Message Specification 1.0 Working Draft Version 26 (EDXL-RM 1.0 v0026); EDXL Hospital Availability Exchange v1.0 Public Review Draft 02 (EDXL-HAVE-1.0-spec-pr02) **Organization:** Organization for the Advancement of Structured Information Standards (OASIS); Department of Homeland Security (DHS); Emergency Interoperability Consortium (EIC) **Classification:** Domain-specific integration interface
National Information Exchange Model (NIEM)	**Description:** NIEM is designed to develop, disseminate and support enterprise-wide information exchange standards and processes that can enable jurisdictions to effectively share critical information in emergency situations, as well as support the day-to-day operations of agencies throughout the nation [NIEM 2011]. **Organization:** A partnership of the U.S. Department of Justice, the U.S. Department of Homeland Security, and the U.S. Department of Health and Human Services. **Classification:** Domain-specific integration interface

6.4. Data Sources

This section identifies databases and other sources of data that may be used to develop or run hazardous material release models, and simulations. The name of the data source, a brief description of its contents, its access location, responsible organization, data formats used, as well a classification of the type of data is given below.

Data Source Title	Overview
Assessment, Cleanup and Redevelopment Exchange System (ACRES)	**Description:** Brown fields are real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. The Assessment, Cleanup and Redevelopment Exchange System (ACRES) is an online database for Brownfields Grantees to electronically submit data directly to the U.S. Environmental Protection Agency (EPA). Cleaning up and reinvesting in these properties protects the environment, reduces blight, and takes development pressures off green spaces and working lands. ACRES data are shared with other online databases [EPA 2010g]. **Data Source:** ACRES, Version, 4.00.030 **Organization:** U.S. Environmental Protection Agency (EPA) **Format:** KML (Keyhole Markup Language) **Classification:** Environment; Controlling Documents
Accidental Release Information Program (ARIP) Database	**Description:** The Accidental Release Information Program (ARIP) is contained in a zip file that contains the ARIP database file and supporting documentation. The ARIP database collects information on accidental releases of hazardous chemicals at fixed facilities [EPA 2010p]. **Data Source:** ARIP 98.dbf **Organization:** Environmental Protection Agency (EPA) **Format:** DBF (Database file name extension); TXT (Text file name extension) **Classification:** Incidents; Environment
Aggregated Computational Toxicology Resource (ACToR)	**Description:** The Aggregated Computational Toxicology Resource (ACToR) is a collection of databases collated or developed by the U.S. Environmental Protection Agency (EPA) National Center for Computational Toxicology (NCCT). It aggregates data from over 500 public sources on over 500,000 environmental chemicals and is made searchable by chemical name and other identifiers and by chemical structure. Chemicals include, but are not limited to, high and medium production volume industrial chemicals, pesticides (active and inert ingredients), and potential ground and drinking water contaminants. It provides a connection to another EPA chemical screening tool called ToxCast [EPA 2010h]. **Data Source:** ACToR _2010q1b **Organization:** Environmental Protection Agency (EPA)

	Format: Record; Table **Classification:** Environment; Controlling Documents
Areal Locations of Hazardous Atmospheres (ALOHA)	**Description:** Areal Locations of Hazardous Atmospheres (ALOHA), part of Computer-Aided Management of Emergency Operations (CAMEO) software suite, is an atmospheric dispersion model used for evaluating releases of hazardous chemical vapors, including toxic gas clouds, fires, and explosions. Using the release information ALOHA generates a threat zone estimate. A threat zone is the area where a hazard (such as toxicity, flammability, thermal radiation, or damaging overpressure) is predicted to exceed a user-specified level of concern. Threat zones can also be plotted on maps with Mapping Applications for Response, Planning, and Local Operational Tasks (MARPLOT). MARPLOT is a mapping application that can be used to quickly create, view, and modify maps) to display the location of facilities storing hazardous materials and vulnerable locations (such as hospitals and schools). Specific information about these locations can be extracted from Computer-Aided Management of Emergency Operations (CAMEO) information modules (that are applications used to assist with data management requirements) to help make decisions about the degree of hazard posed [EPA 2010i]. **Data Source:** ALOHA, Version 5.4.1.2 **Organization:** Environmental Protection Agency (EPA), National Oceanic, Atmospheric Administration (NOAA) **Format:** Map; Data **Classification:** Environment; Controlling Documents; Spatial
Bibliography on Alternatives to the Use of Live Vertebrates in Biomedical Research and Testing (ALTBIB)	**Description:** ALTBIB stands for Bibliography on Alternatives to the Use of Live Vertebrates in Biomedical Research and Testing. The bibliography is to assist in identifying methods and procedures helpful in supporting the development, testing, application, and validation of alternatives to the use of vertebrates in biomedical research and toxicology testing. ALTBIB only maintains information for years 1980-2000 [NIH 2010a]. **Data Source:** ALTBIB；PubMed **Organization:** The National Library of Medicine (NLM) **Format:** TXT (Text file name extension) **Classification:** Resources; Controlling Documents; Environment
Chemical Reactivity Worksheet (CRW)	**Description:** The Chemical Reactivity Worksheet (CRW) is a program that allows users to investigate the reactivity of substances or mixtures of substances. CRW includes a database of reactivity information for more than 5,000 common hazardous chemicals and offers a way to virtually “mix” chemicals—as well as water—to discover what chemical

	combinations are reactive. CRW also allows users to build a "Custom Chemical Database" containing all the unique materials that are present at a particular facility. CRW has been upgraded by NOAA to include a new FileMaker Runtime user interface, which makes it compatible with the latest computer operating systems. The database includes information about the intrinsic hazards of each chemical and about whether a chemical reacts with air, water, or other materials. It also includes case histories on specific chemical incidents, with references [NOAA 2010b]. **Data Source:** CRW, Version 2.0.2 **Organization:** Environmental Protection Agency (EPA); National Oceanic, Atmospheric Administration (NOAA) **Format:** Report **Classification:** Environment; Controlling Documents; Incidents
Climate Monitoring	**Description:** The National Climatic data Center provides a service to monitor climate. It allows to search state of the climate, U.S. products (such as weekly maps and societal impacts) , global products, drought monitoring, U.S. and global extremes, hurricanes/tropical storms, tornadoes, snow and ice data, climate information record data, special reports, other products (such as hazards support, and stratospheric ozone), and climate and network monitoring [NOAA 2010c]. **Data Source:** NOAA Climate Monitoring **Organization:** National Climatic Data Center of the National Oceanic and Atmospheric Administration **Format:** TXT; XML (Extensible Markup Language); RSS (Really Simple Syndication) **Classification:** Resources; Controlling Documents; Environment; Demographic and Behavioral
Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS)	**Description:** The Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) contains information on hazardous waste sites, potentially hazardous waste sites and remedial activities across the nation. The CERCLIS Public Access Database contains a selected set of "non-enforcement confidential" information and is updated by the regions every 90 days. The data describes what has happened at Superfund sites prior to this quarter (updated quarterly). This database includes lists of involved parties (other Federal Agencies, states, and tribes), Human Exposure and Ground Water Migration, and Site Wide Ready for Reuse, Construction Completion, and Final Assessment Decision (GPRA-like measures) for fund lead sites. Other information that is included has been included only as a service to allow public evaluations utilizing this data [EPA 2010j]. **Data Source:** The Environmental Protection Agency (EPA) Superfund Site **Organization:** Environmental Protection Agency (EPA) **Format:** DBF (Database file name extension)

	Classification: Environment; Resources; Controlling Documents
Computer-Aided Management of Emergency Operations (CAMEO) Chemical Database	**Description:** Computer-Aided Management of Emergency Operations (CAMEO) has an extensive chemical database with critical response information for thousands of chemicals, and a tool that tells you what reactions might occur if chemicals were mixed together [EPA 2010k]. **Data Source:** CAMEO Chemicals, Version 2.0.1 **Organization:** Environmental Protection Agency (EPA), National Oceanic, Atmospheric Administration (NOAA) **Format:** Report **Classification:** Environment; Controlling Documents
ECOTOX Database	**Description:** ECOTOX is a comprehensive database, which provides information on adverse effects of single chemical stressors to ecologically relevant aquatic and terrestrial species. ECOTOX includes more than 400,000 test records covering 5,900 aquatic and terrestrial species and 8,400 chemicals. The primary source of ECOTOX data is the peer-reviewed literature, with test results identified through comprehensive searches of the open literature. ECOTOX also includes third-party data collections from U.S. EPA Program Offices, the U.S. Geologic Survey, Russia, and the Organization for Economic Cooperation and Development (OECD) member nations [EPA 2010l]. **Data Source:** ECOTOX Release 4.0 **Organization:** Environmental Protection Agency (EPA) **Format:** XLS (Microsoft Excel file format); Delimited ASCII file; Report **Classification:** Environment; Incidents
Envirofacts Data Warehouse	**Description:** Envirofacts, a single point of access to select U.S. Environmental Protection Agency (EPA) environmental data. Its website provides access to several EPA databases to provide the users with information about environmental activities that may affect air, water, and land anywhere in the United States. With Envirofacts, the users can generate maps of environmental information. Envirofacts provides a feature that allows the user to retrieve a sampling of information pertaining to the user's area by entering a specific ZIP Code, City and State, or County and State. It also provides more in-depth information about a particular subject area, such as Air, Waste, Facility, Land, Toxic Releases, Compliance, Water, Radiation, and Other [EPA 2010m]. **Data Source:** Envirofacts – MultiSystem Search Form **Organization:** Environmental Protection Agency (EPA) **Format:** HTML (Hyper Text Markup Language) **Classification:** Incidents, Environment; Resources; Spatial

Environmental Sensitivity Index (ESI) Maps	**Description:** NOAA's Environmental Sensitivity Index (ESI) is the most widely used approach to sensitive environment mapping in the United States. This approach systematically compiles information in standard formats for coastal shoreline sensitivity, biological resources, and human-use resources. ESI maps are useful for identifying sensitive resources before a spill occurs so that protection priorities can be established and cleanup strategies designed in advance. Using ESIs in spill response reduces environmental consequences of the spill and cleanup efforts. ESI maps provide a concise summary of coastal resources that are at risk if an oil spill occurs nearby. Examples of at-risk resources include biological resources (such as birds and shellfish beds), sensitive shorelines (such as marshes and tidal flats), and human-use resources (such as public beaches and parks) [NOAA 2010d]. **Data Source:** National Ocean Service (NOS) Data Explorer **Organization:** National Oceanic, Atmospheric Administration (NOAA) **Format:** MAP; PDF (Portable Document Format); SHP; .E00 (Arc/Info export format); MOSS; Geo-database **Classification:** Environment; Spatial; Resources; Incidents
Global Environment Outlook (GEO) Data Portal	**Description:** The GEO Data Portal is the authoritative source for data sets used by United Nations Environment Programme (UNEP) and its partners in the Global Environment Outlook (GEO) report and other integrated environment assessments. Its online database holds more than 450 different variables, as national, sub-regional, regional and global statistics or as geo-spatial data sets (maps), covering themes like Freshwater, Population, Forests, Emissions, Climate, Disasters, Health and GDP. Data may be displayed on the fly as maps, graphs, data tables, or downloaded in different formats [UNEP 2010]. **Data Source:** Geo Data Portal **Organization:** United Nations Environment Programme (UNEP) **Format:** CSV (comma-separated values); HTML; SHP; PDF **Classification:** Environment; Controlling Documents; Demographic and Behavioral; Spatial; Resources
Hazardous Waste Data	**Description:** Hazardous waste data is contained in the Resource Conservation and Recovery Act Information (RCRAInfo), a national program management and inventory system about hazardous waste handlers. In general, all generators, transporters, treaters, storers, and disposers of hazardous waste are required to provide information about their activities to state environmental agencies, which is then transmitted to the United States Environmental Protection Agency (EPA). EPA, in cooperation with the States, biennially collects information regarding the generation, management, and final disposition of hazardous wastes. Collection, validation and verification of the Biennial Report (BR) data is the responsibility of RCRA

	authorized states and regions [EPA 2010n]. **Data Source:** RCRAInfo **Organization:** Environmental Protection Agency (EPA) **Format:** PDF **Classification:** Environment; Spatial
Hazards Data Distribution System (HDDS)	**Description:** Hazards Data Distribution System (HDDS) provides quick downloads of U.S. and international disaster response imagery. Its data access and delivery services are provided by the following interfaces: non-graphical download, status-graphic download, and map interface. The users can select pre-event/baseline or event/disaster response. Users are able to obtain full-resolution GeoTIFF images or JPEG images at medium and low quality compressions [USGS 2010b]. **Data Source:** HDDS **Organization:** U.S. Geological Survey, Center for Earth Resources Observation and Science (EROS) **Format:** GeoTIFF; JPEG (Joint Photographic Experts Group), CSV; SHP; KML **Classification:** Incidents; Spatial; Environment; Simulation Support
LandView	**Description:** The LandView database system allows users to retrieve Census 2000 demographic and housing data, EPA Envirofacts data and U.S. Geological Survey (USGS) Geographic Names Information System (GNIS) information. The GNIS contains over 1.2 million records which show the official federally recognized geographic names for all known places, features, and areas in the United States that are identified by a proper name [CENSUS 2010]. **Data Source:** LandView 6 **Organization:** Environmental Protection Agency (EPA), U.S. Census Bureau, and U.S. Geological Survey (USGS), National Oceanic, Atmospheric Administration (NOAA) **Format:** Data; MAP **Classification:** Demographic and Behavior; Spatial; Environment; Resources
Multi-angle Imaging Spectro Radiometer Instrument (MISR)	**Description:** The Multi-angle Imaging SpectroRadiometer instrument (MISR) provides radiometrically and geometrically calibrated images in four spectral bands at each of the angles. MISR measurements are designed to improve our understanding of the Earth's environment and climate. MISR provides new types of information for scientists studying Earth's climate, such as the partitioning of energy and carbon between the land surface and the atmosphere, and the regional and global impacts of different types of atmospheric particles and clouds on climate. MISR data are processed and archived at the NASA Langley Research Center Atmospheric Science Data Center (ASDC) [NASA 2010b]. **Data Source:** ASDC Data Pool

	Format: HDF-EOS (Hierarchical Data Format- Earth Observing System) **Classification:** Environment; Spatial
National Response Center (NRC) Download Data	**Description:** The National Response Center (NRC), the federal government's national communications center, is staffed 24 hours a day by U.S. Coast Guard officers and marine science technicians and serves as the sole federal point of contact for reporting all hazardous substances and oil spills. The NRC maintains reports of all releases and spills in a national database. The NRC has made available yearly data files for download and offline management. Each file represents a particular calendar year and contains data related to incidents that occurred during that year. NRC report categories include aircraft report, continuous release report, fixed report, mobile report, pipeline report, platform report, railroad report, sheen report, storage tank report, and vessel report [USCG 2010]. **Data Source:** NRC DOWNLOAD DATA **Organization:** National Response Center **Format:** XLS; HTML **Classification:** Incidents; Environment; Controlling Documents
Plume Databases	**Description:** The National Aeronautics and Space Administration's plume databases provide plume data such as plume source latitude, plume source longitude, plume direction, date, orbit number, orbit block, and MISR (Multi-angle Imaging Spectro-Radiometer) coordinates [NASA 2010c]. **Data Source:** Plume Database: 2006-01-19 and 2006-02-06 **Organization**: National Aeronautics and Space Administration (NASA) **Format:** CSV **Classification:** Environment
Radiation Information Database (RADINFO)	**Description:** The Radiation Information Database (RADINFO) contains information about facilities that are regulated by U.S. Environmental Protection Agency (EPA) regulations for radiation and radioactivity. The RADINFO Query allows users to retrieve selected data from RADINFO database in Envirofacts. Specify the facilities by using any combination of facility name, geographic location, standard industrial classification, and chemicals. There are two search parameters: location data and regulator data [EPA 2010o]. **Data Source:** RADINFO Query **Organization:** Environmental Protection Agency (EPA) **Format:** Record; Table **Classification:** Resources; Environment
Storm Prediction Center (SPC) Forecast Products	**Description:** The Storm Prediction Center (SPC) of the National Weather Service (NWS) is providing tornado/severe thunderstorm watches, meso-scale discussions, convective day

	1-3 outlooks, fire weather outlooks, and watch, warning and advisory display through Really Simple Syndication (RSS) [NOAA 2010e]. **Data Source:** SPC Products RSS Feeds **Organization:** National Oceanic and Atmospheric Administration (NOAA) **Format:** RSS **Classification:** Incidents; Demographic and Behavior
TOXicology Data NETwork (TOXNET)	**Description:** TOXNET (TOXicology data NETwork) is a cluster of databases covering toxicology, hazardous chemicals, environmental health and related areas. The Toxicology and Environmental Health Information Program (TEHIP) in the Division of Specialized Information Services (SIS) of the National Library of Medicine (NLM) manages it. Toxicology databases include: Hazardous Substances Data Bank (HSDB), Integrated Risk Information System (IRIS), International Toxicity Estimates for Risk (ITER), Chemical Carcinogenesis Research Information System (CCRIS), Genetic Toxicology (GENE-TOX), Toxicology interactive guide (Tox Town), Household Products Database, occupational toxicology database (Haz-Map), toxic chemicals released on map (TOXMAP), Drugs and Lactation (LacMed), and Carcinogenic Potency Database (CPDB) [NIH 2010b]. **Data Source:** TOXNET **Organization:** The National Library of Medicine (NLM) **Format:** Report; XML **Classification:** Controlling Documents; Demographic and Behavior; Environment
Toxics Release Inventory (TRI)	**Description:** The Toxics Release Inventory (TRI) is a publicly available EPA database that contains information on toxic chemical releases and waste management activities reported annually by certain industries as well as federal facilities. TRI.Net – is a high performance Data Engine for querying the Toxics Release Inventory. The tool has capabilities to analyze TRI data effectively, by using Ad hoc queries and integrating them with mapping technologies. It is highly interactive and provides a quick and efficient analytical response. Supports very large queries and complex trends [EPA 2010q]. **Data Source:** Toxics Release Inventory, TRI.NET **Organization:** Environmental Protection Agency (EPA) **Format:** CSV; MAP **Classification:** Environment; Controlling Documents
TRI Explorer Database	**Description:** TRI Explorer is a searchable online database that lets users quickly get information about releases and transfers and other waste management [EPA 2010r]. **Data Source:** TRI Explorer, Version 5.02 **Organization:** Environmental Protection Agency (EPA) **Format:** XLS

	Classification: Environment
Vulnerable Zone Indicator System (VZIS)	**Description:** The Vulnerable Zone Indicator System (VZIS) allows the user to quickly find out if an address of interest to the user – the home, place of work, or child's school – could be affected by a chemical accident. VZIS can be used to determine whether the address may be in the vulnerable zone of a facility that submitted a Risk Management Plan (RMP). Use a street address or Latitude & Longitude to submit the request [EPA 2010s]. **Data Source:** VZIS **Organization:** Environmental Protection Agency (EPA) **Format:** EMAIL **Classification:** Incidents; Environment
Wireless Information System for Emergency Responders (WISER)	**Description:** WISER is a system designed to assist first responders in hazardous material incidents. WISER provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, human health information, and containment and suppression advice [NIH 2010c]. **Data Source:** WISER, Version 4.3; WebWISER; WISER for BlackBerry, Version 1.0; WISER for iPhone/iPod touch, Version 1.0 **Organization:** The National Library of Medicine (NLM) **Format:** Report **Classification:** Incidents; Controlling Documents; Demographic and Behavior; Environment

7. Discussion and Recommendations

This section is intended to capture practices and issues relevant to program sponsors, project managers, researchers, developers, and implementers of M&S of HMR for homeland security applications. The resources presented in section 6 and research, development and implementation experiences are used to identify the best practices to be followed for future efforts and to provide uncertainties, cautions and warnings for use of such applications. Further, the resources in section 6 are compared with the information in sections 4 and 5 to identify the unmet needs and requirements. These unmet needs and requirements are used to identify and prioritize the research, development, standards, and implementation issues that should be addressed going forward. This section hence provides a summary of discussion topics and recommendations that are divided into three major areas:

- Identification of best practices (Section 7.1)
- Uncertainties, cautions and warnings regarding expectations of these models and simulations (Section 7.2)
- Research, development, standards, and implementation issues that may need to be addressed by the research community, program sponsors, and stakeholders to improve the quality and utility of hazardous material release models and simulations (Section 7.3)

7.1. Best Practices

Best practices are really only effective if a methodology is well defined for a given problem solving approach. For example, the LUMAS model shows how learning influences a documented methodology, and the link between L and M in the LUMAS model is where best practice is encountered by the user of a methodology. Computer models and simulations are tools in a variety of problem solving methodologies such as operations research, systems engineering, and management science, where methodology is defined as a collection of related processes, methods, and tools. Methodologies evolve as they are used by practitioners to address new problems and as new technologies and tools are developed to support them. Methodological advances are encouraged by documenting existing methods, processes and tools and by updating these periodically based on lessons learned and best practice from practical experience. This section will identify recommended approaches and best practices for solving different types of hazardous material release modeling problems.

- *Utilize implementation techniques that enable fast (near real-time) computation of predictions for changing weather conditions or release characteristics*
- *Provide tools that can be used at the local level for incident management or training purposes*
- *Use various test methods (inert material releases to validate models)*

7.2. Limitations, Cautions and Warnings

This sub-section is intended to highlight and document the limitations associated with M&S applications to minimize improper use and highlight potential areas for further development. Typical M&S applications require significant effort and hence they should be utilized only when appropriate, i.e., they should be considered for complex problems that cannot be addressed using other analytical options. The level of detail and specificity achieved by using the most sophisticated models and simulations may not be practical or necessary for all HMR scenarios.

M&S and computational science capabilities are continuing to evolve and are providing new insights on many complex phenomena. Since an M&S capability simulates reality, it should be critically evaluated to ensure that the results are credible for their specific intended use. Evaluation of these capabilities should take into account the many factors that affect the quality of the results including the level of understanding or knowledge of the issues being addressed and the experience level of model developers. For example, model developers must fully understand the problem being addressed and form a conceptual model for use as a framework in developing and implementing a computational model. With a clear conceptual model in mind, developers have a number of choices to make in generating results from computer modeling:

For applications that are identified as suitable for HMR M&S applications, it should be recognized that models provide results with varying levels of error and uncertainty. HMR models are particularly susceptible to variations in predicted results due to difficulties in precisely measuring topography and weather conditions. Analysts should ensure that decision-makers understand the uncertainties in M&S results and other limitations such as the ones listed below.

- *What data, knowledge, or theories are available or applicable to address the problem at hand?*
- *Is the data, knowledge, or understanding sufficient in both quality and quantity to address the problem at hand, or will additional data or observations be required to support development?*
- *What is the risk of using erroneous results e.g., will these results be the only input to a decision, or will other sources of information be available to support decision making?*
- *How can the conceptual model be expressed mathematically?*

- *What boundary and initial condition should be used?*
- *What modeling paradigm would be most appropriate to implement the analysis?*
- *Given the developers' experience, what particular codes would be most suitable for implementing the model, considering software, hardware, and other constraints and limitations?*
- *Given the code has been developed, have any mistakes or errors been made in completing this or in entering the data?*
- *Given there are no mistakes or errors found in developing the code or entering the data, are the results realistic, and do they make sense?*
- *What approach should be used to ensure that model results are correct?*
- *How do aleatory and epistemic uncertainties and approximations affect the computational results?*
- *Given that everything else is correct, are the results suitable to address the problem at hand?*
- *How should the results and associated uncertainty be present for use in decision making?*
- *Will data inconsistencies between simulated releases and real incidents may affect the accuracy and usability of results?*

Analysts and decision makers need to be aware of these sorts of issues when using or when presented with M&S results.

7.3. Research, Development, Standards, and Implementation Issues

A number of research, development, standards, and implementation issues remain to be addressed. An initial straw man list follows:

- *Identification of appropriate models, simulations, tools, and databases to address HMR needs*
- *Identification of common models, simulations, tools, and databases that can be shared with the user community*
- *Identification of technical gaps and needs for models, simulations, tools, and databases, e.g., increasing accuracy of model predictions, especially in urban environments*
- *Development of system requirements specifications for HMR models, simulations, tools, and databases*
- *Development of systems dynamics models for addressing strategic issues for different HMR incidents*
- *Development of mechanisms to enable access to and usage of HMR M&S applications by users in the field (non-laboratory personnel), SSAs, partners, and operational personnel*
- *Development of simulation application architectures to enable modular system construction, software re-use, module integration and standard data interfaces to import data from external databases*
- *Use of a system-of-systems engineering approach to the development of applications*
- *Use of UML/SysML in specification of HMR M&S applications*
- *Development of M&S applications as open systems*
- *Use of object-oriented models in HMR M&S*
- *Integration of hazardous material release models and simulations with other simulation and training applications, e.g., incident management systems*
- *Establishment of security and protection mechanisms for sensitive data*
- *Ownership and usage of publicly vs. privately developed models, simulations, tools, and databases*
- *Return on investment to stakeholders and sponsors for research projects*

8. Conclusion

This initial version of the document is the starting point of an effort to capture the current knowledge relevant to M&S of HMR for homeland security applications. It identifies the needs, translates them into requirements and provides summary information on resources available to meet the needs and requirements. The information on needs, requirements, and resources is used together with research, development, and implementation experiences to distill practices and issues for future efforts.

This version will be used to facilitate input from domain experts in a workshop setting. It is hoped that the next version updated with such input will provide value as a reference for program managers, project managers, researchers, developers, and implementers of M&S for HMR for homeland security applications. Use of the updated document as a common reference may help increase the awareness across the associated community and help enhance collaborative efforts for homeland security applications of M&S for HMR.

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