June 14-15, 2011

National Institute
of Standards
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Gaithersburg, MD

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December 2011

Homeland Security & Modeling & Simulation Workshop

A Compendium and Workshop Report

Hazardous Material Releases

Incident Management

Healthcare Systems

Critical Infrastructure Systems

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

NISTIR 7826

DHS/NIST Workshop on Homeland Security Modeling & Simulation

June 14-15, 2011

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Foreword

The U. S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) and the National Institute of Standards and Technology (NIST) Engineering Laboratory (EL) jointly hosted a Homeland Security Modeling & Simulation (M&S) workshop on June 14 - 15, 2011 at NIST in Gaithersburg, Maryland.

The intent of this workshop was to bring together a wide range of individuals from both government and private sectors to exchange information and benchmark knowledge on M&S and M&S-related issues for homeland security. This was successful since more than 70 people attended the workshop that included experts on technical and operational issues from government, industry, and academia. Participants hailed from throughout the U.S., Singapore, and Europe. DHS participation included 13 people from six different Components. This diversity of DHS participants is very unusual for workshops hosted by S&T's Office of Standards. This reflects a broad, general interest in modeling, simulation, and analysis for homeland security.

M&S and analysis covers lots of ground, and this diversity was reflected by the keynote speakers:

- Dr. Keith Holtermann (Director of the DHS Federal Emergency Management Agency (FEMA) National Exercise Division). "Modeling & Simulation – An Exercise Perspective"
- Dr. William Grosshandler (Deputy Director for NIST/EL Building and Fire Research). "Disaster-Resilient Buildings, Infrastructure, and Communities"
- Dr. Charles Hutchings (former Deputy Director, Modeling and Simulation, DHS Test & Evaluation and Standards Division). "Perspective on the Use of Models and Simulations in Problem Solving for Homeland Security"

Further discussion in four parallel working sessions identified important technical issues and provided participants an opportunity to share information in the following domains:

- Incident Management
- Critical Infrastructure Systems
- Hazardous Material Releases
- Healthcare Systems

The discussion topics of the working session included: 1) needs and requirements; 2) M&S resources; 3) best practices; 4) limitations, cautions, and warnings; and 5) research and development, standards, and implementation issues. The findings and recommendations in these proceedings augment compendiums of information on modeling and simulation for homeland security in each of the four technical domains prepared as pre-read materials for the workshop. This work will be of great value to stakeholders in both government and private sector to benchmark our knowledge, and support the advancement of M&S capabilities for homeland security.

Bert M. Coursey, Ph.D.
Director of Standards
Science and Technology Directorate
U.S. Department of Homeland Security

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Contents

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Steven Fernandez – Oak Ridge National Laboratory
William Grosshandler – NIST
David Henry – Lockheed Martin
Matthew Kaufman – US Army TRADOC, G2
Sharon Kemmerer – NIST (Scribe)
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Wee Teik Khoo – Ministry of Home Affairs, Singapore
Y. Tina Lee – NIST
Anthony Lee – MYMIC LLC
Deborah MacPherson – Cannon Design
Michael Maglothin – RhinoCorps, LTD. Co.
Carlos Callejon Martinez – CIMNE-USA
Reid McKeown – Naval Surface Warfare Center

John Nestor – TSA
Rosie Posadas – MITRE Corporation
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Walter Cheek – BreakAway Ltd.
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Paul Nielan – Sandia National Laboratories
Juan Orama – National Guard Bureau
Joshua Rohrback – Bruhn NewTech, Inc.
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1. Executive Summary

The U. S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) and the National Institute of Standards and Technology (NIST) Engineering Laboratory (EL) jointly hosted a Homeland Security M&S workshop on June 14-15, 2011 at NIST in Gaithersburg, Maryland. The intent of this workshop was to bring together a wide range of individuals from both government and the private sector to exchange information and benchmark knowledge on M&S and M&S-related issues for homeland security. More than 70 people attended the workshop that included experts on technical and operational issues from government, industry, and academia. Participants hailed from throughout the U.S., Singapore, and Europe.

Dr. Bert Coursey, Director of Standards, DHS Science and Technology Directorate, and Dr. Vijay Srinivasan, Chief, NIST EL Manufacturing Systems Integration Division (MSID), gave welcoming addresses. The workshop had three keynote speeches including:

- Dr. Keith Holtermann (Director of the DHS Federal Emergency Management Agency (FEMA) National Exercise Division). "Modeling & Simulation – An Exercise Perspective"
- Dr. William Grosshandler (Deputy Director for NIST/EL Building and Fire Research). "Disaster-Resilient Buildings, Infrastructure, and Communities"
- Dr. Charles Hutchings (former Deputy Director, Modeling and Simulation, DHS Test & Evaluation and Standards Division). "Perspective on the Use of Models and Simulations in Problem Solving for Homeland Security"

The workshop program committee assembled a draft compendium of information on modeling and simulation for homeland security in the four technical domains. The compendium was provided to the participants as pre-read materials and served as a baseline for review, discussion, validation, and extension in breakout sessions. Four parallel working sessions provided opportunities to identify important M&S technical issues and share information in the following homeland security domains:

- Incident Management
- Critical Infrastructure Systems
- Hazardous Material Releases
- Healthcare Systems

Sanjay Jain and Charles McLean presented the charge to workshop participants. The identified objectives of the workshop were to 1) amend compendium documents that captured M&S knowledge for the technical domain areas; 2) discuss content in each section in the draft documents - change/expand/ remove; 3) add content beyond that in the draft documents; and 4) suggest additional sections and content.

The discussion topics of the working sessions included:

- Needs and requirements;
- M&S resources that are currently available including project, facilities, and capabilities; tools; standards; and data sources;
- Best practices for implementing models and simulations;
- Limitations, cautions, and warnings pertaining to the use of simulation technology; and
- Research, development, standards, and implementation issues.

Findings and recommendations from the workshop are being made available to stakeholders and the general public in this joint DHS/NIST proceedings and compendium report.

The report contains summaries of keynote presentations, background materials prepared for the workshop, and conclusions resulting from discussions on issues faced by the homeland security M&S community. Participants were invited to join together to review and extend background materials provided prior to the workshop. Those materials were updated based on the input of subject matter experts and other representatives from government, research, and commercial organizations that have a stake in M&S for homeland security.

Section 2 provides a summary of the keynote addresses. It also contains brief biographies of the speakers.

The remainder of this document provides a compendium of homeland security M&S information as modified and expanded through discussions by workshop participants in breakout sessions.

Section 3 introduces the four technical domains that were the focus of the workshop and breakout sessions, namely:

- Hazardous Material Releases (HMR);
- Critical Infrastructure (CI) Systems;
- Incident Management (IM); and
- Healthcare Systems (HS).

Issues addressed within the breakout groups included the establishment of consensus on

- 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;
- Appropriate model evaluation and accreditation practices; and
- Identification of 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.

Section 4 provides general background and perspectives on methodologies, models, and simulations. An initial set of high level user and customer needs for homeland security M&S applications are presented in Section 5. (Appendix A translates the high level needs to a representative set of M&S system capabilities and requirements.) The existing M&S resources and capabilities such as projects, tools, standards, and data sets that have been developed over the years to meet the needs are introduced in Section 6. (A detailed listing of the resources is contained in Appendices B-E to this document.) Section 7 presents a discussion of issues, concerns, and recommendations for advancing homeland M&S, in particular recommendations voiced by workshop participants. Section 8 concludes the document. Section 9 provides definitions for selected acronyms and abbreviations used in this report. Section 10 provides a list of references used.

It should be noted that for the purpose of this report, simulation refers to execution of computer models. It does not include role-playing or live exercises by human subjects, though it does include computer simulation models that may be used in support of live exercises (such as those discussed in Dr. Holtermann's keynote address in Section 2). Overall, the report covers applications of M&S tools across planning, prevention, response, and recovery stages.

2. Keynote Addresses

2.1. Dr. Holtermann Keynote Address

Keith Holtermann, DrPH, MBA, MPH, RN
Director, National Exercise Division
National Preparedness Directorate
Federal Emergency Management Agency (FEMA)
U.S. Department of Homeland Security (DHS)
Washington, DC

Dr. Keith Holtermann serves as the Director of the Federal Emergency Management Agency's National Exercise Division. The National Exercise Division is responsible for providing exercise guidance and planning support to the Nation's emergency preparedness community.

Prior to joining FEMA as a career executive, Dr. Holtermann served as the Associate Dean for Health Sciences at The George Washington University (GWU), School of Medicine and Health Sciences where he held numerous key positions including: Principal investigator at the Response to Emergencies and Disasters Institute; Chief of 9-1-1 Research and Policy Analysis at the Ronald Reagan Institute for Emergency Medicine; and Director of the Emergency Health Services Program. While at GWU, Dr. Holtermann served on an interagency assignment with FEMA as the founding Director of the National Exercise and Simulation Center, a centralized facility located at FEMA headquarters in Washington, DC that coordinates the use of modeling, simulation, and exercise tools to enhance the realism and effectiveness of emergency preparedness exercises. He also served on a 4-year assignment with the U.S. Department of Health and Human Services in the Office of the Assistant Secretary for Preparedness and Response in a variety of executive leadership positions such as the Emergency Operations Branch Chief, the Training Exercises and Lessons Learned Lead, and Developer/Lead of the Office of International Response Policy.

Dr. Holtermann has been in the emergency health services field for more than 35 years as a Registered Nurse, Paramedic, Director of Emergency Medical Services, Forensic Investigator, U.S. Embassy Health Officer, Strategic Arms and Intermediate Range Nuclear Forces treaties Inspector and Monitor, and faculty at multiple colleges and universities. He has performed emergency-related research and/or consulting in Kuwait, Saudi Arabia, Oman, Taiwan, Tatarstan, India, the United Kingdom, Germany, France, Spain, Thailand, Columbia, Bahamas, Jamaica, Mexico, and all of Central America. He is fluent in Spanish and has written a text on EMS Development for the United Nations/World Health Organization/Pan American Health Organization.

Keynote Summary:
"Modeling and Simulation: An Exercise Perspective"

Dr. Holtermann's talk focused on the use of M&S for supporting homeland security exercises via the National Exercise Simulation Center (NESC). He introduced the National Exercise Program (NEP) and discussed its major components. He presented the history of the NESC and the challenges it has faced over the years to arrive at a new business model. The target market of the NESC was defined as including exercises, planning, and operations. The M&S applications in the National Level Exercise 2011 (NLE11) were discussed to exemplify such use. The future trend of moving towards a geo-spatial concept of operations was identified as a key motivation for increasing the use of M&S.

The NEP includes several components, including National-Level Exercises (NLEs) centered on the White House directed strategy; Principal-Level Exercises (PLEs) that are quarterly presidential cabinet level exercises; NEP multi-year schedules of NLEs and PLEs; and schedules of all federal, regional, and local exercises. The NESC mission is to enhance the Department's all-hazards preparedness and response mission through the promotion of effective and efficient large-scale exercises and the application of modeling and simulation to these exercises. The mission indicates the key challenge to be addressed by the NESC is the change of culture of exercises to include M&S as a way of increasing efficiency and providing higher yield through the ability to explore alternative courses of action. The NESC utilizes existing M&S capabilities for decision support including human-based simulation (actors) and computer-based simulation to increase exercise realism and immersion in lifelike scenarios. It focuses on multi-participant exercise simulations. It is advancing the use of M&S across the seven functional areas of planning, design and development, conduct, evaluation, improvement planning, lessons learned, and promotion. NESC serves the exercise market by providing support for exercise design and development, exercise conduct, and exercise evaluation. It supports planners in strategizing and improving their plans through use of M&S. It is exploring ways to utilize M&S for real-time operational planning to predict the impact of an incident before true situational awareness can be obtained.

The NESC strives to provide the exercise community with a common set of exercise support services. It aims to improve standardization and leverage best practices and lessons learned across exercise activities by employing a new business model of long-term procurements and agreements for functional-based services with multiple sources for increased flexibility and competition.

M&S was used effectively for the NLE11 withthe scenario of a catastrophic earthquake in the New Madrid and Wabash Valley seismic zones. NLE11 included 135 sites, 1,400 player/controller accounts via an Emergency Management System enterprise (EMSe) platform, 13,000 injects, and more than 4,000 people from over 43 federal agencies. The M&S tools used in NLE11 include the EMSe platform that provides a common operating picture for players and controllers: On-Line Interactive Virtual Environment (OLIVE) for avatar meetings and damage assessments; America's Army Simulation Engine for visualization of scenario damage; Standard Unified Modeling Mapping Integration Toolkit (SUMMIT) for interaction with damage zones; and Virtual News Network (VNN) for mock media reports. SUMMIT provides capabilities for discovering templates and models for specific scenarios and allows their integrated execution. SUMMIT capabilities developed specifically for NLE11 include data generation for scenario, ground truth and Master Scenario Event List (MSEL), 3D data visualization based on building damage calculated using Hazus data, visualization of 3D data on iPADs, and decision tree support for MSEL development.

The NESC acquires simulation models for use in exercises based on needs of exercise planners and inputs on threats, impacts, and key decisions from subject matter experts. The National Planning Scenarios

(NPSs) are used to identify the threats and impacts that need to be modeled and the associated Emergency Support Functions (ESFs). The analysis based on NPSs and ESFs has been used to identify the key gaps for model development. The more critical gaps requiring models include the following:

- What is the impact/disruption on public safety (law enforcement, fire, EMS, etc.)?
- What is the impact/disruption on public utilities (gas, water, electricity, telecom etc.)?
- What is the extent of cyber disruption?
- What is the extent and nature of the degradation/disruption to infrastructure for a cyber attack?

Dr. Holtermann concluded with a brief discussion of the Federal Interagency Geospatial Concept of Operations **(**GeoCONOPS**)** that is intended to identify and align the geo-spatial resources that are required to support the National Response Framework, ESFs, and supporting federal mission partners. He anticipates that implementation of GeoCONOPS will provide increased opportunities for M&S for homeland security applications.

2.2. Dr. Grosshandler Keynote Address

Dr. William L. Grosshandler
Deputy Director for Building and Fire Research
Engineering Laboratory (EL)
National Institute of Standards and Technology (NIST)
Gaithersburg, Maryland

Dr. William L. Grosshandler is the Deputy Director for Building and Fire Research of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). Dr. Grosshandler is responsible for internal operations of the Laboratory, which deals with construction and materials research, building environment research, and fire research. Dr. Grosshandler led the NIST investigation of The Station nightclub (Warwick, RI) fire and was the associate lead investigator of the National Building and Fire Safety Investigation of the World Trade Center Disaster.

Dr. Grosshandler received his Ph.D. in Mechanical Engineering from the University of California, Berkeley. Prior to his appointment at NIST, he spent three years as the Director of the Thermal Systems Program of NSF. At the same time, he maintained his position as Professor of Mechanical and Materials Engineering at Washington State University, where he had been since 1976. He has also held visiting appointments at Factory Mutual Research Corporation (now FM Global) and the University of Poitiers in France.

Dr. Grosshandler has served on the Board of Directors of the Combustion Institute, the editorial advisory board of Progress in Energy and Combustion Science, advisory boards for the Fire Protection Engineering Departments at the University of Maryland and Worcester Polytechnic Institute, the Research Advisory Committee of the Fire Protection Research Foundation, and is active in the Heat Transfer Division and a Fellow of ASME. He chairs the International Forum of Fire Research Directors (FORUM), serves on the Fire Council for Underwriters Laboratory, and is a member of the Science Advisory Committee of the National Association of State Fire Marshals. Dr. Grosshandler is a recipient of two Silver Medals for meritorious achievement and a Gold Medal for distinguished achievement in federal service from the U.S. Department of Commerce.

Keynote Summary:
"Disaster-Resilient Buildings, Infrastructure and Communities"

Dr. Grosshandler discussed past and ongoing work on disaster-resilient buildings, infrastructure, and communities, one of the three strategic goals of the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He briefly introduced NIST, the Engineering Laboratory, and then delved into describing the work towards this strategic goal including fire risk reduction in communities and buildings, earthquake risk reduction in buildings and infrastructure, and structural performance in multi-hazards.

NIST is an agency within the U.S. Department of Commerce. It has 2,800 federal employees and almost an equal number of associates and facilities' users per year. The Engineering Laboratory is one of four major laboratories within NIST. It has the mission to promote U.S. innovation and industrial competitiveness in areas of critical national priority by anticipating and meeting the measurement science and standards needs for technology-intensive manufacturing and construction in ways that enhance economic prosperity and improve the quality of life. In addition to the topic of the keynote address, the other two strategic goals are sustainable and energy-efficient manufacturing, materials, and infrastructure, and smart manufacturing, construction, and cyber-physical systems.

The work on fire risk reduction in communities includes ensuring effective and safe use of emerging fire service technologies such as critical fire fighting and personal protective equipment while exploiting science-based fire-fighting simulators and training.. The community focused effort also includes reducing risk of fire spread in wildland-urban interface (WUI) communities through the use of predictive WUI fire models from component to community scale and database of fuels in WUI communities. The work on fire risk reduction in buildings has reduction of residential fire losses and engineered fire protection within its scope. The engineered fire protection includes use of M&S in form of numerical models for fire and smoke spread in addition to laboratory work for model evaluation.

The work on earthquake risk reduction in buildings and infrastructure is partly carried out under the National Earthquake Hazards Reduction Program (NEHRP) with NIST in lead agency role for Federal Government's coordinated, long-term, nationwide program to reduce risks to life and property in the United States from earthquakes. The work also includes earthquake risk mitigation research on performance-based tools, guidelines, and standards for design of new buildings and retrofit of existing buildings to resist earthquake effects, improving building safety, and enhancing resilience of communities.

The fourth area of structural performance under multi-hazards includes wind engineering and the National Windstorm Impact Reduction Program, prevention of disproportionate collapse, fire resistance design and rehabilitation of structures, and disaster and failure studies. All of these efforts utilize M&S, primarily physics-based models, for the study of structural performance. Examples of simulation models and physical test setups that were used to study the collapse of part of the Murrow building in Oklahoma City were shared. Examples of models and test setups for behavior of structures under heat generated by fires were also shared. A new National Fire Research Laboratory is being established that will provide the capability to test the performance of real-scale structures and enable validation of complex predictive models of structural fire performance. It will also support development of performance-based standards and codes for design of structures and foster innovation in design and construction of buildings.

The lab has engaged in a number of disaster and failure studies over the years from the study of Hurricane Camille in 1969 and the San Fernando earthquake in 1971, to 2011 incidents including the earthquake in New Zealand, tornadoes in Joplin, Missouri, and fires in Amarillo, Texas. A data repository has been

established for use by NIST and outside researchers with data on all the disasters and failures studied. The study of the World Trade Center collapse was described in a bit more detail and attracted a lot of interest from the audience. The study involved a four-step reconstruction process with aircraft impact simulation, reconstruction of the fires, heating of the structural steel, and simulation of the structural response. The M&S tools employed in the study included LS-DYNA for aircraft impact damage, Fire Dynamics Simulator (FDS) for fire dynamics, and ANSYS for thermal analysis, structural response and failure analysis. The analysis was carried out at various levels of detail with the dimensional resolution ranging from 1-2 to 150 centimeters, and time resolution ranging from microseconds to 10-minute increments. Video clips from physics-based simulations of World Trade Center were shared.

Dr. Grosshandler concluded his talk with an acknowledgement for sponsorship of U.S. Department of Homeland Security, Science and Technology Directorate and the Federal Emergency Management Administration for part of the work reported.

2.3. Dr. Hutchings Keynote Address

Dr. Charles W. Hutchings
Senior Systems Engineer
Program Accountability and Risk Management Division
Management Directorate
U. S. Department of Homeland Security (DHS)
Washington, DC

Dr. Charles W. Hutchings is a Senior Systems Engineer in the Program Accountability and Risk Management Division of the Management Directorate, U. S. Department of Homeland Security (DHS). He is coordinating development of risk management methodology and tools – including models and simulations – to support systems development and program management in DHS.

From November 2007 to February 2011, he was Deputy Director, Modeling and Simulation in S&T's Test and Evaluation and Standards Division, where he provided modeling, simulation, and analysis support, guidance, and policy recommendations to promote the advancement and judicious use of M&S and computational science and engineering capabilities for homeland security. He is the author of four peer-reviewed papers on the management and use of computer models and simulations for homeland security.

From 2001 to 2007, Dr. Hutchings served on active duty and as a civil servant in the U.S. Navy. He was Senior Analyst in the Navy Test, Evaluation, and Technology Division where he provided expertise in M&S and led a program to develop an alternative approach to assess ship survivability using an innovative testing technology and computational models and simulations in lieu of large explosions in the ocean. In the Naval Sea Systems Command (NAVSEA), Dr. Hutchings provided test and evaluation guidance and oversight on multiple programs throughout their acquisition cycle by directly supporting program offices, conducting independent reviews of test programs at selected acquisition milestones, and presenting findings and recommendations to NAVSEA Acquisition Review Boards (ARB) and Program Reviews. Dr. Hutchings qualified as a U.S. Navy Engineering Duty Officer at Portsmouth Naval Shipyard in 1998.

Prior to government service, Dr. Hutchings completed post-doctoral work and was appointed Visiting Professor in the Department of Physics at the University of Nebraska-Lincoln, and authored/co-authored 17 papers in condensed matter physics and surface science. He received a Ph.D. in Physical Chemistry from the University of Heidelberg, Heidelberg, Germany in 1994, and received an M.S. in Physics and B.S. with majors in Mathematics and Physics from Syracuse University, Syracuse New York in 1990 and 1987, respectively.

Keynote Summary:
"Perspective on the Use of Models and Simulations in Problem Solving for Homeland Security"

Complexity, uncertainty, and risk often characterize homeland security problems. Preparation for landfall of a major hurricane, for instance, is a good example. Both individuals and organizations need to address a variety of questions in preparing for and responding to this natural threat. These questions might include:

- Where will the hurricane go?
- When will it arrive?
- What are anticipated impacts such as damaging winds, tidal surge, and expected rainfall?
- What will be the consequences, and how can these be mitigated?
- What's the best course of action to recover after the hurricane has made landfall and its full impacts are known?

Government officials face similar types of questions in addressing a terrorist threat or man-made disaster such as a chemical spill or failure of a critical infrastructure due to a cyber attack. For example:

- What are the risks due to a given threat?
- How can risks be mitigated?
- Given a threat or hazard is realized, what is the best way to respond and recover?

An important role for the U. S. Department of Homeland Security is coordination of an array of activities to prevent, protect, respond, and/or recover from both natural and man-made threats and hazards. Decision makers face a variety of problem situations in securing the Nation. These types of problem situations are multifaceted. They can be static or dynamic. They can be simple in nature or complex and "messy." They can involve physical systems as well as multiple organizations and human beings. They can be routine or unprecedented as with the Deepwater Horizon oil spill in the Gulf of Mexico or the Fukushima nuclear catastrophe. Decision making to resolve a problem situation can be done by individuals or groups using different types of decision models and can be structured or unstructured.

A variety of information science tools, which integrate elements of strategic, knowledge, and operations management; organizational behavior; quantitative methods; and computer science disciplines, have evolved to support problem solving and decision making of all types. These include data processing capabilities, management information systems, decision support tools, and pervasive computing capabilities. Computer models and simulations should be included in this category.

How can computer models and simulations help resolve a problem situation? Consider what happens when a problem situation manifests itself. A person or organization becomes aware of the problem situation that may be obvious or only indirectly apparent. If it is not apparent, the problem must be clearly identified and defined, and M&S capabilities can aid in problem identification and definition by modeling relevant environments, systems, and/or processes for study and analysis. For instance, the Modeling, Virtual Environments, and Simulation (MOVES) Institute at the Naval Postgraduate School uses virtual reality to help identify problems with and make improvements to military doctrine and training.

Next, the responsible stakeholders must decide on the appropriate course of action to resolve the identified problem. Predictive modeling and simulation capabilities – those used to assess the future performance of a given process or system in a specified environment or scenario – can be used to evaluate the courses of

action and make an informed decision. These types of capabilities might include engineering or scientific models to assess various physical threats or hazards to mitigate risks and potential damage. Computer models that forecast hurricane tracks and provide information on the time and location of landfall are good examples. Predictive engineering models are the basis for the NIST post mortem analysis of the collapse of the World Trade Center towers presented by Dr. Grosshandler.

Once the best course of action to address a problem situation is established, communication with all affected stakeholders is the next challenge in effectively implementing the solution. Simulations and M&S data are important here too. Hurricane track forecasts and the output of plume models for hazardous material releases are examples of M&S products, which help provide situational awareness to multiple stakeholders and coordinate an effective response.

For homeland security analysis and problem solving, decision makers at all levels should take advantage of the full range of M&S tools and capabilities from all the sciences (behavioral, biological, management, physical, and social). These tools and capabilities can help analysts understand how communities at various levels (national, regional, state, and local) function normally and how these communities are stressed during a catastrophic event or disaster. With a "big picture" perspective and sound M&S capabilities, decision makers can make informed choices and respond quickly to contain damage and promote resiliency after any disaster.

One of the challenges for better using M&S capabilities for homeland security is that "model," "simulation," and "data" mean different things to different communities; and, it is important to recognize this when dealing with a wide range of models and modelers from different disciplines. For example, the physical science community views data objectively, which is typically acquired from sensors or instruments that provide readings that are observed independently. This community then develops models that capture the behavior of physical systems based on measured data, and evaluation of models, commonly known as 'validation,' is an assessment of how well the simulated or calculated values of a physical system correspond to measurements given uncertainty.

For the social science communities, data is often more subjective, and researchers typically form consensus on what a set or sets of data represent. These communities use models to organize thinking and to study complex phenomena or systems. 'Validation' is usually a check of consistency, plausibility, and whether or not the results make sense given what is understood of the phenomena or system of interest.

The principle challenge for this workshop is to begin sorting through and documenting M&S capabilities and M&S-related issues for better developing, evaluating, and using these important tools for homeland security.

3. Introduction to M&S for Homeland Security

The National Incident Management System (NIMS) [DHS 2008a], developed by the U.S. Department of Homeland Security under the authority granted by the Homeland Security presidential Directive (HSPD)-5, Management of Domestic Incidents, provides a template for the management of large homeland security-related incidents. NIMS provides a national template for federal, state, tribal, and local governments, non-governmental 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.

The NIMS integrates best practices into a comprehensive framework for use nationwide by emergency management/response personnel. The incident management personnel 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).

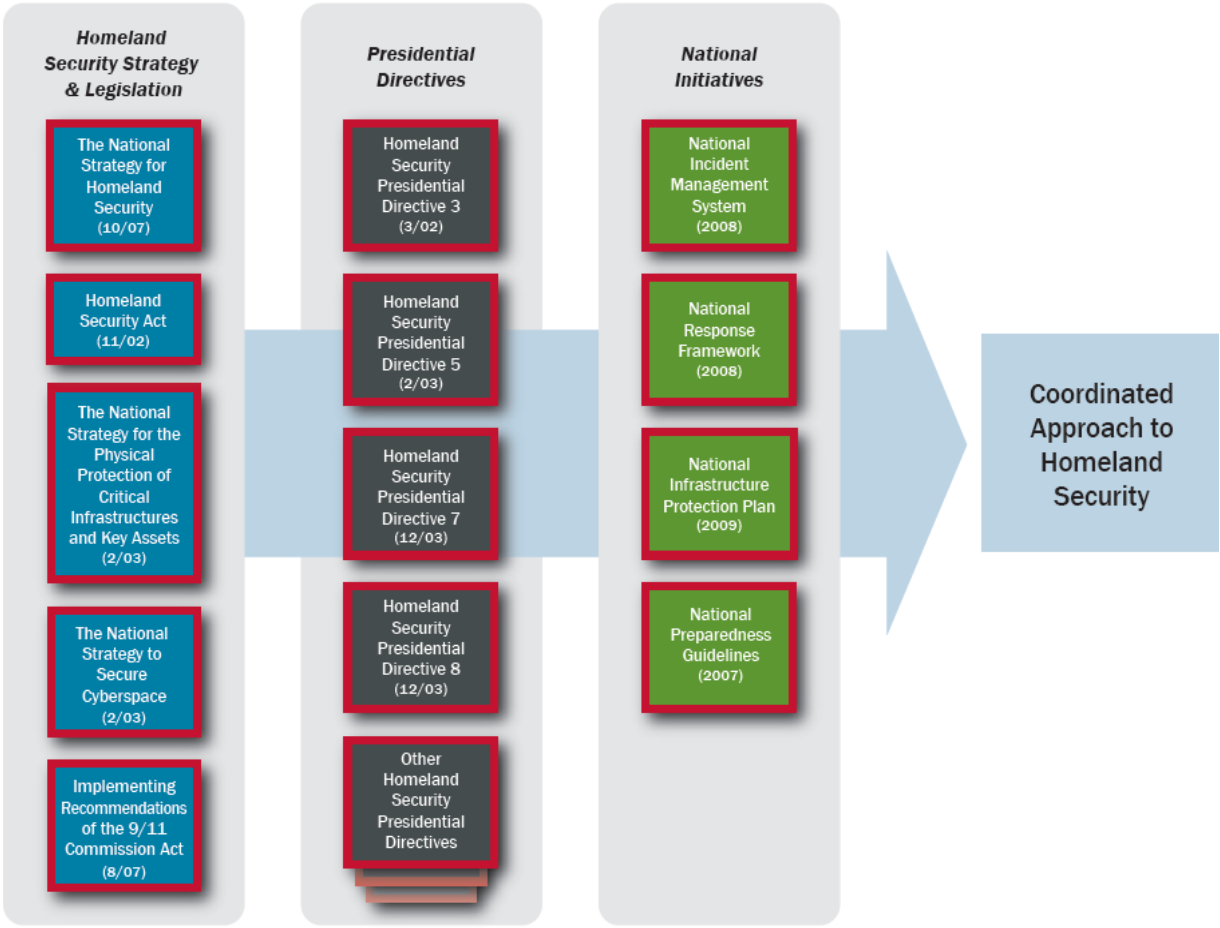

Figure 1: National Framework for Homeland Security (from [DHS 2009a])

The subsections that follow describe four technical domains within the homeland security framework for which modeling and simulation may play a significant role.

3.1. Hazardous Material Releases

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 (heating, ventilation, and air conditioning) 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.

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 a 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 the 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.

The 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. The majority of releases happen during the course of regular operations at fixed facilities [KCOEM 2011] 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). A recent example of HMR due to a natural disaster is the release of radioactive plumes from a nuclear power plant affected by the 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.

HMR is one of the hazards included in the all-hazard context that NIMS addresses. NIMS identifies a specific resource category, hazardous material response, and 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 FEMA to coordinate response support from across the Federal Government and non-governmental organizations. 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) as a single point for the coordination and dissemination of federal dispersion modeling and hazard prediction products that represent the federal position during an actual or potential incident. The IMAAC's goal is to draw upon the best available capabilities and information from all participating agencies. It is not intended to replace dispersion modeling capabilities that government agencies currently have in place to meet agency-specific requirements [DHS 2010f]. The NRF also calls for use of National Oceanic and Atmospheric Administration (NOAA) capabilities 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 the Department of Energy's National Atmospheric Release Advisory Center (NARAC) as a key resource that may be activated [NARAC 2010a]. 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 [NARAC 2010b]. 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's 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 Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) transport and dispersion model [NOAA 2011a].

The Federal Government's blueprint for responding to both oil spills and hazardous substance releases is described in the National Oil and Hazardous Substances Pollution Contingency Plan, more commonly called the National Contingency Plan or NCP [EPA 2011c]. The plan is included in the code of federal regulations in volume 40, part 300. The plan establishes, in response to major discharges of oil or hazardous waste, the National Response Team and its roles and responsibilities, the Regional Response Teams and their roles and responsibilities, and the general responsibilities of Federal On-Scene Coordinators (FOSCs). It requires notification of any discharge or release to the National Response Center through a toll-free telephone number. The NCP includes a Scientific Support Coordinator (SSC) as a special team to the FOSC. In addition to other science coordination activities, the SSC provides access to

air and water modeling in support of oil and hazardous substance releases. NOAA provides the SSC for releases in the coastal zone and EPA for inland zone. The National Response Center (NRC) acts as the central clearinghouse for all pollution incident reporting. The regulations call for use of dispersion modeling for a specific situation, such as, toxic amount emitted from burning of identified materials in metal recovery furnaces, and determination of allowable emission rates of specific compounds. The owners and operators of sites subject to regulation have to certify use of dispersion modeling and identify the tools and version used.

HMR dispersion modeling is also called for international level applications. The verification regime of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) utilizes atmospheric transport modeling (ATM) for identifying a possible release area or to predict the travel path of radionuclides based on a known emission location. Based on high-quality global meteorological data and using ATM, it is possible to trace the various three-dimensional travel paths of any selected radionuclide from any monitoring station where it was measured back to the area where it may have originated [CTBTO 2011].

Another international level application coordinated through National Oceanic and Atmospheric Adminsitration (NOAA) is the determination of hazards to aviation due to volcanic ash. International Volcanic Ash Advisory Centers (VAACs) have been established for collecting the information needed for this task, analyzing the data, forecasting drift of the volcanic cloud, and preparing notices and advisory bulletins. These organizations utilize dispersion models, operational satellite data, seismic monitors, and volcanic observatories for their information [JCEST 2010].

3.2. Critical Infrastructure

Critical Infrastructure and Key Resources (CIKR) models and simulations may be used to understand infrastructure systems, their interdependencies, their vulnerabilities, and the impact of the propagation of damage across interdependent infrastructure systems based upon emergency incidents. They may also be used to support training exercises, performance measurement, conceptual design, impact evaluation, response planning, analysis, acquisition, conceptualizing and evaluating new systems, vulnerability analysis, economic impact, and determining interdependencies between CIKR systems.

The National Infrastructure Protection Plan (NIPP) [DHS 2009a] 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 CIKR protection mission (see Figure 1). The relevant authorities include those that address the overarching homeland security and CIKR protection missions, as well as those that address a wide range of sector-specific CIKR protection-related functions, programs, and responsibilities. Homeland Security presidential Directive 7 (HSPD-7) established U.S. policy for enhancing CIKR protection by creating a framework for NIPP partners to identify, prioritize, and protect the Nation's CIKR from terrorist attacks. The directive identified 17 CIKR sectors and designated a federal Sector-Specific Agency (SSA) to lead CIKR protection efforts in each. The directive allows for the U.S. Department of Homeland Security to identify gaps in existing CIKR sectors and establish new sectors to fill these gaps. Under this authority, the Department established an 18th sector, the Critical Manufacturing Sector, in March 2008.

Protecting and ensuring the continuity of CIKR are essential to the Nation's security, public health and safety, economic vitality, and way of life. Critical Infrastructures are the assets, systems, and networks, whether physical or virtual, so vital to the Nation that their incapacitation or destruction would have a debilitating effect on security, national economic security, public health/safety, or any combination thereof. Key resources are publicly or privately controlled resources essential to the minimal operations of the economy and government [DHS 2009a].

The NIPP identifies CIKR sectors and responsible agencies. The sectors and responsible agencies are identified below:

1. *Agriculture and Food* – This sector is defined as the supply chains for feed, animals, and animal products; crop production and the supply chains of seed; fertilizer; and other necessary related materials. It includes the post- harvesting components of the food supply chain, from processing, production, and packaging, through storage and distribution to retail sales, institutional food services, and restaurant or home consumption. (*Responsible Agencies*: Department of Agriculture, Department of Health and Human Services)
2. *Banking and Finance* – This sector includes institutions that provide the following products and services: deposit, consumer credit, and payment systems; credit and liquidity products; investment products; and risk-transfer products, including insurance. (*Responsible Agency:* Department of the Treasury*)*
3. *Chemical* –This sector can be divided into five main segments, based on the end product produced: basic chemicals, specialty chemicals, agricultural chemicals, pharmaceuticals, and consumer products. (*Responsible Agency:* Department of Homeland Security – Office of Infrastructure Protection*)*
4. *Commercial Facilities* – This sector consists of the following eight subsectors: public assembly (e.g., arenas, stadiums, aquariums, zoos, museums, convention centers); sports leagues (e.g., professional sports leagues and federations); resorts (e.g., casinos); lodging (e.g., hotels, motels, conference centers); outdoor events (e.g., theme and amusement parks, fairs, campgrounds, parades); entertainment and media (e.g., motion picture studios, broadcast media); real estate (e.g., office/apartment buildings, condominiums, mixed-use facilities, self-storage); and retail (e.g., retail centers and districts, shopping malls). (*Responsible Agency:* Department of Homeland Security – Office of Infrastructure Protection*)*
5. *Communications* – This sector includes physical properties such as wire line, wireless infrastructure, satellite, cable, and broadcasting and also services such as the Internet, information services, and cable television networks. (*Responsible Agency:* Department of Homeland Security – Office of Cybersecurity and Communications)
6. *Critical Manufacturing* **–** This sector includes manufacturers that design, produce, and distribute products not covered by other sectors, including: primary metals (e.g., iron and steel mills and ferro-alloy manufacturing, alumina and aluminum production and processing, nonferrous metal, except aluminum, production and processing); machinery (e.g., engines, turbines, and power transmission equipment); electrical equipment, appliances, and components; transportation equipment (e.g., motor vehicles, aerospace product and parts, railroad rolling stock, and other transportation equipment). (*Responsible Agency:* Department of Homeland Security – Office of Infrastructure Protection*)*
7. *Dams* **–** This sector comprises the assets, systems, networks, and functions related to dam projects, navigation locks, levees, hurricane barriers, mine tailings impoundments, or other similar water retention and/or control facilities. It provides a wide range of economic, environmental, and social benefits, including hydroelectric power, river navigation, water supply, wildlife habitat, waste management, flood control, and recreation**.** (*Responsible Agency:* Department of Homeland Security – Office of Infrastructure Protection*)*
8. *Defense Industrial Base* – This sector is subdivided into segments, sub-segments, and commodities that produce or comprise weapon system platforms, components, and expendables. Major segments include missile, aircraft, troop support, space, combat vehicle, ammunition, weapons, information technology, shipbuilding, and electronics. Commodities include mechanical components and systems, structural elements, electrical, and electronics. (*Responsible Agency:* Department of Defense)
9. *Emergency Services* – This sector is a system of response and recovery elements that forms the Nation's first line of defense and prevention and reduction of consequences from any terrorist

attack. It is a sector of trained and tested personnel, plans, redundant systems, agreements, and pacts that provide life safety and security services across the Nation via the first-responder community comprised of federal, state, local, tribal, and private partners. First-responder disciplines included within the sector are: emergency management, emergency medical services, fire, hazardous material, law enforcement, bomb squads, tactical operations/special weapons assault teams, and search and rescue. (*Responsible Agency:* Department of Homeland Security – Office of Infrastructure Protection*)*

10. *Energy* – The energy infrastructure is divided into three interrelated segments: electricity, petroleum, and natural gas. More than 80 percent of the country's energy infrastructure is owned by the private sector. The sector's reliance on pipelines highlights the interdependency with, and the reliance on, the Energy Sector for power, which means that virtually all sectors have dependencies on this sector. (*Responsible Agency:* Department of Energy)
11. *Government Facilities* – This sector includes a wide variety of buildings, owned or leased by federal, state, territorial, local, or tribal governments, located domestically and overseas. Many government facilities are open to the public for business activities, commercial transactions, or recreational activities. Others not open to the public contain highly sensitive information, materials, processes, and equipment. This includes general-use office buildings and special-use military installations, embassies, courthouses, national laboratories, and structures that may house critical equipment and systems, networks, and functions. (*Responsible Agencies*: Immigration and Customs Enforcement, Federal Protective Service)
12. *Healthcare and Public Health* – This sector consists of state and local health departments, hospitals, health clinics, mental health facilities, nursing homes, blood-supply facilities, laboratories, mortuaries, and pharmaceutical stockpiles. (*Responsible Agency*: Department of Health and Human Services)
13. *Information Technology (IT)* – This sector is comprised of virtual and distributed functions necessary to provide IT products and services including hardware, software, IT systems, and services. (*Responsible Agency:* Department of Homeland Security – Office of Cybersecurity and Communications*)*
14. *National Monuments and Icons* – This sector is comprised of a diverse array of assets located throughout the United States and its Territories – many are listed on either the National Register of Historic Places or the List of National Historic Landmarks. They include monuments, physical structures, or objects that are: 1) recognized both nationally and internationally as representing the Nation's heritage, traditions, and/or values or are recognized for their national, cultural, religious, historical, or political significance; and 2) serve the primary purpose of memorializing or representing significant aspects of our Nation's heritage, traditions, or values and serve as points of interest for visitors and educational activities. These assets generally do not have a purpose or function that fits under the responsibility of another sector. (*Responsible Agency:* Department of the Interior*)*
15. *Nuclear Reactors, Materials, and Waste* – The sector includes: nuclear power plants; non-power nuclear reactors used for research, testing, and training; nuclear materials used in medical, industrial, and academic settings; nuclear fuel fabrication facilities; decommissioning reactors; and the transportation, storage, and disposal of nuclear material and waste. (*Responsible Agency:* Department of Energy)
16. *Postal and Shipping* – The sector moves over 720 million messages, products, and financial transactions each day. Postal and shipping activity is differentiated from general cargo operations by its focus on small- and medium-size packages and by service from millions of senders to nearly 150 million destinations. Sector-specific assets include: high-volume automated processing facilities; local delivery units; many and varied collection, acceptance, and retail operations; mail transport vehicles including vans, trucks, tractor-trailers and aircraft; and information and communications networks. Every sector of the economy depends on the service providers in this

sector to deliver time-sensitive letters, packages, and other shipments. (*Responsible Agency:* Department of Homeland Security – Transportation Security Administration)

17. *Transportation Systems* – This sector comprises all modes of transportation (aviation, maritime, mass transit, highway, freight rail, and pipeline) – a vast, open, interdependent networked system that moves millions of passengers and millions of tons of goods each year. (*Responsible Agencies:* Department of Homeland Security – Transportation Security Administration, United States Coast Guard*)*
18. *Water* – This sector includes drinking water and wastewater utilities, facilities, and systems. (*Responsible Agency* – Environmental Protection Agency*)*

To ensure an effective, efficient CIKR protection program over the long term, the NIPP relies on the development, safeguarding, and maintenance of data systems and simulations to enable continuously refined risk assessment within and across sectors and to ensure preparedness for domestic incident management. In particular, the complexity of interdependency calls for use of modeling and simulation capabilities. DHS Office of Infrastructure Protection (IP) is the lead coordinator for modeling and simulation capabilities regarding CIKR protection and resiliency [DHS 2009a]. In this capacity, DHS has several objectives including:

- Specifying requirements for the development, maintenance, and application of research and operations related modeling capabilities for CIKR protection and resiliency;
- Utilizing available relevant modeling and simulation capabilities in training and exercises to familiarize the Sector Specific Agencies (SSAs) and other CIKR partners with them;
- Providing guidance on the vetting of modeling tools; and
- Promoting use of applicable private sector modeling capabilities, including initiatives and expertise, by DHS, SSAs and their CIKR partners.

The principal capability within the IP to support modeling, simulation, and analysis efforts is the National Infrastructure Simulation and Analysis Center (NISAC). NISAC has been tasked with developing advanced modeling, simulation, and analysis capabilities for the Nation's CIKR. These tools and analyses together address CIKR in all-hazards context including physical and cyber dependencies and interdependencies. These sophisticated models better inform decision makers, especially for cross-sector priorities. NISAC is the principal but not the sole source available to CIKR stakeholders in need of modeling, simulation and analysis capabilities. NISAC works with other providers of CIKR analysis to improve overall analytical quality and ensure consistency.

Information regarding sector-specific CIKR-related authorities is addressed in the respective Sector Specific Plans (SSPs). The SSPs provide the means for implementing NIPP across all sectors. SSPs also provide a national framework for each sector that guides the development, implementation, and updating of state and local homeland security strategies and CIKR protection programs [DHS 2009a]. As the responsible agent for the identification of assets and existing databases for their sectors, the SSAs' objectives include:

- Outlining the sector plans and processes for database, data system, and modeling and simulation development and updates in their respective SSPs; and
- Facilitating the collection and protection of accurate information for database, data system, and modeling and simulation use in collaboration with sector partners.

Fourteen of the SSPs are publicly available. The limited current capabilities identified in these SSPs suggest that there are large opportunities for use of M&S in each of the sectors.

3.3. Incident Management

Incident management models and simulations may be used to support analysis, planning, and training needs pertaining to terrorist attacks, national security events, and natural and man-made disasters. Simulation models may be used to understand incident management systems, interdependencies with other systems, their vulnerabilities, and the impact of emergency incidents on the population and responder community. Incident management models and simulations will be used to support training exercises, performance measurement, conceptual design, impact evaluation, response planning, analysis, acquisition, conceptualizing and evaluating new systems, vulnerability analysis, economic impact, and determining interdependencies between incident management and other infrastructure systems.

The NIMS [DHS 2008a] and NRF [DHS 2008b] provide the relevant guidance for the incident management domain. Incidents and their management are defined in NIMS as below.

> **"Incident**: An occurrence, natural or manmade, that requires a response to protect life or property. Incidents can, for example, include major disasters, emergencies, terrorist attacks, terrorist threats, civil unrest, wild land and urban fires, floods, hazardous materials spills, nuclear accidents, aircraft accidents, earthquakes, hurricanes, tornadoes, tropical storms, tsunamis, war-related disasters, public health and medical emergencies, and other occurrences requiring an emergency response."
>
> **"Incident Management**: The broad spectrum of activities and organizations providing effective and efficient operations, coordination, and support applied at all levels of government, utilizing both governmental and non-governmental resources to plan for, respond to, and recover from an incident, regardless of cause, size, or complexity."

From the definitions it is clear that incident management has a broad scope since it involves a wide range of activities, includes a large number of organizations, in response to an even wider range of emergency threats and occurrences. DHS has developed a set of documents to organize and manage the complexity of the broad scope. The two major documents are the NIMS and NRF mentioned above, each with a set of associated documents and components. Homeland Security presidential Directive-5 (HSPD-5) [DHS 2003], called upon the Secretary of Homeland Security to develop a national incident management system. The NIMS provides a systematic approach to guide all involved organizations through the entire life-cycle of preventing, protecting against, responding to, recovering from, and mitigating the effects of incidents while the NRF focuses on preparing for and providing a unified national response to incidents. 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).

NIMS has five major components: Preparedness, Communications & Information Management, Resource Management, Command & Management, and Ongoing Management & Maintenance. The Ongoing Management & Maintenance component specifically refers to M&S. The component has two subsections: National Integration Center (NIC) and Supporting Technologies. NIC's role includes developing M&S capabilities for training and exercise programs and maintaining a repository of best-practices manuals, models, and recommendations.

A major sub-component of the Command &Management component of NIMS is the Incident Command System (ICS). The Incident Command System is "a standardized, on-scene, all-hazards incident management approach that:

- Allows for the integration of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure.

- Enables a coordinated response among various jurisdictions and functional agencies, both public and private.
- Establishes common processes for planning and managing resources." [FEMA 2010]

The ICS calls for use of technical specialists in planning and other parts of the recommended incident command organizational structure. The technical specialists' roles include providing information that may support tactical decisions on an incident. Numerical modelers are specifically identified as a category of technical specialists. M&S experts may thus be included as technical specialists in ICS to provide support for tactical decisions.

The NRF defines the roles and responsibilities, response actions, and organizations, and emphasizes planning as a critical element of the response. It introduces national planning scenarios to be used as a critical element for preparedness. The 15 national planning scenarios [FEMA 2009] may be used to help focus efforts to prepare for natural disasters, terrorist attacks, and other serious incidents. The national planning scenarios are *Improvised Nuclear Device; Aerosol Anthrax; Pandemic Influenza; Plague; Blister Agent; Toxic Industrial Chemicals; Nerve Agent; Chlorine Tank Explosion; Major Earthquake; Major Hurricane; Radiological Dispersal Device; Improvised Explosive Device; Food Contamination; Foreign Animal Disease;* and *Cyber Attack.*

- *Improvised Nuclear Device* scenario is based upon a 10-kiloton nuclear detonation in a large metropolitan area.
- *Aerosol Anthrax* scenario is an aerosol attack spread by a truck in a city.
- *Pandemic Influenza* scenario involves the outbreak of influenza for which there has not been an effective preplanned response.
- *Plague* scenario is a pneumonic plague that strikes three areas of a major metropolitan city.
- *Blister Agent* scenario involves a light aircraft spraying chemical blister agents into a packed college football stadium.
- *Toxic Industrial Chemicals* scenario is an attack where a group of terrorists land helicopters at a petroleum refinery, start fires with rocket-propelled grenades and improvised explosive devices that result in a toxic chemical release.
- *Nerve Agent* scenario involves the release of Sarin vapor into the ventilation systems of three commercial office buildings in a busy metropolitan area.
- *Chlorine Tank Explosion* scenario involves an explosion at an industrial facility and the release of a large quantity of chlorine gas.
- *Major Earthquake* scenario is a 7.2 magnitude quake that occurs along a fault zone in a major city.
- *Major Hurricane* scenario is a Category 5 hurricane that hits a major metropolitan area.
- *Radiological Dispersal Device (RDD)* scenario involves separate Cesium Chloride bomb attacks on three regionally close, moderate-to-large cities.
- *Improvised Explosive Device (IED)* scenario involves IED bombings inside a sports arena, at a parking facility near an entertainment complex, and suicide bomber attacks in an underground public transportation concourse.
- *Food Contamination* scenario involves the distribution of anthrax-contaminated ground beef and orange juice to different states and cities.
- *Foreign Animal Disease* scenario is a coordinated bio-terrorism attack that infects farm animals with foot and mouth disease at several large livestock operations.
- *Cyber Attack* is a computer attack that is directed at several parts of the national financial infrastructure over the course of several weeks.

M&S tools and applications should, wherever possible, support the fifteen national planning scenarios defined by DHS. It is likely that incident management systems will play a significant role in most of the national planning scenarios, with the possible exception of the cyber attack scenario.

The NRF defines 15 emergency support functions (ESFs) that can be used to coordinate response in functions such as transportation, communications, fire fighting, mass care, housing, public health and medical services, search and rescue, and energy. Some of the annexes specifically call for use of M&S. ESF#8 – Public Health and Emergency Services calls for use of Interagency Modeling and Atmospheric Assessment Center (IMAAC) to provide predictions using M&S of hazards associated with atmospheric releases for use in emergency response. ESF#10- Oil and Hazardous Material also calls for use of IMAAC for such predictions and for use of M&S for oil spill trajectory analysis and calculation of pipeline oil discharge volumes. The ESF#12- Energy recommends use of M&S for modeling impact of disruptions to the energy sector on economy, and on other critical infrastructure and key resources. ESF#13 – Public Safety and Security calls for use of modeling and forecasting for crowd size, impact of weather, and other conditions to analyze potential factors that may affect resource allocations. It also notes the possibility of requesting National Aeronautics and Space Administration (NASA) capabilities for geo-spatial modeling and decision support if needed.

3.4. Healthcare Systems

Healthcare System models and simulations may be used to support analysis, planning, and training needs for the healthcare institutions, epidemics, and other healthcare-related emergencies. Simulation models may be used to understand healthcare systems, interdependencies with other systems, their vulnerabilities, and the impact of emergency incidents on the population and healthcare community. These models and simulations will also be used to support training exercises, performance measurement, conceptual design, impact evaluation, response planning, analysis, acquisition, conceptualizing and evaluating new systems, vulnerability analysis, economic impact, and determining interdependencies between healthcare and other infrastructure systems.

The *Healthcare and Public Health* sector consists of state and local health departments, hospitals, health clinics, mental health facilities, nursing homes, blood-supply facilities, laboratories, mortuaries, and pharmaceutical stockpiles. The Responsible Agency for the sector, as designated in the relevant DHS documents, is the Department of Health and Human Services. Organizations that may be involved in addressing sector issues and as well the development of models and simulations include: Center for Disease Control, Food and Drug Administration, Department of Homeland Security (border control for foreign viruses, agricultural pests, etc.), Social Security Administration, the U.S. Public Health Service, public health regulatory agencies such as the Joint Commission, state and local agencies, academic institutions, and research hospitals.

DHS has developed specific plans for all the critical infrastructure and key resources sectors. The sector specific plan for Healthcare and Public Health (HPH) identifies HHS as the sector specific agency [DHS 2011]. HPH sector is responsible for 15 percent of the gross national product. About 85 % of the sector's assets are privately owned and operated. The public health component of the sector is managed across all levels of government from local to national. The HPH sector's vision has been stated as to achieve overall resiliency against all man-made and natural threats. HHS supported establishment of two councils, a Health Sector Coordinating Council for private sector component, and a Government Coordinating Council for the government sector. The councils have established collaborative workgroups on different topics such as, research and development needs and capability gaps for the sector, and measures and metrics for progress towards infrastructure protection goals. The HPH sector R&D goals include strengthening of surge capacity modeling tools [HHS 2007], a goal that would strongly rely on M&S techniques.

The healthcare systems domain includes: modeling of incident victims and existing patients affected by incidents; medical symptoms, physiological processes, and behaviors that patients may experience as the result of a natural disaster, terrorist attack, or epidemic; disease management operations and procedures; the impact of disasters, etc. on the environment as well as the food supply (pollution, contamination, etc.). Issues that may be addressed by simulation applications include: analysis of policies, evaluation of options and predictions concerning the state of public health, spread of communicable diseases, policies for intervention, triage and priority scoring for surgeries or other treatments, vaccination programs, cost-effectiveness analysis, medical emergency response, fatalities management, overall readiness of the healthcare system, hospitals and other related facilities/organizations, surge capacity, operational practices, logistic support systems, resource utilization, emergency department treatment delays and effect on community resources, alternate architectural options for changing the existing function of a space to a space capable of surge such as parking garages and temporary sites, and elements of the pharmaceutical/equipment manufacturing sectors serving healthcare system needs.

Healthcare system models may be comprised of:

- representations of medical personnel and hospitals
- constrained medical resources and work calendars
- hospital facilities (e.g., operation theatres, intensive care units, beds)
- medical equipment, single use devices, and consumables
- administrative documents and processes, and medical procedures
- routing, status, and location of ambulances as well as other Emergency Medical Technician (EMT) resources and processes
- location, cost, status, quality, effectiveness, and dispensation of pharmaceuticals
- logistics of industry practices and processes (e.g., climate controlled containers, other special needs)

Models and simulations may be implemented as computer software, simulation-based training facilities (e.g., emergency and critical-care, medical/surgical patient care, maternity and pediatric rooms), and specialty devices (e.g., mannequins for various applications such as trauma, surgery and emergency care, and disease diagnosis and treatment).

DHS addresses healthcare systems in two contexts: a) as a function included in the response to emergencies in the context of incident management, and b) as a critical infrastructure sector that should be protected against efforts to affect its operation.

The NIMS identifies that an incident may have a mix of implications including political, social, economic, environmental, public safety, public health, and financial, and hence require a coordinated response. For the healthcare systems perspective, the response includes collection of data on public health and environmental modeling using standard techniques. The public health information should be maintained securely given the sensitive nature of data. The information may be collected for investigations and analysis to determine the cause, projecting the spread, and selecting countermeasures for public health events and disease outbreaks. Typically M&S application will be used for projections based on the collected information and for evaluating response strategies. A public information officer should carefully manage release of information on public health.

The NIMS defines the health and medical resource typing for resource management for incidents. The command staff may include a medical advisor for issues of medical and mental health services, mass casualty, acute care, vector control, epidemiology, or mass prophylaxis considerations, particularly in response to a bioterrorism incident. The command staff may also include public health specialists or radiation health specialists depending on the circumstances. Protocols should be developed for

credentialing of volunteer management agencies such as the Red Cross, Medical Reserve Corps, and by organizations such as hospitals. NIMS calls for setting up area command for public health emergencies since the impact may not be immediately identifiable, may be geographically dispersed and evolve over long periods of time.

In addition to concerns for the incident victims, the healthcare systems need to be concerned with the health of emergency responders. The NIMS defines the need for addressing occupational health and mental issues for emergency responders including monitoring of immediate and long term effects of the incidents. The command staff should include a safety officer and/or an occupational safety and health specialist for monitoring and advising on the health and safety of incident personnel. The logistics section should include a medical unit for providing medical services to incident personnel.

The NRF [DHS 2008b] acknowledges that the responsibility for public health and welfare lies with the governments of the states, territories and tribal areas, and that they can request federal assistance if they anticipate their resources will be exceeded. Several federal departments do have the authority to declare disasters or emergencies. The Secretary of Health and Human Services (HHS) can declare a public health emergency. In a coordinated response, the states, territories, and tribal governments should activate special response teams with a public health specialist should the incident warrant such action. The response is followed by short-term recovery that includes providing essential public health and safety services. Restoration of healthcare services would usually include coordinating with private sector owner/operators. The NRF emergency support annexes provide primary operation level mechanism to provide assistance in functional areas including public health and medical services.

The NRF Emergency Support Function ESF#8-Public Health and Medical Services specifically describes the federal coordinated response in case of a public health disaster or potential for one. It identifies HHS as the primary coordinator. The response addresses medical needs and other functional needs of people in the need of medical care. The ESF briefly describes the concept of operations and the organization for the ESF#8 response. It defines initial actions, such as, assessment of public health/ medical needs, health surveillance, providing medical care personnel, equipment, and supplies, patient evacuation and care, and mass fatality management. National Oceanic and Atmospheric Administration (NOAA) and Interagency Modeling and Atmospheric Assessment Center (IMAAC) may be called on for support in case of hazardous material releases being the cause of the emergency. ESF#6 - Mass Care, Emergency Assistance, Housing, and Human Services also calls for a large role for healthcare systems including emergency first aid and physical and mental health services for those in mass care. A number of other ESFs call for support roles dealing with public health.

The NRF also includes incident annexes that describe the specialized application of the response framework to specific situations. The incident annexes include those for biological, nuclear/ radiological, catastrophic, food and agriculture, and mass evacuation incidents. The focus of biological incident annex is to respond to human disease outbreaks of known and unknown origins with the HHS as the primary agency coordinating the response. The actions identified in the incident annex include HHS working with partner organizations to evaluate the incident. While the annex doesn't specifically mention it, M&S can be used to predict the spread of the disease over time to help determine the areas and population at risk. All the other incident annexes include utilization of healthcare systems for caring for incident victims.

Related to the incident management context, the Homeland Security presidential Directive-8 (HSPD-8) calls on DHS to develop mechanisms for improved delivery of federal preparedness assistance to state, tribal, and local governments [DHS 2008a]. Annex I to HSPD-8 provides guidance for the planning and development of an integrated planning system. Fifteen national planning scenarios have been developed that may be used to help focus efforts to prepare for natural disasters, terrorist attacks, and other serious incidents. With the exception of cyber attack scenario, the rest of the scenarios will require the

participation of the healthcare sector for preparedness, response and recovery. Also, a few of the scenarios, such as pandemic influenza and plague, require responses primarily involving healthcare systems. M&S tools and applications should, wherever possible, support the modeling of healthcare systems in the fifteen national planning scenarios defined by DHS.

4. 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."

Another perspective on methodology comes from the International Council on Systems Engineering (INCOSE) where methodology is defined as "a collection of related processes, methods and tools" [INCOSE 2008]:

> "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.

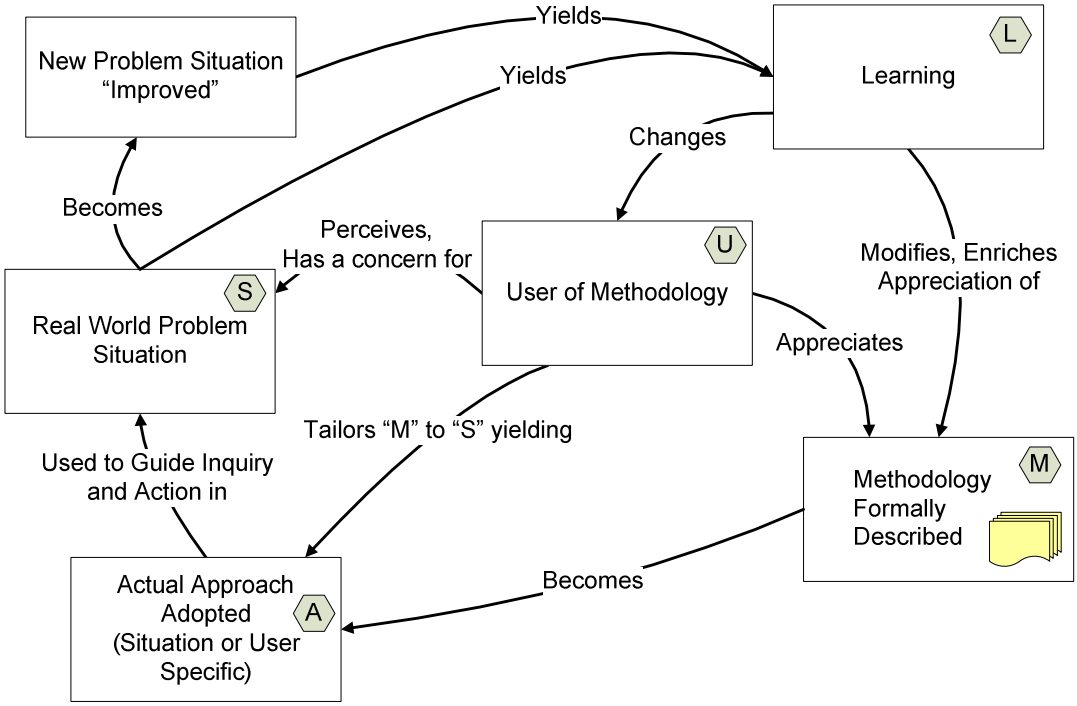

Figure 2: The LUMAS Model [Checkland 2000]

- 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.

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

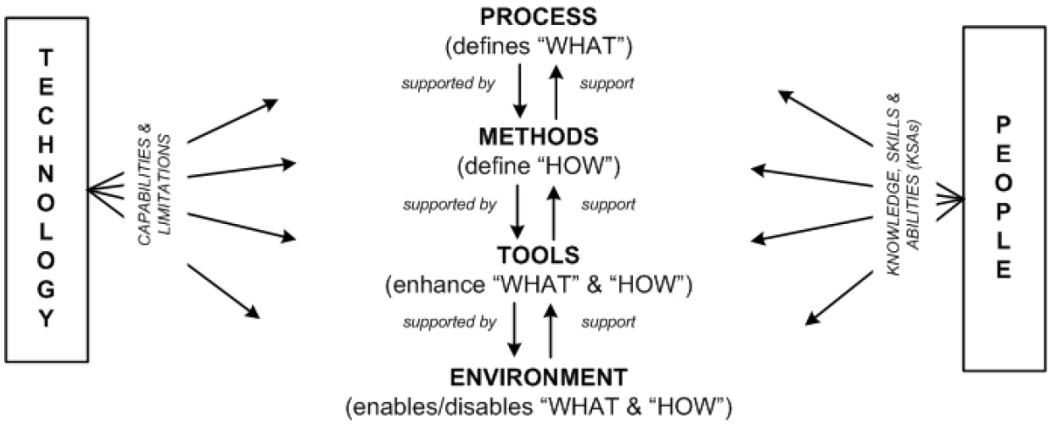

Figure 3: The Process, Methods, Tools, Environments Elements, and Effects of Technology and People [INCOSE 2008]

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

- *Modeling & Simulation*: 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. 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).

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 Figure 2. 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.

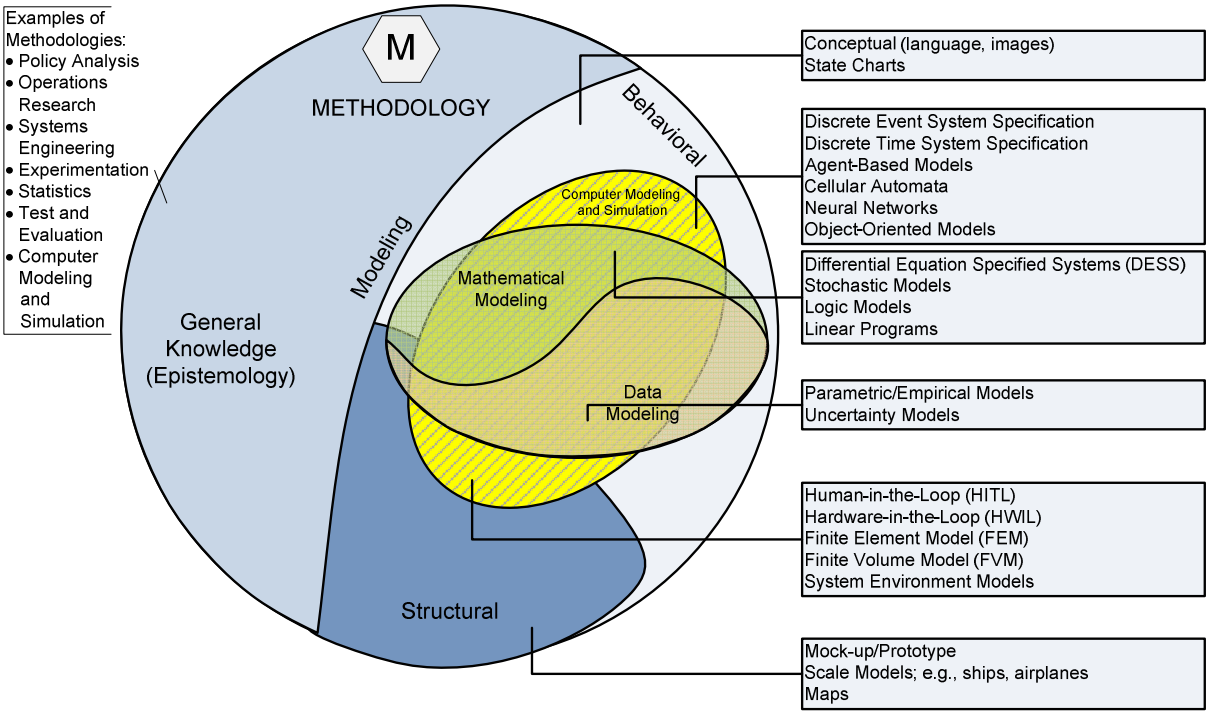

Figure 4: Modeling in Methodology

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:

- 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 include only selected aspects of a system and are implemented in a computing environment; therefore, they 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).

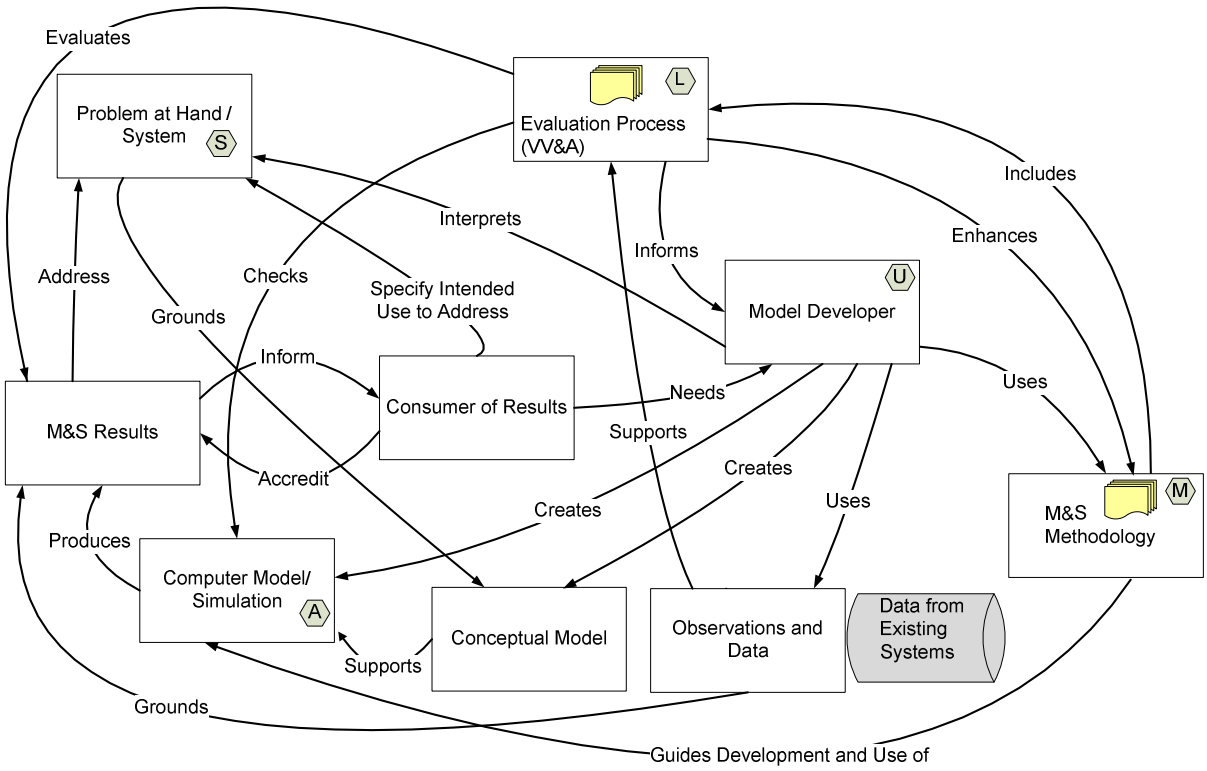

Figure 5: Computer Modeling and Simulation – Developer's Perspective

One of the choices to be made by model developers concerns modeling paradigms. A number of paradigms can be used to create models that can represent selected aspects of a system. There are broadly speaking two paradigms based on modeling of time: discrete event and continuous. A hybrid paradigm combines the discrete event and continuous paradigms. Another paradigm, Monte Carlo simulation, uses random distributions to represent the outcomes of system without modeling the passage of time. Monte Carlo simulation concepts are used to model individual chance event outcomes within discrete event and continuous simulations.

Discrete event simulation representation uses events that make step changes in the status of the system over time. The simulated clock in discrete event paradigm does not have to successively increment the time and can jump from the time of one event to the time of next event since there is no change in the system in between the events. Continuous simulations model changes in system parameters over continuous time. The simulated clock proceeds in continuous time steps and the relevant parameters updated at each time step. The continuous paradigm is generally used for modeling systems that include phenomenon that change continually. For example, the dispersion of a plume happens continually with time and will be difficult to represent with discrete events. The continuous phenomena are typically modeled using differential equations that model such factors as growth, decay, in-flows, and out-flows.

There are a few other prevalent paradigms that can be grouped within the two major paradigms introduced above or their hybrid form. Agent-based models generally follow the discrete event paradigm though they may utilize the hybrid form too. Agent-based models utilize a decentralized representation of systems and allow the system behavior to be determined based on defined behaviors of a number of modeled agents. Their strength lies in modeling systems with large number of agents, such as, a crowd of people affected by an incident. The continuous paradigm includes physics-based models (also referred to as dynamic system models) and system dynamics. Physics-based models mimic the change in system state using laws of physics that are represented by differential equations. They generally model systems at a very detailed level such as movements and changes of state of objects, fluids and gases. System dynamics simulation represents a system using causal relationships that determine system behavior over time using differential equations. It is basically a continuous representation of systems generally at a highly aggregate level.

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 that 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 [Balci 1998]

5. Needs Analysis Overview

This section contains brief summaries of the M&S needs for each of the four technical domains. Appendix A identifies some of the potential capabilities and requirements that are associated with the needs for each domain.

5.1. Hazardous Material Releases M&S Needs

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, and 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.

5.2. Critical Infrastructure M&S Needs

Modeling and simulation should be used to support the needs of the various CIKR sectors, managers, analysts, service providers, and first responders within the homeland security community. Most

importantly, it must support the planning and response needs of the NIPP partners including the Department of Homeland Security and other federal, state, local, tribal, territorial, and private sector organizations. The high-level needs identified below have been derived from the NIPP [DHS 2009a]. High level needs for CIKR modeling and simulation have been grouped into the following categories:

- Model, simulation, tool, and database development,
- M&S maintenance, updates, and security,
- M&S partnering and coordination, and
- M&S resource support and information dissemination.

A list of high level user and customer needs for CIKR M&S follows:

Development of models, simulations, tools, and databases –

- Provide modeling, simulation, and analysis of the CIKR assets and systems to enhance preparedness, protection, response, recovery, and mitigation activities.
- Develop, protect, and maintain data systems and simulations to enable continuously refined risk assessment within and across sectors and to ensure preparedness for domestic incident management.
- Use models and simulations to comprehensively examine the potential consequences from terrorist attacks, natural disasters, and manmade accidents that affect CIKR and to analyze sector, cross-sector, and regional dependencies and interdependencies, including the cyber domain.
- Conduct pre-planned, short-term, and long-term analyses; as well as unplanned, priority analytical projects that are based on higher-level tasking or that are related to current threats to CIKR (e.g., hurricane CIKR impact analysis).
- Conduct pre-incident studies (e.g., hurricane scenario studies) that are posted and available for downloading on the Homeland Security Information Network (HSIN).
- Work with end-users to design operations-related tools that provide maximum utility and clarity for CIKR protection activities in both emergencies and routine operations.
- Identify and integrate existing databases and other data services into CIKR databases and data systems, such as the Infrastructure Data Warehouse (IDW), to reduce the duplication of effort; ensure that available data are consistent, current, and accurate; and provide users with a consolidated picture across all CIKR sectors.
- Facilitate the actual integration of supporting databases or the importation of data into CIKR protection databases and data systems using a common, standardized format, data scheme, and categorization system or taxonomy specified by DHS in coordination with the SSAs.
- Provide guidance on the vetting of modeling tools to include the use of private sector operational, technical, and business expertise.
- Provide mechanisms for accessing and inputting information into models, simulations, tools, and cross-sector interdependency analyses.
- Develop long-term capabilities by maintaining expertise in the development, application of improved processes and analysis tools in support of longer-term DHS projects.
- Predict damage to infrastructure primarily affected by an incident to help develop initial response until the situation awareness information becomes available. Utilize predicted damage information to develop initial recovery plans until detailed damage assessments are performed.
- Predict cascading damage to other infrastructure.
- Predict impact on human populace due to damage to the infrastructure (including evacuation models).
- Analyze trade-offs between investments and risks to improve resiliency of critical infrastructure in disasters.

- Provide predictions of critical infrastructure performance across the whole range from micro and macro scale, for example, models that predict cracks in individual buildings to models that address impact of a hurricane on all the infrastructure systems in a region.

M&S maintenance, updates, and security –

- Continuously update, maintain, and/or develop new tools and key databases to keep pace with the constantly evolving threat, technology, and business environments to produce reliable projections.
- Protect sensitive information associated with M&S tools and databases.
- Work with end-users to design appropriate information protection plans for sensitive information used and produced by CIKR protection modeling tools.
- Outline in the sector plan processes for database, data system, and modeling and simulation development and updates.
- Specify the timelines, milestones, and schedules for the initial population of CIKR databases, as well as regular maintenance and updates.
- Define the schedule for integrating data and databases into such systems as the IDW.

M&S partnering and coordination –

- Partner with the private sector on M&S activities to add value to industry's ability to assess risk and refine its own business continuity and security plans, as well as to contribute to the security and sustained economic vitality of the for CIKR protection and resiliency.
- Develop and maintain simulation and modeling capabilities in coordination with partners that have relevant modeling capabilities to create appropriate mechanisms for the development, maintenance, and use of such for CIKR protection as directed by HSPD-7.
- Review existing private sector modeling initiatives and opportunities for joint ventures to ensure that DHS, the Sector Specific Areas (SSAs), and their CIKR partners make the maximum use of applicable private sector modeling capabilities.
- Work with sector partners, as appropriate, to facilitate the collection and protection of accurate information for database, data system, and modeling and simulation use and to enhance abilities to innovate and to provide products, services, and technologies to quickly focus on mission needs.
- Establish robust relationships that are useful for sharing and protecting sensitive information regarding threats, vulnerabilities, countermeasures, and best practices.
- Encourage industry and other partners to participate as early as possible in policy development, initiatives, risk analysis, and the management framework so as to help focus corporate and government planning, resource investment, and NIPP implementation.
- Enable greater information sharing regarding specific threats and hazards enabled by the issuance of security clearances to private sector partners.
- Encourage the leveraged application of preparedness guidelines and self-assessment tools within and across sectors so that risks can be managed more effectively and efficiently from the corporate level down to the individual facility level.
- Coordinate and plan across multiple agencies for those assets and facilities that are considered to be at the greatest risk.
- Participate in national-level and cross-sector training and exercise programs, as well as the National Incident Management System.
- Establish informal networks among private sector partners and between the private sector and the various federal agencies that can be used for all-hazards planning and response.
- Encourage industry to go beyond efforts already justified by corporate business needs to assist in broad-scale CIKR protection.
- Coordinate with the DHS Science and Technology Directorate (S&T) and the SSAs on the specification of requirements for the development, maintenance, and application of research- and operations-related modeling capabilities.

- Create an environment that encourages and supports incentives and recognition for companies to voluntarily adopt widely accepted security practices.
- Work with industry to develop and clearly prioritize key missions and enable the protection and/or restoration of related CIKR.

M&S resource support and information dissemination –

- Provide the resources necessary to enable cross-sector interdependency studies, exercises, symposiums, training sessions, and computer modeling; and otherwise support business continuity planning.
- Provide information on the availability of relevant modeling and simulation capabilities to SSAs, federal agencies and departments, and other CIKR partners that have CIKR responsibilities through outreach meetings, training, and exercises with sectors, analysts, and consumers.
- Articulate the benefits of CIKR M&S to government, private sector partners, e.g., corporate leaders, through the use of public platforms and private communications, both the business and national security benefits of investing in security measures that exceed their business case.
- Promote understanding of CIKR assets, systems, networks, and facilities, and other capabilities through industry ownership and management of a vast majority of CIKR in most sectors.
- Provide private sector owners and operators with timely, accurate, and useful analysis and information on threats to CIKR.
- Enable time-sensitive information sharing, restoration, and recovery support to CIKR partners and priority CIKR facilities and services during emerging threat and incident management situations.
- Target application of limited resources to the highest risk issues, to include federal grant funding where appropriate.
- Provide support for M&S R&D initiatives that are needed to enhance future CIKR protection efforts.
- Establish and conduct joint R&D and modeling, simulation, and analysis programs.
- Provide operational support to DHS and other Federal Government entities on an as-needed basis in the form of analysis, simulation, and scenario development.
- Reproduce selected products for widespread dissemination in hard copy, by email, or via electronic media.

5.3. Incident Management M&S Needs

Modeling and simulation should be used to support the needs of various managers, analysts, service providers, and first responders within the homeland security community. Most importantly, it must support the planning and response needs of the NIPP partners including the Department of Homeland Security and other federal, state, local, tribal, territorial, and private sector organizations. The high level needs, identified below, have been derived from the NIPP, the National Infrastructure Simulation and Analysis Center (NISAC) mission statement [NISAC 2010a], as well as a number of other DHS documents, and outside sources. A list of high level user/customer needs for incident management M&S follows:

- Provide models of the normal operations of incident management systems, as well as the effects of epidemics, natural disasters, and terrorist attacks upon them to support analysis, planning, and response activities of homeland-security incident-management-system partners.
- Establish incident management models, simulations, and data sets that support the national planning scenarios.
- Support planning for facility defense and security, selection and placement of incident management monitoring devices and system sensors to update status information, damage assessment, coordinated shutdown, and accelerated recovery of incident management systems.

- Provide M&S capabilities to help establish priorities and potential mitigation strategies for protecting and/or isolating the impact of events on the population and incident management systems.
- Predict economic impacts of disasters and other relevant incident management events.
- Provide decision makers the ability to assess policy, investment, and resource allocation options that address incident management needs – near and long term.
- Provide an integrating function that includes the identification and modeling of incident management system interdependencies. Supported interdependencies should include physical, geographic, cyber, and logical (see [Rinaldi 2004]); enable the integration of national, regional, local systems and data sources; and bring together disparate users, information providers, and individual infrastructure sector leaders.
- Move towards predictive capabilities that use science-based tools to understand the behavior and expected performance of inter-related infrastructures. Predictive capabilities should support various conditions, incident management systems, and event parameters such as time of day for events, level of demand for the incident management system, system weaknesses, capacity of facilities, mobilization resources, surge capacity, temporary support organizations, their systems, and functions.
- Define a standard classification of incident management problems.
- Establish virtual capabilities that provide portals for Nation-wide remote access and communications to incident management-related modeling, simulation, and analysis capabilities, and guidance for selection of appropriate capabilities for defined incident management problems.
- Identify user data and interfaces needed for each incident management model and event type.
- Provide standard formats for the import and export of data between the portal and external data sources.
- Assist in planning for the backup and/or remote sitting of critical data sources outside of regions affected by events, e.g., hurricane disaster areas.
- Provide simulation and analysis capabilities to a wide range of users that will enhance the understanding of vulnerabilities, risks, and event consequences to incident management systems.
- Provide education and training to public and private decision makers on how to cope effectively with crisis events.
- Provide capabilities for coordinating incident management operations with other government agencies, and other organizations as well as conducting media interactions.
- Provide M&S capabilities that provide timely information to decision makers for incident management.

5.4. Healthcare Systems M&S Needs

Modeling and simulation should be used to support the needs of various managers, analysts, service providers, and first responders within the homeland security community. Most importantly, it must support the planning and response needs of the NIPP partners including the Department of Homeland Security and other federal, state, local, tribal, territorial, and private sector organizations. The high level needs identified below have been derived from the National Infrastructure Simulation and Analysis Center (NISAC) mission statement, as well as a number of other DHS documents, and outside sources. An initial list of high level user/customer needs for healthcare M&S follows:

- Provide simulation and analysis capabilities to a wide range of users that will enhance the understanding of vulnerabilities, risks, and event consequences to healthcare systems.
- Provide M&S capabilities to help establish priorities and potential mitigation strategies for protecting and/or isolating the impact of events on the population and healthcare systems.
- Provide models of the normal operations of healthcare systems, as well as the effects of epidemics, natural disasters, and terrorist attacks upon them to support analysis, planning, and response activities of homeland-security healthcare system partners.

- Predict economic impacts of disasters and other relevant healthcare events.
- Support planning for facility defense and security, selection and placement of healthcare monitoring devices and system sensors to update status information, damage assessment, coordinated shutdown, and accelerated recovery of healthcare systems.
- Establish healthcare models, simulations, and data sets that support the national planning scenarios.
- Provide decision makers the ability to assess policy, investment, and resource allocation options that address healthcare systems needs – near and long term.
- Provide an integrating function that includes the identification and modeling of healthcare system interdependencies; supported interdependencies should include physical, geographic, cyber, and logical [Rinaldi 2004]; enable the integration of national, regional, local systems and data sources; bring together disparate users, information providers, and individual infrastructure sector leaders.
- Move towards predictive capabilities that use science-based tools to understand the behavior and expected performance of inter-related infrastructures. (Predictive capabilities should support various conditions, healthcare systems, and event parameters such as time of day for events, level of demand for the healthcare system, system weaknesses, capacity of facilities, mobilization resources, surge capacity, temporary support organizations, their systems, and functions).
- Provide education and training to public and private decision makers on how to cope effectively with crisis events.
- Establish virtual capabilities that provide portals for Nation-wide remote access and communications to healthcare-related modeling, simulation, and analysis capabilities.
- Identify data and interfaces needed for each healthcare model and event type.
- Provide standard formats for the import and export of data between the portal and external data sources.
- Develop situational awareness for healthcare systems at local, regional, and national level following a large-scale incident.
- Help plan for the backup and/or remote sitting of critical data sources outside of regions affected by events, e.g., hurricane disaster areas.

Other possible application scenarios that may help to define M&S user needs and system requirements for healthcare systems include:

- Resource planning, capacity analysis, and deployment,
- Care prioritization and management,
- Patient diagnosis, treatment, and other medical processing models,
- Emergency medical response operations,
- Layout of hospital facilities, departments, and processes,
- Flow of health care documentation and information,
- Mass preventative measures,
- Public health strategies (e.g., quarantines, vaccinations),
- Coordination with other government agencies, health maintenance organizations (HMOs), and other organizations,
- Laboratory test procedures and identification of biological agents,
- Decontamination and treatment for radiation exposure, and
- Media interactions for healthcare-related preventative activities and emergency incidents.

6. Identification of M&S Resources

This section introduces existing M&S resources that support homeland security and are possibly relevant to meeting some of the needs and requirements presented in the previous sections. A detailed listing of the resources in each of these categories is contained in the appendices to this document. Topics addressed include:

- Projects, facilities, and capabilities (Appendix B),
- Simulation models and tools (Appendix C),
- Relevant standards and guidelines (Appendix D), and
- Data sources (Appendix E).

6.1. Projects, Facilities, and Capabilities

Modeling, simulation, and analysis have been recognized as important capabilities that can significantly contribute towards improving the security of the Nation [NRC 2002]. Over the years, the U.S. Department of Homeland Security and other agencies have been developing capabilities, establishing facilities and sponsoring and executing projects that employ M&S for initiatives focused on improving security. The government agencies have also sponsored such projects and supported development of M&S capabilities at the national laboratories, other government contract organizations, and universities. It is clearly important that knowledge of projects, facilities, and capabilities that significantly employ M&S be shared among all involved in or contemplating to be involved in such developments. Such knowledge sharing will help avoid duplication of efforts and facilities and may help create synergies among different efforts. This section provides an overview of the projects, facilities, and capabilities that employ M&S. Appendix B provides a number of such projects, facilities, and capabilities organized by the four domains addressed in this report. The lists and descriptions have been developed based on literature and on-line searches without any assessment on the quality of the organization. Inclusion in this report should not be construed as a recommendation.

An example of a facility that actively employs M&S is the National Exercise Simulation Center (NESC) described by Dr. Holtermann, the key note speaker on the opening day of the workshop. NESC utilizes a number of M&S tools for creating security incident scenarios in support of national-level exercises. With its broad mission of supporting national-level exercises across a wide range of scenarios, NESC utilizes M&S tools that are applicable in different domain areas. Many of the facilities that employ M&S in a significant manner are focused on specific domain areas. The National Infrastructure Simulation and Analysis Center (NISAC) is focused on the critical infrastructure domain area, though it should be noted that the domain includes eighteen identified infrastructures and an associated range of threats that together create a need for a large variety of M&S tools. Thus, NISAC has developed M&S tools specific to selected infrastructures and has a number of ongoing projects that are enhancing existing or developing new capabilities specific to individual, or in some cases multiple, infrastructures. While NISAC is a part of DHS, there are other facilities that are sponsored by multiple agencies. The National Atmospheric Release Advisory Center (NARAC) operates under a partnership of eight government agencies and uses M&S for analysis and predictions of atmospheric dispersions. A few of the agencies maintain their own simulation labs such as the U.S. Fire Administration and U.S. Secret Service.

Some of the facilities have evolved at universities, others at private corporations, and yet others with partnerships among universities and corporations. Some have been sponsored by DHS or other government agencies, while others formed consortiums for development of the associated field. The Texas Engineering Extension Service, a member of the Texas A&M University System, operates the Emergency Operations Training Center that utilizes M&S for creating a range of scenarios for training incident

management personnel in managing large scale crisis. The Center for Integration of Medicine and Innovative Technology (CIMIT) in Boston is a non-profit consortium of teaching hospitals focused on improving patient care. This consortium is involved in several initiatives on various aspects of healthcare. One of CIMIT's projects is focused on utilizing M&S for emergency health care and thus contributes to improving homeland security.

Similar to facilities and associated capabilities, projects utilizing M&S for homeland security applications are being carried out at a wide range of organizations including:

- Government organizations, such as:
  - DoD laboratories
  - NIST Engineering Laboratory
  - U.S. Nuclear Regulatory Commission
- Government contractors and federally funded organizations, such as, national labs.
- Academia
  - University institutes and research centers focused on M&S, such as:
    - Arizona Center for Integrative Modeling and Simulation (ACIMS), joint effort of Arizona State University (ASU) and University of Arizona
    - Institute for Simulation and Training at University of Central Florida (UCF)
    - Modeling, Virtual Environments and Simulation (MOVES) Institute at Naval Postgraduate School (NPS)
    - University of Alabama Huntsville (UAH) Center for Modeling, Simulation and Analysis
    - Virginia Modeling And Simulation Center (VMASC) at Old Dominion University (ODU)
  - University labs, such as, Johns Hopkins University/Applied Physics Laboratory (JHU/APL)
  - Universities offering M&S graduate programs – ASU, ODU, UCF, NPS, etc.
- Professional organizations in the area of simulation such as, Society for Computer Simulation, SimSummit, and Simulation Interoperability Standards Organization (SISO)
- International research centers – particularly in the European Union, Japan, Singapore, e.g., CIMNE (International Center for Numerical Methods in Engineering), and Spain

Most of the projects mentioned in this report are being carried out with DHS sponsorship. The information on projects provided here is admittedly of a transient nature and may get outdated soon after publication of this report. In fact, it is possible that some projects may have already been completed; but the corresponding source web sites were not updated. Nevertheless, the information provided in this report will provide the reader with an understanding of the type of projects and organizations involved. Hopefully, it will provide the motivation to identify other projects of interest before initiating new projects involving M&S for homeland security applications.

The Complex Event Modeling, Simulation, and Analysis Project focuses on interdependencies, cascading effects, and the dynamics of multi-event and multi-vector attacks. The Training, Exercise & Lessons Learned (TELL) project developed a federated, simulation-based training and exercise capability for large and complex events in a virtual/constructive/live environment. The Complex Incident Response Training System (CIRTS)-Combat Medics (CM) project being executed by MYMIC LLC under a Small Business Innovation Research Phase II contract award is developing a simulation game-based training system for scene and patient management care following blast injuries sustained from explosives including Improvised Explosive Devices (IEDs). Appendix B provides brief descriptions on the projects, facilities, and capabilities mentioned above and others.

6.2. Simulation Models and Tools

Simulation models and tools are the primary means for employing M&S for applications. Some computer-based models are used by simulation experts to study and analyze the issue at hand and advise the decision makers. Other models are encapsulated in tools focused on a specific intended use that reduces the requirement for simulation expertise on the part of the users. Still others are used for training purposes and utilize interactions with users. The models and tools enhance M&S capabilities and are employed at the facilities discussed in the previous section. Projects similar to those mentioned in the previous section often include the development of models and tools.

It should be noted that for the purpose of this report, simulation refers to execution of computer models. It does not include role-playing or live exercises by human subjects, though it does include computer simulation models that may be used in support of live exercises. In homeland security exercises, many times simulation is used for live exercises with no use of computer-based models. Similarly in the healthcare area, the term "simulation" is used to include a wide variety of modalities. The Center for Immersive and Simulation-based Learning (CISL) at Stanford School of Medicine [Stanford 2010] defines the following simulation modalities in the healthcare context: standardized patient actors, part-task physical trainers, virtual reality and visualization, desktop simulation and virtual worlds, and mannequin-based simulation. M&S, the focus of this report aligns primarily with the desktop simulation and virtual worlds and overlaps somewhat with the virtual reality and visualization modalities in the CISL list.

The simulation models and tools for homeland security applications can be grouped in many ways. They can be classified based on their high-level objective into simulation and gaming. The simulation models can be grouped by the five major phenomena modeled: social behavior, physical phenomena, environment, organizations, and infrastructure systems. Gaming elements can be grouped by the five roles offered: civilian population and opposing forces, on scene responses, response management, support institutions, and live elements [Jain 2008]. While these grouping schemes address the interests of researchers and developers, they may not serve the needs of the target audience of this document. That audience primarily includes federal, state, local & tribal personnel responsible for homeland security. For example, personnel involved in incident management may need to look through all the five simulation groups since incidents may involve multiple phenomena. More specifically, a dirty bomb incident on a public site may require modeling of the crowd following the explosion (social behavior), prediction of the path of the plume generated by the bomb (physical phenomena and environment), actions of the emergency response personnel (organizations), and the impact on the operations of the public transportation systems such as metro railway (infrastructure system). Similarly, someone using gaming tools for homeland-security-related training may utilize elements from multiple gaming groups.

The needs of personnel with homeland security responsibilities are anticipated to be based on the domain in which they are involved. For example, for someone involved in incident response or management of the models and tools that cover various aspects of the incident will be of interest. At the same time, it is understood that some of the incidents may require more specialized analysis based on the associated domain. The atmospheric release of toxic material, for example, will require incident management capabilities plus specialized expertise in hazardous material release to predict the dispersion of the released agent. The simulation models and tools in this publication, hence, are organized by domains. In particular, the models and tools captured in Appendix C have been organized by the four major domains that were addressed in this workshop: critical infrastructure systems, incident management, hazardous material release, and healthcare systems. A few of the models and tools are considered to be useful for multiple domains and are repeated in the list with the anticipation that readers interested in one domain may only go through the corresponding part of Appendix C. The simulation models and tools are listed in alphabetical order for each domain. Sub-classification, using for example the criteria discussed previously, is not used for further grouping of the tools within each domain. For example, simulation and gaming

tools are not separated out since only a few gaming tools were found. These include DI-Guy in incident management domain and GameTT in healthcare systems domain.

A number of models and tools are available from various sources including commercial, government, non-profit, and academic organizations. For example, for critical infrastructure (CI) systems the list includes those developed by Department of Energy's National Laboratories (e.g., NISAC Agent-Based Laboratory for Economics, N-ABLE), those developed by commercial vendors (e.g., IntePoint Vu), and those developed at universities (e.g., MIT Screening Methodology, MSM). While offerings primarily from domestic organizations are included, occasionally tools developed by overseas organizations are also included. For example, the list of CI models and tools includes Critical Infrastructure Protection (CIP) Modeling and Analysis (CIPMA) developed under sponsorship of government of Australia, Critical Infrastructure Simulation by Interdependent Agents (CISIA) developed by a consortium of Italian universities, AIMSUN, a traffic modeling tool from a vendor in Spain, and Infrastructure Interdependencies Simulation (I2SIM) being developed at the University of British Columbia in Canada.

There are several cases of tools with similar, and in a few cases the same, acronyms. For example, the list of tools for CI systems includes Crisis Information Management Software (CIMS) and CIMSuite (CIMS). The list of tools for Healthcare systems includes EDS, Edsim, EDSIM, and ED Simulation, all of which are different tools. This suggests that readers and potential users of M&S should consider the full information about the particular tool when comparing multiple options.

The simulation models and tools included in Appendix C are again based on literature and on-line searches; as such, their inclusion in this report should not be construed as a recommendation. While the list is current at the time of publication, it is recommended that potential users conduct an on-line search to explore any new tools that may have become available. Potential users should also look for lists created through other surveys and reports that appear with appreciable frequency. For example, a report from a NIST workshop on M&S for emergency response [Jain 2003] includes brief description of 63 tools for the purpose; a survey performed by Idaho National Laboratory [Pederson 2006] under the sponsorship of the U.S. Technical Support Working Group identified 30 tools for critical infrastructure interdependency modeling.

The information in Appendix C is intended to provide an example of the kinds of simulation models and tools available for purposes identified by the developing organization and relevant for homeland security applications in the corresponding domain. Potential users can determine the number of available tools that address the general area of interest and use the list as the initial group to explore further. The list of models and tools with their identified purposes may also help new users understand the possible uses of M&S. If the list does not include any relevant tools, a new tool may be needed. For example, the list includes a number of tools to model CI systems at high levels – mainly to study interdependencies. Few focus on modeling CI systems in detail. Potential users with the need to do so may have to sponsor development of such tools.

The necessary capabilities of simulation models and tools should be guided by requirements. Before making a selection, users and their advisors should create a detailed list of requirements based on the identified need. These may be based on those specified in Appendix A. Candidate models and tools can then be identified using the lists provided in Appendix C. The set of critical requirements should be used for initial screening of that list. The models and tools remaining on the list after the initial screening should be evaluated in detail against the complete set of requirements.

The evaluation should consider the expected difficulty involved in using the model or tool for the intended purpose. This type of assessment can be based on discussion with the vendor or the organization that

developed the model or tool (such as an academic or research organization). Use of a majority or all the recommended practices discussed in [Jain 2011] can help with such an assessment.

The solution with the best evaluation and assessment can then be selected for use. Additional custom development may be needed if the requirements that are not met are deemed to be essential for the intended purpose.

Please refer to Appendix C for list of tools with associated brief descriptions of simulation models and tools for each of the four domains addressed during the workshop.

6.3. Relevant Standards and Guidelines

Many modeling, simulation, and analysis (MSA) software applications have been developed or are currently under development. However, there is little likelihood that these applications will be capable of being integrated or readily adapted to support different local needs of incident management organizations across the Nation. MSA tools, like many other software applications, are costly to develop and may be impossible to integrate if they are independently created by different organizations. Consensus standards could help reduce the costs associated with simulation model construction and interoperability between simulation and other software applications. Standards can enable and encourage software and data re-use. Standards can also enable the integration of independently developed modules to rapidly model a specific scenario. Thus standards are critical to facilitate the design, development, and implementation of simulations and models and to help the homeland security community make more effective and efficient use of MSA applications. Standards may result from consensus standardization processes within standards development organizations (SDOs), DHS mandates, or interfaces that are defined by commercial developers that are accepted as de facto standards.

Standardization of integration architectures, specifications of module scope and functionality, data interfaces and protocols, application programmer interfaces, VV&A procedures and other test methods, data sets, and other interoperability mechanisms would help maximize the potential of MSA applications. Appendix D lists the available standards and guidelines relevant to the four domains addressed in this report. The standards and guidelines listed in the appendix include those that have been approved by the standard organizations, those that are undergoing the approval process, and de facto standards that have been adopted widely by users but have not been formally approved. The list and descriptions have been developed based on literature and on-line searches. Some standard/guideline items in Appendix D might appear in more than one domain; this is due to its extended scope which covers aspects of multiple domains. To make searching for relevant topics easier for readers, Appendix D is presented as follows.

- D.1 – Domain-Independent Standards and Guidelines
  - D.1.1 – Conceptual Modeling Standards and Guidelines
  - D.1.2 – Distributed Simulation Standards and Guidelines
  - D.1.3 – Geographic Information System Standards and Guidelines
  - D.1.4 – Communication Standards and Guidelines
  - D.1.5 – Training System Standards and Guidelines
  - D.1.6 – 3D Modeling Standards and Guidelines
- D.2 – Hazardous Material Release Standards and Guidelines
- D.3 – Critical Infrastructure Standards and Guidelines
- D.4 – Incident Management Standards and Guidelines
- D.5 – Healthcare Systems Standards and Guidelines

The *title*, *description*, *standard type*, *responsible organization*, and *classification* are noted with each associated standard/guideline presented in Appendix D. The *title* identifies the name of the standard or

guideline. The *description* provides a brief introduction of the standard/guideline. The *standard type* is the identification of the standard or guideline assigned by the responsible organization. The *organization* identifies the responsible organization of the standard or guideline. There are a number of organizations whose standards missions relate directly or indirectly to the four domains addressed in this report. Examples of these organizations are

- American National Standards Institute (ANSI)
- Department of Defense (DoD)
- Department of Homeland Security (DHS)
- Emergency Interoperability Consortium (EIC)
- Environmental Systems Research Institute (ESRI)
- Federal Geographic Data Committee (FGDC)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Committee for Information Technology Standards (INCITS)
- International Organization for Standardization (ISO)
- National Fire Protection Association (NFPA)
- Object Management Group (OMG)
- Organization for the Advancement of Structured Information Standards (OASIS)
- Simulation Interoperability Standards Organization (SISO)
- Synthetic Environment Data Representation and Interchange Specification (SEDRIS)
- The Agency of Healthcare Research & Quality (AHRQ)
- The Centers for Disease Control and Prevention (CDC)
- The National Institute of Standards and Technology (NIST)
- The Joint Commission Resources (JCR)
- The Open Geo-spatial Consortium, Inc. (OGC)
- Web 3D Consortium (WEB3D)
- World Meteorological Organization (WMO)
- World Wide Web Consortium (W3C)

The *classification* of standards/guidelines is based on the categorization scheme identified by McLean, Jain, and Lee [McLean 2008]. The categories include *Architectures*, *General Purpose Integration Interfaces*, *Domain-specific Integration Interfaces*, *Equipment Specifications*, *Operational Guidelines*, and *Document Formats*.

- *Architectures* support the overall design or structure of a system or system environment. Interface standards facilitate interoperation or data exchange between structural components.
- *General Purpose Integration Interfaces* are used to integrate a wide variety of computer applications and are not specific to homeland security or related mission areas. Example interfaces include markup languages, image file formats, and database query languages.
- *Domain-specific Integration Interfaces* are specific to homeland-security-related areas; e.g., emergency communications message formats.
- *Equipment Specifications* define required capabilities, functional characteristics, or rules that ensure quality, safety, and health of users.
- *Operational Guidelines* define organizational structures, policies, procedures, and protocols.
- *Document Formats* specify layout and structure for documents in word processing, database, spreadsheet, graphic, presentation, printed, and encoded formats.

6.4. Data Sources

MSA applications need to access many different types of homeland-security-related information that originates from various sources. The distribution of timely and accurate information is a key to enhancing the ability to manage homeland security planning, incident management, routine security operations, and emergency response. Example data sources are Areal Locations of Hazardous Atmospheres (ALOHA), which is maintained by the National Oceanic and Atmospheric Administration (NOAA); Global Terrorism Database (GTD), which is maintained by the DHS and the National Consortium for the Study of Terrorism and Responses to Terrorism (START); and the Emergency Response Safety and Health Database, which is maintained by the Centers for Disease Control and Prevention (CDC) and the National Institute of Occupational Safety & Health (NIOSH).

Much of the information used to develop or run homeland security models and simulations are publicly available, but scattered. Appendix E presents a number of such data sources organized by the four domains addressed in this report. The list and descriptions have been developed based on literature and on-line searches without any assessment of the accuracy or reliability of the information. The *title*, *description*, *data source*, *responsible organization*, *format*, and *classification* are noted with each of the associated standard/guideline item of Appendix E. The *title* identifies the name of the data source. The *description* provides a brief introduction of data content included in the data source. The *data source* is the identification and version of the data source assigned by the responsible organization or data provider. The *responsible organization* may be groups or companies, or even the entire emergency response community including federal, state, local, and tribal governments, and the private sector. The *format* identifies the data format. The data may be stored as plain text files, structured interchange formats, or remote databases. The format of this data may be based on standards or proprietary formats of information providers. The *classification* identifies the data type, which is based on the categorization scheme identified by McLean, Jain, and Lee [McLean 2008]. The major categories of data sets include *Incidents, Environment, Resources, Controlling Documents, Geography and Layout, Demographic and Behavioral, Investigative Intelligence, Training, Systems Engineering,* and *Simulation Support.*

- *Incidents* data include incident summaries, chronologies, response operations, models, message logs, media files, reports and other records, and after action reviews.
- *Environmental* data include climate, weather, societal, political, economic, biosphere, and chemical properties/hazard effects data.
- *Resources* data include organizations, funds, facilities, personnel, systems, vehicles, other equipment, communications channels, document media, and consumable supplies.
- *Controlling Documents* data include policies, plans, protocols, and procedures.
- *Geography and Layout* data includes definitions of geographical regions and other areas, maps, layouts, and models.
- *Demographic and Behavioral* data include demographic and behavioral data.
- *Investigative Intelligence* include various databases that are mined to gather intelligence for combating terrorism including locations, facilities, organizations, individuals, components, documents, money, weapons, vehicles, and drugs.
- *Training* data include course syllabi, lesson plans, instructional materials, tests, exercises, and references.
- *System Engineering* data include requirements analyses, design specifications, system documentation, test plans and procedures, and test data sets.
- *Simulation Support* data include software assets, statistical distributions, and programming scripts.

7. Discussions and Recommendations

This section is intended to capture practices and issues relevant to program sponsors, project managers, researchers, developers, and implementers of M&S for homeland security applications. The resources introduced in Section 6 (and detailed in the appendices) 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 Section 5 and Appendix A 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. Hence, this section provides a summary of discussion topics and recommendations that are divided into four major areas:

- Summaries of workshop breakout group discussions and recommendations,
- Identification of best practices,
- Uncertainties, cautions, and warnings regarding expectations of these models and simulations, and
- 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 models and simulations.

7.1. Breakout Groups Summaries

The subsections that follow contain brief summaries of the discussions in each of the four parallel breakout groups. The editors carefully considered all the input from the workshop breakout groups and modified this document and its appendices as appropriate. Notes from the breakout groups for each domain are captured in Appendix F. The readers are encouraged to peruse the notes for domain-specific inputs as some of the information is not included in other sections or appendices of the report.

7.1.1. Hazardous Material Release Breakout Group Summary

The HMR breakout group identified two key needs for the HMR area. First, there is a need for coupling of M&S and decision support tools to allow M&S results to be communicated to decision makers through systems that they use for managing HMR incidents. Such systems may include GIS-based solutions and response asset planning models. Second, a need for standards for products and VV&A was highlighted. HMR M&S products should utilize standard presentation of customer products including use of same contour levels and colors for chemical effects and use of federal protective action guideline levels for radiological impacts. While it was recognized that there are multiple challenges to defining standard VV&A approaches for HMR applications, a need for such standards was identified.

The group also identified two key issues both related to communication of M&S outputs. First, it is critical to ensure that results of M&S products are correctly communicated to the users and hence the outputs should include information to support the right interpretation. The issue extends to communication to the public based on M&S results. The second issue emanates from the difficulty to understand and communicate uncertainty in M&S results. Standard approaches incorporating rigorous statistical methods are needed to incorporate all sources of uncertainty. Communicating uncertainty to the users continues to be a major challenge.

Overall, the group concluded that the workshop contributed to the progress towards meeting the need for general guidance to developer and user communities on M&S tools. Such guidance will be addressed as a part of an-ongoing long-term discussion in the communities. The group identified communicating the

complex information provided by, and the limitations of, M&S tools to the complete range of users as a developing new challenge.

7.1.2. Critical Infrastructure Breakout Group Summary

The CI breakout group had a larger challenge than other breakout groups given the wide scope of the domain that is comprised of 18 identified critical infrastructure sectors and key resources. Somewhat predictably, given the wide scope of the domain, one of the key need areas identified centered on modeling capabilities. The group came up with a long list of capabilities needed with strong interest in modeling human and crowd behavior, actions of organizations, damage to infrastructure components due to various causes such as explosions, and modeling of damaged infrastructure with and without shoring up. The second key need area focused on modeling of cascading impact of single and multiple incidents across different critical infrastructures to develop understanding of interdependencies and associated socio-economic impact of overlapping CI sectors. A third need area revolved around VV&A practices that was considered to be more challenging than other domains due to the need to validate integrated models of multiple interdependent infrastructure.

The key issues discussed by the CI breakout group also included one focused on communication of M&S results to decision makers and the users, similar to the discussion in the HMR breakout group. A number of attendees expressed concern for the possibility of misuse of M&S results due to incorrect understanding of M&S capabilities. Failure to convey critical information on limitations of M&S models to decision makers and users can lead to erroneous extrapolations since tools don't have automated means to stop application in inappropriate situations. The second key issue that dominated the discussion was the limited availability of data for M&S that may lead to use of old data and in turn lead to erroneous results. It was mentioned that some crowd evacuation data is from the 1970s. Also, generally the infrastructure facilities data are not updated to include the modifications that happen over the years.

Overall, the group saw a large opportunity for improving the prevention, preparedness, response, and recovery from incidents for critical infrastructure systems through use of M&S and called for concerted efforts to develop validated modeling capabilities and addressing the issues of communication of M&S capabilities and data availability.

7.1.3. Incident Management Breakout Group Summary

The incident management breakout group identified two major needs areas. One concerned the issue of standards to support M&S. Standard classifications are needed for incident management problems that in turn will allow quick determination of associated approaches and tools needed. Clear problem definition will also help development of requirements and evaluation of candidate M&S tools. Standards are also needed for data structures, data interfaces, geo-spatial display and visualization, and nomenclature. The second major need focused on the ability to identify the M&S tools applicable for an incident. A searchable on-line index of models appropriate to a given situation, like the "experts book" used by journalists, will be useful to analysts in emergency operation centers for utilizing M&S. The index will also be useful for identifying M&S tools for other purposes such as prevention, preparedness, and recovery.

The key issues that surfaced in the discussions included the challenge of providing M&S tools across different levels of organizations involved in incident management. An organizational behavior research effort may be required to determine how different levels use information and M&S, and that may point to how to measure benefits of M&S. Another issue revolved around optimizing effort in validating and using M&S tools. At what point should analysts and users conclude validation efforts? Similarly, in incident management decision making, at what point should the analysts and decision makers consider that enough

analysis has been done to make a decision? There appears to be no consensus on approaches to answer such questions across different incident management situations. Answering such questions will help optimize the validation effort and decision making supported by M&S tools.

7.1.4. Healthcare System Breakout Group Summary

The healthcare systems breakout group felt that there is a critical need for a healthcare model exemplar. Availability of an exemplar will help improve use of M&S for healthcare systems in emergency response by enabling better understanding of the applicability of M&S potential users. While there is increasing use of M&S for healthcare applications, there is still a large part of the healthcare community involved in emergency response that needs to be educated on the potential of M&S in such applications. The group spent some time outlining the exemplar as a comprehensive model of the healthcare system including its supply chain applicable in disaster situations. The model should include the timeline from pre-event actions to post-event long-term recovery. The pre-event activities may include vaccinations, training, alternate resource planning, and interagency coordination. Modeling of events may include operations under full to partial loss of capabilities of facilities, records, supplies, staff, and technicians. The post event modeling may include living and fatality response, patients, responders, and after-trauma.

Another key need identified by the group concerned data input and output for M&S tools. Healthcare systems use a wide range of systems and formats for data. Developing new standards may not help due to the large effort and costs for converting the legacy systems. Data translators are needed that can allow accessing required data from a myriad of legacy systems.

The key issues identified by the group revolved around the human side of the equation. The group brought attention to the limited understanding of M&S with healthcare professionals and recommended an effort for healthcare simulation training in education included in curriculums in multiple disciplines including nursing, medical schools, ancillary health programs, engineering, architectural, and business. An associated issue focused on lack of confidence in analyst capabilities and led to a recommendation of certification of healthcare simulation professionals.

7.2. 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 (L) influences a documented methodology (M). The link between L and M in the LUMAS model is where the user of a methodology encounters best practices.

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.

A variety of M&S approaches, methodologies, and tools are currently available. Some are more suitable to solving certain classes of problems than others. The risk management framework defined in the NIPP [DHS 2009a] provides the high level methodology relevant to use of modeling and simulation for critical infrastructure systems. The best practices included here will primarily focus on those used for modeling and simulation tool development, deployment, and use in support of the NIPP risk management framework.

Other approaches and best practices for solving different types of homeland security modeling and simulation problems include:

- Design M&S tools to meet usability requirements and to minimize user errors.
- Perform data collection and experimentation at multi-scales running in parallel with code development and benchmarking of models against data early in the development cycle (used in Navy's Dynamic System Mechanics Advanced Simulation (DYSMAS) project).
- Use the scenario-driven-development process for M&S tools (used in Navy's Combat weapon system (AEGIS)).
- Follow a structured process for developing of M&S tools that includes keeping the user involved from the beginning and sharing accreditation guidelines upfront with the developers.
- Use various test and validation methods to ensure the correctness of models and the usability of results, e.g., use of historical data or release of inert materials to validate HMR models, use of post incident data, demonstrations and live events.
- Provide tools that can be used at the local level for analysis, evaluation, or training purposes.
- Provide tools that do not require sophisticated and expensive system support.
- Provide distributed web-based tools that allow organizations to develop and run custom exercises.
- Utilize implementation techniques that enable fast (near real-time) computation of predictions, for example, changing weather conditions or hazardous material release characteristics.
- Provide capabilities to continually update inputs to M&S tools based on real data from the field and provide updated predictions to incident managers.
- Provide quantified confidence levels with M&S results (such as satisfaction/regret curves provided by Critical Infrastructure Protection Decision Support System – Decision Model (CIPDSS-DM)).
- Use reach-back centers to support use of M&S by incident managers and responders (e.g., NARAC and NISAC).
- Sustain appropriate maintenance of M&S tools and processes for user feedback.

For best practices identified by workshop attendees specific to each technical domain, see the Breakout Group Notes (Appendix F).

7.3. 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 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.

The level of detail and specificity achieved by using the most sophisticated models and simulations may not be practical or necessary for all assets, systems, or networks. In these circumstances, a simplified

dependency and interdependency analysis based on expert judgment may provide sufficient insight to make informed risk management decisions in a timely manner [DHS 2009a].

For applications that are identified as suitable for M&S applications, it should be recognized that models provide results with varying levels of error and uncertainty. Analysts should ensure that decision makers understand the uncertainties in M&S results and other limitations and ask themselves questions 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?
- Is the tool being used within the range of its intended purpose? For example, is a model originally designed for training being used for incident management?
- Are sufficient model documentation, reference data sets, and access to experts (or knowledge) available to facilitate the use of tools?
- How should the results and associated uncertainty be present for use in decision making?
- In the case of simulation-based training exercises, have the stress conditions and state of mind in the response personnel that could occur during a real incident such as a massive failure or attack on a critical infrastructure system been adequately created? If not, how will this affect the quality of training and conclusions drawn from the exercise? Also data inconsistencies between simulated exercises and real incidents may affect exercise results and trainee perceptions. Communication difficulties and incompatibilities between systems may not be accurately reflected in training exercises.
- Incident command or incident management models are particularly susceptible to variations in predicted results due to difficulties in modeling human behaviors precisely and random occurrences in real incidens; various agencies and local governments often define similar organizations, operations, and responsibilities differently; and incident data may be required in different formats for different agencies and local governments complicating the implementation of simulation-based exercises or analytical models. How will these factors affect the results of these models and simulations?
- HMR models are particularly susceptible to variations in predicted results due to difficulties in precisely measuring topography and weather conditions. Epidemic models are particularly susceptible to variations in predicted results due to difficulties in precisely modeling human behaviors and random occurrences of transmission of diseases. How will these factors affect conclusions and actions that may be taken by responders based on these variations?

Analysts and decision makers need to be aware of these sorts of issues when using or when presented with M&S results. For related discussion of limitations, cautions, and warning for each technical domain, see the Breakout Group Notes (Appendix F).

7.4. Research, Development, Standards, and Implementation Issues

A number of research, development, standards, and implementation issues remain to be addressed. A list of major issues is below.

Research and Development

- Convey uncertainty of the M&S outputs (how to do this is a key gap!)
- Identification of technical gaps and needs for models, simulations, tools, and databases, e.g., increasing accuracy of hazardous material release model predictions in urban environments.
- Develop system requirements specifications for homeland security models, simulations, tools, and databases.
- Develop systems dynamics models for addressing strategic issues for different homeland security incidents and protection of critical infrastructures.
- Develop mechanisms to enable access to and usage of M&S applications by users in the field (non-laboratory personnel), SSAs, partners, critical infrastructure managers and staff, operational personnel, emergency response personnel, and healthcare system providers.
- Develop simulation application architectures to enable modular system construction, software re-use, module integration and standard data interfaces to import data from external databases
- Use a system-of-systems engineering approach to the development of applications.
- Use UML/SysML in specification of homeland security M&S applications.
- Develop M&S applications as open systems.
- Increase reality in simulation-based training exercises and devices.
- Extend models to include Geo-spatial Concept of Operations (GeoCONOPS) capabilities.
- Provide capabilities for simulation of all hazards, including individual and simultaneous multiple events, e.g., impact of earthquake and tsunami together at nuclear plants.
- Provide capabilities to model human and organizational behaviors.
- Develop benchmarking data sets for identified applications within each domain.
- Develop techniques to validate models of systems involving human behavior.
- Provide guidance for drawing conclusions based on a combination of uncertain and accurate input data.
- Provide guidance for analyzing trade-offs between risk and investment in M&S and identify point of diminishing return.

Standards

- Establish standards and guidelines for the development and implementation of sharable object-oriented models and simulations.
- Standardize VV&A approaches across domains for identified application types.
- Standardize domain specific models.
- Develop standards for volunteered geo-spatial data (from sensors, tweets, utilities etc) and streaming data to populate databases and rapid injects into infrastructure interdependency models.
- Develop metadata standards for models and data for interoperability.
- Standardize nomenclature for each domain and across domain for common concepts.

Implementation

- Identify appropriate models, simulations, tools, and databases to address homeland security needs.

- Identify and develop common models, simulations, tools, and databases that can be shared with the user community.
- Develop a central repository/ directory/ authoritative source of models and tools with related information such as guidance on use and quality.
- Integrate models and simulations implemented for different technical domains as well as with other homeland security software applications and databases.
- Establish security and protection mechanisms for sensitive data.
- Address issues of ownership and usage of publicly vs. privately developed models, simulations, tools, and databases.
- Ensure adequate return on investment to stakeholders and sponsors for research projects.
- Address the major constraint of organizational resistance to sharing data – biggest obstacle may be policy and culture, not technology.

For more detailed identification of issues and recommendations for each technical domain, see the Breakout Group Notes (Appendix F).

8. Conclusion

This proceedings document is the starting point of an effort to capture the current knowledge relevant to M&S for homeland security applications. It focuses on four homeland security domains: hazardous material releases, critical infrastructure systems, incident management, and healthcare systems. For each of these domains, the document identifies needs, translates those needs into required M&S capabilities, 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.

The compendium of homeland security M&S information contained in this document was used to facilitate input from more than 70 domain experts and stakeholders in a workshop setting. The U.S. Department of Homeland Security and the National Institute of Standards and Technology hosted the workshop at NIST's Gaithersburg, Maryland campus in June 2011. It is hoped that this document will provide value as a reference for program managers, project managers, researchers, developers, and implementers of M&S for homeland security applications. Use of this 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 homeland security.

The workshop attendees found the initial workshop information very useful and generated ideas for future work for refining and making the information on M&S more accessible. The information should be made available on-line to allow frequent refreshing of contents to stay updated. Needs and requirements for M&S may vary based on the application being used in preparedness, response, or recovery and hence may be enhanced accordingly. The value of information on M&S can be increased through future efforts defining a criteria for inclusion of M&S tools that provide a consistent level of detail, grouping by application (vs. current alphabetical listing). Complementary to the defined criteria would be to provide information or links to information on validity evaluations and quality, intended uses (training, decision support, level of organization), limitations of models, availability, currency, complexity, and ease of use. Effort is also needed to present M&S in a larger framework of analysis tools to encourage its appropriate use. Domains with limited prior exposure to M&S will gain from development of exemplars that demonstrate models, data inputs and outputs for applications of interest, and encourage good practices.

9. Selected Acronyms and Abbreviations

AHRQ – The Agency of Healthcare Research & Quality
AIA – American Institute of Architects
ALOHA – Area Locations of Hazardous Atmospheres
ANSI – American National Standards Institute
AOO – area of operations
CBRNE – chemical, biological, radiological, nuclear, and explosive
CDC – The Centers for Disease Control and Prevention
CI – Critical Infrastructure Systems
CIKR – Critical Infrastructure and Key Resources
CIMIT – Center for Integration of Medicine and Innovative Technology
CIP – Critical Infrastructure Protection
CIPDSS-DM – Critical Infrastructure Protection Decision Support System – Decision Model
CIRTS – Complex Incident Response Training System
CISL – Center for Immersive and Simulation-based Learning
CM – Combat Medics Project
CMMI – Capability Maturity Model Integration
CNN – Cable News Network
DHS – Deparment of Homeland Security
DoD – Department of Defense
DOE – Department of Energy and Design of Experiments
DOT – Department of Transporation
DTRA – Defense Threat Reduction Agency
EIC – Emergency Interoperability Consortium
EL – Engineering Laboratory
EMS – Emergency Management System
EMT – Emergency Medical Technician
EPA – Environmental Protection Agency
ESF – Emergency Support Function
ESRI – Environmental Systems Research Institute
EU – European Union
FEMA – Federal Emergency Management Agency
FGDC – Federal Geographic Data Committee
GIS – geographic information system
GTD – Global Terrorism Database
GWU – George Washington University
Hazmat – hazardous material
HAZUS – HAZards United States
HHS – Health and Human Services
HIPAA – Health Insurance Portability and Accountability Act
HMR – Hazardous Material Releases
HS – Healthcare Systems
HSIN – Homeland Security Information Network
HSPD – Homeland Security presidential Directive
HVAC – heating, ventilation, and air conditioning
ICS – Incident Command System
IDW – integrated data warehouse
IED – Improvised Explosive Device
IEEE – Institute of Electrical and Electronics Engineers

IM – Incident Management
IMAAC – Interagency Modeling and Atmospheric Assessment Center
INCITS – International Committee for Information Technology Standards (INCITS)
IND – Improvised Nuclear Device
IP – Office of Infrastructure Protection
ISO – International Organization for Standardization
IT – information technology
JCR – The Joint Commission Resources
KML **–** Keyhole Markup Language
LLNL – Lawrence Livermore National Laboratory
LUMAS – Learning, User of methodology, Methodology formally described, Actual approach adopted, and real world problem Situation
MOVES – Modeling, Virtual Environments, and Simulation Institute
MS or M&S – modeling and simulation
MSA – modeling, simulation, and analysis
MSEL – Master Scenario Event List
NARAC – National Atmospheric Release Advisory Center
NASA – National Aeronautics and Space Administration
NEHRP – National Earthquake Hazards Reduction Program
NEP – National Exercise Program
NESC – National Exercise Simulation Center
NFPA – National Fire Protection Association
NGO – non-governmental organization
NIC – National Integration Center
NICOE – National Intrepid Center of Excellence
NIMS – National Incident Management System
NIOSH – National Institute of Occupational Safety & Health
NIPP – National Infrastructure Protection Plan
NISAC – National Infrastructure Simulation and Analysis Center
NIST – National Institute of Standards and Technology
NLE – National Level Exercises
NOAA – National Oceanic and Atmospheric Administration
NPS – National Planning Scenario or Naval Postgraduate School
NRC – National Research Council or Nuclear Regulatory Commission
NRF – National Response Framework
NRL – Naval Research Laboratory
NSS – National Security System
OASIS – Organization for the Advancement of Structured Information Standards
OFCM – Office of the Federal Coordinator for Meterology
OGC – The Open Geo-spatial Consortium, Inc.
OLIVE – Online Interactive Virtual Environment
OMG – Object Management Group
PLE – Principal-Level Exercises
R&D – research and development
S&T – DHS Science and Technology Directorate
SDO – standards development organization
SEDRIS – Synthetic Environment Data Representation and Interchange Specification
SISO – Simulation Interoperability Standards Organization
SOP – standard operating procedure
SSA – Sector-Specific Agency
SSP – Sector Specific Plans

START – National Consortium for the Study of Terrorism and Responses to Terrorism
SUMMIT – Standard Unified Modeling Mapping Integration Toolkit
T&E – test and evaluation
TELL – Training, Exercise & Lessons Learned Project
VMASC – Virginia Modeling And Simulation Center
VNN – Virtual News Network
VVA or VV&A – verification, validation and accreditation
W3C – World Wide Web Consortium
WEB3D – Web 3D Consortium
WMO – World Meteorological Organization
WUI – wildland-urban interface

10. References

[AAI 2007]	Healthcare Modeling Studio. Automation Associates Inc. Available via: http://www.blueminegroup.com/aai/pos_healthcare_modeling_studio.asp [accessed Jan. 3, 2011]
[Abdalla 2007]	Abdalla, R., Tao, V., Cheng, Q., Li, J., 2007, A network-centric modeling approach for infrastructure interdependency, Photogrammetric Engineering & Remote Sensing, 73(6), 681-690.
[ABSA 2010]	Risk Group Classification for Infectious Agents. American Biological Safety Association (ABSA). Available via: http://www.absa.org/riskgroups/bacteria.html [Accessed Dec. 12, 2010]
[ADL 2011]	Advanced Distributed Learning Sharable Content Object Reference Model (SCORM). Available via: http://www.adlnet.gov/Technologies/scorm/default.aspx [accessed Jan. 10, 2011].
[AFCESA 2001]	Protective Actions For A Hazardous Material Release. Headquarters, Air Force Civil Engineer Support Agency Tyndall Air Force Base, Florida 32403. Available via: http://www.emc.ornl.gov/CSEPPweb/data/Reports/Misc. Reports/HAZMAT.pdf [accessed April 3, 2011]
[AHADATA 2010a]	Health Care Statistics and Market Research: AHA Data. American Hospital Association (AHA). Available via: http://www.ahadata.com/ahadata_app/index.jsp [Accessed Dec. 12, 2010]
[AHADATA 2010b]	Hospital Electronic Health Records (EHR) Adoption Database. American Hospital Association (AHA). Available via: http://www.ahadata.com/ahadata/html/EHRdatabase.html [Accessed Dec. 12, 2010]
[AHADATA 2011]	Health Care Statistics & Market Research: AHA Data. Available via: http://www.ahadata.com/ahadata_app/index.jsp [accessed Mar. 25, 2011].
[AHD 2011]	American Hospital Directory. Available via: http://www.ahd.com/ [accessed Mar. 25, 2011].
[AHRQ 2010a]	Community-Based Mass Prophylaxis. Agency for Healthcare Research and Quality (AHRQ). Available via: http://www.ahrq.gov/research/cbmprophyl/cbmpro.htm [Accessed Dec. 12, 2010]
[AHRQ 2010b]	Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality (AHRQ). Available via: http://www.ahrq.gov/data/hcup/ [Accessed Dec. 12, 2010]
[AHRQ 2011a]	Community-Based Mass Prophylaxis – A Planning Guide for Public Health Preparedness. Agency for Health Research and Quality (AHRQ). Available via: http://www.ahrq.gov/research/cbmprophyl/cbmpro.htm [accessed Mar. 25, 2011].
[AHRQ 2011b]	Emergency Preparedness Resource Inventory (EPRI): A Tool for Local, Regional, and State Planners. Agency for Health Research and Quality (AHRQ). Available via: http://www.ahrq.gov/research/epri/ [accessed Mar. 25, 2011].
[ANL 2010a]	LPAT: Logistics and Process Analysis Tool. Decision and Information Sciences Division. Argonne National Laboratory. Available via: http://www.dis.anl.gov/projects/lpat.html [accessed Nov. 21, 2010]

[ANL 2010b]	RESTORE. Technology Development and Commercialization. Argonne National Laboratory. Available via: http://www.anl.gov/techtransfer/Software_Shop/RESTORE/RESTORE.html [accessed Nov. 21, 2010]
[ANL 2011a]	Electricity Market Complex Adaptive System (EMCAS). Decision and Information Sciences. Argonne National Laboratory. Available via: http://www.dis.anl.gov/projects/emcas.html [accessed Jan. 13, 2011].
[ANL 2011b]	CEEESA Natural Gas Systems Analysis Tools. Center for Energy, Environmental, and Economic Systems Analysis (CEEESA), Decision and Information Sciences. Argonne National Laboratory. Available via: http://www.dis.anl.gov/projects/NaturalGasAnalysisTools.html [accessed Jan. 13, 2011].
[ANL 2011c]	Restore: Modeling Interdependent Repair/Restoration Processes. Decision and Information Sciences. Argonne National Laboratory. Available via: http://www.dis.anl.gov/pubs/60362.pdf [accessed Jan. 13, 2011].
[ANL 2011d]	Threat Ensemble Vulnerability Assessment (TEVA). Decision and Information Sciences. Argonne National Laboratory. Available via: http://www.dis.anl.gov/projects/teva.html [accessed Jan. 13, 2011].
[ANL 2011e]	CVMDM: Community Vaccination and Mass Dispensing Model. Decision and Information Sciences, Argonne National Laboratory. Available via: http://www.dis.anl.gov/projects/cvmdm.html [accessed Jan. 3, 2011]
[ANS 2011]	American Nuclear Society (ANS) Standards Store. Available via: http://www.new.ans.org/store/i_240246 [accessed Mar. 25, 2011].
[ANSI 2010]	American National Standards Institute (ANSI) Standards Store – Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE). American National Standards Institute. Available via: http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+INCITS+353-2006 [accessed Jan. 15, 2011].
[ANSI 2011a]	American National Standards Institute (ANSI) Standards Store – Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE). American National Standards Institute. Available via: http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+INCITS+353-2006 [accessed Jan. 15, 2011].
[ANSI 2011b]	American National Standards Institute (ANSI) Standards Store – Homeland Security Mapping Standard: Point Symbology for Emergency Management. American National Standards Institute. Available via: http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+INCITS+415-2006 [accessed Mar. 25, 2011].
[ANSI 2011c]	American National Standards Institute (ANSI) Standards Store – Unified Modeling Language (UML). American National Standards Institute. Available via: http://webstore.ansi.org/RecordDetail.aspx?sku=ISO%2fIEC+19501%3a2005&source=google&adgroup=iso9&keyword=iso%2Fiec%2019501 [accessed Jan. 28, 2011].
[ANSYS 2010]	ANSYS FLUENT Flow Modeling Software. ANSYS, Inc. Canonsburg, PA. Available via: http://www.fluent.com/software/fluent/index.htm [accessed Nov. 2, 2010]
[ANSYS 2011]	ANYSYS Multiphysics Solutions. ANSYS, Inc. Available via: http://www.ansys.com/staticassets/ANSYS/staticassets/resourcelibrary/brochure/multiphysics-solutions-brochure.pdf [accessed Aug. 15, 2011]

[Apostolakas 2005]	Apostolakas, G., and Lemon, D., 2005. A Screening Methodology for the Identification and Ranking of Infrastructure Vulnerabilities Due to Terrorism. Risk Analysis, Vol. 25, No. 2, pp. 361-376.
[APTATCIP 2011]	American Public Transportation Association (APTA) Transit Communications Interface Profiles (TCIP) Standard Development Program. Available via: http://aptatcip.com/ [accessed Mar. 25, 2011].
[ASTM 2011]	ASTM Standards and Engineering Digital Library. ASTM International. Available via: http://www.astm.org/Standard/index.shtml?complete [Accessed May 2, 2011]
[ASTM 2011a]	Standard Practice for Metadata to Support Archived Data Management Systems. ASTM International, Inc. (ASTM). Available via: http://www.astm.org/Standards/E2468.htm [accessed Mar. 25, 2011].
[ASTM 2011b]	Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems — 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications. ASTM International, Inc. (ASTM). Available via: http://www.astm.org/Standards/E2213.htm [accessed Mar. 25, 2011].
[ASTM 2011c]	Standard Specification for Archiving ITS-Generated Traffic Monitoring Data. ASTM International, Inc. (ASTM). Available via: http://www.astm.org/Standards/E2665.htm [accessed Mar. 25, 2011].
[ATC 2010]	Emergency and Disaster Management Simulation. Applied Training Solutions, LLC. Available via: http://www.ipsysi.com/sub/edmsim.php [accessed Aug. 15, 2011]
[ATSDR 2010]	Toxic Substances Portal. Agency for Toxic Substances and Disease Registry (ATSDR). Available via: http://www.atsdr.cdc.gov/MHMI/index.asp# / [accessed Nov. 17, 2010]
[AUTODESK 2010]	DXF Format. AutoDesk. Available via: http://www.autodesk.com/techpubs/autocad/acad2000/dxf/dxf_format.htm [Accessed Dec. 12, 2010]
[Bagheri 2007]	Bagheri, E., H. Baghi, A.A. Ghorbani, and A. Yari, 2007. An Agent-based Service-Oriented Simulation Suite for Critical Infrastructure Behavior Analysis, International Journal of Business Process Integration and Management , 2(4), 312 – 326. Available via: http://glass.cs.unb.ca/~ebrahim/papers/ijbpim.pdf [accessed Jan. 12, 2011].
[Baker 2011]	Baker, V. 2011. Modeling & Simulation Capability for Resource Consumption and Consequence Management. 2011 ESRI International User Conference. July 12, 2011. Available via: http://events.esri.com/uc/2011/infoweb/onlineagenda/?fa=ofg_details_form&ScheduleID=8 [accessed Aug. 15, 2011]
[Balci 1998]	Verification, Validation, and Testing. In Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice. Edited by J. Banks. Wiley-Interscience.
[Barton 2004]	Barton, D.C., E.D. Edison, D.A. Schoenwald, R.G. Cox, and R.K. Reinert. 2004. Simulating Economic Effects of Disruptions in the Telecommunications Infrastructure. Report no. SAND2004-0101. January 2004. Sandia National Laboratories, Albuquerque, NM and Livermore, CA.
[Beck 2009]	Beck, T., J. Bergenthal, D. Macannuco, 2009. Federation of authoritative disaster models with incident management constructive simulation. In Proceedings of the IEEE Conference on Technologies for Homeland Security, 2009 (HST '09). May 11-12, Boston, MA. Pages 401-408.

[Belk 2006]	Belk, D., M. Burger, J. Moran, M. Newbauer, and J. Roth, 2006. WPL: Simulation Technology to Support Homeland Defense. In Proceedings of the 2006 Spring Simulation Interoperability Workshop, Paper No. 06S-SIW-081. Available on-line via Digital Library of the Simulation Interoperability Standards Organization: http://www.sisostds.org/DigitalLibrary.aspx [accessed May 2, 2011]
[BLM 2011]	National Integrated Land System (NILS). Bureau of Land Management (BLM). Available via: http://www.blm.gov/nils/ [accessed Mar. 25, 2011].
[BMET 2010]	Interim Life Safety Measures. Wikia. Available via: http://bmet.wikia.com/wiki/Interim_Life_Safety_Measures [Accessed Dec. 12, 2010]
[BostonDyn 2007]	DI-Guy: Human Simulation Software. Boston Dynamics. Available via: http://www.diguy.com/diguy/ [accessed Nov. 21, 2010]
[Boyd 2009]	Boyd, D., 2009. Virtual USA. Briefing delivered during the Commercial Mobile Alert Service (CMAS) Forum, July 30, 2009. Available via: http://cmasforum.com/docs/Forum_Master_Slide_Deck_FINAL.ppt [accessed Jan. 12, 2011].
[Breakaway 2010a]	Incident Commander™ NIMS-compliant training tool for Homeland Security. Breakaway Ltd. Available via: http://www.breakawaygames.com/serious-games/solutions/homeland/ [accessed Nov. 21, 2010]
[Breakaway 2010b]	Serious Games for Homeland Security. Breakaway Ltd. Available via: http://www.breakawaygames.com/serious-games/solutions/homeland/ [accessed Jan. 3, 2011]
[Brutzman 2006]	Brutzman, D., C. Blais, and T. Norbraten, 2006. Modeling and 3D Visualization for Evaluation of Anti-Terrorism/Force Protection Alternatives Phase II Final Report. Naval Postgraduate School, Monterey, CA. 21 November 2006. Available via: http://edocs.nps.edu/npspubs/scholarly/TR/2006/NPS-MV-06-002.pdf [accessed Jan. 12, 2011].
[BTS 2011]	Bureau of Transportation Statistics, Research and Innovative Technology Administration, U.S. Department of Transportation. Data and Statistics. Available via: http://www.bts.gov/ [accessed Aug. 26, 2011]
[Carreras 2009]	Carreras, B.A., D.E. Newman, I. Dobson, and M. Zeidenberg. 2009. A simple model for the reliability of an infrastructure system controlled by agents. Proceedings of the 42nd Hawaii International Conference on System Sciences.
[CDC 2010]	Interim Planning Guidance for Preparedness and Response to a Mass Casualty Event Resulting from Terrorist Use of Explosives. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/masscasualties/pdf/CDC_Guidance-508.pdf [accessed Nov. 17, 2010]
[CDC 2010a]	After a Terrorist Bombing: Health and Safety Information for the General Public. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/masscasualties/afterbombing.asp [accessed Nov. 2, 2010]
[CDC 2010aa]	Mass Casualty Event Preparedness and Response. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/masscasualties/ [Accessed Dec. 12, 2010]
[CDC 2010b]	Radiation Emergencies. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/ [accessed Nov. 2, 2010]

[CDC 2010c]	Anthrax: Short and Extended Messages. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/firsthours/anthrax/messages.asp [accessed Nov. 2, 2010]
[CDC 2010cc]	NIOSH Pocket Guide to Chemical Hazards. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/niosh/npg/ [Accessed Dec. 12, 2010]
[CDC 2010d]	Chemical Emergency Information for First Responders. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/chemical/responders.asp [accessed Nov. 2, 2010]
[CDC 2010dd]	Population Monitoring in Radiation Emergencies. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/pdf/population-monitoring-guide.pdf [accessed Nov. 2, 2010]
[CDC 2010e]	Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/niosh/docs/2002-139/ [accessed Nov. 2, 2010]
[CDC 2010ee]	Preparing for a Terrorist Bombing: A Common Sense Approach. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/masscasualties/preparingterroristbombing.asp [Accessed Dec. 12, 2010]
[CDC 2010f]	Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/niosh/docs/2002-139/ [accessed Nov. 2, 2010]
[CDC 2010g]	National Toxic Substance Incidents Program (NTSIP). Centers for Disease Control and Prevention (CDC). Available via: http://www.atsdr.cdc.gov/ntsip/index.html [accessed Nov. 2, 2010]
[CDC 2010h]	Interim Recommendations for the Selection and use of Protective Clothing and Respirators against Biological Agents. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/documentsapp/anthrax/protective/10242001protect.asp [accessed Nov. 2, 2010]
[CDC 2010hh]	Roundtable on Population Monitoring Following a Nuclear/Radiological Incident. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/pdf/population-monitoring-roundtable.pdf [accessed Nov. 2, 2010]
[CDC 2010i]	Medical management Guidelines for Chemical Agents. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/chemical/mmg.asp [accessed Nov. 2, 2010]
[CDC 2010ii]	Shelter-in-Place in a Radiation. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/shelter.asp [Accessed Dec. 12, 2010]
[CDC 2010j]	NIOSH Pocket Guide to Chemical Hazards. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/niosh/npg/ [accessed Nov. 2, 2010]
[CDC 2010jj]	Ambulatory Health Care Data. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/nchs/ahcd.htm [Accessed Dec. 12, 2010]

[CDC 2010k]	Population Monitoring in Radiation Emergencies. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/pdf/population-monitoring-guide.pdf [accessed Nov. 2, 2010]
[CDC 2010kk]	Behavioral Risk Factor Surveillance System (BRFSS). Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/brfss/about.htm [Accessed Dec. 12, 2010]
[CDC 2010l]	The Public Health Response to Biological and Chemical Terrorism. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/documents/planning/planningguidance.pdf [accessed Nov. 2, 2010]
[CDC 2010ll]	CDC WONDER Online Databases. Centers for Disease Control and Prevention (CDC). Available via: http://wonder.cdc.gov/ [Accessed Dec. 12, 2010]
[CDC 2010m]	Recognition of Illness Associated with the Intentional Release of a Biologic Agent. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5041a2.htm [accessed Nov. 2, 2010]
[CDC 2010mm]	CDC.gov Widgets and Gadgets. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/widgets/ [Accessed Dec. 12, 2010]
[CDC 2010n]	Agency for Toxic Substances and Disease Registry – Redirect. Centers for Disease Control and Prevention (CDC). Available via: http://www.atsdr.cdc.gov/MHMI/mmg170.html [Accessed Dec. 12, 2010]
[CDC 2010nn]	Data2010: the Healthy People 2010 Database. Centers for Disease Control and Prevention (CDC). Available via: http://wonder.cdc.gov/data2010/ [Accessed Dec. 12, 2010]
[CDC 2010o]	Shelter-in=Place in a Radiation Emergency. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/shelter.asp [accessed Nov. 2, 2010]
[CDC 2010oo]	The Emergency Response Safety and Health Database. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/NIOSH/ershdb/about.html [Accessed Dec. 12, 2010]
[CDC 2010p]	Managing Hazardous Materials Incidents (MHMIs). Centers for Disease Control and Prevention (CDC). Available via: http://www.atsdr.cdc.gov/MHMI/index.asp [Accessed Dec. 12, 2010]
[CDC 2010pp]	Injury Prevention and Control: Data and Statistics. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/injury/wisqars/index.html [Accessed Dec. 12, 2010]
[CDC 2010q]	The Public Health Response to Biological and Chemical Terrorism. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/documents/planning/planningguidance.pdf [accessed Nov. 2, 2010]
[CDC 2010r]	Bioterrorism Readiness Plan: A template for Healthcare Facilities. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/ncidod/dhqp/pdf/bt/13apr99apic-cdcbioterrorism.pdf [Accessed Dec. 12, 2010]
[CDC 2010r]	Recognition of Illness Associated with the Intentional Release of a Biologic Agent. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5041a2.htm [accessed Nov. 2, 2010]

[CDC 2010s]	Facts about the Laboratory Response Network. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/lrn/factsheet.asp [accessed Nov. 2, 2010]
[CDC 2010u]	Guidance for Public Health Departments and Clinicians Caring for Individuals Who May have Been Recently Exposed to Polonium 210 (Po-210). Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/isotopes/polonium/clinicians.asp [Accessed Dec. 12, 2010]
[CDC 2010v]	Guidelines for Handling Decedents Contaminated with Radioactive Materials. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/pdf/radiation-decedent-guidelines.pdf [Accessed Dec. 12, 2010]
[CDC 2010w]	Interim Guidelines for Hospital Response to Mass Causalities from a Radiological Incident. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/radiation/pdf/MassCasualtiesGuidelines.pdf [Accessed Dec. 12, 2010]
[CDC 2010x]	Interim Recommendations for the Selection and use of Protective Clothing and Respirators against Biological Agents. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/documentsapp/anthrax/protective/10242001protect.asp [accessed Nov. 2, 2010]
[CDC 2010y]	Classification of Diseases, Functioning, and Disability. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/nchs/icd.htm [Accessed Dec. 12, 2010]
[CDC 2011a]	Classification of Diseases, Functioning, and Disability. Centers for Disease Control and Prevention (CDC). Available via: http://www.cdc.gov/nchs/icd/icd10cm.htm [accessed Mar. 25, 2011].
[CDC 2011b]	Public Health Emergency Response Guide for State, Local, and Tribal Public Health Directors. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/planning/responseguide.asp [accessed Mar. 25, 2011].
[CDC 2011c]	Smallpox Response Plan and Guidelines. Centers for Disease Control and Prevention (CDC). Available via: http://www.bt.cdc.gov/agent/smallpox/response-plan/ [accessed Mar. 25, 2011].
[CEC 2011]	North American Environmental Atlas. Available via: http://www.cec.org/Page.asp?PageID=924&SiteNodeID=495&AA_SiteLanguageID=1 [accessed Mar. 25, 2011].
[CENSUS 2010]	LandView. U.S. Census Bureau. Available via: http://www.census.gov/geo/landview/ [accessed Nov. 2, 2010]
[CENSUS 2010g]	TheDataWeb. U.S. Census Bureau. Available via: http://dataferrett.census.gov/datasets.html [accessed Nov. 17, 2010]
[CENSUS 2011b]	American Community Survey. U.S. Census Bureau. Available via: http://www.census.gov/acs/www/ [accessed Mar. 25, 2011].
[CENSUS 2011c]	American FactFinder. U.S. Census Bureau. Available via: http://factfinder.census.gov/home/saff/main.html?_lang=en [accessed Mar. 25, 2011].
[CENSUS 2011d]	American Housing Survey (AHS). U.S. Census Bureau. Available via: http://www.census.gov/hhes/www/housing/ahs/ahs.html [accessed Mar. 25, 2011].

[CENSUS 2011e]	State and County QuickFacts. U.S. Census Bureau. Available via: http://quickfacts.census.gov/qfd/faq.html [accessed Mar. 25, 2011].
[CENSUS 2011f]	Topologically Integrated Geographic Encoding and Referencing System (TIGER). U.S. Census Bureau. Available via: http://www.census.gov/geo/www/tiger/ [accessed Mar. 25, 2011].
[CERC 2010]	Environmental Software: Accidental Releases, Cambridge Environmental Research Consultants, Cambridge, UK. Available via: http://www.cerc.co.uk/environmental-software.html [accessed Nov. 2, 2010]
[Chamberlain 2006]	Chamberlain, R., and T. Metivier, 2006. Joint Non-kinetic Effects Model (JNEM) – A Six Month Success Story. In Proceedings of the 2006 Interservice/Industry Training, Simulation & Education Conference (I/ITSEC). Available via: http://ntsa.metapress.com/link.asp?id=elk893hvkevccjnn; Presentation slides available via: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/41283/1/06-3712.pdf [accessed July 21, 2010]
[CHDS 2011]	SIMULATIONS: CIP Simulations, Tools and Software. Center for Homeland Defense and Security. Naval Postgraduate School. Available via: https://www.chds.us/?media/resources&collection=53&type=SIMULATION [accessed Jan. 13, 2011].
[Checkland 2000]	Checkland, Peter. SSM: A Thirty-Year Retrospective. Systems Research and Behavioral Science, November 2000.
[Cheng 2007]	Cheng, Q., 2007, A fuzzy relation analysis method implemented in GIS for modeling infrastructure interdependency, in Geomatics Solutions for Disaster Management, J. Li, S. Zlatanova & A. Fabbri (eds.), Springer Berlin, p. 351-367.
[CHICAGO 2011]	Chicago Maps. Available via: https://gisapps.cityofchicago.org/mapchicago/viewer.htm [accessed Mar. 25, 2011].
[CIMIT 2002]	RIPS: Real-time Incident Preparedness Simulator. Center for Integration of Medicine and Innovative Technology. Available via: http://www.medicalsim.org/rips.htm [accessed Jan. 3, 2011]
[CIMIT 2010]	CIMIT: Center for Integration of Medicine and Innovative Technology. Available via: http://www.cimit.org/ [accessed Dec. 29, 2010]
[CISN 2010]	The California Integrated Seismic Network (CISN). Advanced National Seismic System (ANSS). Available via: http://www.cisn.org/ [accessed Nov. 17, 2010]
[CMAS 2010]	Community Modeling and Analysis System, a website established by the Center for Environmental Modeling for Policy Development contracted by U.S. EPA through the University of North Carolina at Chapel Hill Institute for the Environment. Available via: http://www.cmascenter.org/ [accessed Nov. 2, 2010]
[CMS 2010]	Hospital Compare. Center for Medicare and Medicaid Services. Available via: http://www.cms.gov/HospitalQualityInits/11_HospitalCompare.asp [Accessed Dec. 12, 2010]
[COCO 2011]	Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS). Available via: http://www.cocorahs.org/ [accessed Mar. 25, 2011].
[COLLADA 2011]	Collaborative Design Activity (COLLADA): Digital Asset & FX Exchange Schema. Available via: https://collada.org/mediawiki/index.php/COLLADA [accessed Mar. 25, 2011].

[ColoState 2008]	Wind Engineering and Fluids Laboratory (WEFL), Colorado State University. Available via: http://www.windlab.colostate.edu/ [accessed Nov. 2, 2010]
[Connelly 2004]	Connelly, L.G., and A.E. Bair, 2004. Discrete Event Simulation of Emergency Department Activity: A Platform for System-level Operations Research. Academic Emergency Medicine, 11(11):1177-1185. Available via: http://heather.cs.ucdavis.edu/~matloff/156/PLN/Bair.pdf [accessed Jan. 3, 2011].
[COST 2011]	Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments. European Cooperation in Science and Technology, Earth System Science and Environmental Management COST Action ES1006. Available via: http://www.cost.esf.org/domains_actions/essem/Actions/ES1006 [Accessed Sep. 7, 2011]
[CreateASoft 2011]	SimCare Process Simulator. CreateASoft. Available via: http://www.createasoft.com/processImprovementSimulator/leanProcessSimulationSoftware/SimCareProcessSimulator7.2.html [accessed Jan. 3, 2011].
[Crowther 2005]	Crowther, K. G. and Haimes, Y. Y. 2005. Application of the inoperability input—output model (IIM) for systemic risk assessment and management of interdependent infrastructures. Systems Engineering. Vol. 8, No. 4 (Nov. 2005), 323-341. DOI= http://dx.doi.org/10.1002/sys.v8:4.
[CTBTO 2011]	Atmospheric Transport Modeling and Data Fusion. The International Data Center, Verification Regime, Comprehensive Test Ban Treaty Organization. Available via: http://www.ctbto.org/verification-regime/the-international-data-centre/atmospheric-transport-modellingand-data-fusion/page-1-atmospheric-transportmodelling-and-data-fusion/ [Accessed Sep. 3, 2011]
[CU 2011]	United State –Mexico Data Collection (US-MEX): Census Data. Available via: http://www.ciesin.columbia.edu/repository/metadata/ig/Browse/UnitedStatesMexicoDataCollectionUSMEXCensusData.html [accessed Mar. 25, 2011].
[CWID 2004]	Area Security Operations Command and Control ASSOC. Joint Warrior Interoperability Demonstration 2004 Final Report. Coalition Warrior Interoperability Demonstration (CWID). Available via: http://www.cwid.js.mil/public/cwid05fr/htmlfiles/u209war.html [accessed Nov. 21, 2010]
[DATA 2011]	Open Government Directive Agency Datasets. Available via: http://www.data.gov/open/raw [accessed Mar. 25, 2011].
[DATAFED 2011]	DATAFed.NET for Effective Use of Aerosol Data. Available via: http://datafed.net/ [accessed Mar. 25, 2011].
[DC 2011]	DC Atlas: District of Columbia Geographic Information System. Available via: http://octo.dc.gov/DC/OCTO/Maps+and+Apps/Online+Mapping/All+Online+Maps/DC+Atlas+All-in-One+User+Guide [accessed Mar. 25, 2011].
[De Porcellinis 2008]	De Porcellinis, S., R. Setola, S. Panzieri, and G. Ulivi, 2008. Simulation of heterogeneous and interdependent critical infrastructures. International Journal of Critical Infrastructures, 4(1-2), 110 – 128.
[DEVS 2011]	Discrete-Event Modeling and Simulation (DEVS) Standardization Group. Available via: http://cell-devs.sce.carleton.ca/devsgroup/ [accessed Jan. 25, 2011].
[DHS 2003]	HSPD-5 Homeland Security presidential Directive #5. Available via: http://www.dhs.gov/xnews/releases/press_release_0105.shtm [accessed November 15, 2010]

[DHS 2008a]	National Incident Management System. U.S. Department of Homeland Security. Available via: http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf [accessed April 3, 2011]
[DHS 2008b]	National Response Framework. U.S. Department of Homeland Security. Available via: http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf [accessed April 3, 2011]
[DHS 2009a]	National Infrastructure Protection Plan. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pdf [accessed Feb. 27, 2011]
[DHS 2009b]	Infrastructure and Geophysical Projects. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/files/programs/gc_1218480826191.shtm#content [accessed November 15, 2010]
[DHS 2010a]	DHS Lexicon: Terms and Definitions. Office of the Secretary, Executive Secretariat, U.S. Department of Homeland Security. January 2010 edition (with 9/14/2010 update).
[DHS 2010b]	National Emergency Communications Plan. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/xlibrary/assets/national_emergency_communications_plan.pdf [accessed Nov. 17, 2010]
[DHS 2010c]	National Strategy for Homeland Security. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/xlibrary/assets/nat_strat_homelandsecurity_2007.pdf [accessed Nov. 17, 2010]
[DHS 2010d]	The Integrated Modeling, mapping, and Simulation (IMMS) Program. U.S. Department of Homeland Security. Available via: Integrated Modeling, Mapping, and Simulation. U.S. Department of Homeland Security. Available via: https://dhs-summit.us/files/201002_IMMS_program_overview.pdf [accessed Nov. 22, 2010]
[DHS 2010e]	Guidance on Initial Responses to a Suspicious Letter/Container with a Potential Biological Threat. Available via: http://cryptome.quintessenz.at/mirror/fbi-dhs-guide.htm [Accessed Dec. 12, 2010]
[DHS 2010f]	Interagency Modeling And Atmospheric Assessment Center. U.S. Department Of Homeland Security, Office of Operations Coordination & Planning. Document no. LLNL-BR-444173. July 2010.
[DHS 2011]	Healthcare and Public Health Sector Snapshot. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/files/programs/gc_1188490299862.shtm [accessed April 17, 2011]
[DHS 2011a]	Chemical Sector Supply Chain and Economics Project. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/files/programs/gc_1218480826191.shtm#8 [accessed Jan. 12, 2011].
[DHS 2011b]	Sector-Specific Plans. U.S. Department of Homeland Security. Available via: http://www.dhs.gov/files/programs/gc_1179866197607.shtm [accessed Mar. 25, 2011].
[DHS 2011c]	Automated Critical Asset Management System (ACAMS). U.S. Department of Homeland Security. Available via: http://www.dhs.gov/files/programs/gc_1190729724456.shtm [accessed Mar. 25,

	2011].
[DHS 2011d]	About the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC). U.S. Department of Homeland Security. Available via: http://www.dhs.gov/xabout/structure/gc_1257526699957.shtm [accessed Aug. 30, 2011]
[DIESIS 2011]	Design of an Interoperable European federated Simulation network for critical infrastructures. Available via: http://www.diesis-project.eu/ [accessed Jan. 12, 2011].
[DoD 2003]	Integrated Chemical and Biological Defense Program Research, Development and Acquisition Plan for the Departments of Defense and Energy: Bio Point Detection. U.S. Department of Defense. April 2003. Available via: http://www.hsdl.org/?view&did=450559 [accessed Sep. 2, 2011]
[DoD 2006]	VV&A Recommended Practices Guide (RPG). U.S. Department of Defense Modeling and Simulation Coordination Office. RPG Build 3.0. September 2006. Available on-line via: http://vva.msco.mil/ [last accessed Oct. 1, 2010].
[DoD 2009]	DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A). Department of Defense Instruction Number 5000.61. December 9, 2009. Available on-line via: http://www.dtic.mil/whs/directives/corres/pdf/500061p.pdf [last accessed October 4, 2010]
[DoD 2010]	DoD Modeling and Simulation Glossary. U.S. Department of Defense. March 2010. Available via: http://www.msco.mil/files/Draft_MS_Glossary_March_B_version.pdf [accessed April 20, 2011]
[DODCCRP 2004]	Morse, K. 2004. Web Enabling HLA Compliant Simulations to Support Network Centric Applications. 2004 Command and Control Research and Technology Symposium. Available via: http://www.dodccrp.org/events/2004_CCRTS/CD/presentations/172.pdf [accessed Mar. 25, 2011]
[DODCCRP 2011]	Katherine Morse. 2004. Web Enabling HLA Compliant Simulations to Support Network Centric Applications. Available via: http://www.dodccrp.org/events/2004_CCRTS/CD/presentations/172.pdf [accessed Mar. 25, 2011]
[DOL 2010]	The Health Insurance Portability and Accountability Act (HIPAA): Portability of Health Coverage. U.S. Department of Labor. Available via: http://www.dol.gov/dol/topic/health-plans/portability.htm [Accessed Dec. 12, 2010]
[DOT 2008]	Emergency Response Guidebook (ERG). U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. Available via: http://www.phmsa.dot.gov/hazmat/library/erg [Accessed Sep. 1, 2011]
[DOT 2010]	Incident Command System. U.S. Department of Transportation. Available via: http://ops.fhwa.dot.gov/eto_tim_pse/about/ics.htm [accessed Nov. 17, 2010]
[DOT 2010a]	Highway Evacuations in Selected Metropolitan Areas: Assessment of Impediments. U.S. Department of Transportation. Report FHWA-HOP-10-059. April 2010. Available via: http://ntl.bts.gov/lib/38000/38800/38824/fhwahop10059.pdf [accessed Sep. 5, 2011]
[DoT 2011]	Subway Environment Simulation. U.S. Department of Transportation. Available via: http://www.fta.dot.gov/printer_friendly/research_4507.html [accessed Aug. 15, 2011]

[DPG 2010]	Joint Ambient Breeze Tunnel. Dugway Proving Grounds, U.S. Army. Available via: http://www.dugway.army.mil/index.php/index/content/id/284 [accessed Nov. 8, 2010]
[DRDC 2009]	Backgrounder - Government of Canada Invests $2 Million to Bolster Canada's Safety and Security. Defence Research and Development Canada. April 6, 2009. Available via: http://www.css.drdc-rddc.gc.ca/publications/backgrounders-documentation/2009_04_06-eng.asp [accessed Jan. 12, 2011].
[Dudenhoeffer 2006]	Dudenhoeffer, D.D, M. R. Permann, and M. Manic, 2006. CIMS: A Framework For Infrastructure Interdependency Modeling And Analysis. In Proceedings of the 2006 Winter Simulation Conference, ed. L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto. 478-485. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, 2006. Available via: http://www.informs-sim.org/wsc06papers/058.pdf [accessed Jan. 12, 2011].
[ECIG 2010]	EAS-CAP Industry Group Working Group Documents. EAS-CAP Industry Group. Available via: http://www.eas-cap.org/documents.htm [accessed Nov. 17, 2010]
[ECS 2010]	Emergency Management Staff Trainer (EMST). Engineering & Computer Simulations , Inc. Available via: http://www.ecsorl.com/solutions/products/web-based-simulations/emergency-management-staff-trainer-emst/ [accessed Nov. 21, 2010]
[EDD 2011]	Electrical Distribution Design (EDD) Integrated Solutions. Available via: http://www.edd-us.com/ [accessed Jan. 12, 2011].
[EIA 2011]	Energy Information Administration (EIA), U. S. Department of Energy. Energy information. Available via: http://www.eia.gov/about/ [accessed Aug. 26, 2011]
[EMAP 2010]	The Emergency Management Accreditation Program (EMAP). Available via: http://www.emaponline.org/ [accessed Nov. 17, 2010]
[EPA 2009]	Guidance on the Development, Evaluation, and Application of Environmental Models, Office of the Science Advisor, Council for Regulatory Environmental Modeling EPA/100/K-09/003 March 2009
[EPA 2010a]	Exposure Research: EPA's National Exposure Research Laboratory. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/nerl/ [accessed Nov. 2, 2010]
[EPA 2010b]	Emergency Management: What is CAMEO? U.S. Environmental Protection Agency. Available via: http://www.epa.gov/OEM/content/cameo/what.htm#haz [accessed Nov. 2, 2010]
[EPA 2010c]	Alternative Models. Technology Transfer Network Support Center for Regulatory Atmospheric Modeling. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/scram001/dispersion_alt.htm [accessed Nov. 2, 2010]
[EPA 2010d]	Other Applicable Guidance. Technology Transfer Network Support Center for Regulatory Atmospheric Modeling. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/scram001/guidance_other.htm [accessed Nov. 9, 2010]
[EPA 2010e]	Guidance on the application of refined dispersion models for hazardous/toxic air releases. EPA National Library Network. U.S. Environmental Protection Agency. Available via: http://cfpub.epa.gov/ols/catalog/catalog_display.cfm?&FIELD1=SUBJECT&INPUT1=Air%20Quality%20Display%20Model&TYPE1=EXACT&item_count=

	5 [accessed Nov. 9, 2010]
[EPA 2010f]	National Ambient Air Quality Standards (NAAQS). Air and Radiation. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/air/criteria.html [accessed Nov. 9, 2010]
[EPA 2010g]	Assessment, Cleanup, and Redevelopment Exchange System (ACRES). U.S. Environmental Protection Agency. Available via: http://www.epa.gov/region5brownfields/htm/acres.htm [accessed Nov. 9, 2010]
[EPA 2010h]	Aggregated Computational Toxicology Resource (ACToR). U.S. Environmental Protection Agency. Available via: http://www.epa.gov/ncct/download_files/factsheets/ACToR_ToxRefDB_Fact_Sheet.pdf [accessed Nov. 2, 2010]
[EPA 2010i]	CAMEO. U.S. Environmental Protection Agency and National Oceanic and Atmospheric Administration. Available via: U.S. Environmental Protection Agency. Available via: http://www.epa.gov/osweroe1/content/cameo/aloha.htm [accessed Nov. 2, 2010]
[EPA 2010j]	Superfund. U.S. Environmental Protection Agency. Available via: U.S. Environmental Protection Agency. Available via: http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm [accessed Nov. 2, 2010]
[EPA 2010k]	CAMEOfm. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/oem/content/cameo/cameo.htm [accessed Nov. 2, 2010]
[EPA 2010l]	ECOTOX Database. U.S. Environmental Protection Agency. Available via: http://cfpub.epa.gov/ecotox/ [accessed Nov. 2, 2010]
[EPA 2010m]	Envirofacts. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/envirofw/index_java.html [accessed Nov. 2, 2010]
[EPA 2010n]	Hazardous Waste. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/osw/inforesources/data/ [accessed Nov. 2, 2010]
[EPA 2010o]	Radiation Information Database (RADINFO). U.S. Environmental Protection Agency. Available via: http://www.epa.gov/enviro/html/rad/rad_query_java.html [accessed Nov. 2, 2010]
[EPA 2010p]	EPA Databases and Tools. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/oem/tools.htm#arip [accessed Nov. 2, 2010]
[EPA 2010q]	Toxics Release Inventory (TRI) Program. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/tri/ [accessed Nov. 2, 2010]
[EPA 2010r]	Toxics Release Inventory (TRI) Explorer. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/triexplorer/ [accessed Nov. 2, 2010]
[EPA 2010s]	Vulnerable Zone Indicator System. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/oem/content/vzis.htm [accessed Nov. 2, 2010]
[EPA 2011a]	Computer-Aided Management of Emergency Operations (CAMEO). U.S. Environmental Protection Agency. Available via: http://www.epa.gov/emergencies/content/cameo/index.htm [accessed Mar. 25, 2011].
[EPA 2011b]	Envirofacts. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/enviro/facts/multisystem.html [accessed Mar. 25, 2011].
[EPA 2011c]	National Oil and Hazardous Substances Pollution Contingency Plan Overview. U.S. Environmental Protection Agency. Available via: http://www.epa.gov/oem/content/lawsregs/ncpover.htm [Accessed Sep. 3, 2011]

[EPIcode 2010]	EPIcode – a chemical Dispersion modeling software product. Homann Associates, Inc. Available via: http://www.epicode.com/ [accessed Nov. 2, 2010]
[ESRI 2010]	ESRI Shapefile Technical Description. Environmental Systems Research Institute, Inc. (ESRI). Available via: http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf [accessed Nov. 2, 2010]
[ESRI 2011a]	ERSI Shapefile Technical Description. Environmental Systems Research Institute (ESRI), Inc. Available via: http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf [accessed Mar. 25, 2011].
[ESRI 2011b]	Geodatabase. Environmental Systems Research Institute (ESRI), Inc. Available via: http://www.esri.com/software/arcgis/geodatabase/index.html [accessed Mar. 25, 2011].
[ETC 2010a]	Incident Command (ADMS-COMMAND). Environmental Tectonics Corporation. Available via: http://www.admstraining.com/products_incident.php [accessed Nov. 21, 2010].
[ETC 2010b]	Emergency Operations Center (ADMS-EOC). Environmental Tectonics Corporation. Available via: http://www.admstraining.com/products_eoc.php [accessed Nov. 21, 2010].
[ETSI 2011]	Traffic Manage Channel (TMC) and Traffic Protocol Experts Group (TPEG) standards. Traveller Information Services Association. Available via: http://docbox.etsi.org//Workshop/2009/200902_ITSWORKSHOP/TISA_Hendricks.pdf [accessed Mar. 25, 2011].
[EVMS 2009]	National Center for Collaboration in Medical Modeling and Simulation. Eastern Virginia Medical School. Available via: http://www.evms.edu/nccmms/ [accessed Dec. 29, 2010]
[FCC 2011]	Connectionless data Bearer System (CDBS) Public Access. Federal Communications Commission (FCC). Available via: http://licensing.fcc.gov/prod/cdbs/pubacc/prod/cdbs_pa.htm [accessed Mar. 25, 2011].
[FDIC 2011]	Federal Deposit Insurance Corporation (FDIC). Industry Analysis. Available via: http://www.fdic.gov/bank/ [accessed Aug. 26, 2011].
[FEDSTATS 2010]	FedStats. FedStates.gov. Available via: http://www.fedstats.gov/ [accessed Nov. 17, 2010]
[FEMA 2004]	NIMS and the Incident Command System. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/txt/nims/nims_ics_position_paper.txt [accessed November 15, 2010]
[FEMA 2009]	National Planning Scenarios. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/pdf/media/factsheets/2009/npd_natl_plan_scenario.pdf [accessed November 15, 2010]
[FEMA 2010]	Incident Command System (ICS). Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/emergency/nims/IncidentCommandSystem.shtm [accessed November 15, 2010]
[FEMA 2010a]	Developing and maintaining Emergency Operations Plans. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/about/divisions/cpg.shtm [accessed Nov. 17, 2010]

[FEMA 2010b]	National Incident Management System. 2008. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf [accessed Nov. 17, 2010]
[FEMA 2010c]	National Preparedness Guidelines. 2007. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/pdf/government/npg.pdf [accessed Nov. 17, 2010]
[FEMA 2010d]	National Response Framework. 2008. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf [accessed Nov. 17, 2010]
[FEMA 2010e]	Open Web Services. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/about/programs/disastermanagement/open/index.shtm [accessed Nov. 17, 2010]
[FEMA 2010f]	National Incident Management System- Incident Resource Inventory System (NIMS-IRIS). Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/pdf/emergency/nims/nims_iris_fact_sheet.pdf [Accessed Dec. 12, 2010]
[FEMA 2010f]	Resource Management. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/emergency/nims/ResourceMngmnt.shtm [accessed Nov. 17, 2010]
[FEMA 2010g]	Emergency Managers - National Situation Updates. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/emergency/reports/index.shtm [accessed Nov. 17, 2010]
[FEMA 2010h]	Exercise. Federal Emergency Management Agency (FEMA). Available via: http://www.fema.gov/prepared/exercise.shtm [accessed Nov. 22, 2010]
[Ferrin 2007]	Ferrin, D.M., M.J. Miller, and D.L. McBroom, 2007. Maximizing Hospital Financial Impact and Emergency Department Throughput with Simulation. In Proceedings of the 2007 Winter Simulation Conference, eds. S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, 1566-1573. Piscataway, NJ: Institute of Electrical and Electronics Engineers, Inc. Available via: http://www.northernlightsnav.com/documents/WSC07%20ED%20Sim%20St%20%20Mary%27s%20v4.pdf [accessed Jan. 3, 2011].
[FGDC 2010]	Geographic Information Framework Data Standard. Federal Geographic Data Committee (FGDC). Available via: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/GI_FrameworkDataStandard_Part5_GovernmentalUnitBoundaries.pdf [accessed January 31, 2011].
[FGDC 2011a]	Content Standard for Digital Geo-spatial Metadata. Federal Geographic Data Committee (FGDC). Available via: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/metadata/base-metadata/?searchterm=FGDC-STD-001 [accessed Mar. 25, 2011].
[FGDC 2011b]	Content Standard for Digital Geo-spatial Metadata: Extensions for Remote Sensing Metadata. Federal Geographic Data Committee (FGDC). Available via: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/csdgm_rs_ex/MetadataRemoteSensingExtens.pdf/view?searchterm=FG

	DC-STD-012 [accessed Mar. 25, 2011].
[FGDC 2011c]	Geographic Information Framework data Standard. Federal Geographic Data Committee (FGDC). Available via: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-data-standard/framework-data-standard [accessed Mar. 25, 2011].
[FGDC 2011d]	Spatial Data Transfer Standard (SDTS). Federal Geographic Data Committee (FGDC). Available via: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/SDTS/?searchterm=sdts [accessed Mar. 25, 2011].
[FGDC 2011e]	United States National Grid. Federal Geographic Data Committee (FGDC). Available via: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/usng/fgdc_std_011_2001_usng.pdf [accessed Mar. 25, 2011].
[Flexsim 2011]	Flexsim Healthcare – Overview. Flexsim Software Products, Inc. Available via: http://www.flexsim.com/products/healthcare/ [Accessed Sep. 5, 2011]
[Garvey 2009]	Garvey, P.R., and C.A. Pinto. 2009. Introduction to Functional Dependency Network Analysis (FDNA). Second International Symposium on Engineering Systems, Massachusetts Institute of Technology, 17 June 2009. Available via: http://esd.mit.edu/symp09/presentations/day3.session4c.garvey.pdf [accessed Aug. 15, 2011]
[GBRA 2010]	Hazard Mitigation Plan Update, Draft: September 2010. Guadalupe-Blanco River Authority. Available via: http://www.gbra.org/hazardmitigation/default.aspx [accessed April 3, 2011]
[GEOAPI 2011]	GeoAPI 3.0 Standard. GeoAPI Standard Working Group. Available via: http://www.geoapi.org/charter.html [accessed Mar. 25, 2011].
[GEOCOMM 2010]	GIS Data Depot. GeoCommunity. Available via: http://data.geocomm.com/ [accessed Nov. 17, 2010]
[GEOMAC 2010]	The Geo-spatial Multi-Agency Coordination Group or GeoMAC. U.S. Geological Survey. Available via: http://www.geomac.gov/index.html [accessed Nov. 17, 2010]
[GEOMAC 2011]	The Geo-spatial Multi-Agency Coordination Group (GeoMAC). Available via: http://www.geomac.gov/index.shtml [accessed Mar. 25, 2011].
[GEOTIFF 2011]	GeoTIFF FAQ. Available via: http://www.remotesensing.org/geotiff/faq.html [accessed Mar. 25, 2011].
[Gillette 2002]	Gillette, J., R. Fisher, J. Peerenboom, R. Whitfield, 2002. Analyzing Water/Wastewater Infrastructure Interdependencies. 6th International Conference on Probabilistic Safety Assessment and Management, San Juan (PR), June 23-28. Available on-line: http://www.dis.anl.gov/pubs/42598.pdf [accessed Jan. 12, 2011].
[GOOGLE 2011]	Google Earth. Google.com. http://www.google.com/earth/index.html [accessed July 18, 2011]
[HHS 2007]	Public Health & Healthcare: Critical Infrastructure and Key Resources Sector-Specific Plan as input to the National Infrastructure Protection Plan (Redacted). May 2007. Department of Health and Human Services. Available via: http://www.phe.gov/Preparedness/planning/cip/Documents/healthssp_08_508.pdf [accessed April 17, 2011]
[HHS 2010a]	The Health Insurance Portability and Accountability Act (HIPAA). U.S. Department of Health and Human Services. Available via: http://www.cms.gov/HIPAAGenInfo/ [Accessed Dec. 12, 2010]

[HHS 2010b]	Health Information Privacy. U.S. Department of Human Services. Available via: http://www.hhs.gov/ocr/privacy/hipaa/administrative/securityrule/ [Accessed Dec. 12, 2010]
[HL7 2010]	HL7 Standards. Health Level Seven International. Available via: http://www.hl7.org/implement/standards/index.cfm?ref=nav [Accessed Dec. 12, 2010]
[HL7 2011a]	HL7 Standards. Health level Seven International. Available via: http://www.hl7.org/implement/standards/index.cfm?ref=nav [accessed Mar. 25, 2011].
[HL7 2011b]	Visual Integration/Clincial Context Object Workgroup (CCOW). Health level Seven International. Available via: http://www.hl7.org/implement/standards/ccow.cfm [accessed Mar. 25, 2011].
[HL7 2011c]	Clinical Document Architecture. Health level Seven International. Available via: http://www.hl7.org/implement/standards/cda.cfm [accessed Mar. 25, 2011].
[HL7 2011d]	HL7 Version 2.x Messaging Standard. Health level Seven International. Available via: http://www.hl7.org/implement/standards/v2messages.cfm [accessed Mar. 25, 2011].
[HL7 2011e]	HL7 Version 3 Messaging Standard. Health level Seven International. Available via: http://www.hl7.org/implement/standards/v3messages.cfm [accessed Mar. 25, 2011].
[Holtermann 2010]	Holtermann, K., 2010. Exercise Modeling & Simulation Briefing. March 4. Available via: http://info.publicintelligence.net/FEMAexercisesimulation.pdf [accessed Nov. 22, 2010]
[HSI 2009]	IMAAC VV&A Workshop Report. Homeland Security Institute. Publication number: RP08-67-01. 20 April 2009.
[Hydra 2010]	History of Hydra/Minerva. Hydra/Minerva User Group. Available via: http://www.hydra-minerva.com/history/history.htm [accessed Nov. 21, 2010].
[IAEA 2010]	Long Term Structure of the IAEA Safety Standards and Current Status. IAEA. Available via: http://www-ns.iaea.org/downloads/standards/status.pdf [accessed Mar. 28, 2011]
[IEC 2011]	Airborne instrumentation for measurement of terrestrial gamma. radiationIEC Projects for TC 45. IEC. Available via: http://www.iecchallenge.com/cgi-bin/procgi.pl/www/iecwww.p?wwwlang=english&wwwprog=pro-det.p&progdb=db1&He=IEC&Pu=61134&Pa=&Se=&Am=&Fr=&TR=&Ed=1 http://www.iecchallenge.com/cgi-bin/procgi.pl/www/iecwww.p?wwwlang=e&wwwprog=sea1122.p&progdb=db1&css_color=purple&class=&refno=&search=committee&committee=45&pubno=&part=&se=&header=IEC&pcomm=&dcom=&class=&dref= [accessed July 18, 2011]
[IEEE 1989]	IEEE Standard Glossary of Modeling and Simulation Terminology (IEEE 610.3-1989). IEEE, 01-Jan-1989. ISBN: 1559376384
[IEEE 2010]	IEEE 1512-2006 Standard for Common Incident management Message Sets for Use by Emergency Management Centers. IEEEXplore. Available via: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1673309 [Accessed Dec. 12, 2010]
[IEEE 2011a]	Guide for Implementing IEEE Standard 1512. IEEE. Available via: http://grouper.ieee.org/groups/scc32/imwg/guide.pdf [accessed Mar. 25, 2011].

[IEEE 2011b]	IEEE Standard for Data Dictionaries for Intelligent Transportation Systems. IEEEXplore. Available via: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=803526 [accessed Mar. 25, 2011].
[IEEE 2011c]	[IEEE 2011c] IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA). IEEEXplore. Available via: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=803526 [accessed Mar. 28, 2011].
[IEEE 2011d]	IEEE Safety and Security Standards Series, Vol.2, Computers and Networks. IEEE. Available via: http://www.safetyonline.com/product.mvc/IEEE-Safety-and-Security-Standards-Series-Vol-0001 [accessed Mar. 25, 2011].
[IEEE 2011e]	IEEE Safety and Security Standards Series, Vol.3, Electrical. IEEE. Available via: http://www.safetyonline.com/product.mvc/IEEE-Safety-and-Security-Standards-Series-Vol-0002 [accessed Mar. 25, 2011].
[IEEE 2011f]	IEEE Safety and Security Standards Series, Vol.1, Critical Infrastructure. IEEE. Available via: http://www.safetyonline.com/product.mvc/IEEE-Safety-and-Security-Standards-Series-Vol-0003 [accessed Mar. 25, 2011].
[IFAD 2011]	MUSTER 2.0. IFAD Denmark. Available via: http://www.ifad.dk/index.php?option=com_content&task=view&id=15&Itemid=31 [accessed Jan. 3, 2011]
[IHS 2011]	2006 U.S. DOT Releases New Standards Fact Sheets. IHS. Available via: http://auto.ihs.com/news/2006/dot-fact-sheets.htm [accessed Mar. 25, 2011].
[IHS 2011a]	IEEE 1278.2 Standard for Distributed Interactive Simulation – Communication Services and Profiles. IHS. Available via: http://electronics.ihs.com/document/abstract/ZEVZCBAAAAAAAAAA [accessed Jan. 28, 2011].
[IIIA 2007]	Our Research Projects. Institute for Infrastructure and Information Assurance, Harrisonburg, VA. Available via: http://www.jmu.edu/iiia/research/research_current.html [accessed Jan. 13, 2011].
[IICD 2011]	Infrastructure Information Collection Division (IICD), Office of Infrastructure Protection, Department of Homeland Security. Critical infrastructure and key resources data. Available via: http://www.dhs.gov/xabout/structure/gc_1227556492382.shtm [accessed Aug. 26, 2011]
[INCIWEB 2010]	InciWeb – Incident Information System. Inciweb.org. Available via: http://www.inciweb.org/ [accessed Nov. 17, 2010]
[INCOSE 2008]	International Council on Systems Engineering. INCOSE-TD-2007-003-01: Survey of Model-Based Systems Engineering (MBSE) Methodologies. Seattle, WA 98133. 10 June 2008.
[INL 2007]	CIMSuite: Critical Infrastructure Modeling. Idaho National Laboratory. Available on-line: http://www.inl.gov/factsheets/docs/cimsuite.pdf [accessed Jan. 12, 2011].
[INL 2008]	Protecting the Nation's Infrastructure: The Idaho Test Range. Idaho National Laboratory. Available via: http://www.inl.gov/nationalsecurity/factsheets/docs/critical_infrastructure_test_range.pdf [accessed Jan. 12, 2011].
[INL 2010]	Modeling and Simulation. Idaho National Laboratory. Available via: https://inlportal.inl.gov/portal/server.pt/community/national_and_homeland_security/273/modeling_and_simulation/1707 [accessed Jan. 13, 2011].

[IntePoint 2008]	IntePoint Vu. IntePoint. Available via: http://intepoint.com/solutions/index.html [accessed Jan. 13, 2011].
[ISO 2011a]	NEW ISO Standard for Building Escape and Evacuation Plans is a Potential Life Saver. ISO. Available via: http://www.iso.org/iso/pressrelease.htm?refid=Ref1207 [accessed Jan. 15, 2011].
[ISO 2011b]	ISO Standards. ISO. Available via: http://www.iso.org/iso/iso_catalogue.htm [accessed Mar. 25, 2011].
[ISO 2011c]	ISO 15628 Road Transport and Traffic Telematics – Dedicated Short range Communication (DSRC) – DSRC Application Layer. ISO. Available via: http://engineers.ihs.com/document/abstract/RLWQXBAAAAAAAAAA [accessed Mar. 25, 2011].
[ISO 2011d]	Electronic data Interchange for Administration, Commerce and Transport (EDIFACT). ISO. Available via: http://www.iso.org/iso/catalogue_detail.htm?csnumber=37020 [accessed Mar. 25, 2011].
[IST 2009]	Human Patient Simulators – New Dimensions in Training to Treat Mass Casualties. Institute for Simulation and Training, University of Central Florida. Available via: http://www.ist.ucf.edu/emt/hps.htm [accessed Dec. 30, 2010]
[ISU 2010]	Play2Train where people learn to play. Institute of Rural Health, Idaho State University. Available via: http://play2train.org [accessed Nov. 21, 2010]
[Jain 2003]	Jain, S., and C. McLean. 2003. Modeling and Simulation for Emergency Response- Workshop Report, Standards and Tools. NIST Interagency Report NISTIR-7071, Dec. 2003. Available via: http://www.mel.nist.gov/msidlibrary/doc/nistir7071.pdf [Accessed Sep. 3, 2011]
[Jain 2008]	Jain, S., and C.R. McLean. 2008. Components for an Incident Management Simulation and Gaming Framework and Related Developments. SIMULATION, Vol 84, No. 1, 2008, pp. 3-25.
[Jain 2011]	Jain, S., and C.R. McLean. 2011. Best Practices for Modeling, Simulation and Analysis (MS&A) for Homeland Security Applications. National Institute of Standards and Technology. NIST Interagency/Internal Report (NISTIR) 7655.
[Janes 2007]	Janes, M. 2007. Ground Truth real-time-strategy game is serious business for Sandia software engineer. Sandia Lab News, August 17, 2007. Available via: http://www.sandia.gov/LabNews/070817.html [accessed Nov. 22, 2010]
[JCAHOSTD 2010]	2006 Hospital Accreditations Standards for Emergency Management Planning, Emergency management Drills, Infection Control, Disaster Privileges. Joint Commission on Accreditation of Healthcare Organizations (JCAHO). Available via: http://www.efilmgroup.com/efg/blurbimage/JCAHOStdforEmergency.pdf [Accessed Dec. 12, 2010]
[JCEST 2010]	CAN NNS06AA05G Nasa Volcanic Cloud Data For Aviation Hazards. Joint Center for Earth Systems Technology /University of Maryland Baltimore County. Available via: http://appliedsciences.nasa.gov/pdf/projectreports10/WX-VolcanosCloudAviation.pdf [Accessed Sep. 3, 2011]
[JCR 2011]	2012 Crosswalk of the Joint Commission Environment of Care Standards for Hospitals. Joint Commission Resources, Inc.. Available via: http://www.jcrinc.com/Books-and-E-books/CWECH12/3995/ [Accessed Nov. 10, 2011]
[Jones 2011]	D.A. Jones, J.L. Farkas, O. Bernstein, C.E. Davis, A. Turk, M.A. Turnquist, L.K. Nozick, B. Levine, C.G. Rawls, S.D. Ostrowski and W.J. Sawaya. 2011.

	"U.S. Import/Export Container Flow Modeling and Disruption Analysis," Research in Transportation Economics, Volume 32, Issue 1, p. 3-14.
[KCOEM 2011]	Hazardous Material Release. King County Office of Emergency Management. Available via: http://www.kingcounty.gov/safety/prepare/residents_business/Hazards_Disasters/HazardousMaterials.aspx [accessed April 3, 2011]
[LACOUNTY 2011]	GIS-NET. Los Angeles County. Available via: http://planning.lacounty.gov/gisnet [accessed Mar. 25, 2011].
[LANL 2010a]	QUIC (Quick Urban and Industrial Complex) Dispersion Modeling System. Los Alamos National Laboratory. LA-UR-02-2559. Available via: http://www.lanl.gov/projects/quic/open_files/QUIC_factsheet.pdf [accessed Nov. 3, 2010]
[LANL 2010b]	NISAC Tools: EpiSimS: Epidemic Simulation System. Los Alamos National Laboratory. Available via: http://www.lanl.gov/programs/nisac/episims.shtml [accessed Jan. 3, 2011]
[LBNL 2010a]	Indoor Environment Department Facilities and Instrumentation. Lawrence Berkeley National Laboratory. Available via: http://eetd.lbl.gov/IEP/IEDfacilities.html [accessed Nov. 3, 2010]
[LBNL 2010b]	COMIS Multizone Air Flow Model. Lawrence Berkeley National Laboratory. Available via: http://epb.lbl.gov/comis/ [accessed Nov. 9, 2010]
[LBNL 2010c]	Integrated Simulation Tools. Airflow and Pollutant Transport group, Lawrence Berkeley National Laboratory. Available via: http://eetd.lbl.gov/ie/apt/APT_tIST.html [accessed Nov. 9, 2010]
[LeClaire 2009]	LeClaire, R., Hirsch, G.B., and Bandlow, A., 2009. Learning Environment Simulator: A Tool for Local Decision Makers and First Responders. In Proceedings of the 27th International Conference of the System Dynamics Society, July 26 – 30, 2009, Albuquerque, New Mexico, USA. Available via: http://www.systemdynamics.org/conferences/2009/proceed/papers/P1391.pdf [accessed Jan. 3, 2011]
[Lee 2005]	Lee, E., A. Wallace, J.E. Mitchell and D. Mendonça. 2005. Decision technologies for protection of critical infrastructures. In Proceedings of Working Together: R&D Partnerships in Homeland Security, Boston, May 2005. Available via: http://www.rpi.edu/~mitchj/papers/decisiontechnologies.html [accessed Jan. 13, 2011].
[Leone 2001]	Leone, Jr., J.M., J.S. Nasstrom, D.M. Maddix, D.J. Larson, G. Sugiyama and D.L. Ermak. 2001. Lagrangian Operational Dispersion Integrator (LODI) User's Guide Version 1.0. Available via: https://narac.llnl.gov/uploads/Leone2001_LODIManual-V1-8JUN2005_212798_upbhd.pdf [accessed Nov. 3, 2010]
[Li 2009]	Li, H., Apostolakis, G.E., Gifun, J., VanSchalkwyk, W., Leite, S., and Barber, D. 2009. Ranking the Risks from Multiple Hazards in a Small Community. Risk Analysis, 29:438-456, 2009.
[Linebarger 2007]	Linebarger, J.M., M.E. Goldsby, D. Fellig, M.F. Hawley, P.C. Moore, and T.J. Sa. 2007. Smallpox Over San Diego: Joint Real-Time Federations of Distributed Simulations and Simulation Users under a Common Scenario. 21st International Workshop on Principles of Advanced and Distributed Simulation (PADS'07). IEEE Computer Society. Available via: http://www.sandia.gov/nisac/docs/Smallpox%20over%20San%20Diego.pdf [accessed Nov. 9, 2010]
[LLNL 2001]	Simulating How the Wind Blows. S&TR October 2001. Lawrence Livermore

	National Laboratory. Available via: https://www.llnl.gov/str/October01/pdfs/10_01.3.pdf [accessed Nov. 2, 2010]
[LLNL 2004]	Computer Simulation for Emergency Incident Management: Report of the Department of Homeland Security Incident Management Simulation Workshop. Lawrence Livermore National Laboratory. Report UCRL-CONF-208718. Available via: https://e-reports-ext.llnl.gov/pdf/314549.pdf [Accessed Sep. 5, 2011]
[LLNL 2010]	Incident Command Analytic Training System (ICATS): A Simulation Approach to Training Incident Managers. Systems and Decision Sciences Technology. Lawrence Livermore National Laboratory. Available via: https://www-eng.llnl.gov/sys_dec/sys_dec_training.html [accessed July 19, 2010].
[LLNL 2011]	DYNA3D. Methods Development Group. Lawrence Livermore National Laboratory. Available via: https://www-eng.llnl.gov/mdg/mdg_codes_dyna3d.html [accessed Jan. 12, 2011].
[Loud Squirrel 2011]	ED Simulation. Loud Squirrel, Inc. Available via: http://www.edsimulation.com/ [accessed Jan. 3, 2011].
[LSTC 2011]	LS-DYNA. Livermore Software Technology Corporation. Available via: http://www.lstc.com/lsdyna.htm [accessed Aug. 15, 2011]
[Martin 1996]	Martin, James N., Systems Engineering Guidebook: A Process for Developing Systems and Products, CRC Press, Inc.: Boca Raton, FL, 1996.
[Massaguer 2006]	Massaguer, D., V. Balasubramanian, S. Mehrotra, and N. Venkatasubramanian, 2006. Synthetic Humans in Emergency Response Drills. In Proceedings of Fifth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS'06), May 8–12, 2006, Hakodate, Hokkaido, Japan. Pages 1469–1470. Association for Computing Machinery (ACM), New York, NY.
[Mazzola 1995]	Mazzola, C.A., Addis, R.P., and Emergency Management Laboratory, 1995, Atmospheric Dispersion Modeling Resources, Second Edition. Available via: http://www6.uniovi.es/gma/admr.pdf - includes 94 tools identified in the 1995 survey.
[McGrath 2006]	McGrath, D., D. Hill, and A. Hunt, "IC2020: Embedded Simulation for Next Generation Incident Command Software", Proceedings of the 2006 Huntsville Simulation Conference, Huntsville, AL, 18-19 October 2006. Available on-line via: http://www.ists.dartmouth.edu/library/211.pdf [accessed July 19, 2010].
[McLean 2008]	McLean, C. R., Jain, S., and Lee, Y. T., 2008, A Taxonomy of Homeland Security Modeling, Simulation, and Analysis Applications, Proceedings of 2008 Spring Simulation Interoperability Workshop. Available via: http://www.nist.gov/customcf/get_pdf.cfm?pub_id=824440 [accessed August 12, 2011].
[MCMD 2011]	Montgomery County Government Map Viewer. Montgomery County, Maryland. Available via: http://gis2.montgomerycountymd.gov/ims/mcgmaps/viewer.htm [accessed Mar. 25, 2011].
[MIL 2010]	Vector Product Format (VPF) – MIL-STD-2407(1). DoD. Available via: http://www.gwg.nga.mil/documents/asfe/MIL-STD-2407(1).pdf [accessed Nov. 2, 2010]
[Moyer 2008]	Moyer, T. 2008. Full Ship Shock Test Modeling. High Performance Computing User Forum, April 2008, Norfolk, VA. Presentation available via: http://www.hpcuserforum.com/presentations/Norfolk/HPCMO_UF_UNDEX_Final.ppt [accessed Aug. 15, 2011]

[MYMIC 2010a]	Press Release: MYMIC LLC awarded new phase ii simulation contract award. Feb. 11, 2010. Available via: http://www.mymic.net/news.php?id=31 [accessed Jan. 3, 2011]
[MYMIC 2010b]	GameTT. MYMIC LLC. Available via: http://www.mymic.net/answers.php?id=4 [accessed Jan. 3, 2011]
[NARAC 2010a]	National Atmospheric Release Advisory Center. Lawrence Livermore National Laboratory. Available via: http://narac.llnl.gov [accessed Nov. 2, 2010]
[NARAC 2010b]	Overview of LLNL Services and Tools for the National Atmospheric Release Advisory Center (NARAC) and Interagency Modeling and Atmospheric Assessment Center (IMAAC). Lawrence Livermore National Laboratory. UCRL-PRES-223394-Rev1. https://narac.llnl.gov/uploads/Ovrvw-Aug2006-IM-Rev1_sxpav.pdf
[NARAC 2010c]	HOTSPOT: Health Physics Codes for the PC. National Atmospheric Release Advisory Center. Available via: https://www-gs.llnl.gov/hotspot/index.htm [accessed Nov. 2, 2010]
[NASA 2010a]	Flexible Image Transport System (FITS). National Aeronautics and Space Administration (NASA). Available via: http://fits.gsfc.nasa.gov/ [accessed Nov. 2, 2010]
[NASA 2010b]	Multi-angle Imaging SpectroRadiometer (MISR). National Aeronautics and Space Administration (NASA). Available via: http://www-misr.jpl.nasa.gov/ [accessed Nov. 2, 2010]
[NASA 2010c]	Plume Databases. National Aeronautics and Space Administration (NASA). Available via: http://www-misr2.jpl.nasa.gov/EPA-Plumes/suggestions4UsingData.cfm [accessed Nov. 2, 2010]
[NASA 2011]	EOS Data Gateway (EDG). NASA. Available via: http://outreach.eos.nasa.gov/EOSDIS_CD-02/docs/edgsteps.htm [accessed Mar. 25, 2011].
[NCDC 2011a]	National Environmental Satellite, Data, and Information Service ((NESDIS): Data Access Tools. NOAA. Available via: http://www.ncdc.noaa.gov/oa/dataaccesstools.html [accessed Mar. 25, 2011].
[NCDC 2011b]	National Environmental Satellite, Data, and Information Service ((NESDIS): Metadata Resources. NOAA. Available via: http://www.ncdc.noaa.gov/oa/metadata/metadataresources.html#ports [accessed Mar. 25, 2011].
[NCJRS 2010]	Guide for the Selection of Personal Protective Equipment for Emergency First Responders (Percutaneous Protection – Apparel). National Institute of Justice. Available via: http://www.ncjrs.gov/pdffiles1/nij/191521.pdf [accessed Nov. 2, 2010]
[NEMA 2010]	Digital Imaging and Communications in Medicine (DICOM). The Association of Electrical and Medical Imaging Equipment Manufacturers (NEMA). Available via: http://medical.nema.org/ [Accessed Dec. 12, 2010]
[NEMSIS 2010]	NEMSIS Tools. National EMS Information System (NEMSIS). Available via: http://www.nemsis.org/ [Accessed Dec. 12, 2010]
[NEMSIS 2011]	National EMS Information System (NEMSIS). Intermountain Injury Control Research Center, Salt Lake City, UT. Available via: http://www.nemsis.org/theProject/whatIsNEMSIS/index.html [accessed Mar. 25, 2011].
[Neuman 2006]	Neuman, S., L. Glascoe, B. Kosovic, K. Dyer, W. Hanley, J. Nitao and R. Gordon. 2006. Event Reconstruction with the Urban Dispersion Model. Lawrence Livermore National Laboratory. UCRL-PROC-216842. Available

	via: https://narac.llnl.gov/uploads/Neuman_et_al2006_EvenRecon_UDM_216842_wqejr.pdf [accessed Nov. 3, 2010]
[NFPA 2010]	NFPA 472: Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents. National Fire Protection Association (NFPA). Available via: http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=472&cookie%5Ftest=1 [Accessed Dec. 12, 2010]
[NFPA 2011]	NFPA Catalog. National Fire Protection Association (NFPA). Available via: http://www.nfpa.org/catalog/ [accessed Mar. 25, 2011].
[NGA 2011]	Military Standard Vector Product Format (VPF). Department of Defense. Available via: http://earth-info.nga.mil/publications/specs/printed/VPF/vpf.html [accessed Mar. 25, 2011].
[NGDC 2011]	National Geophysical Data Center. NOAA. Available via: http://www.ngdc.noaa.gov/ngdcinfo/accesssystems.html [accessed Mar. 25, 2011].
[NI2CIE 2009]	CARVER2. National Infrastructure Institute - Center for Infrastructure Expertise, Portsmouth, NH. Available via: http://www.ni2cie.org/CARVER2.asp [accessed Jan. 12, 2011].
[NIEM 2011]	National Information Exchange Model (NIEM). NIEM.gov. Available via: http://www.niem.gov/ [accessed Jan. 24, 2011].
[NIH 2010a]	ALTBIB – Bibliography on Alternatives to the Use of Live Vertebrates in Biomedical Research and Testing. U.S. National Library of Medicine (NLM), National Institutes of Health. Available via: http://www.nlm.nih.gov/pubs/factsheets/altbibfs.html [accessed Nov. 2, 2010]
[NIH 2010b]	TOXNET – Toxicology Data Network. U.S. National Library of Medicine (NLM), National Institutes of Health. Available via: http://toxnet.nlm.nih.gov/ [accessed Nov. 2, 2010]
[NIH 2010c]	Wireless Information System for Emergency Responders (WISER). U.S. National Library of Medicine (NLM), National Institutes of Health. Available via: http://wiser.nlm.nih.gov/ [accessed Nov. 2, 2010]
[NIH 2010d]	Clinical Data Repository (CDR). National Institutes of Health (NIH). Available via: http://www.cc.nih.gov/isd/cdr.html [Accessed Dec. 12, 2010]
[NIH 2010e]	Directory of Health Organizations. National Institutes of Health (NIH). Available via: http://dirline.nlm.nih.gov/ [Accessed Dec. 12, 2010]
[NIH 2010f]	Drug Information Portal. National Institutes of Health (NIH). Available via: http://www.nlm.nih.gov/pubs/factsheets/druginfoportalfs.html [Accessed Dec. 12, 2010]
[NIH 2010g]	Haz-Map: Occupational Exposure to Hazardous Agents. National Institutes of Health (NIH). Available via: http://hazmap.nlm.nih.gov/ [Accessed Dec. 12, 2010]
[NIJ 2002]	Crisis Information Management Software (CIMS) Feature Comparison Report. National Institute of Justice. Available on-line via: http://www.ncjrs.gov/pdffiles1/nij/197065.pdf. [accessed July 21, 2010]
[NIMCS 2010a]	Incident Command System Model Procedures Guide for Incidents Involving Structural Fire Fighting, High Rise, Multi Casualty, Highway, and Managing Large-Scale Incidents Using NIMS-ICS: Book 1. National Incident Management System Consortium (NIMCS). Available via: http://www.ims-consortium.org/NIMSBook1.htm [accessed Nov. 17, 2010]

[NIMCS 2010b]	Special Operations – Incidents Involving Hazardous Materials/WMD, Structural Collapse, Wildland, and Managing Large-Scale Incidents Using NIMS-ICS: Book 2. National Incident Management System Consortium (NIMCS). Available via: http://www.ims-consortium.org/NIMSBook2.htm [accessed Nov. 17, 2010]
[NISAC 2007]	Uncertainty Analysis of Pandemic Influenza Impacts on National Infrastructure: Supplement to the National Population and Infrastructure Impacts of Pandemic Influenza Report. National Infrastructure Simulation & Analysis Center, Infrastructure Analysis and Strategy Division Office of Infrastructure Protection, U.S. Department of Homeland Security, 15 October 2007. Available via: www.sandia.gov/nisac/docs/UncertaintyAnalysis.doc [accessed Jan. 12, 2011].
[NISAC 2009]	National Infrastructure Simulation and Analysis Center. SIERRA: System for Import/Export Routing and Recovery Analysis, Report to the Department of Homeland Security, 28 February 2009.
[NISAC 2010a]	National Infrastructure Simulation and Analysis Center. Sandia National Laboratories. Available via: http://www.sandia.gov/mission/homeland/programs/critical/nisac.html [accessed November 15, 2010]
[NISAC 2011a]	National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/ [accessed Jan. 12, 2011].
[NISAC 2011b]	Network Optimization Models. National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/net_op.html [accessed Jan. 12, 2011].
[NISAC 2011c]	Fast Analysis Infrastructure Tool (FAIT). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/fait.html [accessed Jan. 13, 2011].
[NISAC 2011d]	Interdependent Environment for Infrastructure System Simulations (IEISS). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/ieiss.html [accessed Jan. 13, 2011].
[NISAC 2011e]	Advanced Modeling & Techniques Investigation (AMTI). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/amti.html [accessed Jan. 13, 2011].
[NISAC 2011f]	Multi-Scale Integrated Information and Telecommunications System (MIITS). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/miits.html [accessed Jan. 13, 2011].
[NISAC 2011g]	NISAC Agent Based Laboratory for Economics (N-ABLE). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/nable.html [accessed Jan. 13, 2011].
[NISAC 2011h]	Transportation Analysis Simulation System (TRANSIMS). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/transims.html [accessed Jan. 13, 2011].
[NISAC 2011i]	Urban Infrastructure Suite (UIS). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/uis.html [accessed Jan. 13, 2011].
[NISAC 2011j]	Water Infrastructure Simulation Environment (WISE). National Infrastructure Simulation & Analysis Center. Available via: http://www.sandia.gov/nisac/wise.html [accessed Jan. 13, 2011].
[NIST 2008]	CONTAM 2.4. NIST Multizone Modeling Website. National Institute of Standards and Technology. Available via: http://www.bfrl.nist.gov/IAQanalysis/CONTAM/overview/1.htm [accessed

	Nov. 9, 2010]
[NIST 2009]	Fire Growth and Smoke Transport Modeling with CFAST. National Institute of Standards and Technology. Available via: http://fast.nist.gov/ [accessed Nov. 9, 2010]
[NIST 2010a]	FIPS Publications. National Institute of Standards and Technology (NIST). Available via: http://csrc.nist.gov/publications/PubsDrafts.html#800-66-Rev1[Accessed Dec. 12, 2010]
[NIST 2010b]	Fire Dynamics Simulator and Smokeview (FDS-SMV). National Institute of Standards and Technology. Available via: http://fire.nist.gov/fds/index.html [accessed Nov. 9, 2010]
[NIST 2011]	Strategic Goal: Measurement Science for Disaster-Resilient Structures and Communities. Engineering Laboratory. National Institute of Standards and Technology. Available via: http://www.nist.gov/el/disasterresilientstructuresgoal.cfm [accessed Aug. 30, 2011]
[NMAP 2011]	The National Map. U.S. Geological Survey. Available via: http://nationalmap.gov/ [accessed Mar. 25, 2011].
[NNSA 2010]	Federal Radiological Monitoring and Assessment Center. National Nuclear Security Administration. Available via: http://nnsa.energy.gov/aboutus/ourprograms/emergencyoperationscounterterrorism/respondingtoemergencies/consequencemanageme-1 [accessed Nov. 9, 2010]
[NOAA 2010a]	HYSPLIT – Hybrid Single Particle Lagrangian Integrated Trajectory Model. Air Resources Laboratory, National Oceanic and Atmospheric Administration (NOAA). Available via: http://www.arl.noaa.gov/HYSPLIT_info.php [accessed Nov. 2, 2010]
[NOAA 2010b]	Chemical Reactivity Worksheet (CRW). National Oceanic and Atmospheric Administration (NOAA). Available via: http://www.response.restoration.noaa.gov/type_subtopic_entry.php?RECORD_KEY(entry_subtopic_type)=entry_id,subtopic_id,type_id&entry_id(entry_subtopic_type)=328&subtopic_id(entry_subtopic_type)=24&type_id(entry_subtopic_type)=3 [accessed Nov. 2, 2010]
[NOAA 2010c]	National Climatic Data Center. National Oceanic and Atmospheric Administration (NOAA). Available via: http://www.ncdc.noaa.gov/climate-monitoring/index.php [accessed Nov. 2, 2010]
[NOAA 2010d]	Environmental Sensitivity Index (ESI) Maps. National Oceanic and Atmospheric Administration (NOAA). Available via: http://response.restoration.noaa.gov/type_subtopic_entry.php?RECORD_KEY%28entry_subtopic_type%29=entry_id,subtopic_id,type_id&entry_id(entry_subtopic_type)=74&subtopic_id(entry_subtopic_type)=8&type_id(entry_subtopic_type)=3 [accessed Nov. 2, 2010]
[NOAA 2010e]	Storm Prediction Center. National Oceanic and Atmospheric Administration (NOAA). Available via: http://www.spc.noaa.gov/products/ [accessed Nov. 2, 2010]
[NOAA 2010f]	Storm Prediction Center. National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA). Available via: http://www.spc.noaa.gov/products/ [accessed Nov. 17, 2010]
[NOAA 2011]	NWS Directives System, National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA). Available via: http://www.nws.noaa.gov/directives/faqs.htm [accessed July 20, 2011]

[NOAA 2011a]	Volcanic Ash Makes for Unfriendly Skies. National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Available via: http://www.noaa.gov/features/03_protecting/volcanicash.html [Accessed Sep. 3, 2011]
[NGA 2011a]	National Geospatial-Intelligence Agency. Digital Terrain Elevation Data. Available via: https://www1.nga.mil/ProductsServices/TopographicalTerrestrial/DigitalTerrainElevationData/Pages/default.aspx [accessed Sept. 8, 2011]
[NGA 2011b]	National Geospatial-Intelligence Agency. GEOIT Online. Available via: https://www1.nga.mil/GEOINTOnline/Pages/Overview.aspx [accessed Sept. 8, 2011]
[NRC 2002]	Committee on Science and Technology for Countering Terrorism, National Research Council, Making the Nation Safer: The Role of Science and Technology in Countering Terrorism. National Academy Press, Washington, DC, 2002.
[NRC 2003]	Committee on the Atmospheric Dispersion of Hazardous Material Releases, National Research Council, Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases: Implications for Homeland Security. National Academy Press, Washington, DC, 2003.
[NRC 2007a]	Committee on Planning for Catastrophe: A Blueprint for Improving Geospatial Data, Tools, and Infrastructure, National Research Council. Successful Response Starts with a Map: Improving Geospatial Support for Disaster Management. National Academy Press, Washington, DC, 2007.
[NRC 2007b]	Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications, Volume 1: Main Report. U.S. Nuclear Regulatory Commission Report no. NUREG-1824; Electric Power Research Institute Report no. EPRI 101199. Available via: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1824/v1/sr1824v1-final.pdf [accessed Sep. 19, 2011]
[NRC 2010]	NRC Freedom of Information Act (FOIA) Data. National Response Center (NRC). Available via: http://www.nrc.uscg.mil/foia.html [accessed Nov. 17, 2010]
[NRC 2011]	Computer Codes. U.S. Nuclear Regulatory Commission (NRC). Available via: http://www.nrc.gov/about-nrc/regulatory/research/comp-codes.html [accessed Aug. 30, 2011]
[NREL 2011]	Dynamic Maps, GIS Data, and Analysis Tools. National Renewable Energy Laboratory. Available via: http://www.nrel.gov/gis/about.html [accessed Mar. 25, 2011].
[NRL 2010a]	COAMPS Overview. Marine Meteorology Division. Naval Research Laboratory. Available via: http://www.nrlmry.navy.mil/coamps-web/web/view [accessed Nov. 2, 2010]
[NRL 2010b]	CT-Analyst. Technology Transfer Office, Naval Research Laboratory. Available via: http://www.nrl.navy.mil/techtransfer/fs.php?fs_id=IT05 [accessed Nov. 2, 2010]
[NSIDC 2010]	Hierarchical Data Format-Earth Observing System (HDS-EOS). National Snow and Ice Data Center (NSIDC). Available via: http://nsidc.org/data/hdfeos/ [accessed Nov. 2, 2010]
[NTCIP 2011]	The National Transportation Communications for ITS Protocol (NTCIP) ONLINE Resource. NTCIP. Available via: http://www.ntcip.org/library/documents/ [accessed Mar. 25, 2011].

[NWS 2010a]	Digital Weather Markup Language Specification. National Weather Service (NWS). Available via: http://www.nws.noaa.gov/mdl/XML/Design/MDL_XML_Design.pdf [accessed Nov. 2, 2010]
[NWS 2011a]	National Digital Forecast Database. National Weather Service. Available via: http://www.nws.noaa.gov/ndfd/ [accessed Mar. 25, 2011].
[NWS 2011b]	File/Web Services Retrieval Procedures. National Weather Service. Available via: http://www.nws.noaa.gov/tg/dataprod.html [accessed Mar. 25, 2011].
[NYU 2009]	Planning with Large Agent-Networks against Catastrophes (PLAN C). Center for Catastrophe Preparedness & Response, New York University. Available via: http://www.nyu.edu/ccpr/laser/plancinfo.html [accessed Nov. 21, 2010]
[NYU-CCPR 2009]	Planning with Large Agent-Networks against Catastrophes (PLAN C). The Center for Catastrophe Preparedness & Response, New York University. Available via: http://www.nyu.edu/ccpr/laser/plancinfo.html [accessed Jan. 3, 2011]
[OASIS 2010a]	Application Security Standards. Organization for the Advancement of Structured Information Standards (OASIS). Available via: http://xml.coverpages.org/appSecurity.html [accessed Nov. 17, 2010]
[OASIS 2010b]	XML and Emergency Management. Organization for the Advancement of Structured Information Standards (OASIS). Available via: http://xml.coverpages.org/emergencyManagement.html [accessed Nov. 17, 2010]
[OASIS 2011a]	Common Alert Protocol (CAP). Organization for the Advancement of Structured Information Standards (OASIS). Available via: http://www.oasis-emergency.org/cap [accessed Jan. 15, 2011].
[OASIS 2011b]	Emergency Data Exchange Language (EDXL). Organization for the Advancement of Structured Information Standards (OASIS). Available via: http://xml.coverpages.org/edxl.html [accessed Mar. 25, 2011].
[ODATSD 2010]	Specialized Radiological Monitoring and Hazard Assessment Capabilities. Internet supplement to DRAFT DoD 3150.08-M "Nuclear Weapon Accident Response Procedures" (NARP). Office of the Deputy Assistant to the Secretary of Defense for Nuclear Matters (ODATSD(NM)). Available via: http://www.acq.osd.mil/ncbdp/narp/Radiation_Data/Specialized_Radiological.htm [accessed Nov. 2, 2010]
[OFCM 2004]	Federal R&D Needs and Priorities for Atmospheric Transport & Diffusion. Office of the Federal Coordinator for Meteorological Services and Supportng Research, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Report FCM-R23-2004. Sep. 2004. Available via: http://www.ofcm.gov/r23/r23-2004/fcm-r23.htm [Accessed Sep. 1, 2011]
[OFCM 2010a]	Office of the Federal Coordinator for Meteorology (OFCM) Directory of Atmospheric Transport and Diffusion Consequence Assessment Models (http://www.ofcm.gov/atd_dir/pdf/frontpage.htm) – includes 63 tools identified in a survey in 1999.
[OFCM 2010b]	General and Specific Characteristics of the model: VLSTRACK. Office of the Federal Coordinator for Meteorology (OFCM). Available via: http://www.ofcm.gov/atd_dir/pdf/vlstrack.pdf [accessed Nov. 9, 2010]
[OFCM 2011]	OFCM Highlights for Fiscal Year 2010 and Plans for Fiscal Year 2011. Office of the Federal Coordinator for Meteorological Services and Supporting Research, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 2011. Available via:

	http://www.ofcm.gov/homepage/text/FedCoordandPlanningFY2011.pdf [Accessed Sep. 1, 2011]
[OGC 2010]	Critical Infrastructure Protection Initiative. Open Geo-spatial Consortium (OGC). Available via: http://www.opengeo-spatial.org/projects/initiatives/cipi1.2 [accessed Nov. 17, 2010]
[OGC 2011a]	CityGML: OpenGIS City Geography Markup Language Encoding Standard. Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.opengeo-spatial.org/standards/citygml [accessed Jan. 15, 2011].
[OGC 2011b]	OGC KML. Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.opengeo-spatial.org/standards/kml [accessed Mar. 25, 2011].
[OGC 2011c]	Simple Feature Access. Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.opengeo-spatial.org/standards/sfa [accessed Mar. 25, 2011].
[OGC 2011d]	Tiger/GML - U.S. Census. Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.ogcnetwork.net/node/220 [accessed Mar. 25, 2011].
[OGC 2011e]	Web Coverage Service (WCS). Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.opengeo-spatial.org/standards/wcs [accessed Mar. 25, 2011].
[OGC 2011f]	OpenGIS Web Feature Service (WFS) Implementation Specification. Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.opengeo-spatial.org/standards/wfs [accessed Mar. 25, 2011].
[OGC 2011g]	OpenGIS Web Map Service (WMS) Implementation Specification. Open Geo-spatial Consortium, Inc. (OGC). Available via: http://www.opengeo-spatial.org/standards/wms [accessed Mar. 25, 2011].
[OJP 2010]	The Global Justice XML Data Model (Global JXDM). U.S. Department of Justice. Available via: http://it.ojp.gov/jxdm/ [accessed Nov. 17, 2010]
[OMG 2011]	OMG Systems Modeling Language (SysML). Object Management Group, Inc. (OMG). Available via: http://omgsysml.org/ [accessed Mar. 25, 2011].
[Optima 2011]	Optima Predict. The Optima Corporation. Available via: http://www.theoptimacorporation.com/optima-predict [accessed Jan. 3, 2011].
[ORAU 2010]	Chemical Protective Action Criteria (PACs)/ Temporary Emergency Exposure Limit (TEEL) Values. U.S. Department of Energy. Available via: http://orise.orau.gov/emi/scapa/teels.htm [accessed Nov. 2, 2010]
[ORNL 2004]	Visual Interactive Site Analysis Code (VISAC). Oak Ridge National Laboratory. Available via: http://visac.ornl.gov/ [accessed Jan. 13, 2011].
[ORNL 2006]	WebTRAGIS: Transportation Routing Analysis Geographic Information System. Oak Ridge National Laboratory. Available via: https://tragis.ornl.gov/ [accessed Jan. 13, 2011].
[ORNL 2010a]	Radiation Safety Information Computational Center, Oak Ridge National Laboratory. Available via: https://www-rsicc.ornl.gov/ [accessed Nov. 3, 2010]
[ORNL 2010b]	RASCAL 3.0.5: Radiological Assessment for Consequence AnaLysis for Windows, Version December 2006 with December 2008 Updates. Code package CCC-553. Radiation Safety Information Computational Center, Oak Ridge National Laboratory. Available via: http://www-rsicc.ornl.gov/codes/ccc/ccc5/ccc-553.html [accessed Nov. 3, 2010]
[ORNL 2010c]	Guidelines for Archiving Data in the NARSTO Permanent Data Archive. North American Research Strategy for Tropospheric Ozone (NARSTO). Available via: http://cdiac.ornl.gov/programs/NARSTO/Guidelines_for_Archiving_NARSTO_Data.pdf [accessed Nov. 3, 2010]

[ORNL 2010d]	Oak Ridge Evacuation Modeling System. Oak Ridge National Laboratory. Available via: http://emc.ornl.gov/CSEPPweb/CSEPPOREMS.html [accessed Nov. 22, 2010]
[ORNL 2010e]	VISAC Visual Interactive Site Analysis Code. Oak Ridge National Laboratory. Available via: http://visac.ornl.gov/ [accessed Nov. 21, 2010]
[ORNL 2011]	Oak Ridge National Laboratory (ORNL). LandScan. Available via: http://www.ornl.gov/sci/landscan/ [accessed Aug. 26, 2011]
[OSTI 2010]	Turbo FRMAC 2.0. Software Abstract. Energy Science & Technology Software Center. Office of Science and Technology Information. U.S. Department of Energy. Available via: http://www.osti.gov/estsc/details.jsp?rcdid=4250 [accessed Nov. 9, 2010]
[Outkin 2006]	Outkin, A. and S. Flaim, 2006. FinSim: Financial Infrastructure as a Complex Decentralized System. 26th Annual Conference of Center for Nonlinear Studies Socio-Technical Systems: Bridging the Scales. August 14-18, Oppenheimer Center, Los Alamos National Laboratory, Los Alamos, NM, USA. Abstract available via: http://cnls.lanl.gov/annual26/abstracts.html [accessed March 11, 2010].
[Pederson 2006]	Pederson, P., D. Dudenhoeffer, S. Hartley, and M. Permann. 2006. Critical Infrastructure Interdependency Modeling: A Survey of U.S. and International Research. August 2006. Idaho National Laboratory. Available via: http://www.inl.gov/technicalpublications/Documents/3489532.pdf [accessed Jan.12, 2011].
[Pittman 2010]	Pittman, E. 2010. L.A. Police Department's Hydra System Promotes Training for Command-Level Officers. Emergency Management. September 14, 2010. Available via: http://www.emergencymgmt.com/training/LA-Police-Department-Training-Hydra.html [accessed November 21, 2010]
[Powell 2007]	Powell, D., B. Bush, L. Dauelsberg, D. LeClaire, S. DeLand, and M. Samsa, 2007. Critical Infrastructure Protection Decision Support System Overview. Los Alamos National Laboratory report LAUR-07-1769.
[Previstar 2008]	Previstar Continual Preparedness System. Previstar, Inc. Available via: http://www.previstar.com/Solutions/solutions_em.asp [accessed Nov. 21, 2010]
[ProModel 2010a]	ED Simulator™ - because "Best Practices don't always yield Best Results©. ProModel Corporation. Available via: http://www.promodel.com/products/edsimulator/ [accessed Jan. 3, 2011].
[ProModel 2010b]	MedModel – The Industry Standard for Healthcare Simulation. ProModel Corporation. Available via: http://www.promodel.com/products/medmodel/ [accessed Jan. 3, 2011].
[PUCO 2011]	Public Utilities Commission Interactive Maps. The Public Utilities Commission of Ohio. Available via: http://www.puco.ohio.gov/PUCO/GIS/MapInfo.cfm?id=5754 [accessed Mar. 25, 2011]
[RAND 2010a]	Database of Worldwide Terrorism Incidents. RAND Corporation. Available via: http://www.rand.org/nsrd/projects/terrorism-incidents/about/scope.html [accessed Nov. 17, 2010]
[RAND 2010b]	Public Health Systems and Preparedness. RAND Corporation. Available via: http://www.rand.org/health/centers/preparedness.html [accessed Nov. 17, 2010]
[RAND 2010c]	RAND Databases and Research Tools. RAND Corporation. Available via: http://www.rand.org/about/tools.html [Accessed Dec. 12, 2010]
[Redfish 2011]	Agent-Based Model of Crowd Dynamics During Disaster Evacuation. Redfish Group. Available via: http://www.redfish.com/stadium/ [accessed Sep. 1, 2011]

[Rinaldi 2004]	Rinaldi, S. (2004). "Modeling and simulating critical infrastructure and their interdependencies." 37th Hawaii International Conf. on System Science, IEEE Available via: http://portal.acm.org/citation.cfm?id=962881 [accessed Jan9, 2011]
[RKB 2010]	Responder Knowledge Base (RKB). The Federal Emergency management Agency (FEMA). Available via: https://www.rkb.us/ [accessed Nov. 17, 2010]
[Roney 2010]	Roney, J.A., D.A. Burrows, C. Tobin. 2010. RUSTIC/MESO, a rapid transport and dispersion modeling system. The Fifth International Symposium on Computational Wind Engineering (CWE2010), Chapel Hill, North Carolina, USA May 23-27, 2010. Available via: ftp://ftp.atdd.noaa.gov/pub/cwe2010/Files/Papers/544_Roney.pdf [accessed Nov. 9, 2010]
[RSSBOARD 2010]	RSS Specification, Tutorials, Discussion. Really Simple Syndication (RSS) Advisory Board. Available via: http://www.rssboard.org/rss-specification [accessed Nov. 17, 2010]
[SAE 2011a]	On-Board Land Vehicle Mayday Reporting Interface. SAE International. Available via: http://standards.sae.org/j2313_199909/ [accessed Mar. 25, 2011].
[SAE 2011b]	Converting Atis Message Standards from Asn.1 to XML. SAE International. Available via: http://www.sae.org/servlets/works/documentHome.do?comtID=TEITSATIS&docID=J2630_200312&inputPage=dOcDeTaIlS [accessed Mar. 25, 2011].
[Saeger 2007]	Saeger, K., J. Ambrosiano, R.M. Roberts, and T. Cleland, 2007. CrowdSim: An Agent-based Framework for Simulating Large-crowd Dynamics. 2007 Risk Symposium, March 26-28 2007, Santa Fe, New Mexico.
[SAIC 2011]	Integrated Water Quality Security System (IWQSS). Science Applications International Corporation (SAIC). Available via: http://eh2o.saic.com/iwqss/ [accessed Jan. 13, 2011]
[SAIC 2011a]	Consequences Assessment Tool Set (CATS). Science Applications International Corporation (SAIC). Available via: http://www.saic.com/products/security/cats/ [accessed Sep. 1, 2011]
[Samuelson 2007]	Samuelson, D. A. 2007. Mass Egress and Post-disaster Responses. OR/MS Today - October 2007. Available via: http://www.orms-today.org/orms-10-07/mass.html [accessed Sep. 1, 2011]
[Sandia 2008]	Sandia's BioWatch Indoor Reachback Center contributing to Department of Homeland Security effort. Press Release. Sandia National Laboratory. March 13, 2008. Available via: https://share.sandia.gov/news/resources/releases/2008/biowatch.html [accessed Nov. 9, 2010]
[Sandia 2011]	CTH Shock Physics. Sandia National Laboratories. Available via: http://www.sandia.gov/CTH/ [accessed Aug. 15, 2011]
[Schanze 2007]	Schanze, J., and A. Sauer. 2007. Development of DSS for long-term planning – Review of existing tools. Report number T18-06-01. Sixth Framework Programme for European Research and Technological Development. February 2007. Available via: http://www.floodsite.net/html/partner_area/project_docs/T18_06_01_DSS_Review_D18_1_V2_2_P01.pdf [accessed Aug. 15, 2011]
[SEDRIS 2011a]	The Source for Environmental Data Requirement & Interchange. SEDRIS.org. Available via: http://sedris.org/ [accessed Mar. 25, 2011].
[SEDRIS 2011b]	SEDRIS Data. SEDRIS.org. Available via: http://data.sedris.org/ [accessed Mar. 25, 2011].

[SERRI 2007]	Fact Sheet: South East Regional Research Initiative, Department of Homeland Security. Available via: http://www.serri.org/publications/Documents/Ole%20Miss%20Project%206388 8%20Fact%20Sheet%20on%20Particle%20Dynamics%20Simulation%20(Chen g).pdf. [accessed Jan. 12, 2011].
[SFGOV 2011]	San Francisco Enterprise GIS Program. City and County of San Francisco. Available via: http://gispub02.sfgov.org/ [accessed Mar. 25, 2011].
[Shih 2009]	Shih, C.Y., C.D. Scown, L. Soibelman, H.S. Matthews, J.H. Garrett Jr., K. Dodrill, and S. McSurdy, 2009. Data Management for Geo-spatial Vulnerability Assessment of Interdependencies in U.S. Power Generation. Journal of Infrastructure Systems, Vol. 15, No. 3, September. 179–189.
[SIMBIOS 2010]	Simbios: NIH Center for Biomedical Computation at Stanford. Available via: http://simbios.stanford.edu/ [accessed Dec. 29, 2010]
[Simulia 2011]	Abaqus Multiphysics. Simulia, Dassault Systèmes. Available via: http://www.simulia.com/products/abaqus_multiphysics.html [accessed Aug. 15, 2011]
[Smith 2005]	Smith, T.R., 2005. Joint Effects Model (JEM) Briefing to CBIS. Joint Project Manager Information Systems. Available via: http://www.dtic.mil/ndia/2005st_cbis/tuesday/smith.pdf [accessed Nov. 3, 2010]
[Stanford 2010]	Simulation Modalities. Center for Immersive and Simulation-based Learning, Stanford School of Medicine. Available via: http://cisl.stanford.edu/what_is/sim_modalities/ [accessed Dec. 29, 2010]
[START 2010]	Global Terrorism Database (GTD). National Consortium for the Study of Terrorism and Responses to Terrorism (START). Available via: http://www.start.umd.edu/gtd/ [accessed Nov. 17, 2010]
[Stroud 2007]	Stroud P.D., S.Y. Del Valle, S.J. Sydoriak, J.M. Riese, and S.M. Mniszewski, 2007. Spatial Dynamics of Pandemic Influenza in a Massive Artificial Society. Journal of Artificial Societies and Social Simulation 10(4)9. Available on-line via: http://jasss.soc.surrey.ac.uk/10/4/9.html. [Accessed July 21, 2010]
[Sveen 2010]	Sveen, F.O., E. Rich, J.M. Torres, J. Hernantes, and J.J. Gonzalez, 2010. A Group Model Building Approach for Identifying Simulation Scenarios in Critical Infrastructure. 43rd Hawaii International Conference on System Sciences. Koloa, Kauai, Hawaii, January 05-January 08.
[TEEX 2010]	Emergency Operations Training Center. Texas Engineering Extension Service. Available via: http://www.teex.com/teex.cfm?pageid=NERRTCprog&area=NERRTC&templateid=1800 [accessed Nov. 21, 2010]
[THEDATAWEB 2010]	TheDataWeb. U.S. Census Bureau. Available via: http://www.thedataweb.org/browser.html [Accessed Dec. 12, 2010]
[TISN 2010]	TISN for Critical Infrastructure Resilience: Modelling and Analysis. Trusted Information Sharing Network (TISN), Commonwealth of Australia. Available via: http://www.tisn.gov.au/www/tisn/content.nsf/Page/Modelling_and_analysis [accessed Jan. 12, 2011].
[TNRIS 2010]	Texas Natural Resources Information System (TNRIS). Texas Water Development Board. Available via: http://www.tnris.state.tx.us/DataCatalog/Index.aspx [accessed Nov. 17, 2010]
[TSS 2010]	Aimsun: The Integrated Transport Modeling Software. Transport Simulation Systems. Available via: http://www.aimsun.com/site/ [accessed Jan.12, 2011].

[U.S. Army 2007]	Secret Service Training Environments. America's Army Information Site. U.S. Army. Available via: http://info.americasarmy.com/projects.php?id=5 [accessed Nov. 22, 2010]
[UBC 2007]	Infrastructure Interdependencies Simulation (I2SIM) Team. University of British Columbia, Canada. http://www.ece.ubc.ca/~jiirp/ [accessed Jan. 13, 2011].
[UCAR 2010]	NCAR Research Applications Laboratory: National Security Applications Program. University Corporation for Atmospheric Research, Boulder, CO. Available via: http://www.ral.ucar.edu/nsap/ [accessed Nov. 3, 2010]
[Uddin 2009]	Uddin, M.Y.S., D. Nicol, T. Abdelzaher, and R. Kravets, 2009. A Post-Disaster Mobility Model for Delay Tolerant Networking. In Proceedings of the 2009 Winter Simulation Conference, eds. M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin, and R. G. Ingalls, Piscataway, NJ: IEEE. 2785-2796.
[UIC 2011]	National Emergency Medical Services Information System (NEMSIS). U.S. Department of Transportation. Available via: http://www.uic.edu/depts/glstrknet/doc/NEMSIS_Data_Dictionary_v2.2.1.pdf [accessed Mar. 25, 2011].
[UICDS 2010]	Unified Incident Command and Decision Support (UICDS) . Department of Homeland Security. Available via: http://www.uicds.us/files/UICDS%20in%20Brief%20Gov.pdf [accessed Nov. 17, 2010]
[UMD 2011]	Global Terrorism Database. National Consortium for the Study of Terrorism and Responses to Terrorism (START). Available via: http://www.start.umd.edu/gtd/about/GTDTeam.aspx [accessed Mar. 25, 2011].
[UNEP 2010]	GEO Data Portal. United Nations Environment Programme. Available via: http://geodata.grid.unep.ch/ [accessed Nov. 3, 2010]
[USACE 2010]	Fort Future Utilities Analysis Tools. Engineering Research and Development Center, U.S. Army Corps of Engineers. Available via: http://www.cecer.army.mil/td/tips/product/details.cfm?ID=736 [accessed Jan. 13, 2011].
[USACE 2011]	Discrete Element Modeling of Debris, Ice, Barges, and Tows. Engineering Research and Development Center, U.S. Army Corps of Engineers. Available via: http://www.erdc.usace.army.mil/pls/erdcpub/docs/erdc/images/Discrete_Element_Modeling_of_debris.pdf [accessed Jan. 12, 2011].
[USCG 2010]	NRC FOIA Data. National Response Center (NRC). Available via: http://www.nrc.uscg.mil/foia.html [accessed Nov. 3, 2010]
[USDA 2010]	USDA Forest Service Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire Mapping Program. U.S. Department of Agriculture. Available via: ttp://activefiremaps.fs.fed.us/faq.php [accessed Nov. 17, 2010]
[USFA 2010a]	National Fire Department Census Database. U.S. Fire Administration, Federal Emergency Management Agency, U.S. Department of Homeland Security. Available via: http://www.usfa.dhs.gov/applications/census/ [accessed Nov. 17, 2010]
[USFA 2010b]	National Fire Incident Reporting System. U.S. Fire Administration, Federal Emergency Management Agency, U.S. Department of Homeland Security. Available via: http://nfirs.fema.gov/?eventsDate=2009-09 [accessed Nov. 22, 2010]
[USFA 2010c]	Simulation Laboratory. U.S. Fire Administration, Federal Emergency Management Agency, U.S. Department of Homeland Security. Available via:

	http://www.usfa.dhs.gov/fireservice/subjects/incident/simlab.shtm [accessed Nov. 22, 2010]
[USFA 2011]	National Fire Department Census. U.S. Fire Administration. Available via http://www.usfa.dhs.gov/applications/census/ [accessed Mar. 25, 2011].
[USGS 2010]	Earthquake Hazards Program. U.S. Geological Survey. Available via: http://earthquake.usgs.gov/earthquakes/catalogs/ [accessed Nov. 17, 2010]
[USGS 2010b]	Hazards Data Distribution System (HDDS). U.S. Geological Survey (USGS). Available via: http://hdds.usgs.gov/hdds2/ [accessed Nov. 3, 2010]
[USGS 2011a]	USGS Response to an Urban Earthquake Northridge '94. U.S. Geological Survey. Available via: http://pubs.usgs.gov/of/1996/ofr-96-0263/commun.htm [accessed Jan. 15, 2011].
[USGS 2011b]	National Geochemical Survey Database. U.S. Geological Survey. Available via: http://tin.er.usgs.gov/geochem/ [accessed Mar. 25, 2011]
[USGS 2011c]	The Geographic Names Information System (GNIS). U.S. Geological Survey. Available via: http://geonames.usgs.gov/domestic/index.html [Accessed Mar. 25, 2011]
[USU 2010]	National Capital Area Medical Simulation Center. Uniformed Services University. Available via: http://simcen.usuhs.edu/ [accessed Dec. 29, 2010]
[UWA 2011]	Spatial Data Modelling Language (SDML). Available via: http://local.wasp.uwa.edu.au/~pbourke/dataformats/sdml/index.html [accessed Mar. 25, 2011].
[Wall 2009]	Wall, J. 2009. Panel: Regional Initiatives in Modeling & Simulation: Southwest & Midwest. 2009 Modeling & Simulation Leadership Summit. National Defense Industrial Association. Available via: http://proceedings.ndia.org/91C0/Panel3/4_Wall.ppt [accessed Nov. 21, 2010]
[Walsh 2009]	Walsh, S., S. Cherry, and L. Roybal, 2009. Critical infrastructure modeling: an approach to characterizing interdependencies of complex networks & control systems. In *Proceedings of the 2nd Conference on Human System interactions* (Catania, Italy, May 21 – 23, 2009). IEEE Press, Piscataway, NJ, 634-638.
[Wang 2008]	Wang, J., D. Rosca, W. Tepfenhart, A. Milewski, and M. Stoute, 2008. Dynamic Workflow Modeling and Analysis in Incident Command Systems. IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans. Vol. 38 Issue 5, pages 1041 - 1055.
[WARRP 2011]	Wide Area Recovery & Resiliency Program (WARRP). Available via: http://www.warrp.org/[accessed Aug. 30, 2011]
[WCNY 2011]	Geographic Information Systems: Mapping Westchester County. Westchester County. Available via: http://giswww.westchestergov.com/gismap/default.aspx? [accessed Mar. 25, 2011].
[WEB3D 2011a]	The Virtual Reality Modeling Language (VRML). Available via: http://www.web3d.org/x3d/specifications/vrml/VRML1.0/index.html [accessed Mar. 25, 2011].
[WEB3D 2011b]	X3D. Web/3D Consortium. Available via: http://www.web3d.org/about/overview/ [accessed Mar. 25, 2011].
[WHO 2011a]	Communicable Disease Surveillance and Response Systems. World Health Organization. Available via: http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_1.pdf [accessed Mar. 25, 2011].
[WHO 2011b]	WHO Pandemic Phase Descriptions and Main Actions by Phase. World Health Organization. Available via:

	http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_2.pdf [accessed Mar. 25, 2011].
[WHO 2011c]	World Health Organization. Available via: http://www.who.int/csr/disease/influenza/pandemic_phase_descriptions_and_actions.pdf [accessed Mar. 25, 2011].
[WHO 2011d]	Global Alert and Response (GAR): Protocol for the Assessment of National Communicable Disease Surveillance and Response Systems. Guidelines for Assessment Teams. World Health Organization. Available via: http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_CSR_ISR_2001_2_EN/en/ [accessed Mar. 25, 2011].
[WHO 2011e]	Global Alert and Response (GAR): WHO SARS Risk Assessment and Preparedness Framework October 2004. World Health Organization. Available via: http://www.who.int/csr/resources/publications/WHO_CDS_CSR_ARO_2004_2/en/index.html [accessed Mar. 25, 2011].
[WISER 2010]	Wireless Information System for Emergency Responders (WISER). U.S. National Library of Medicine (NLM). Available via: http://wiser.nlm.nih.gov/ [accessed Nov. 17, 2010]
[WMO 2010a]	A Guide to the Code Form FM 92-IX Ext. GRIB. World Health Organization. Available via: http://www.wmo.int/pages/prog/www/WDM/Guides/Guide-binary-2.html [accessed Nov. 3, 2010].
[WRF 2010]	The Weather Research and Forecasting Model. Available via: http://wrf-model.org/index.php [accessed Nov. 9, 2010]
[YNHHS 2010]	Weapons of Mass Destruction (WMD), Emergency Management and Medical Web Sites. Available via: http://www.ynhhs.org/emergency/US_DHHS_web_sites.pdf [Accessed Dec. 12, 2010]
[YSASoft 2009]	The next generation atmospheric model A2C, Atmosphere to CFD. YSA Soft. Available via: http://www.ysasoft.com/software/capabilities.html [accessed Nov. 2, 2010]
[Zajic 2010]	Zajic, D., M.J. Brown, and M.D. Williams. 2010. Source Inversion For Ground-Level Line Source Releases In Steady-State Conditions. 16th Conference on Air Pollution Meteorology. January 17-21. Atlanta, GA. Available via: http://ams.confex.com/ams/90annual/techprogram/paper_163296.htm [accessed Nov. 9, 2010]
[Zhang 2005]	Zhang, P., Peeta, S., and Friesz, T. 2005. “Dynamic Game Theoretic Model of Multi-Layer Infrastructure Networks,” Networks and Spatial Economics, Vol. 5, No. 2, pp. 147-178.

Appendix A – Capabilities and Requirements Specifications

This section provides a high level list of capabilities and requirements for homeland security model implementations. Capabilities and requirement specifications are categorized into five major areas:

- Intended Use,
- Functionality,
- Data,
- User interfaces,
- Performance, and
- Verification, validation, and accreditation.

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

A.1 - HMR M&S Capabilities and Requirements

A.1.1 - Intended Use

Incident managers and emergency planners, support and training personnel will use hazardous material release models and simulations to:

a) Analyze hazardous material releases and provide predictive data to incident management personnel.
b) Support training exercises, drills, emergencies, tests, alerts, and real world incidents (terrorist attacks, industrial accidents, and natural disasters, e.g., clouds from volcanic eruptions).
c) Determine the readiness of healthcare systems to respond to various types of emergencies.
d) Model past hazardous material releases for education, training, and analysis purposes.

A.1.2 - Functionality

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.

A.1.3 - Data

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, anthropogenic heating, direction, and precipitation
b) Source description data to define the scenario in the source model (where, when, what, how much). For example:
    - Plume release mechanisms and their attributes: explosions, fires, compressed gas cylinders, tank ruptures, and manual release of powders
    - 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)
c) Hazardous agent characteristics including form (gas, liquid, or powder), chemical and physical properties, material properties, particle size and weight distributions, cohesion, and lethality
d) Specification of the incident area including location of source, terrain, and buildings, geo-spatial data, and data on critical infrastructure in the area that may be affected
e) Population location, density, and attributes by time of day
f) Demographics data
g) Health action levels associated with the known or suspected released agents

A.1.4 - User Interfaces

This section identifies user interface capabilities that may be supported for hazardous material release models and simulations. The user interface requirements will depend on the scope and capabilities of the M&S application. For example, the requirements will be different for a system that can quickly run on a laptop at the incident site to determine immediate risks as compared to systems that can provide predictions over time and over a large area at higher accuracies with support from experts for interpretation of results. The brief list below provides high level requirements as a starting point; additional requirements will need to be developed based on the scope and the user for specific applications and should be driven by user domain analysis.

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 on the fly
c) Generate graphical views of plume dispersion over a 2D or 3D representation of area of interest with appropriate legends and documentation
d) Provide user control mechanisms that effect rapid execution/playback of animation to move forward and back to desired points in time
e) Use various standard 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 (such as Keyhole Markup Language (KML) files, shape files to input GIS systems) that can be used to transfer results for viewing or playback using other software tools
g) Provide output products in standardized formats including graphical and associated metadata and data files based on type of release and users
h) Specify uncertainty using appropriate graphical and numerical means in various output products
i) Provide interpretation of output products and what it means while identifying the impact of assumptions used in the model
j) Define legal coverage and disclaimers as appropriate for indemnification

A.1.5 - Performance

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

A.1.6 – Credibility and Evaluation

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

A.2 - Critical Infrastructure M&S Capabilities and Requirements

This section translates the high level needs discussed in the previous section to a set of requirements. The requirements are intended to be common across all the CI and hence at a high level. These requirements will serve as the starting set that may need to be enhanced for specific CI for unique intended use. A separate document with a more detailed set of common requirements is being developed in a related effort.

A.2.1 - Intended Use

CIKR models and simulations will be used by analysts, CIKR managers, emergency planners, first responders, and training personnel to:

a) Analyze the resource requirements, behavior, and performance of CIKR systems,
b) Determine the readiness of CIKR systems to respond to various types of emergencies,
c) Analyze interdependencies between CIKR systems,
d) Model past incidents and system failures for education, training, and analysis purposes,
e) Evaluate security measures and practices developed for CIKR systems, and
f) Conduct training exercises, drills, emergencies, tests, alerts, real world incidents, and planning for national security events.

A.2.2 - Functionality

This section identifies possible functions and capabilities that may be included in CIKR models and simulations.

a) Create and evaluate models/computer simulations that provide more information about interdependencies, and promote rapid response, repair, and recovery from attacks
b) Simulate incidents requiring a response based on policies and procedures established for the entity involved
c) Predict the impact of vulnerabilities and protective measures
d) Create simulations and tabletop exercises for national-level multi-agency events
e) Conduct tabletop exercises that simulate real-world security emergency in order to assess and improve the emergency response and preparedness of owners and operators, State and local law enforcement, and local emergency responders
f) Simulate response to catastrophic incidents
g) Simulate threats, identify vulnerabilities in CIKR systems, measure potential impacts, and evaluate countermeasure, mitigation, and response strategies
h) Perform cross-sector interdependency analyses
i) Test facilities protective measures using trained teams of simulated adversaries to help asset owners and operators determine the effectiveness of their protection programs and prepare staff to respond quickly and properly in the event of an actual incident
j) Establish capabilities for modeling and simulation of strategies for quickly evacuating large crowds (e.g., 50,000–130,000 individuals)
k) Develop modeling and simulation methods to determine the resilience of the sector when an event or incident occurs
l) Create multi-use tools that supports situational awareness, command and control operations, planning, simulations, research, training, and re-analysis of past events
m) Conduct cyber-security assessments of control systems and related technologies
n) Develop advanced control system technologies using modeling and simulation to better evaluate risk

o) Develop and participate in threat simulations and exercises, including those that test cyber-security readiness and response capabilities
p) Use system studies, models, simulations, and analyses to identify, develop, and submit gaps that represent mission needs
q) Provide simulations to train security personnel to secure facilities against a potential attack and handle the aftermath of an attack
r) Provide simulation capabilities for modeling, simulation, and visualization of the Internet as it relates to each CIKR sector
s) Setup more realistic simulations of failure scenarios and the consequences of full or partial failure of CIKR systems
t) Provide capabilities to model chains-of-events, transactions, etc. that lead to CIKR system failures
u) Provide software resources including the tools, models, and communications databases needed to assess network performance, perform modeling and simulation, and visualize network topologies as they relate to CIKR systems
v) Provide capabilities for dependency identification and its utility with other sectors for their own risk analysis and management efforts
w) Support broader national-level interdependency analyses conducted by enhancing the modeling and simulation capabilities of national laboratories and government agencies
x) Provide functions to create high level models of CIKR evolutions over time to support analysis of system vulnerabilities, security, readiness, performance and resource requirements
y) Provide training and exercise simulations for CIKR systems that provide functionality for various incident and exercise parameters, exercise control, and after action reviews
z) Provide various types of training implementations including tabletop exercises, 2D and 3D computer gaming, and immersive virtual reality environments
aa) Provide capabilities to refine simulations based on actual incident data, field measurements, and sensor data
bb) Support vector and raster representations of geography, buildings, and other CIKR structures and systems
cc) Support a range of different grid resolutions on critical infrastructure models, maps, and displays, e.g., 30 meter, 100 meter, 1 kilometer, 10 kilometer
dd) Support the integration and/or distributed execution of interrelated CIKR and other models including hazardous material release exposure and effects, incident management systems, healthcare systems, weather, and watershed flows
ee) Identify regions where the exposed population will experience life threatening, serious long-lasting or notable effects from incidents or failure of CIKR systems
ff) Include capabilities to model cyber-security attacks on CIKR control systems, such as, Supervisory Control And Data Acquisition (SCADA) systems

A.2.3 - Data

This section identifies data management issues as well as input and output data types that may be supported for CIKR models and simulations.

a) Establish a data taxonomy, meta-data framework, and detailed information models for CIKR simulation and modeling data to help support analyses and support data interoperability and data/information fusion
b) Establish standard data structures, databases, and exchange mechanisms for CIKR data used in models and simulations
c) Establish a CIKR M&S data warehouse that categorizes each item in a data item into non-overlapping region to support filtering, grouping, and labeling

d) Establish processes to ensure data quality and provide traceability mechanisms to track data back to original sources
e) Establish an information assurance program to manage risks related to the use, processing, storage, and transmission of information or data and the systems and processes used for those purposes
f) Provide information assurance measures that protect and defend information and information systems by ensuring their availability, integrity, authentication, confidentiality, and non-repudiation of CIKR M&S data
g) Support the Protected Critical Infrastructure Information (PCII) Program that enhances information sharing between the private sector and the government in order to analyze and secure critical infrastructure and protected systems, identify vulnerabilities and develop risk assessments, and enhance recovery preparedness measures
h) Use geographical information systems-based methods to track and model the effects of incidents on CIKR systems, e.g., the flow and concentration of contaminants in source water supplies
i) Establish a data taxonomy, information models, databases, and exchange mechanisms for CIKR data including:
    - Structure and layout of CIKR systems and support organizations
    - CIKR system data flows
    - Inventory of CIKR resources
    - Standard CIKR management operations, processes and procedures
    - Message logs and incident time lines
    - Specification of the incident area including event types and parameters, timing of events, schedule of restoration activities, terrain and buildings in affected areas
    - Demographics data: population location, density, and attributes by time of day
    - Meteorological data: observed and forecast weather conditions that may affect an incident including wind speed, direction, and precipitation
    - Plume data for hazardous material releases and explosions
j) Support of appropriate existing data standards in model implementations, training and exercise simulations, e.g., SCORM – Shareable Content Object Reference Model [ADL 2011].
k) Include capability for geographic models to utilize raster and elevation data.

A.2.4 - User Interfaces

This section identifies user interface capabilities that may be supported for CIKR models and simulations.

a) Provide three-dimensional urban imagery with data visualization, zoom capabilities, and high-spatial resolution
b) Provide after-action reporting capabilities to identify weaknesses and issues identified from exercises, assign offices to be responsible for correcting problems, and track these assignments to ensure completion
c) Provide tools for modeling, simulation, and visualization of information technology systems
d) Provide capabilities to configure simulation runs with specific CIKR systems, incident types and associated parameters, affected populations, responder resources, weather conditions, and geographic regions
e) Generate graphical views of CIKR systems, failures, incident and responder activities over a 2D or 3D representation of area of interest at different levels of resolution
f) Provide user control mechanisms that affect rapid execution/playback of simulation runs to move forward and back to desired points in time
g) Use various DHS standard symbology, maps, and representation schemes to display incident parameters, resource locations, and time lines
h) Provide virtual reality interfaces to support 3D gaming for critical infrastructure exercises

i) Provide exercise controller interfaces for the initiation, execution, as well as playback of exercise simulations for after action reviews and hot washes
j) Provide interfaces to generate still image and video files that can be used to transfer results for viewing or playback using other software tools
k) Provide displays that help users understand the uncertainty associated with M&S results

A.2.5 - Performance

This section identifies possible performance considerations for CIKR models and simulations.

a) Support various simulation techniques as appropriate, such as system dynamics modeling, discrete event simulation, business process modeling, agent-based modeling, and computational fluid dynamics models as appropriate to create specific individual-based computational models for modeling complex systems, emergence, Monte Carlo Methods, computational sociology, multi-agent systems, and evolutionary programming
b) Support time scaling of models and simulations and abilities to move forward rapidly in time to focus on events of interest (real-time for training and faster than real-time to support planning and analysis during actual incidents)
c) Provide for updates from real time CIKR system information, meteorological databases and observations
d) Share model predictions with other software applications
e) Provide capabilities for interoperable networked implementations at different sites by different organizations

A.2.6 - Credibility and Evaluation

This section identifies considerations for ensuring the credibility and evaluating CIKR models and simulations.

a) Support the Systems-Based Risk Management (SBRM) process
b) Establish cross-sector working groups to support the development and evaluation of simulation models
c) Support evaluation of M&S tools using standard validated scenarios with data and results
d) Support evaluation of M&S tools through identification of standard processes and techniques for the purpose that may be customized to CIKR sectors if needed
e) Establishing procedures for evaluating credibility of CIKR and other data used as input for M&S tools
f) Provide guidance for generating uncertainty data with results from M&S tools

A.3 - Incident Management M&S Capabilities and Requirements

A.3.1 - Intended Use

Incident management models and simulations will be used by incident managers, emergency planners, first responders, and training personnel to:

a) Analyze the resource requirements, behavior, and performance of incident management systems,
b) Conduct training exercises, drills, emergencies, tests, alerts, real world incidents, and planning for national security events,
c) Determine the readiness of incident management systems to respond to various types of emergencies, and
d) Model past incidents for education, training, and analysis purposes

A.3.2 - Functionality

This section identifies possible functions that may be included in incident management models and simulations.

a) Provide functions to create high level models of responder evolutions over time to support system performance and resource analysis – the models should comprehend the possibility that intended responders are among the victims.
b) Provide training and exercise simulations for incident management that provide functionality for various incident and exercise parameters, exercise control, and after action reviews
c) Provide simulations that can be used through multiple phases including training, day-to-day operations and incident response planning and operations to allow personnel to develop and reinforce the expertise over time
d) Provide various types of training implementations including table top exercises, 2D and 3D computer gaming, and immersive virtual reality environments
e) Provide capabilities to refine simulations based on actual incident data, field measurements, and sensor data
f) Support vector and raster representations of geography, buildings, and other structures
g) Support a range of different grid resolutions on incident management models, maps and displays, e.g., 30 meter, 100 meter, 1 kilometer, 10 kilometer
h) Support the integration and/or distributed execution of interrelated models including hazardous material release exposure and hazard effects, critical infrastructure systems, healthcare systems, weather, and watershed flows
i) Identify regions where the exposed population will experience life threatening, serious long-lasting or notable effects from incidents

A.3.3 - Data

This section identifies input and output data types that may be supported for incident management models and simulations.

a) Structure of responder organizations and inventory of responder resources
b) Standard incident management processes and procedures
c) Message logs and incident time lines
d) Specification of the incident area including event types and parameters, timing of events, schedule of responder activities, terrain and buildings in affected areas
e) Demographics data: population location, density, and attributes by time of day
f) Meteorological data: observed and forecast weather conditions that may affect an incident including wind speed, direction, and precipitation
g) Plume data hazardous material releases and explosions
h) Support of appropriate data standards in model implementations, training and exercise simulations, e.g., SCORM - Shareable Content Object Reference Model [ADL 2011]

A.3.4 - User Interface

This section identifies user interface capabilities that may be supported for incident management models and simulations.

a) Provide capabilities to configure simulation runs with specific incident types and associated parameters, affected populations, responder resources, weather conditions, and geographic regions

b) Generate graphical views of incident and responder activities over a 2D or 3D representation of area of interest at different levels of resolution
c) Provide user control mechanisms that affect rapid execution/playback of simulation runs to move forward and back to desired points in time
d) Use various DHS standard symbology, maps, and representation schemes to display incident parameters, resource locations, and timelines
e) Provide virtual reality interfaces to support 3d gaming for incident management exercises
f) Provide exercise controller interfaces to effect the initiation, execution, as well as playback of exercise simulations for after action reviews and hot washes
g) Provide interfaces to generate still image and video files that can be used to transfer results for viewing or playback using other software tools

A.3.5 - Performance

This section identifies possible performance considerations for incident management models and simulations.

a) Support time scaling of models and simulations and abilities to move forward rapidly in time to focus on events of interest (real-time and faster than real-time to support analysis during actual incidents)
b) Provide for updates from real time meteorological databases and observations
c) Share model predictions with other software applications
d) Provide capabilities for interoperable networked implementations at different sites by different organizations

A.3.6 - Credibility and Evaluation

This section identifies approaches that may be used to evaluate and determine the credibility of incident management models and simulations.

a) Conduct walkthroughs of simulation models of incident management simulations and models with experienced incident managers and first responders
b) Compare results and predictions of incident management models against past events using historical data
c) Conduct side by side training exercises using conventional techniques (e.g., tabletop exercises) and computer-based simulations to compare effectiveness in achieving intended goals such as training objectives, realism, and exercise resource requirements

A.4 - Healthcare Systems M&S Capabilities and Requirements

This section translates the high level needs discussed in the previous section to a set of requirements. The requirements are intended to be common across all healthcare systems and hence at a high level. These requirements will serve as the starting set that may need to be enhanced for specific healthcare system for unique intended use. A separate document with a more detailed set of common requirements is being developed in a related effort.

A.4.1 - Intended Use

Healthcare organization managers, emergency planners, first responders, doctors and nurses, support and training personnel will use healthcare systems models and simulations to:

a) Analyze the resource requirements, behavior, and performance of healthcare systems,

b) Conduct training exercises, drills, emergencies, tests, alerts, and support real world incidents (natural disasters, terrorist attacks, and epidemics),
c) Determine the readiness of healthcare systems to respond to various types of emergencies,
d) Model past incidents for education, training, and analysis purposes,
e) Support communication of current status and available response options,
f) Evaluate and implement response options based on real-time information. Update responses as situation unfolds, and
g) Build consensus for response decisions.

A.4.2 - Functionality

This section identifies possible functions that may be included in healthcare system models and simulations.

a) Provide functions to create high level models of healthcare system operations and evolutions over time to support system performance and resource analysis
b) Provide training and exercise simulations for healthcare personnel that provide functionality for various incident and exercise parameters, exercise control, and after action reviews
c) Provide various types of training implementations including tabletop exercises, 2D and 3D computer gaming, immersive virtual reality environments, training facilities, and mannequins
d) Provide capabilities to refine simulations based on actual incident data, hospital usage data, medical assessments, and field measurements
e) Support representations of geography, buildings, disease exposure and spread, lethality levels, healthcare institutions, equipment, personnel, victims, patients
f) Support the integration and/or distributed execution of interrelated models including epidemics, hazardous material release exposure and hazard effects, critical infrastructure systems, incident management systems, and weather
g) Identify regions where the exposed population will experience life threatening, serious long-lasting, or notable effects from incidents
h) Identify and specify the system state for different health care domains across integrated health emergency Area of Operations (AOO) over time
i) Integrate healthcare response with law enforcement plans and authority
j) Provide capability to analyze impact of incident and response actions at different resolution levels from population to individuals

A.4.3 - Data

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

a) Structure of healthcare organizations and inventory of resources
b) Standard healthcare processes and procedures (e.g., triage and treatments)
c) Message logs and incident time lines
d) Specification of the incident area including event types and parameters, timing of events, schedule of responder and healthcare personnel activities, population, terrain and buildings in affected areas
e) Pre-incident protocols and associated resource requirements
f) Casualty data including injury analysis, trauma types
g) Treatment plans for casualties of different types and associated resource requirements
h) Demographics data: population location, density, and attributes by time of day
i) Meteorological data: observed and forecast weather conditions that may affect an incident including wind speed, direction, and precipitation

j) Plume data hazardous material releases and explosions
k) Support of appropriate data standards in model implementations, training and exercise simulations, e.g., Shareable Content Object Reference Model [ADL 2011]

A.4.4 - User Interfaces

This section identifies user interface capabilities that may be supported for healthcare system models and simulations.

a) Provide capabilities to configure simulation runs with specific incident types and associated parameters, affected populations, responder and healthcare system resources, weather conditions, and geographic regions
b) Generate graphical views of incident, responder, and healthcare system activities over a 2D or 3D representation of area of interest at different levels of resolution
c) Provide user control mechanisms that affect rapid execution/playback of simulation runs to move forward and back to desired points in time
d) Use various DHS standard symbology, maps, and representation schemes to display incident parameters, resource locations, and timelines
e) Provide virtual reality interfaces to support 3D gaming for healthcare exercises
f) Provide exercise controller interfaces to effect the initiation, execution, as well as playback of exercise simulations for after action reviews and hot washes
g) Provide interfaces to generate still image and video files that can be used to transfer results for viewing or playback using other software tools
h) Integrate simulations with other healthcare system models and with other related domain models, such as, with traffic models for accurate representation of ambulance travel times
i) Generate alternate scenarios and analyses to develop insights in to healthcare system operations and its capabilities

A.4.5 - Performance

This section identifies possible performance considerations for healthcare system models and simulations.

a) Support time scaling of models and simulations and abilities to move forward rapidly in time to focus on events of interest (real-time for training and faster than real-time to support analysis during actual incidents and planning)
b) Provide for updates from real time epidemic, incident, meteorological databases and observations
c) Share model predictions with other software applications
d) Provide capabilities for distributed execution of interoperable networked implementations at different sites by different organizations

A.4.6 - Credibility and Evaluation

This section identifies approaches that may be used to evaluate and determine the credibility of healthcare models and simulations.

a) Conduct walkthroughs of simulation models of healthcare simulations and models with experienced healthcare personnel, incident managers and first responders.
b) Compare results and predictions of healthcare system models against past events using historical data.

c) Conduct side by side training exercises using conventional techniques (e.g., tabletop exercises) and computer-based simulations to compare effectiveness in achieving intended goals such as training objectives, realism, and exercise resource requirements.

Appendix B – Projects, Facilities, and Capabilities

B.1 – HMR 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.

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 as 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].

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.

Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments: This action of the European Cooperation in Science and Technology (COST) under its Earth System Science and Environmental Management area is aimed at developing an inventory of the different models and methodologies currently in use for predicting the dispersion of hazardous materials in urban areas. It also aims to characterize their performance and to establish strategies for their improvement. It has been identified as a first cross-community initiative to harmonize European efforts in threat assessment and reduction for local-scale airborne hazards [COST 2011].

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].

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].

Joint Urban Test Bed (JUTB): The OFCM formed the Joint Action Group for Joint Urban Test Beds (JAG/JUTB) under the Working Group for Urban Meteorology (WG/UM) for recommending criteria for multifunctional joint urban test beds. During FY 2010, the JAG/JUTB continued work on an operational concept document for multifunctional joint urban test beds intended to provide services and data to model developers, test and evaluation personnel, and other users and stakeholders. The operational concept document includes capabilities and benefits, management structure, infrastructure requirements, selection process, implementation framework, definitions, and characteristics of urban scales. For Fiscal Year (FY) 2011, the goals of the JAG/JUTB are to finalize criteria for establishing urban test beds and establish a JUTB Prototype Model Site in National Capital Region. [OFCM 2011]

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 tudies of incidents involving a wide variety of hazards, including nuclear, radiological, chemical, biological, and natural emissions [NARAC 2010a].

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].

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].

HMR Relevant Project Reports/ Documents:

- *Emergency Response Guidebook* (Orange Book; [DOT2008]): The Emergency Response Guidebook (ERG2008) was developed jointly by the US Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation of Mexico (SCT) for use by firefighters, police, and other emergency services personnel who may be the first to arrive at the scene of a transportation incident involving a hazardous material. It is primarily a guide to aid first responders in (1) quickly identifying the specific or generic classification of the material(s) involved in the incident, and (2) protecting themselves and the general public during this initial response phase of the incident. The ERG is updated every three to four years to accommodate new products and technology. The next version is scheduled for 2012.
- *Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases* [NRC 2003]: This is a report of a workshop by the same name. The workshop concluded that atmospheric observational and modeling tools can contribute substantially to preparation and planning for possible future events involving release of hazardous materials, to emergency response in the minutes to hours after such an event, and to the recovery and analysis following such events. The report discusses user needs, ways to enhance observational resources, strengthening modeling capabilities and applications to emergency response.
- *Successful Response Starts with a Map: Improving Geospatial Support for Disaster Management* [NRC 2007a]: This report is about the use of geospatial data for incident management. Despite the technological advances in geospatial data and related technology, it has seen limited use in incident management. The report identifies the factors that have inhibited such use and provides recommendations for addressing them.
- *Federal R&D Needs and Priorities for Atmospheric Transport & Diffusion* [OFCM 2004]: The report provides a comprehensive view of federal capability to provide atmospheric transport & diffusion modeling support. It discusses user needs and recommends strategies to address those needs.
- *Integrated Chemical and Biological Defense Program Research, Development and Acquisition Plan for the Departments of Defense and Energy: Bio Point Detection [DoD 2003]:* The report provides a technology area focused roadmap for chemical and biological defense (CBD) research

development and acquisition (RDA). This report is the third one in a series of report and is relevant since it added modeling and simulation roadmap to the areas covered. Appendix C of the document reports on acquisition and transition activities involving information system and includes information on a number of M&S tools.

- *IMAAC Interagency VV&A Workshop Report* [HSI 2009]: The workshop's objectives included informing the development of the IMAAC VV&A process, addressing the technical aspects, and including specific consideration of the needs of stakeholders in the VV&A process. It presents a simple VV&A process arrived at with the purpose of being achievable, appropriate, and understandable.

B.2 – CI Projects, Facilities, and Capabilities

A number of projects have been initiated to address CI M&S issues. Although some have been sponsored by DHS, there have been others conducted by outside organizations both within and outside of the U.S. A representative list of projects follows:

Canada's Public Security Technical Program CIP Projects: The M&S of elements of Canada's critical infrastructure—and particularly the area of dependencies and interdependencies between sectors and sub-sectors—is developing as a unique, horizontal CI research area with opportunities to support all CI sectors. Two ongoing projects are: PSTP Study 08-0120CI (2009 to 2010) – Conducting a HAZMAT scenario-based live simulation of telecommunication CI business continuity capability that will include the development and validation of "as-is" and "to-be" models (using an established architecture framework); PSTP Study 08-100CI (2009 to 2010) –Integrated Evaluation of Critical Infrastructure Interdependencies for Major Event Planning, using M&S technologies [DRDC 2009].

Chemical Sector Supply Chain and Economics Project: This project is a key component of a larger effort to deliver Enabling Homeland Security Capabilities (EHCs) for the Modeling, Mapping, and Simulation program. The first goal of this project is to populate a detailed data set of the chemical and petrochemical manufacturing, supply and distribution components that comprise the chemical infrastructure supply chain. The second goal is to develop a means to mathematically analyze not only the consequence of significant threats, but also the resiliency of the supply chain to recover from these impacts [DHS 2011a].

Complex Event Modeling, Simulation, and Analysis (CEMSA) Project: This project focuses on interdependencies, cascading effects, and the dynamics of multi-event and multi-vector attacks. This effort will provide significant improvements in timelines, quality and usability of information to provide decision makers up-to-date information to make informed decisions during an event. The program will leverage the capabilities developed for the Critical Infrastructure Protection Decision Support System (CIPDSS) and sector-specific modeling, simulation and analysis (MSA). The project is within the Infrastructure Protection Thrust Area and the Modeling, Simulation and Analysis Program of the Infrastructure and Geophysical Division [DHS 2009b]. (Also included in section B.3 Incident Management Projects, Facilities, and Capabilities)

Critical Infrastructure Test Range Complex (CITRC): CITRC at Idaho National Laboratory is a national, comprehensive program that researches, develops, and tests technologies, systems, and policies to protect the Nation's infrastructure. CITRC is comprised of the sites formerly occupied by the Auxiliary (originally Army) Reactor Area (ARA) and the Power Burst Facility (PBF), later part of the Waste Reduction Operations Complex (WROC). The remainder of INL land not occupied by facilities is designated part of the site-wide critical infrastructure test range (CITR), and serves as a real-world natural laboratory. CITR has industrial-scale infrastructure components, including an isolatable full-scale electric power grid with a 61-mile transmission loop, seven independent substations, and a control room for conducting comprehensive interoperability, vulnerability and risk assessments [INL 2008].

Design of an Interoperable European federated Simulation network for critical InfraStructures (DIESIS): This project proposes to establish the basis for a European modeling and simulation e-Infrastructure based upon open standards to foster and support research on all aspects of critical infrastructures with a specific focus on their protection. This European e-Infrastructure will support full cooperation of the different partners in charge for studying (inter)dependencies of critical infrastructures, while preserving the confidentiality of the proprietary knowledge embedded into the different models and simulation packages. The project aims to address the following: availability of models and data for single infrastructures, interoperable simulation of multiple infrastructures, and testbeds and benchmarks for protection solutions [DIESIS 2011].

Disaster-Resilient Structures and Communities Programs and Projects: These programs and projects at the Engineering Laboratory of the National Institute of Standards and Technology contribute to the goal of developing the technical basis for the standards, technology, and practices needed for cost-effective improvements to the safety and security of buildings and building occupants, including evacuation, emergency response procedures, and threat mitigation. The disaster resilience of structures and communities is determined by building codes, standards, and practices used when structures were built—most older structures have only minimal resilience. Most codes, standards, and practices are highly prescriptive, simplified, and inconsistent with respect to risk—stifling innovation and increasing cost. This program fulfills a national knowledge transfer role that is not well-supported by a fragmented U.S. construction industry and helps NIST its specific statutory responsibilities including: the Fire Prevention and Control Act (1974); the National Earthquake Hazards Reduction Program Reauthorization Act (1977, amended 2004); the National Windstorm Impact Reduction Act (2004); and the National Construction Safety Team Act (2002). [NIST 2011]

FLOODsite Project: This project was carried out under the European Community's Sixth Framework Programme and focused on identifying advantages and disadvantages of existing tools for long-term flood risk management and derived concrete demands for future development. The project identified 19 tools and conducted an in-depth evaluation on them. The tools considered were predominately developed in Germany, The Netherlands, and United Kingdom and included: Planning Kit, Water Manager, IRMA-Sponge Large Rivers, IVB-DOS, STORM Rhine, MDSF, EUROTAS, Flood Ranger, DESIMA, NaFRA, PAMS, HzG, DSS-Havel, WRBM-DSS, Elbe-DSS, INFORM 2.0/DSS, RISK/RISC, FLIWAS, and FLUMAGIS. Four other tools – RAMFLOOD, ANFAS, MIKE 11 DSS, and EFAS are also briefly described. [Schanze 2007]

Group Model Building for Critical Infrastructure Simulation: A group of researchers from Europe and the U.S. are utilizing group model building workshops to develop systems dynamics models of critical infrastructure. In initial reported effort Group Model Building (GMB) and system dynamics were used to develop plausible scenarios for a CI & Information Technology (IT) crisis with cross-border effects. Expert consensus was achieved about the crisis causal structure "driving" the event into a cross-border crisis. The model showed the negative effects of uncoordinated single country action on crisis perception and resource misallocation, in turn escalating crisis duration and severity. It is particularly severe if the crisis is exacerbated by IT failures [Sveen 2010].

Homeland Infrastructure Threat and Risk Analysis Center (HITRAC): HITRAC is the infrastructure-intelligence fusion center for DHS and incorporates analysts from the Office of Infrastructure Protection and the Office of Intelligence and Analysis. HITRAC creates actionable risk-informed analysis for federal, state, local, tribal, territorial, private sector, and international partners. The analyses include: critical infrastructure, regional, and cyber threat analysis, critical infrastructure prioritization, analytic support to state and local partners, and infrastructure modeling and simulation. The risk-informed analytic products are intended to provide decisionmakers charged with protecting critical infrastructure and key

resources with a common understanding of the risks facing the country. The center also provides the tools, methodologies, and approaches to translate that shared understanding into actionable risk mitigation strategies. [DHS 2011d]

Modeling & Simulation Capability for Resource Consumption and Consequence Management: The Modeling & Simulation Capability for Consequence Management prototype allows emergency planners to design and run dynamic, time aware, GIS based "what-if" gaming simulations depicting the impacts upon critical infrastructure and resource consumption during a large-scale mass evacuation from the National Capital Region to a host-State. The capability enables emergency planners to run multiple iterations of a simulated event with different resource allocations including the ability to activate and deactivate shelters, place barriers, and enforce fuel rationing. The prototype is being developed for the All Hazards Consortium Regional Catastrophic Preparedness Grant Program (FEMA Region 3) focusing on the eastern panhandle of West Virginia; however the simulation logic is being designed for extensibility to encompass all state-wide counties, neighboring states and geographical regions/districts. [Baker 2011]

Modeling Delay Tolerant Networking following Communication Infrastructure Disruption in a Disaster: Delay Tolerant Networking (DTN) is needed for communications following disruptions in communications infrastructure in a disaster. In a disaster scenario people with hand-held wireless devices (e.g., cell phone, PDA, even laptops), houses with WiFi routers and automobiles with radios can be connected in an effective way using DTN devices to form a functional communication network. This project is developing a mobility model that includes the impact of the disaster on the transportation network, and that models population and relief vehicle movement. The researchers are augmenting the "Opportunistic Network Environment" (ONE) simulator of DTNs with required extensions for the purpose [Uddin 2009].

National Infrastructure Simulation and Analysis Center (NISAC): NISAC is a modeling, simulation, and analysis program within DHS comprising personnel in the Washington, D.C., area as well as from Sandia National Laboratories (Sandia) and Los Alamos National Laboratory (LANL). A facility dedicated to NISAC is located at Sandia Albuquerque. Congress mandated that NISAC serve as a "source of national expertise to address critical infrastructure protection" research and analysis. NISAC prepares and shares analyses of critical infrastructure and key resources (CIKR), including their interdependencies, vulnerabilities, consequences, and other complexities. Its mission is to improve the robustness of the Nation's critical infrastructures by providing an advanced modeling and simulation capability that will enable an understanding of how the infrastructure operates; help identify vulnerabilities; determine the consequences of infrastructure outages; and optimize protection and mitigation strategies. NISAC's objectives are to leverage the existing capabilities of the NISAC partners to provide leadership in critical infrastructure interdependencies modeling, simulation, and analysis [NISAC 2011a].

Particle Dynamic Simulation for Critical Infrastructure Protection: The project utilizes particle modeling for the simulation of dynamic fracture phenomena in homogeneous and heterogeneous materials such as encountered in blasts on a concrete wall. Particle modeling is a dynamic simulation method that typically uses a lattice of small (but not molecular level) particles, evolving according to laws of mechanics, as a discrete representation of fluids and/or solids. The analysis will be used to establish design requirements for nanoparticle reinforcement of concrete structural components to meet severe loading (i.e., blast and seismic) demands [SERRI 2007].

Virtual USA – A DHS program, called Virtual USA, will enable first responders nationwide to link disparate tools and technologies in order to share the location and status of critical assets and information. These may include power and water lines, flood detectors, helicopter-capable landing sites, emergency vehicle and ambulance locations, weather and traffic conditions, evacuation routes, and school and government building floor plans [Boyd 2009].

Wide Area Recovery & Resiliency Program (WARRP): This program will leverage existing applied technologies and solutions developed; formalize long term working relationships among DHS, EPA, HHS, DoD, State, regional and local stakeholders; establish the body of knowledge to support operational

planning; and document approaches to reduce the time and resources required to recover and re-occupy

wide urban areas, military installations, and other critical infrastructure following a catastrophic chemical, biological, or radiological incident. In addition to overall recovery of wide urban areas, emphasis will be placed on community resiliency and how, at the local level, communities and local officials are better

prepared to manage a large scale incident and re-establish economic, environmental and social

functionality within the Denver urban area. [WAARP 2011]

CIKR Relevant Project Reports:

- *Highway Evacuations in Selected Metropolitan Areas: Assessment of Impediments* [DoT 2010a]: This report was developed in response to a request from U.S. Congress. It provides an assessment of mass evacuation plans for 26 metropolitan areas in the U.S. and identifies and prioritizes deficiencies on those routes that could impede evacuations. It also provides results of an analysis of how national highway system (NHS) projects under construction west of the National Capital Region (NCR) could increase the NCR's evacuation capacity and a detailed plan to accelerate such projects.
- *Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications* [NRC 2007b]: This report documents the verification and validation (V&V) of five fire models that are commonly used in nuclear power plant applications. The results of this V&V are reported in the form of ranges of accuracies for the fire model predictions.

B.3 – IM Projects, Facilities, and Capabilities

A number of projects have been initiated to address incident management M&S issues, although some have been sponsored by DHS, there have been others conducted by outside organizations both within and outside of the U.S. A preliminary list of projects follows:

Complex Event Modeling, Simulation, and Analysis Project: This project focuses on interdependencies, cascading effects, and the dynamics of multi-event and multi-vector attacks. This effort will provide significant improvements in timelines, quality and usability of information to provide decision makers up-to-date information to make informed decisions during an event. The program will leverage the capabilities developed for the Critical Infrastructure Protection Decision Support System (CIPDSS) and sector-specific modeling, simulation and analysis (MSA). The project is within the Infrastructure Protection Thrust Area and the Modeling, Simulation and Analysis Program of the Infrastructure and Geophysical Division [DHS 2009b]. (Also included in section B.2 CIKR Projects, Facilities, and Capabilities)

Emergency Operations Training Center (EOTC), Texas Engineering Extension Service: Located in College Station, Texas, the center is a state-of-the-art emergency management and incident command

training facility operated by the National Emergency Response and Rescue Training Center, a division of the Texas Engineering Extension Service. The EOTC's goal is to provide participants (including government agencies, corporate industrial teams, and jurisdictions from across the Nation) the skills they need to respond to, manage, and recover from large-scale incidents. The EOTC provides a wide spectrum of possible operations, ranging from the incident command post perspective to the emergency operations center and multi-agency coordination viewpoint at the local, regional or state levels. The overall incident management structure used in the EOTC replicates the Incident Command System and follows the NIMS as required in the NRF. The 32,000-square-foot EOTC uses state-of-the-art simulation and computer-based technologies to train incident managers, supervisors, and jurisdiction officials in the management of a large-scale crisis using a unified command approach, which can be tailored to any group [TEEX 2010].

Incident Management Simulation Laboratory (Simlab), U.S. Fire Administration, Emmitsburg, MD: The laboratory is configured to afford candidates "real-world" training in a variety of emergency situations encompassing incidents such as dwelling fires, commercial and large structure fires, catastrophic disasters and major emergency events, such as hazardous materials releases and mass casualty incidents. 3D computer models are used to provide visual clues, which are generated through the use of commercial off-the-shelf special effects, graphics, and animation software, and controlled through a standard personal computer by menu driven software. The goal of the simulation training is to provide the student with a variety of visual and auditory cues that will enhance the decision-making process in practical situations. This training provides realistic experience in the application of the principles of the NIMS and conversancy with the recognition primed decision-making model of higher order cue-based decision-making [USFA 2010c].

Integrated Modeling, Mapping, and Simulation (IMMS) program and Standard Unified Modeling and Mapping Integration Toolkit (SUMMIT): The IMMS program is designing and prototyping a simulation and collaboration environment for linking together existing and future modeling and simulation tools to enable analysts, emergency planners, and incident managers to more effectively, economically, and rapidly prepare, analyze, train, and respond to real or potential incidents. When complete, the IMMS program will demonstrate an integrated modeling and simulation capability that supports emergency managers and responders with 1) conducting “what-if” analyses and exercises to address preparedness, analysis, training, operations, and lessons learned, and 2) effectively, economically, and rapidly verifying response tactics, plans and procedures. IMMS program is developing the Standard Unified Modeling and Mapping Integration Toolkit (SUMMIT), a software framework for rapidly linking together these resources, and supporting collaboration across user communities. SUMMIT will enable discovery and exploitation of models, simulations, data, and archived analyses that are relevant to a specific scenario or event of interest and bringing together users and modeling resources from many locations while ensuring that access to existing data and models is controlled by the resource owners [DHS 2010d].

National Exercise Simulation Center, Federal Emergency Management Agency (FEMA): The National Exercise Simulation Center (NESC) is a Congressionally-mandated state-of-the-art training and exercise facility within FEMA Headquarters, and serves as a key element within the Federal Coordination Center (FCC). The FCC draws on the specialized capabilities of its FEMA elements, including the Disaster Operations Directorate, the National Preparedness Directorate, the Office of National Capital Region Coordination, and others as needed, to collaborate with and support deliberate planning, training, exercises and response operations coordination [FEMA 2010h]. The NESC is focused on utilizing decision support simulation to increase exercise realism and immersion in lifelike scenarios. It integrates Human Based Simulations (actors) and Computer Based Simulations for the purpose [Holtermann 2010].

Simulation Based Incident Planning and Response project: This project provides FEMA analysts, decision makers, policy makers as well as emergency managers, and operators an integrated modeling and simulation capability to effectively, economically, and rapidly verify and validate response tactics, plans

and procedures and to conduct "what-if" type analyses prior to an incident (preparedness, analysis, training) and during/after an incident (operational, lessons learned) [DHS 2009b].

Security and Incident Modeling Lab (SIMLAB), U.S. Secret Service: SIMLAB uses MS&A assets and technologies to develop simulated training exercises for the Service's protective detail teams, tactical response units and counter-surveillance units. SIMLAB also employs modeling and simulation for planning and analysis. These projects are typically for prototyping emergency preparedness strategies, defensive and counter-measure analyses, vulnerability and risk assessments, resource threshold studies and many other contingency examinations [U.S. Army 2007].

Training, Exercise & Lessons Learned (TELL) project: The TELL project is developing a federated simulation-based training and exercise capability that uses advanced computer models and will allow responders at all levels to affordably train and exercise for large and complex events in a virtual/constructive/live environment. TELL will link multiple agencies, functions, and jurisdictions to improve preparedness and decision-making for emergency responders and managers. TELL incorporates training objectives, scenarios, and metrics defined by other programs, and the capability to capture lessons learned to improve future emergency response capabilities [DHS 2009b].

IM Relevant Project Reports/ Documents:

- *Emergency Response Guidebook* (Orange Book; [DOT2008]) – Please see B.1 for a brief description of this document.
- *Computer Simulation for Emergency Incident Management: Report of the Department of Homeland Security Incident Management Simulation Workshop* [LLNL 2004]: This workshop report captures joint input from senior representatives of the emergency response and incident-management communities and the M&S technologists from Department of Energy laboratories. It includes a summary of simulation capabilities that are relevant to incident-management training, recommendations for the use of simulation in both incident management and associated training, and future R&D needs.

B.4 – HS Projects, Facilities, and Capabilities

The term “simulation” is used to include a wide variety of modalities in healthcare area. The Center for Immersive and Simulation-based Learning (CISL) at Stanford School of Medicine [Stanford 2010] defines the following simulation modalities in the healthcare context: standardized patient actors, part-task physical trainers, virtual reality and visualization, desktop simulation and virtual worlds, and mannequin-based simulation. M&S, the focus of this report, has been defined to focus on computer based simulation and hence aligns primarily with the desktop simulation and virtual worlds and overlaps somewhat with the virtual reality and visualization modalities in CISL list.

A number of projects and facilities focus on healthcare simulation. However a majority of them focus on standardized patient actors, part-task physical trainers, and mannequin-based simulation. A preliminary list of projects, facilities, and capabilities that include the categories of our interest, i.e., desktop simulation and virtual worlds, and virtual reality and visualization, is provided below.

Center for Integration of Medicine and Innovative Technology (CIMIT) – CIMIT focuses on health care technologies, providing the resources and infrastructure to address technology application issues at the national and international level. CIMIT acts as a bridge between individual investigators and implementation of their ideas. It connects the investigators with a team of experts, and provides a nurturing collaborative environment to help the idea grow towards multiple uses, multiple partners, and multiple programs to address complex patient care problems. The work of simulation group at CIMIT

includes building desktop simulation tools such as the Real-time Incident Preparedness Simulation (RIPS) [CIMIT 2010].

Complex Incident Response Training System (CIRTS)-Combat Medics (CM) project – MYMIC LLC is developing CIRTS-CM under a Small Business Innovation Research Phase II contract award in early December 2009. CIRTS-CM is a simulation game based training system for scene and patient management care following blast injuries sustained from explosives including Improvised Explosive Devices (IEDs). Eventually, CIRTS-CM support will expand to other medical domains, such as training combat lifesavers, individual soldiers and marines, military combat support hospitals, civilian emergency medical technicians, other emergency first responders and incidents other than IEDs [MYMIC 2010a].

Medical Emergencies Simulation Lab, Institute for Simulation and Training, University of Central Florida – The lab builds on simulators developed by others to create sophisticated medical simulation capabilities that can enhance military, civil defense, and crisis management training. For example, the lab developed HLA-compliant software packages that allow simulated casualties generated during combat exercises to queue up for treatment by combat medics using a human patient simulator. The playing-field-to-emergency treatment model also has been used to train EMTs in civilian mass casualty exercises [IST 2009].

NIH Center for Biomedical Computation at Stanford (Simbios) – Simbios is the NIH Center for physics-based Simulation of Biological Structures. Simbios provides infrastructure, software, and training to help biomedical researchers understand biological form and function as they create novel drugs, synthetic tissues, medical devices, and surgical interventions. Simbios is investigating a wide scale of biological structures – from molecules to organisms. Driving biological problems include RNA folding, protein folding, myosin dynamics, cardiovascular dynamics, and neuromuscular biomechanics. Simbios is developing and disseminating the SimTK core simulation toolkit, an open-source software that includes capabilities for modeling the geometry and physics of biological systems. To ensure utility and accuracy, the software and training material is being developed and tested in close collaboration with biomedical scientists. Simbios has developed OpenSim, an application for advanced neuromuscular modeling that uses the SimTK toolkit, and is making it openly available [SIMBIOS 2010].

National Capital Area Medical Simulation Center – The SimCenter is part of the Uniformed Services University of the Health Sciences (USUHS) located in the Forest Glen Annex Silver Spring, Maryland. It has facilities for simulating medical procedures that are high risk or high consequence for patient safety. The simulations allow healthcare personnel develop and maintain the cognitive and psychomotor skills necessary to perform medical tasks safely and effectively. The Virtual Medical Environment Lab at the center includes surgical, emergency room and field hospital simulations, medical gaming as well as large-scale simulations designed to train medical teams in battlefield and natural-disaster scenarios [USU 2010].

National Center for Collaboration in Medical Modeling and Simulation – The NCCMMS is a joint project of Eastern Virginia Medical School (EVMS) and Old Dominion University (ODU) and a variety of academic, governmental and commercial partners. Its mission is to improve both the quality and quantity of medical care available to U.S. military forces. This is accomplished by providing a collaborative environment where basic and applied medical modeling and simulation research can be undertaken by EVMS and ODU researchers within the context of a comprehensive academic medical center that provides a convenient clinical test bed for new technologies and approaches. The center has access to the expertise of the large U.S. military medical community as represented by the Naval Medical Center, Portsmouth, the Uniformed Services University of the Health Sciences, and other military medical facilities. Projects at NCMMS include homeland security, emergency training and response, and gaming simulations [EVMS 2009].

Research Into Global Healthcare Tools (RIGHT) – The RIGHT project is being carried out by a consortium in the United Kingdom that is led Brunel University and involves several universities as core partners, government organizations, and private companies. The project aims to employ modeling and simulation methods for healthcare service planning. The aim is to achieve similar kind of performance gain as have been achieved in other sectors, such as industry & manufacturing, aerospace and the military through the use of M&S.

Appendix C – Simulation Models and Tools

C.1 – Hazardous Material Release M&S Tools

A large number of dispersion modeling tools have been created or are used by 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. A number of reports in the past have also included information on HMR M&S tools. These include:

- Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases [NRC 2003],
- Federal R&D Needs and Priorities for Atmospheric Transport & Diffusion [OFCM 2004], and
- Integrated Chemical and Biological Defense Program Research, Development and Acquisition Plan for the Departments of Defense and Energy: Bio Point Detection [DoD 2003].

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: air flows over complex terrain, air flows 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 that 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 NOAA and 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 web site [CMAS 2010].
ANSYS	ANSYS Multiphysics simulation solutions allow engineers and designers to create virtual prototypes of structures operating under real-world multiphysics conditions. It enables simulation of the interactions between structural mechanics, heat transfer, fluid flow and electromagnetics within a single, unified engineering simulation environment. It allows prediction of forces, stresses, and thermal and catastrophic effects. The software is ISO-9001 certified and has NQA-1 quality classification for use in nuclear structural analysis. [ANSYS 2011]
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 1,000 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 2010b].
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) [NARAC 2010a]. 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 2010a].
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 2010b].
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].

C.2 – Critical Infrastructure M&S Tools

Tool Acronym	Brief Description
ABAQUS	Abaqus Unified FEA product suite has following significant capabilities that are used to solve multiphysics problems such as impact of forces on critical structures: Computational Fluid Dynamics (CFD), Coupled Eulerian Lagrangian, Hydrostatic-Fluid-Mechanical, Piezoelectric-Mechanical, Structural-Acoustic, Thermal-Electrical, Thermal-Mechanical, Thermal-Fluid-Mechanical, and Structural-Pore Pressure. [Simulia 2011]
AIMS	The AIMS system is designed to aid research into critical infrastructures and the interdependencies between them. The simulation suite focuses on the types of services that are provided by infrastructure components. Each infrastructure system component is modeled as an agent and its services as its behavior [Bagheri 2007].
AIMSUN	Developed by Transport Simulation Systems, Spain, AIMSUN provides integrated modeling of traffic at macro-meso-micro scales. It provides advanced traffic models capable of fast execution [TSS 2010]. It is one of the tools used in the M&S Integration Framework project at the National Center for the Study of Preparedness and Catastrophic Event Response (PACER) located at Johns Hopkins University.

ANSYS	ANSYS Multiphysics simulation solutions allow engineers and designers to create virtual prototypes of structures operating under real-world multiphysics conditions. It enables simulation of the interactions between structural mechanics, heat transfer, fluid flow and electromagnetics within a single, unified engineering simulation environment. It allows prediction of forces, stresses, and thermal and catastrophic effects. The software is ISO-9001 certified and has NQA-1 quality classification for use in nuclear structural analysis. [ANSYS 2011]
ATFP	Anti Terrorism/ Force Protection (ATFP) tool has been developed at the Naval Postgraduate School and can be used for planning for waterside security for ships in a port. It combines agent-based simulation with X3D based visualization. The target users are personnel in charge of port security and Coast Guard [Brutzman 2006].
ATOM	Air Transportation Optimization Model (ATOM) is a network flow model of the air transportation system of the Nation. It can be used to determine the impact of disruptions and to develop optimal re-routing schemes [NISAC 2011b].
CARVER2	The CARVER2 vulnerability assessment tool is designed to quickly and easily identify and compare potential natural disaster and/or terrorist targets at the local, state and national levels in order to assist government officials in the allocation of protective resources. It does not have any simulation capability. Developed under the sponsorship of the National Institute of Standards and Technology, it is available free of charge to federal, state, and local government officials and agencies [NI2CIE 2009].
CASCADE	The CASCADE model can be used for analyzing the potential of catastrophic disruptions of large, interconnected infrastructure systems due to cascading failures. It is a probabilistic model of load depending cascading failure. It has been extended to include a dynamic component. It can be used to evaluate the impact of policies on the reliability of infrastructure for various operation ranges [Carreras 2009].
CI^3	Critical Infrastructure Interdependencies Integrator (CI^3) has been developed at Argonne National Labs to estimate (through Monte Carlo simulation) the time and/or cost to restore a given infrastructure component, a specific infrastructure system, or an interdependent set of infrastructures to an operational state. CI^3 also provides a framework for incorporating uncertainty into the analysis of critical infrastructures [Gillette 2002].
CIMS	Critical Infrastructure Modeling System (CIMS) has been developed to examine the interrelationships between infrastructure networks and more specifically, the emergent systems behaviors that develop when one or more nodes within the system are perturbed. It takes a command-level approach seeking to provide decision makers with sufficient information in terms of mission [Dudenhoeffer 2006].
CIMSuite	Critical Infrastructure Modeling (CIMSuite) software offers powerful, easy-to-use tools for both modeling and simulating complex interactions of infrastructure systems and predicting emergent behaviors through time. CIMSuite software gives users the potential to integrate multiple systems and visualize the results of cascading events including factors such as human social dynamics. The CIMSuite software data structure lends itself to both 3-D visualization and further algorithmic treatment, including time-step simulations, real-time data integration and analysis using methods

	such as genetic algorithms and neural networks [INL 2007].
CIPDSS	Critical Infrastructure Protection Decision Support System (CIPDSS) has been developed jointly by LANL, Sandia and Argonne National Labs (ANL). The set of tools under the CIPDSS program models the impact of CI on the economy, government, and population. LANL developed the city level models, Sandia developed the national level models while ANL provided the decision support part. The set of tools is intended to provide "orders of magnitude" results quickly. It was used for the analysis underlying NISAC's report on potential impact of pandemic influenza [Powell 2007].
CIPDSS-DM	CIPDSS-DM is a model used to compute the relative preference of alternative intervention strategies based on multi-attribute decision theory and was developed specifically as an aid to making decisions under conditions of uncertainty and risk. It helps decision makers integrate the large amount of quantitative information and insights generated by consequence simulations into a single measure of relative merit that informs the decision maker's comparison of available alternative intervention strategies. The relative preference model is combined with an analysis model that calculates the level of confidence in choosing any one intervention strategy over another and quantifies maximum and expected levels of satisfaction and regret [NISAC 2007].
CIPMA	The Critical Infrastructure Protection (CIP) Modeling and Analysis (CIPMA) Program is a key component of the Australian Government's efforts to enhance the protection of the critical infrastructure. The capability includes a series of 'impact models' to analyze the effects of a disruption to critical infrastructure services. This information is assisting the development and direction of government policy in national security and critical infrastructure protection (CIP), and helping owners and operators to better protect their critical infrastructure [TISN 2010].
CIPR/Sim	Critical Infrastructure Protection and Resiliency Simulator (CIPR/sim) allows emergency planners to visualize the real-time cascading effects of multiple infrastructure failures before an actual emergency occurs. It uses a common operating framework that allows the tool to import real-time data from numerous existing analysis modules, including RTDS (Real Time Digital Simulator) for electric grid analysis, QualNet for telecommunications analysis, and PC Tide for wind speed and flood surge analysis [Walsh 2009].
CISIA	Critical Infrastructure Simulation by Interdependent Agents (CISIA) is a simulator that uses a modular and sufficiently abstract representation of the different infrastructures' components to allow consistent descriptions, starting from the incomplete and generic data acquirable from stakeholders. Each component interacts with the others via a multitude of mechanisms that codify different concepts of proximity. The simulator has been used to analyze, in a simplified scenario, crisis evolution in the urban area of Rome in the presence of a failure in the electric power system [De Porcellinis 2008].
CommAspen	CommAspen is an agent-based model for simulating the interdependent effects of market decisions and disruptions in the telecommunications infrastructure on other critical infrastructures in the U.S. economy such as banking and finance, and electric

	power. CommAspen extends and modifies the capabilities of Aspen-EE, an agent-based model previously developed by Sandia National Laboratories to analyze the interdependencies between the electric power system and other critical infrastructures [Barton 2004].
CTH (ChartD to Three Halves)	CTH models multidimensional, multi-material, large deformation, strong shock wave physics. CTH has several models that are useful for simulating strong shock, large deformation events. Both tabular and analytic equations of state are available. CTH can model elastic-plastic behavior, high explosive detonation, fracture, and motion of fragments smaller than a computational cell. A programmed burn model is available for modeling high explosive detonation. Fracture can be initiated based on pressure or principle stress. A special model is available for moving fragments smaller than a computational cell with statistically the correct velocity. [Sandia 2011]
DEM	The Discrete Event Model (DEM) has been combined with hydraulic simulation model (Adaptive Hydraulic model [ADH]) to produce an integrated set of tools for addressing a wide range of navigation and operational problems at Corps locks and dams and commercial facilities and thus investigate issues with waterways transportation infrastructure [USACE 2011].
DEW	Distributed Engineering Workstation (DEW) can be used to create integrated system models, incorporating entire power distribution network from substations to service points. It supports interconnected, multidisciplinary models (i.e. Power, Fluid, Gas) and system interdependencies and provides analytical tools for advanced system planning, design, and operation [EDD 2011].
DYNA3D	DYNA3D ("Dynamics in 3 Dimensions") is an explicit finite-element code that addresses the behavior of structures as they deform and fail. Homeland security applications of the code include: blast-effect analyses, mass transit vulnerability analysis (underwater tunnel), blast resistant trash can analysis, and analysis of effects of destructive earthquakes and major accidents on bridges and dams. Some of the analyses include use of related codes such as ALE3D (Arbitrary Lagrangian Eulerian in 3D code for modeling explosive processes), NIKE3D (Nonlinear implicit 3D finite element code for modeling dynamic deformations) and SPH (Smooth Particle Hydrodynamics code for modeling a hole in an underwater tunnel) [LLNL 2011].
DYSMAS	Dynamic System Mechanics Advanced Simulation (DYSMAS) is a fully-coupled hydrocode for simulating underwater explosion phenomena and their effects on naval structures. It provides system design/qualification support and structural damage prediction capability [Moyer 2008]. The tool can be useful for modeling impact of underwater explosions on ships in general.
EMCAS	The Electricity Market Complex Adaptive System (EMCAS) models the electricity market representing its diverse participants as "agents." All agents have their own set of objectives, decision-making rules, and behavioral patterns. Further, agents can draw on an array of historical information (e.g., past power prices) and projected data (e.g., next-day load) to support their unique decision process. EMCAS has been used to study electricity market restructuring issues in the U.S., Europe, and Asia [ANL 2011a].

FAIT	Fast Analysis Infrastructure Tool (FAIT) is used to determine the significance and interdependencies associated with elements of the Nation's critical infrastructure. It utilizes system expert-defined object-oriented interdependencies, encoded in a rule-based expert systems software language (JESS), to define relationships between assets across different infrastructures. These interdependencies take into account proximity, known service boundaries, ownership, and other unique characteristics of assets found in their associated metadata [NISAC 2011c].
FDNA	Functional Dependency Network Analysis (FDNA) is a methodology that enables planners to measure the ripple effects of degraded operability in one or more entities or feeder-receiver chains on system capabilities, due to the potential realization of adverse events [Garvey 2009]. It can be used to study the cascading effect of an incident across interdependent infrastructure systems.
FEPVA	The Framework for Electricity Production Vulnerability Assessment (FEPVA) can be used to assess the potential impact of natural disasters or malicious attacks for both response and preventative purposes. In particular, it can be used to identify the power plants that will be potentially affected and to what degree given a disruption of fuel supply due to a disaster. The framework has three major capabilities: (1) requirement analysis, data acquisition, and data processing; (2) development of the data warehouse; and (3) visualization and data mining [Shih 2009].
FinSim	Financial System Infrastructure Model (FinSim) represents the U.S. financial services sector as a complex decentralized system with multiple interacting autonomous decision nodes, or agents. Those nodes represent different types of real-world agents, such as banks, traders, markets, and brokers. The financial system interactions are executed through an explicit message exchange, intermediated by the telecommunications system with electric power dependencies for the purpose of investigating possible vulnerabilities [Outkin 2006].
Fort Future VI	Fort Future Virtual Installation (VI) is meant for installation level infrastructure modeling. It integrates utility system simulations with each other and with a resource contention process model. Results from utility simulations include detailed operating data, such as flow rates and pressures in water systems and voltages and currents in electrical systems. The VI incorporates rules of thumb (heuristics) to translate simulation results into actionable information based on the question at hand [USACE 2010].
FRAM	The Fuzzy Relation Analysis Method (FRAM) method has been implemented in GIS for modeling and analyzing interdependencies of critical infrastructures. The modeling processes include the following four components: (1) an asymmetrical fuzzy relation matrix representing direct relationships between nodes in infrastructure networks; (2) an asymmetrical fuzzy relation matrix representing direct and cascade relationships between infrastructure networks; (3) a mathematical transformation converting asymmetric relations in to transitive relations with properties of direct relations stronger than indirect relations; and (4) a method for ranking infrastructures in terms of their relative importance [Cheng 2007].
I2SIM	Infrastructure Interdependencies Simulation (I2SIM) is being developed under the Joint Infrastructure Interdependencies Research Program (JIIRP) at the University of

	British Columbia in Canada. It is intended to capture the complex time line dynamics that occur in a system of multiple infrastructures as events develop during large disaster situations. The system modeling and solution approach implemented in I2SIM is based on a dynamic time-sensitive coordination of the delivery of the vital goods and services required to maximize human survivability. I2SIM models the network of networks that results when multiple CIs are brought into the picture simultaneously [UBC 2007].
IEISS	Interdependent Environment for Infrastructure System Simulations (IEISS) is a flexible and extendible software framework designed for MS&A of multiple interdependent infrastructures. It allows study of complex, nonlinear and emergent system behaviors through a system-of-systems modeling approach and a unified view of physical interdependencies. It includes the following infrastructure models: electric power, natural gas, water, petroleum (POL), telecomm and SCADA. It includes interactive 2D and 3D visualizers. It is accessible through HYDRA, a service oriented architecture, and INDRA, a browser enabled client for risk based decision support [NISAC 2011d].
IIM	Inoperability Input–Output Model (IIM) estimates the cascading inoperability and economic losses that result from interdependencies within large-scale economic and infrastructure systems. Based on the Nobel Prize-winning W. Leontief economic model, the IIM is a computationally efficient, inexpensive, holistic method for estimating economic impacts. It can be used to calculate higher-order effects from attacks to vulnerabilities and implementation of risk management policies in large-scale economic systems and to evaluate risk management options against multiple objectives [Crowther 2005].
INTEPOINT VU	IntePoint Vu uses a combination of techniques to analyze complex environments and model system-wide interdependencies across physical, virtual and social networks. It utilizes Agent-Based Simulation to model the behavior of dynamic systems. It allows developing a broad understanding of an incident and its implications and facilitates effective, timely decisions to plan for the unknown [IntePoint 2008].
Loki Toolkit	Loki is a generalized networked-agent modeling toolkit. It includes a set of components that can be selected, customized, and combined to create abstract models of diverse networks including power systems, pipelines, social networks, and financial networks. The ability to combine networks allows modeling the interactions across these networks. The toolkit includes analysis and visualization resources, such as network displays and statistical summaries to allow analysts to rapidly gain insights into the behavior of networked systems. Loki-Infect, a social network model for evaluating disease cascades, has been used to identify and evaluate mitigation strategies for disease spread [NISAC 2011e].
LS-DYNA	LS-DYNA is a general purpose transient dynamic finite element program capable of simulating complex real world problems. It is a strongly coupled multi-physics solver that can be used for modeling critical infrastructure behavior under an earthquake and other forces. It has a combined Implicit/Explicit solver for highly nonlinear transient problems enabling the solution of coupled multi-physics and multi-stage problems. [LSTC 2011]

MACCS2	MACCS2 Accident Consequence Analysis Code is used to calculate dispersion of radioactive material to the environment and the population. It uses a dose-response model to determine the health consequences of a severe nuclear facility accident in terms of early fatalities (how many people in a population would die in the weeks or months following exposure) and latent cancer risk (how many people in a population would contract a fatal cancer as a result of exposure).[NRC 2011]
MBRA	The MBRA tool supports the Model-Based Risk Assessment technique. There are two key components of MBRA: the network analysis and the fault tree analysis. These two parts can be performed independently or together. The network analysis models an infrastructure network and helps the analyst to determine which components are the most critical. The fault tree is an engineering technique used to model possible faults to related parts of a system and then to determine how best to allocate resources to those parts to minimize overall risk [CHDS 2011].
MELCOR	MELCORE is an integrated, engineering-level computer code used to model the progression of postulated accidents in light-water reactors, as well as non-reactor systems (e.g., spent fuel pool and dry cask). It is a modular code consisting of three general types of fast-running, parametric model packages for (a) basic physical phenomena, (b) reactor-specific phenomena, and (c) support functions. These packages model the major systems of a nuclear power plant and their associated interactions. [NRC 2011]
MIITS	Multi-Scale Integrated Information and Telecommunications System (MIITS) module is a scalable, end-to-end simulation environment for representing and analyzing extremely large, complex communication networks of any type, including cellular networks, public switched telephone networks (PSTNs), the Internet, and ad hoc mesh networks. MIITS offers network representation in several resolutions, ranging from packet-level simulation to flow-based approaches. It is used as a part of the Urban Infrastructure Suite (UIS) at NISAC [NISAC 2011f].
MIN	A three-layer Multi-Layer Infrastructure Networks (MIN) model is used to model auto, urban freight, and data infrastructure and solved using Agent-Based Simulation. This modeling uses a game-theoretic approach because the auto and freight flow dynamics are based on a fixed-point formulation of a Cournot-Nash equilibrium of games while travelers, travel information providers, freight shippers, and carriers are treated as self-interest players in the games [Zhang 2005].
MSM	The MIT Screening Methodology (MSM) has been developed at the Massachusetts Institute of Technology (MIT) for the identification and prioritization of vulnerabilities in infrastructures. The infrastructures are modeled as interconnected digraphs and employ graph theory to identify the candidate vulnerable scenarios. These scenarios are screened for the susceptibility of their elements to a terrorist attack, and a prioritized list of vulnerabilities is produced. The prioritization methodology is based on multi-attribute utility theory. The impact of losing infrastructure services is evaluated using a value tree that reflects the perceptions and values of the decisionmaker and the relevant stakeholders. These results, which are conditional on a specified threat, are provided to the decisionmaker for use in risk management [Li 2009], [Apostolakas 2005].

MUNICIPAL	Multi-Network Interdependent Critical Infrastructure Program for Analysis of Lifelines (MUNICIPAL) is a decision support system for the design and assessment of protection strategies including: identifying key elements to reduce the impact of disruptions, determining what levels of effort are required to restore service, designing alternative paths to reduce vulnerability, and determining where to site emergency response resources to rapidly restore services after a disruption. MUNICIPAL supports response and restoration following disruptions, facilitates analysis of threat scenarios and supports emergency preparation and training activities [Lee 2005].
N-ABLE	NISAC Agent-Based Laboratory for Economics (N-ABLE) is a large-scale microeconomic simulation tool that captures complex internal supply chain and market dynamics of businesses in the U.S. economy. It can be used to evaluate policies through simulation of millions of interacting firms. It has been used to study the impact of chlorine transportation disruption with a model of 3,300 related firms and 15,000 links [NISAC 2011g].
Net-Centric GIS	A network-centric modeling approach is used and an infrastructure interdependency knowledgebase is implemented in a WEBGIS environment for effective decision-making process. The spatial knowledgebase mimics interrelationships between selected critical infrastructure sectors. The approach can be used for effectively addressing the issues of infrastructure interdependency during emergencies [Abdalla 2007].
NG Analysis Tools	Natural gas (NGx) analysis tools allow modeling of the natural gas pipeline infrastructure. NGflow identifies critical links and nodes in a network topology. NGanalyzer assists users in analyzing identified gas engineering vulnerabilities, such as the number of city-gates, available storage, and pipeline capacity and interconnection. NGcut determines network component failure sets that could isolate a specific location or site from all supply sources. NGdepletion addresses outage duration times and determines whether and when a component outage will affect a specific location or site. NGpressure determines how the loss of a critical link or node under various operating conditions might affect a natural gas system [ANL 2011b].
NSRAM	Network Security Risk Assessment Model (NSRAM) is a tool for determining the probability of failure and repair/recovery time of complex systems composed of a network or system of networks. It models interconnected networks, such as electrical grids, communication systems, and roadways. Its features include: a time domain probabilistic risk assessment method, an ability to analyze the interaction of disparate network elements, and a detailed repair simulation capability [IIIA 2007].
PARCS	The Purdue Advanced Reactor Core Simulator (PARCS) is a computer code that solves the time-dependent two-group neutron diffusion equation in three-dimensional Cartesian geometry using nodal methods to obtain the transient neutron flux distribution. The code may be used in the analysis of reactivity-initiated accidents in light-water reactors where spatial effects may be important. [NRC 2011]
PipelineNet	PipelineNet is a Windows stand-alone PC application that integrates hydraulic and water quality models from EPA's EPANET 2.0 with existing databases to give emergency managers real time information for estimating the risks to public water

	supplies. PipelineNet simulates the flow and concentration of biological or chemical contaminants in a city or municipality's water distribution system from single and multiple sources, simulates water tracing and ageing, aids in the location of monitoring sites, provides tools for regulatory compliance and helps to evaluate contamination mitigation alternatives [SAIC 2011a].
RADTRAD	RADionuclide Transport and Removal And Dose (RADTRAD) estimation code uses a combination of tables and numerical models of source term reduction phenomena to determine the time-dependent dose at specified locations for a given nuclear accident scenario. It also provides the inventory, decay chain, and dose conversion factor tables needed for the dose calculation. It can be used to assess occupational radiation exposures, typically in the control room; to estimate site boundary doses; and to estimate dose attenuation due to modification of a facility or accident sequence. [NRC 2011]
Restore	Restore models complex sets of steps required to accomplish a goal, such as repairing a ruptured natural gas pipeline, when the time required to complete a step may be uncertain due to such factors as the time of day, weather, and availability of crew. Restore allows a user to estimate the time and cost (which may also be uncertain) needed to achieve an intermediate stage of completion, as well as overall completion. The tool also identifies the "most active path" through the network of tasks. It generates output graphs of probability distributions for overall and intermediate completion times [ANL 2011c].
R-NAS	R-NAS is a network flow model of primary rail tracks, yards, bridges and other rail facilities in the continental U.S., with flow based on commodity movement data from the Department of Transportation. The model can be used for quantifying the impact of disruptions in the network. Network flow optimization routines can be used to reroute the flows to support trans-incident operations support. The model has been used to analyze the impact of Hurricane Katrina on the rail network [NISAC 2011b].
RTDS	Real Time Digital Simulator (RTDS) provides power systems simulation technology for study of power systems with complex High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC) networks. It is a fully digital electromagnetic transients power system simulator that operates in real time. Since the simulator functions in real-time the power system algorithms are calculated quickly enough to continuously produce output conditions which realistically represent conditions in a real network. The simulator can be directly connected to the power system control and protection equipment for running simulations [INL 2010].
SIERRA	SIERRA (System for Import/Export Routing and Recovery Analysis) is a network model that represents container movements between the U.S. and 46 other countries that account for the vast majority of U.S. imports and exports. It predicts flows between the ports including, the total volumes handled (import and export) by each port, the modal volumes (truck and rail) moving domestically into and out of each port, and volumes between each port and a set of transportation analysis zones within the U.S. It was created to allow analysis of the changes in flow patterns that would occur under a variety of potential conditions (e.g., port disruptions, extensive security-related delays, etc.) related to container ports and movements. [NISAC 2009] [Jones 2011]

Subway Environmental Simulation (SES)	The Subway Environment Simulation (SES) Computer Program and Subway Environmental Design Handbook were developed in the early 1970's under sponsorship of the Federal Transit Administration to assist in the planning, design, and construction of subway ventilation systems. It provides tunnel designers with the tools to: properly size and locate ventilation shafts, evaluate tunnel geometry and fan size, optimize temperature, and model the effects of heat and smoke resulting from fires and other sources. [DoT 2011]
TEVA	Threat Ensemble Vulnerability Assessment (TEVA) is a probabilistic framework for assessing the vulnerability of a water utility to a large range of contamination attacks. TEVA addresses the spatial and temporal complexities of water-distribution networks by integrating network hydraulic models with water-quality models, health-impact models, and sensor-placement algorithms. The integrated set of models allows decision makers to assess the potential health impacts of a variety of contamination scenarios; to design and evaluate possible mitigation strategies, such as a contaminant warning system; and to plan effective response activities, such as containment and public health intervention [ANL 2011d].
TRACE	The TRAC/RELAP Advanced Computational Engine (TRACE) is a modernized thermal-hydraulics code designed to to analyze large/small break loss of coolant accidents and system transients in both pressurized- and boiling-water reactors. The capability exists to model thermal hydraulic phenomena in both one-dimensional (1-D) and three-dimensional (3-D) space. This is the NRC's flagship thermal-hydraulics analysis tool. [NRC 2011]
TRAGIS	The Transportation Routing Analysis Geographic Information System (TRAGIS) model is used to calculate highway, rail, or waterway routes within the United States. TRAGIS is a client-server application with the user interface and map data files residing on the user's personal computer and the routing engine and network data files on a network server. The user can also view a detailed listing of the route and population-density information, which can be used with other risk models [ORNL 2006].
TRANSIMS	Transportation Analysis Simulation System (TRANSIMS) simulates the daily activities and movements of individuals in an urban region. The individuals are synthetic—they do not represent actual people—but a census taken on the entire synthetic population would be statistically identical. The locations visited by individuals are real street addresses and reflect actual land-use patterns in the region. It provides the following information about the synthetic population and its mobility: household structure and demographics, activity locations, times, and durations, and trips between activities, including route plans and execution of the route plans on the transportation network. It is also used as a module in Urban Infrastructure Suite (UIS) at NISAC [NISAC 2011h].
UIS	Urban Infrastructure Suite (UIS) is a set of seven interoperable modules that employ advanced modeling and simulation methodologies to represent urban infrastructures and populations. These simulation-based modules are linked through a common interface for the flow of information between UIS sector simulations to model urban transportation, telecommunications, public health, energy (IEISS), financial

	(commodity markets), and water-distribution (WISE) infrastructures and their interdependencies [NISAC 2011i].
VISAC	Visual Interactive Site Analysis Code (VISAC) is a Java-based expert system that provides mission planners with a coordinated capability to predict and analyze the outcomes of different accidents/incidents at various nuclear and industrial facilities. The incidents can range from simple individual equipment sabotage to complex sorties that utilize a range of military weapons, simulated truck or car bombs, or satchel charges. The target facility is generated by either customizing existing 3-D CAD models for near real-time analysis or creating a new model from scratch. Using event/fault tree methodology, VISAC provides the probability of facility kill, the probability of undesirable collateral effects (chemical or radiological releases), and an estimate of facility down time [ORNL 2004].
WISE	Water Infrastructure Simulation Environment (WISE) is an analytic framework supporting the evaluation of water infrastructure in terms of both infrastructure specific and interdependency issues. Analysts can use WISE to study transmission scale water distribution systems, define and simulate flood events due to excess rainfall and hurricane storm surge, create spatial estimates of water demand, simulate water distribution system hydraulics and water quality using EPANET, build water distribution network models within a GIS and visualize output from EPANET within a GIS [NISAC 2011j].

C.3 – Incident Management M&S Tools

A number of incident management modeling and training tools have been developed through the efforts of federal agencies, universities, research organizations and commercial companies. This section lists existing tools that have been identified through Internet searches and site visits to known organizations involved in M&S of incident management systems. The tools are arranged alphabetically based on their developer's acronyms, or in some cases, abbreviations assigned by the authors for purposes of the readability of this document.

Tool Acronym	Brief Description
ACATS	Advanced Conflict and Tactical Simulation (ACATS) software is for training first responders in the event of a chemical, biological, radiological (CBR), or nuclear terrorist attack in an urban scenario. ACATS provides the ability to model contaminant flows throughout urban environments and into buildings through their HVAC systems. ACATS is able to look at conceptual operations through additional modeling capabilities that include human injuries and fatalities, portable CBR sensors, building evacuation, crowd behavior, and responder tactics [LLNL 2010].
ADMS	Advanced Disaster Management Simulator (ADMS) is available in two versions. ADMS-COMMAND is an on-scene incident command training simulator for first responders and on-scene commanders in mono and multi-agency operations, from basic incidents to complex disasters. It bridges the gap between tabletop exercises and real world experience. Common learning objectives are Command, Control, Coordination and Communication [ETC 2010a].

ADMS-EOC	ADMS-EOC is for training strategic level incident management teams, and Emergency Operations Center personnel. ADMS-EOC includes additional learning objectives such as Planning, Mapping, Logistics and Information Management. ADMS-EOC can be combined with ADMS-COMMAND to train on-scene and strategic command at the same time [ETC 2010b].
ASOCC	Area Security Operations Command and Control (ASOCC) is an interactive computer-based system designed to provide real-time situational awareness capabilities. It can provide graphic and imagery-based photographs and maps with supporting data, collaboration capabilities, a log and alert function, and a means to access and display updated information from web-based status board and databases. It was originally developed by the Defense Information Systems Agency (DISA) for U.S. military use. ASSOC may provide access to data on current situation needed for simulation of response options [CWID 2004].
BioDAC	Biological Weapons of Mass Destruction Decision Analysis Center has been developed at Sandia. It combines multiple simulations for analysis of decisions related to a biological agent release. The simulation includes: threat, population, health monitoring, environmental monitoring, and incident management roles of multiple involved groups. It was used to support an exercise in San Diego. Insights gained from the exercise and analyses have been incorporated in to the development of National Bio-Monitoring Architecture [Linebarger 2007].
CATS	Consequences Assessment Tool Set (CATS) provides incident manager and first responder tools for analyzing and assessing the impact of potential disasters from natural and technological sources. CATS assesses the consequences of technological disasters on population, resources, and infrastructure. CATS analyzes the damage to the environment, the risk to the well-being of the exposed population, and provides real-time resource allocation information to mitigate the consequences. [SAIC 2011]
CEMPlanner	Comprehensive Emergency Management Planner (CEMPlanner) is a web-based planning system that creates industry compliant plans. It provides customizable templates that collect the information and generates emergency operation plans (EOP), site plans and all of their components. The software is included in this list since it may be possible to input the generated plans in to simulation models for evaluation [Previstar 2008].
Commander	Commander is a situational awareness tool built on the Geo-spatial Information System (GIS) application developed by Intergraph known as GeoMedia. It includes other critical information such as vehicle tracking, plume cloud distribution, dynamic building and vehicle gate status. It also allows resource tracking, interfacing with the Warfighter Protection Lab (WPL) simulation suite, and as a front-end driver for the Center for Domestic Preparedness Incident Command Course tool [Belk 2006].
CPS	The Continual Preparedness System (CPS) is primarily a crisis information management software (CIMS) from Previstar, but it includes predictive modeling capabilities including a bio-agents model set for infectious and non-infectious diseases and hurricane debris model. A model builder is available for users to build their own models [Previstar 2008].

CrowdSim	Developed at LANL, CrowdSim is an agent-based framework for simulating large crowd dynamics. It simulates behavior of pedestrians in a crowd. It has been used to model the national mall. It was originally built on Repast and includes event handler and visualization. It is now being enhanced using particle and cell modeling computational techniques [Saeger 2007].
DI-Guy	Dismounted Infantry Guy (DI-Guy) Scenario was developed by Boston Dynamics as an interactive, three-dimensional simulation depicting individuals and their behaviors. The Warfighter Protection Lab employs DI-Guy to create scenarios and control the placement and behavior of characters in detailed urban environments, allowing emergency responders to train for situational scenarios outside of actual emergency events [BostonDyn 2007].
DrillSim	The DrillSim simulator is a multi-agent crisis simulator that can play out the activities of the response (e.g., evacuation) during a crisis from the perspective of IT solution integration. The simulator can model different response activities at both the macro and micro level, and model the information flow between different entities. IT solutions, models, etc. can be plugged in at different interfaces between these activities to study the effectiveness of research solutions in disaster management and tested for utility in disaster response. DrillSim is being developed at the University of California at Irvine [Massaguer 2006].
EDMSIM	Emergency and Disaster Management Simulation (EDMSIM) is an entity-based, real-time constructive simulation for training the Emergency Operations Center (EOC) staff by replacing the traditional "Table Top model" and Master Scenario Events List (MSEL) exercises with a computer simulation. EDMSIM runs on multiple computers for training EOC staff and leaders: First Responders operate the simulation and report to EOC, EOC makes decisions, and Decisions are tested within the simulation and feedback provided. [ATC 2010]
*EM*ES*	Emergency Management Exercise System (EM*ES) is a scenario-driven simulation-supported exercise environment that offers great flexibility with respect to the targeted training audience and types of incidents introduced in the scenario. It is available in both web-based and distributed application variants. It can be used operationally as a command and control system and blurs the line between training and operations. It provides a common operational picture for emergency management personnel thereby facilitating a higher state of situational awareness for all participants. It is fully compliant with the National Incident Management System (NIMS) [Wall 2009].
EMST	Emergency Management Staff Trainer (EMST) is a multi-player simulation-based exercise system geared toward emergency response professionals. EMST provides scenarios, exercises, and other capabilities that support the structure of the National Incident Management System (NIMS), including both individual and team training for the fifteen FEMA Emergency Support Functions (ESFs). EMST is an all-hazards trainer, with a range of scenarios including natural disasters, terrorist attacks, pandemic, and civil unrest. Each EMST exercise scenario presents an unfolding situation through email, news videos, web site articles, simulated phone calls, meetings, maps, images, and other injects, and requires the participant to take action

	to respond to or mitigate the situation [ECS 2010].
Ground Truth	Ground Truth is designed for high-level incident commanders who need to understand how to best allocate their resources. The game also educates users on the dangers faced by on-scene emergency responders. The serious game has been developed at Sandia National Laboratory at Livermore with support from University of Southern California's GamePipe Laboratory [Janes 2007].
Hydra	Hydra is a training simulator designed to provide incident command officers and senior-investigating officers with training that is as close to the real thing as possible. The Hydra system provides students with a chance to experience the management of large-scale criminal investigations and major critical incident command. It includes support for fast-time and slow-time decision making, tactical and strategic levels of command, complex information and action flow, simulated resource management, and decision tracking and audit [Hydra 2010]. Developed in the United Kingdom, the simulation system is in use at the Los Angeles Police Department [Pittman 2010].
IC2020	Incident Command 2020 (IC2020) is being developed at Dartmouth College as a prototype of a next-generation incident command software architecture that combines situational awareness, embedded simulation, and planning functions. It is designed to be a realization of the NIMS incident command system and common operational picture, and to be a research and demonstration platform for simulation, sensor integration, and human factor studies. The simulation that supports IC2020 manages the state of simulated objects (vehicles, personnel, equipment) and generates event notifications [McGrath 2006].
ICATS	Incident Command Analytic Training System (ICATS) is being developed at LLNL with ACATS at its core (see earlier entry for ACATS). ICATS is a collection of simulations and technologies that provides a solution for the training of our federal, state, and local emergency incident managers. ICATS is being used to evaluate and train incident command staff making critical decisions in a stressful virtual-catastrophe environment. It links them simultaneously from distributed locations and jurisdictions and enables them, individually and collectively, to experience the immediate consequences of their decisions and determine the best course of response [LLNL 2010].
ICWM	Incident Command Workflow Modeling has been developed at Monmouth University. It provides on the fly modification and validation of workflow for ICS. It has been designed with volunteers in mind who may need intuitive features for the description and modification of the workflow [Wang 2008].
Incident Commander	Incident Commander is a PC-based simulation developed for the U.S. Department of Justice by BreakAway to train first responders, emergency personnel and multi-agency personnel to plan, and prepare for emergency and crisis situations. Incident Commander can train up to 16 players simultaneously, with users assuming roles as either the commander or members of the operations team. The game simulates various crisis scenarios, including a natural disaster, a school hostage situation, and a terrorism incident in a hypothetical any town, USA setting [Breakaway 2010a].

JNEM	Joint Non-kinetic Effects Model (JNEM) developed at the Jet Propulsion Lab is a tool developed for DoD requirements to model non-kinetic effects such as the reaction of crowd and civilians in areas surrounding a force action. The tool models a number of situations such as power outages, water shortages, and sewage spill, and their impact on civilian mood. Civilian concerns and mood are in turn modeled based on perceived autonomy, safety, culture and quality of life. The tool is also applicable to homeland security scenarios and has been used to support Ardent Sentry – Northern Edge 07 exercise conducted jointly by DoD and DHS [Chamberlain 2006].
LMIS	LMIS is a simulation-based exercise and training capability whose focus is on disaster response and recovery. LMIS is derived from DoD simulations including the Joint Semi Automated Forces (JSAF) code base, which is a highly scalable civilian model utilizing entity-level modeling with aggregate-level network data and behavior models; the Warfighters Simulation (WARSIM), an aggregate-level command and staff training simulation with in-depth logistics models and interfaces to operational command & control (C2) and situational awareness systems; and a variety of additional models and capabilities specific to the domain of disaster response [Beck 2009].
LPAT	Logistics Process Analysis Tool (LPAT) has been developed at ANL. The LPAT model helps the planners quantitatively evaluate the transportation and logistics aspects of their emergency plans through a "from warehouse to citizen" simulation. Planners are able to use LPAT's macro-level logistics and transportation component independently or together with its micro-level process simulation component to test, analyze and understand the interactive elements of the supply chain, the impact of conflicting priorities, and the consequences of logistics decisions before implementation of the plan. By using LPAT, planners can define the range and scope of a logistical operation and predict the type and quantity of assets required for a particular response or recovery effort [ANL 2010].
OREMS	Oak Ridge Evacuation Modeling System (OREMS) can be used to estimate evacuation time and to develop evacuation plans for different events or scenarios (e.g., good vs. bad weather conditions, day vs. nighttime evacuations) for user-defined spatial boundaries. The system permits experimentation with alternate routes, destinations, traffic control management strategies, and evacuee response rates. For every scenario it is possible to identify evacuation or clearance times, traffic operational characteristics (e.g., average evacuation speed), bottlenecks, and other information necessary to develop effective evacuation plans and to conduct transportation infrastructure vulnerability studies [ORNL 2010d].
PLAN C	Planning with Large Agent-Networks against Catastrophes (PLAN C) is an agent-based simulation tool for emergency managers, urban planners and public health officials to prepare and evaluate Pareto-optimal plans to respond to urban catastrophic situations. PLAN C uses a large-scale computational multi-agent based disaster simulation framework involving thousands of agents. It has been able to simulate the complex dynamics of emergency responses in different urban catastrophic scenarios (e.g., chemical agent, bomb explosion, food poisoning, and smallpox). It can devise plans that optimize multiple objective functions (e.g., number of casualties, economic impact, time to recovery) in terms of their Pareto frontier in a high-dimensional space; for this purpose, it uses an evolutionary genetic search algorithm. It is designed to be

	used and parameterized by relatively unsophisticated users. The technology can be transferred to any urban setting, to multiple computer platforms, and to different modes (offline or online) of planning [NYU 2009].
Play2Train	Play2Train is a virtual training space in SecondLife designed to support Strategic National Stockpile (SNS), Simple Triage Rapid Transportation (START), Risk Communication and Incident Command System (ICS) training. This virtual environment, which currently comprises a town and two hospitals, spreads over three islands Asterix, Obelix and Getafix (65536 x 3 sq. meters). Play2Train provides opportunities for training through interactive role playing. This project implements one of the distance learning methodologies proposed by the Idaho Bioterrorism Awareness and Preparedness program (IBAPP) project [ISU 2010].
Restore	Developed at ANL, Restore models complex sets of steps required to accomplish a goal, such as repairing a ruptured natural gas pipeline, when the time required to complete a step may be uncertain due to such factors as the time of day, weather, and availability of crew. Restore allows a user to estimate the time and cost (which may also be uncertain) needed to achieve an intermediate stage of completion, as well as overall completion. It can also model workarounds and a simultaneous complete repair to obtain a distribution for the earliest time until service (either temporary via the workaround or normal via complete repair, whichever comes first) can be restored. The tool also identifies the "most active path" through the network of tasks. It generates output graphs of probability distributions for overall and intermediate completion times [ANL 2011c].
Stadium	The tool uses agent-based simulation to analyze mass egress following an improvised explosive device (IED) attack on a stadium. The results can be used to support new policy recommendations and training capabilities. The stadium model depicts PNC Park, the major-league baseball stadium in Pittsburgh, Pa. Anti-IED countermeasures modeled include guidance to exits, egress onto the playing field, and shock- and shrapnel-absorbing baffles inside the spiral stairways that provide the largest-volume routes of egress. [Samuelson 2007][Redfish 2011]
VISAC	Visual Interactive Site Analysis Code (VISAC), developed at ORNL, is a Java-based expert system that provides mission planners with a coordinated capability to predict and analyze the outcomes of different accidents/incidents at various nuclear and industrial facilities. The incidents can range from simple individual equipment sabotage to complex sorties that utilize a range of military weapons, simulated truck or car bombs, or satchel charges. The target facility is generated by either customizing existing 3-D CAD models for near real-time analysis or creating a new model from scratch. Using event/fault tree methodology, VISAC provides the probability of facility kill, the probability of undesirable collateral effects (chemical or radiological releases), and an estimate of facility down time [ORNL 2010e].

C.4 – Healthcare Systems M&S Tools

A number of healthcare and epidemic modeling tools have been developed through the efforts of federal agencies, universities, research organizations and commercial companies. This section lists existing tools that have been identified through Internet searches and site visits to organizations involved in M&S of healthcare systems. The tools are arranged alphabetically based on their developer's acronyms, or in some

cases, abbreviations assigned by the authors for purposes of the readability of this document. Similar to the previous sub-section, the focus is on models and tools for desktop simulation and virtual worlds, and virtual reality and visualization.

Tool Acronym	Brief Description
Code Orange	BreakAway developed a training simulation called ”Code Orange” for the Washington Hospital Center to train staff in the job roles they would have to assume in a mass casualty incident. Based on job descriptions and tasked outlined in the Hospital Emergency Incident Command System (HEICS) protocol, this simulation allows users to assume roles in triaging patients outside the hospital and inside the ER [Breakaway 2010b].
CVMDM	Community Vaccination and Mass Dispensing Model (CVMDM) simulates the allocation and distribution of pharmaceutical materials across a jurisdiction and the dispensing of those materials through points of dispensing (PODs). Given a request time for initial supplies from the Center for Disease and Prevention Control’s Strategic National Stockpile, estimated resupply intervals, population size and age distribution, and POD personnel resources, the model calculates the estimated start time for public vaccinations, POD queue times and throughput, and operation closure. Linked with a disease progression submodel, CVMDM tracks and reports the number of infections and fatalities based on disease characteristics and the performance of prophylaxis supply logistics and PODs [ANL 2011e].
EDS	ED Simulator (EDS) is a tool for Emergency Department throughput, staffing, patient flow, and efficiency analysis. EDS combines the power and analytical capabilities of simulation with database and data analysis technologies. It is designed to be used at the unit Manager level as a tool for ongoing process analysis, continuous process improvement, and accurate, objective internal benchmarking. It is based on MedModel simulation “engine” [ProModel 2010a].
Edsim	Edsim is a semi-reusable product to quickly model and test alternative design scenarios for existing and proposed hospital emergency departments. It meets the needs of hospital administrators to improve Key Performance Indicators (KPIs), such as patient length of stay (LOS), bed utilization, elimination of bottlenecks, etc. Edsim is also useful for predicting performance of proposed emergency departments before finalizing architectural designs [Ferrin 2007].
EDSIM	Emergency Department SIMulation (EDSIM) was developed through a cooperative effort involving the University of California, Davis, Medical Center (UCDMC) Department of Emergency Medicine and the UCDMC billing department using the Extend Suite v.5 modeling platform developed by Imagine-That, Inc. It provides modules that are connected by conduits that carry data elements representing patients, staff, orders, laboratory results, images, etc. It combines continually updated job queue prioritization and mid-task preemption capabilities that together allow the model to capture the chaotic nature of ED staff activity [Connelly 2004].
ED Simulation	ED Simulation is a desktop application designed specifically for quickly modeling and simulating Emergency Departments. It reduces the programming by pre-building Emergency Department workflow processes. Its applications include: minimizing

	patient waiting times and ED overcrowding, identifying workflow "bottlenecks," evaluating the effect of patient arrival and symptom mix, and testing disaster preparedness scenarios [Loud Squirrel 2011].
EpiSimS	The epidemic simulation engine, EpiSimS is a C++ application that runs on high-performance computing clusters. It is stochastic agent-based discrete event model that explicitly represents every person in a city, and every place within the city where people interact. A city or region is represented physically by a set of road segment locations and a set of business locations. EpiSimS can simulate various pharmaceutical and non-pharmaceutical interventions, including panic-based stay-home behavior, therapeutic and prophylactic use of antivirals, contact tracing, vaccination, wearing of masks, social distancing behaviors (increased inter-personal separation, hand washing, cough etiquette, etc.), household quarantine, and closures of schools [LANL 2010b].
Flexsim Healthcare	Flexsim Healthcare is a 3D simulation tool with animation for medical facilities. Its features include drag and drop model building, healthcare object library, interfaces with commonly used databases and spreadsheets, statistics tracking, and a dashboard with dynamic charts and graphs. It has been used for modeling emergency room operations. [Flexsim 2011]
GameTT	Games For Team Training (GaMeTT) is an immersive avatar based, virtual environment designed for distributed medical team training. Participants log in to GaMeTT from their own office or homes to work collectively towards team training objectives, optimizing the time available for training and the opportunity for team interaction. GaMeTT utilizes game-based technology to produce visually engaging scenes, user-friendly interfaces, and intuitive user commands. The tool is suitable for distributed medical teams such as the Disaster Medical Assistance Teams (DMAT) that are comprised of 35 volunteers who come together from different parts of the country to form a team in case of a disaster [MYMIC 2010b].
HMS	Healthcare Modeling Studio. A simulation modeling solution, is used to build custom analysis tools for a variety of healthcare facilities, including emergency departments, operating rooms, admissions, clinical labs and ancillary services. The tool can be tailored to each client's specific processes, organization, terminology and metrics, HMS helps healthcare professionals improve administrative and operational efficiency, reduce cost and maximize ROI, validate process change or facility expansion, and predict the impact of staffing changes or equipment upgrades [AAI 2007].
LES	Learning Environment Simulator (LES) developed at Los Alamos National Labs has been built as an interface to Critical Infrastructure Protection Decision Support System (CIPDSS). It is designed to engage decision makers at the grass-roots level (local/city/state), deepen their understanding of an evolving crisis, enhance intuition and let them test their own strategies. The initial version is based on a pandemic influenza outbreak and has been tested with a group of hospital administrators and first responders. LES is a simulated environment allowing the user to experience the complexities of a crisis before it happens, including impacts to critical infrastructures with their interdependencies and estimating human health & safety and economic impacts [LeClaire 2009].

MEDMODEL	MedModel is a simulation tool designed specifically for the healthcare industry for evaluation, planning and redesign of hospitals, clinics, and other healthcare systems. MedModel models can be used to identify inefficiencies in an existing process and test a variety of scenarios. Typical applications include: department specific productivity improvement, facilities design (labs, clinics, radiology, emergency rooms, etc.), planning for future changes, staff planning, analyzing patient capacity, equipment planning and logistical analysis, emergency preparedness, and bed capacity management [ProModel 2010b].
MUSTER	MUSTER is a simulation tool for Multi-user Emergency Response training. MUSTER supports training of doctors, nurses, Paramedics, EMT's, rescue workers, disaster medicine rescue teams and others in disaster medicine and management. The core of the training simulator is the patient model. Danish doctors have developed the model. It is able to simulate a patient's condition dynamically based on the injuries and the treatment he receives. Patients in a scenario can be defined individually [IFAD 2011].
Optima Predict	Optima Predict is an interactive strategic planning solution for emergency services that provides a platform for effective planning and simulation of requirements of resources such as ambulances. Optima Predict takes into account key performance indicators such as response times, vehicle types and coverage, shift rosters, post locations and hospital ramp times to enable users to quickly build scenarios that make logistical and business sense [Optima 2011].
PLAN C	Planning with Large Agent-Networks against Catastrophes (PLAN C) is an agent based simulation tool for emergency managers, urban planners and public health officials to prepare and evaluate Pareto-optimal plans to respond to urban catastrophic situations. PLAN C has been used to simulate emergency responses in different urban catastrophic scenarios (e.g., chemical agent, bomb explosion, food poisoning, small pox). It can devise plans that optimize multiple objective functions (e.g., number of casualties, economic impact, time to recovery, etc.) in terms of their Pareto frontier in a high-dimensional space; for this purpose, it uses an evolutionary genetic search algorithm [NYU 2009].
RIPS	Real-time Incident Preparedness Simulation developed by the SimGroup at the Center for the Integration of Medicine and Innovative Technology (CIMIT) is a training tool for emergency response personnel. It is an incident simulator with game like qualities and it provides a platform for creating disaster scenarios, sharing them, and then training on them with other professionals. It is based on the NIMS hierarchy [CIMIT 2002].
SimCare	SimCare Process Simulator 9.0 is a process simulation software for the healthcare industry. SimCare pro healthcare simulation includes support for hospitals, clinics, and blood centers. It allows for importing CAD files for the facilities such as emergency departments, and historical data for rapid model development of the model [CreateASoft 2011].

Appendix D – Relevant Standards and Guidelines

This appendix lists standards and guidelines that may be used to develop or run homeland security models and simulations. The appendices are organized as follows:

- D.1 – Domain-Independent Standards and Guidelines
  - D.1.1 – Conceptual Modeling Standards and Guidelines
  - D.1.2 – Distributed Simulation Standards and Guidelines
  - D.1.3 – Geographic Information System Standards and Guidelines
  - D.1.4 – Communication Standards and Guidelines
  - D.1.5 – Training System Standards and Guidelines
  - D.1.6 – 3D Modeling Standards and Guidelines
- D.2 – Hazardous Material Release Standards and Guidelines
- D.3 – Critical Infrastructure Standards and Guidelines
- D.4 – Incident Management Standards and Guidelines
- D.5 – Healthcare Systems Standards and Guidelines

The name of standard or guideline, a brief description of its contents, type of standard or guideline, responsible organization, as well a classification of the type of standard is given below.

D.1 – Domain-Independent Standards and Guidelines

D.1.1 – Conceptual Modeling Standards and Guidelines

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

D.1.2 – Distributed Simulation Standards and Guidelines

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

D.1.3 – Geographic Information System Standards and Guidelines

Standard Title	Overview
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
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 Geo-spatial Consortium, Inc. (OGC) **Classification:** Domain-specific integration interface
Content Standard for Digital Geo-spatial 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 geo-spatial 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 Geo-spatial 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 geo-spatial data obtained from remote sensing, within the framework of the FGDC Content Standard for Digital Geo-spatial Metadata (CSDGM) standard. The extensions provide a means to use standard FGDC content to describe geo-spatial data derived from remote sensing measurements. This standard is intended to support the collection and processing of geo-spatial 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 Geo-spatial 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 geo-spatial 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
Keyhole Markup Language (KML)	**Description:** This standard is about an XML grammar and file format for modeling and storing geographic features such as

	points, lines, images, and polygons for display in GIS applications. KML is focused on geographic visualization, including annotation of maps and images. Geographic visualization includes not only the presentation of graphical data on the globe, but also the control of the user's navigation in the sense of where to go and where to look [OGC 2011b]. **Standard Type:** KML 2.2-2007 **Organization:** Google Inc.; Open Geo-spatial Consortium (OGC) **Classification:** Document format
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 geo-spatial 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 Geo-spatial Consortium, Inc (OGC) **Classification:** Domain-specific integration interface
Schema for Coverage Geometry and Functions	**Description:** The standard defines a conceptual schema for the spatial characteristics of coverage, which support mapping from a spatial, temporal or spatiotemporal domain to feature attribute values where feature attribute types are common to all geographic positions within the domain. A coverage domain consists of a collection of direct positions in a coordinate space that may be defined in terms of up to three spatial dimensions as well as a temporal dimension [ISO 2011b]. **Standard Type:** ISO 19123: 2005 **Organization:** ISO **Classification:** Domain-specific integration interface
Shapefiles (.shp)	**Description:** A shapefile stores non-topological geometry and attribute information for the spatial features in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates. A geo-spatial format provides users a graphical method to display geographic data. Shapefiles are a geo-spatial vector data format for geographic information systems software. Shapefiles spatially describe points, polygons, polylines. A "shapefile" commonly refers to a collection of files with ".shp", ".shx", ".dbf", and other extensions on a common prefix name (i.e., "lakes.*") [ESRI 2011a]. **Standard Type:** Industry specification **Organization:** Environmental Systems Research Institute (ESRI) **Classification:** Document format

Spatial Data Modeling Language (SDML)	**Description:** SDML format is very simple text, which provides for easy parsing and support for attribute information [UWA 2011]. **Standard Type:** SDML 1.0 **Organization:** Silicon Graphics **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
Spatial Referencing by Coordinates	**Description:** The standard defines the conceptual schema for the description of spatial referencing by coordinates, optionally extended to spatio-temporal referencing. It describes the minimum data required to define one-, two- and three-dimensional spatial coordinate reference systems with an extension to merged spatial-temporal reference systems. It allows additional descriptive information to be provided. The part 2 of the standard, ISO 19111-2:2009, specifies the conceptual schema for the description of spatial referencing using parametric values or functions. It applies the schema of ISO 19111 to combine a position referenced by coordinates with a parametric value to form a spatio-parametric coordinate reference system (CRS). The spatio-parametric CRS can optionally be extended to include time [ISO 2011b]. **Standard Type:** ISO 19111: 2007; ISO 19111-2: 2009 **Organization:** ISO **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
Standard Representation of Geographic Point Location by	**Description:** The standard is a representation of latitude, longitude and altitude for geographic point locations. The order

Coordinates	of the elements is the latitude, the longitude and the altitude. Representation includes units of measure and coordinate order [ISO 2011b]. **Standard Type:** ISO 6709:2008 **Organization:** ISO **Classification:** Domain-specific integration interface
Topologically Integrated Geographic Encoding and Referencing /Geography Markup Language (TIGER/GML)	**Description:** A GML (an OGC specification for encoding geographic features in XML) data format for TIGER (Topologically Integrated Geographic Encoding and Referencing) data is a standards-based alternative to the TIGER/Line format. The TIGER/Line files are extracts of selected geographic and cartographic information from the Census Bureau's TIGER database. TIGER/GML data can be viewed as JPEG, PNG, and TIFF images and SVG maps [OGC 2011d]. **Standard Type:** TIGER/GML v3.0 **Organization:** Open Geo-spatial Consortium, Inc (OGC); U.S. Census Bureau **Classification:** Domain-specific integration interface
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 Geo-spatial-Intelligence Agency **Classification:** General purpose Integration Interfaces
Web Coverage Service (WCS)	**Description:** Web Coverage Service (WCS) defines a standard interface and operations that enables interoperable access to geo-spatial coverage that refers to content such as satellite images, digital aerial photos, digital elevation data, and other phenomena represented by values at each measurement point [OGC 2011e]. **Standard Type:** OGC WCS 2.0 Interface Standard, WCS Implementation Standard 1.1.2 **Organization:** The Open Geo-spatial Consortium, Inc (OGC) **Classification:** Domain-specific integration interface
Web Feature Service (WFS)	**Description:** This specification describes the Web Feature Service (WFS) operations. The WFS operations support INSERT, UPDATE, DELETE, LOCK, QUERY and DISCOVERY operations on geographic features using HTTP as the distributed computing platform. In the context of this specification, a transaction is a logical unit of work that is composed of one or more data manipulation operations [OGC 2011f]. **Standard Type:** OpenGIS WFS Implementation Specification, Version 1.1.0; OpenGIS WFS Interface Standard Version 2.0; ISO 19142 **Organization:** The Open Geo-spatial Consortium, Inc (OGC);

	ISO **Classification:** Domain-specific integration interface
Web Map Service (WMS)	**Description**: The specification provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geo-spatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not [OGC 2011g]. **Standard Type:** OpenGIS WMS Implementation Specification Version 1.3.0; ISO 19128:2005 **Organization:** The Open Geo-spatial Consortium, Inc. (OGC); ISO **Classification:** Document format

D.1.4 – Communication Standards and Guidelines

Standard Title	Overview
Caltech-USGS Broadcast of Earthquakes (CUBE) Message Format	**Description:** A message format used to report earthquake broadcast message from the Caltech-USGS Broadcast of Earthquakes (CUBE) system, a real-time notification system for earthquake information. CUBE message consists of an identification segment, earthquake's time, location, magnitude, depth, etc. [USGS 2011a]. **Standard Type:** Government specification **Organization:** California Institute of Technology Seismological Laboratory (Caltech); United States Geological Survey (USGS) **Classification:** Document format
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

D.1.5 – Training System Standards and Guidelines

Standard Title	Overview
Sharable Content Object Reference Model (SCORM)	**Description:** SCORM is an XML-based framework used to define and access information about learning objects so they can be easily shared among different learning management systems (LMSs). SCORM was developed in response to a United States Department of Defense (DoD) initiative to promote

	standardization in e-learning. SCORM integrates a set of related technical standards, specifications, and guidelines designed to meet SCORM's high-level requirements—accessible, interoperable, durable, and reusable content and systems. SCORM content can be delivered to your learners via any SCORM-compliant LSM using the same version of SCORM [ADL 2011]. **Standard Type:** SCORM 1.1, SCORM 1.2, SCORM 1.3 **Organization:** U. S. Department of Defense (DoD) **Classification:** Document format

D.1.6 – 3D Modeling Standards and Guidelines

Standard Title	Overview
The Collaborative Design Activity (COLLADA)	**Description:** COLLADA is for establishing an open standard digital asset schema for interactive 3D applications [COLLADA 2011]. The schema supports all the features that modern 3D interactive applications need including programmable shade effects and physics simulation. **Standard Type:** COLLADA 1.4.0 **Organization:** The Khronos Group **Classification:** Document format
Virtual Reality Modeling Language (VRML)	**Description:** VRML is a proposed design based on the Silicon Graphics Open Inventor ASCII file format. VRML is a language for describing multi-participant interactive simulations – virtual worlds networked via the global Internet and hyper-linked with the World Wide Web. All aspects of virtual world display, interaction and internetworking can be specified using VRML. It is the intention of its designers that VRML become the standard language for interactive simulation within the World Wide Web [WEB3D 2011a]. **Standard Type**: VRML 1.0 **Organization:** Silicon Graphics, Inc. **Classification:** Domain-specific integration interface
X3D	Description: X3D is a royalty-free open standards file format and run-time architecture to represent and communicate 3D scenes and objects using XML. It is an ISO ratified standard that provides a system for the storage, retrieval and playback of real time graphics content embedded in applications, all within an open architecture to support a wide array of domains and user scenarios [WEB3D 2011b]. **Standard Type:** ISO/IEC 19774:2006 (Humanoid Animation); ISO/IEC 19775-1:2008 (Architecture and base components); ISO/IEC 19775-2:2010 (Scene access interface); ISO/IEC 19776-1:2009 (XML encoding); NEN-ISO/IEC 19776-2:2008 en (Classic VRML encoding); ISO/IEC 19776-3.2:2010

	(Compressed binary encoding); ISO/IEC 19777-1:2005 (ECMAScript binding); ISO/IEC 19777-2:2006 (Java binding) **Organization:** The Web3D Consortium **Classification:** Document format

D.2 – Hazardous Material Release 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.

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 2011]. **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	**Description:** Format specifications for representing meteorological, non-grid-point data (alphanumeric text) [ANSI

Data (BUFR)	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 geo-spatial 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 2010s]. **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 2011]. **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 2011]. **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 (MHMIs)	**Description:** The Managing Hazardous Material Incidents (MHMIs) series was developed to provide emergency medical services (EMS) personnel and hospital emergency departments (EDs) with the necessary guidance to plan for, and improve their ability to respond to, incidents that involve human exposure to hazardous materials. The guidelines inform emergency personnel how to appropriately decontaminate, treat, and recommend follow-up care to exposed persons, as well as take measures to protect themselves. The MHMI series contain 3 volumes: "Emergency medical services: A planning guide for the management of contaminated patients;" "Hospital emergency departments: A planning guide for the management of contaminated patients;" and "Medical management guidelines (MMGs) for acute chemical exposures" [ATSDR 2010]. **Standard Type:** ATSDR MHMIs Version 2001 **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 Protection Data	**Description:** A specification that provides a common language and definitions to define and describe pre-incident environments, fire and other emergency incidents, post-incident damage assessments, and fire service data [NFPA 2011]. **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	**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

Public Health Officials	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
SEDRIS Technologies	**Description:** SEDRIS is an infrastructure technology that enables information technology applications to express, understand, share, and reuse environmental data. SEDRIS technologies provide the means to represent environmental data (terrain, ocean, air, and space), and promote the unambiguous, loss-less, and on-proprietary interchange of environmental data. SEDRIS technologies have been assembled into the specifications and associated language bindings that include: SEDRIS functional specification, SEDRIS abstract transmittal format, SEDRIS transmittal format binary encoding, SEDRIS language binding, Spatial Reference Model (SRM), the Environmental Data Coding Specification (EDCS), EDCS language bindings, and SRM binding. Relies on its five core technology components. These are the SEDRIS Data Representation Model (DRM), the Environmental Data Coding Specification (EDCS), the Spatial Reference Model (SRM), the SEDRIS interface specification (API), and the SEDRIS Transmittal Format (STF) [SEDRIS 2011a]. **Standard Type:** ISO/IEC 18023-1; ISO/IEC 18023-2; ISO/IEC 18023-3; ISO/IEC 18024-4; ISO/IEC 18025; ISO/IEC 18026; ISO/IEC 18041-4; ISO/IEC 18042-4 **Organization:** ISO/IEC; SEDRIS

	Classification: Document format and Domain-specific integration interface
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:** The standard identifies the minimum levels of competence required by responders to emergencies involving hazardous materials/weapons of mass destruction (WMD). 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 hazmats/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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 [ASTM 2011]-. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **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 2011]. **Standard type:** ASTM E2601-08 **Organization:** ASTM International **Classification:** Operational Guidelines

D.3 – Critical Infrastructure Standards and Guidelines

Standard Title	Overview
Building Escape and Evacuation Plans	**Description:** The standard establishes design principles for displayed escape plans that provide information vital to fire safety, escape, evacuation, and rescue of a facility's occupants. These plans may also be used by intervention forces in case of terrorist attack [ISO 2011a]. **Standard Type:** ISO 23601:2009 **Organization:** ISO **Classification:** Operational guidelines

Center-to-Center (C2C) Naming Convention Specification	**Description:** This standard provides a standard way for transportation management centers to uniquely name entities for which data are exchanged with other centers. It also lists the requirements for establishing names for management systems and for the objects managed by those systems [NTCIP 2011]. **Standard Type:** NTCIP 1104:2008 Version 01.09 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Domain-specific integration interface
Common Incident Management Message Sets for use by Emergency Management Centers (IEEE 1512 Family of Standards)	**Description:** An IEEE Family of standards for traffic incident management that provides incident management message sets common to traffic management, public safety, and hazardous materials incident response activities. The standards address the intercommunication needs of emergency management centers and other types of centers engaged in transportation incident management [IEEE 2011a]. **Standard Type:** IEEE 1512-2006; IEEE 1512.1-2003; IEEE 1512.2-2004; IEEE 1512.3-2006 **Organization:** Institute of Electrical and Electronics Engineers (IEEE); Federal Highway Administration (FHWA) **Classification:** Domain-specific integration interface
Communicable Disease Surveillance and Response Systems: A Guide to Planning	**Description:** This planning guide is to assist Member States to develop and/or refine comprehensive and cohesive plans for implementing and strengthening surveillance and response systems. It is anticipated that planners at all levels of the health system will find this guide useful as a general framework for developing a vision, strategies and routine operational plans for strengthening surveillance and response systems [WHO 2011a]. **Standard Type:** WHO/CDS/EPR/LYO/2006.1 **Organization:** The World Health Organization (WHO) **Classification:** Operational guidelines
Communicable Disease Surveillance and Response Systems: Guide to Monitoring and Evaluating	**Description:** This guide is to support implementation of monitoring and evaluation of communicable disease surveillance and response systems at country level. It was reviewed by experts in communicable disease surveillance and response systems, and pre-tested in Estonia and Ethiopia. This guide aims to assist countries in formulating and implementing monitoring and evaluation strategies [WHO 2011b]. **Standard Type:** WHO/CDS/EPR/LYO/2006.2 **Organization:** the World Health Organization (WHO) **Classification:** Operational guidelines
Community-Based Mass Prophylaxis: A Planning Guide for Public Health Preparedness	**Description:** A planning guide is used to help state, county, & local officials meet federal requirements to prepare for public health emergencies. Outlines five components of mass

	prophylaxis response to epidemic outbreaks: surveillance, stockpiling, distribution, dispensing, and follow up. Addresses dispensing operations using a comprehensive operational structure for Dispensing/Vaccination Centers (DVCs) based on the National Incident Management System (NIMS) [AHRQ 2011a]. **Standard Type:** Specification **Organization:** The Agency of Healthcare Research & Quality (AHRQ) **Classification:** Operational guidelines
Converting ATIS Message Standards from ASN.1 to XML	**Description**: This SAE Standard presents a set of rules for transforming an Abstract Syntax Notation (ASN.1) message set definition into an eXtensible Markup Language (XML) schema. The result is intended to be a stand-alone XML Schema that is fully consistent with an existing ASN.1 information model [SAE 2011b]. **Standard Type:** SAE J2630 **Organization:** Society of Automotive Engineers (SAE) International **Classification:** Domain-specific integration interface
Data Dictionaries for Intelligent Transportation Systems	Description: The expanding use of digital communications among subsystems of the transportation infrastructure has spawned the development of data dictionaries for the communications between these subsystems. A format for intelligent transportation system (ITS) data dictionaries, including common terms (e.g. time, date, location), as well as the meta-attributes necessary to document ITS data concepts, is addressed in this standard [IEEE 2011b]. **Standard Type:** IEEE 1489-1999 **Organization:** IEEE **Classification:** Domain-specific integration interface
Earthquake Instrumentation Criteria for Nuclear Power Plants	**Description:** This standard specifies the required earthquake instrumentation for the site and structures of light-water-cooled, land-based nuclear power plants. It may be used for guidance at other types of nuclear facilities [ANS 2011]. **Standard Type:** ANSI/ANS-2.2-2002 **Organization:** ANSI; American Nuclear Society (ANS) **Classification:** Operational guidelines
Electronic Data Interchange for Administration, Commerce, and Transport (EDIFACT)	**Description:** EDIFACT is an international electronic data interchange (EDI) standard developed under the United Nations and has been adopted by ISO as the ISO standard, ISO 9735. The standard gives syntax rules for the preparation of messages to be interchanged between partners in the fields of administration, commerce, and transport. ISO/TS 20625:2002 (or Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT) – Rules for Generation of XML

	Scheme Files (XSD) on the Basis of EDI(FACT) implementation guidelines), describes how to derive XML from UN/EDIFACT Message Implementation Guides (MIGs) [ISO 2011d]. **Standard Type:** ISO 9735-1:2002; ISO 9735-2:2002; ISO 9735-3:2002; ISO 9735-4:2002; ISO 9735-5:2002; ISO 9735-6:2002; ISO 9735-7:2002; ISO 9735-8:2002; ISO 9735-9:2002; ISO 9735-10:2002; ISO/TS 20625:2002 **Organization:** ISO **Classification:** Domain-specific integration interface
Field Management Stations (FMS) – Part 1: Object Definitions for Signal System Masters	**Description:** This standard provides the vocabulary (commands, responses and information) necessary for traffic management and operations personnel to control, manage and monitor signal system masters. The standard also includes a protocol requirements list (PRL) and a requirements traceability matrix providing object conformity information [NTCIP 2011]. **Standard Type:** NTCIP 1210:2009 Version 01.52 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Domain-specific integration interface
IEEE Safety and Security Standards Series	**Description:** The IEEE standards Association has prepared a three-volume Safety & Security standard series to assist the development of the organization's safety, security, and emergency management plans where Volume 1 is about critical infrastructure, Volume 2 is about computers and networks, and Volume 3 is about electrical systems. [IEEE 2011d] [IEEE 2011e] [IEEE 2011f]. **Standard Type:** IEEE STDVU121; IEEE STDVU122; IEEE STDVU123 **Organization:** IEEE **Classification:** Operational guidelines
Information Technology – Multimedia Content Description Interface	Description: ISO/IEC 15938 is a family of standards, under the general title of *Information technology – Multimedia content description interface*, provides multimedia content description interface including geographic. It consists of 8 parts: systems, description definition language, visual, audio, multimedia description schemes, reference software, conformance testing, and extraction and use of Multimedia Content Description Interface (MPEG-7) description [ISO 2011b]. **Standard Type:** ISO/IEC 15938-1:2002, ISO/IEC 15938-1:2002/Amd 1:2005/Cor 1:2005; ISO/IEC 15938-1:2002/Cor 1:2004; ISO/IEC 15938-1:2002/Cor 2:2005; ISO/IEC 15938-1:2002/Amd 1:2005; ISO/IEC 15938-1:2002/Amd 2:2006; ISO/IEC 15938-2:2002; ISO/IEC 15938-3:2002; ISO/IEC 15938-4:2002; ISO/IEC 15938-5:2003; ISO/IEC 15938-6:2003; ISO/IEC 15938-7:2003; ISO/IEC TR 15938-8:2002; ISO/IEC

	15938-9:2005; ISO/IEC 15938-10:2005; ISO/IEC TR 15938-11:2005; ISO/IEC 15938-12:2008 **Organization:** ISO; International Electrotechnical Commission (IEC) **Classification:** Domain-specific integration interface
International Classification of Diseases	**Description:** An official system of assigning codes to diagnoses and procedures associated with hospital utilization. The National Center for Health Statistics (NCHS), the Federal agency responsible for use of the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) in the United States, has developed a clinical modification of the classification for morbidity purposes. The ICD-10 is used to code and classify mortality data from death certificates, having replaced ICD-9 for this purpose as of January 1, 1999. ICD-10-CM is planned as the replacement for ICD-9-CM [CDC 2011a]. **Standard Type:** International Classification of Diseases, 10th Revision; Clinical Modification (ICD-10-CM) **Organization:** World Health Organization (WHO); National Center for Health Statistics (NCHS); Centers for Medicare and Medicaid Services **Classification:** Operational guidelines
National Weather Service (NWS) Directives System (NDS)	**Description:** This NDS is the NWS Directives System. It translates the ideas, goals, or principles contained in the NWS mission, vision, and strategic plan into action-related directives [NOAA 2011]. **Standard Type**: NWSI 10-517 2005 **Organization:** National Weather Service (NWS); NOAA **Classification:** Domain-specific integration interface
National Highway Traffic Safety Administration (NHTSA) Data Dictionary	**Description:** The data dictionary, used to create the National Highway Traffic Safety Administration's Uniform Pre-Hospital Emergency Medical Services (EMS) Dataset, provides over 400 definitions that can be implemented by an Emergency Medical Services (EMS) system. Information provided in the dictionary includes name, definition, data type, medical record information, variables associated, relation to other national data tools, data provider, etc. [UIC 2011]. **Standard Type**: NHTSA Uniform PreHospital EMS Dataset Version 2.2.1 (2006) **Organization:** National Highway Traffic Safety Administration (NHTSA) **Classification:** Document format
National Infrastructure Protection Plan (NIPP)	**Description:** The National Infrastructure Protection Plan (NIPP) is a coordinated strategy that defines critical infrastructure and key resources (CIKR) protection roles and responsibilities for federal, state, local, tribal, and private sector security partners. The NIPP sets national priorities, goals, and requirements for

	effective distribution of resources that will enable the government, economy, and public services to continue in the event of a terrorist attack or other disaster. The plan provides the unifying structure for the integration of a wide range of efforts for the enhanced protection and resiliency of the Nation's CIKR into a single national program [DHS 2009a]. **Standard Type:** The 2009 National Infrastructure Protection Plan **Organization:** Department of Homeland Security **Classification:** Operational guidelines
Object Definitions for Actuated Traffic Signal Controller Units	**Description:** A National Transportation Communications for the Institute of Transportation Engineers (ITS) Protocol (NTCIP) standard where NTCIP is a family of communication protocols for traffic management devices. The standard defines the data elements and conformance requirements for actuated traffic signal controllers (ASC) [NTCIP 2011]. The data in the standard is defined using specifications from the internet, and expresses a signal system's operating parameters, functional controls, and status information. Some of these functions include: signal phases, detectors, coordination, preemption, upload and download, and block object data for efficient device configuration. **Standard Type:** NTCIP 1202:2005, Version 02 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Document format
Object Definitions for Closed Circuit Television (CCTV) Camera Control	**Description:** This standard defines data elements required to control video cameras and also defines standardized object Groups which can be used for conformance statements [NTCIP 2011]. It provides the vocabulary – commands, responses and information – necessary for traffic management and operations personnel to control, manage, and monitor cameras, lenses and pan/tilt units. This standard contains object definitions to support the functionality of these devices as used for transportation and traffic monitoring applications. The standard includes conformance group requirements and conformance statements to support compliance with the standard. **Standard Type:** NTCIP 1205:2001, Version 01.08 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Document format
Object Definitions for Dynamic Message Signs (DMS)	**Description:** This standard provides the vocabulary – commands, responses, and information – necessary for traffic management and operations personnel to advise and inform the

	vehicle operators of current highway conditions by using dynamic message signs. A dynamic message sign is any sign that can change the message presented to the viewer. The standard also includes a Protocol Requirements List table, standardized data exchange dialogs, a Requirements Traceability Matrix, etc. [NTCIP 2011]. **Standard Type:** NTCIP 1203: 1997, Version 01.15 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Document format
Object Definitions for Environmental Sensor Stations (ESS)	**Description:** The standard provides the vocabulary – commands, responses, and information – necessary for the management of environmental sensor stations, including road weather information systems (RWIS), air quality monitoring systems, and pavement treatment systems (PTS) [NTCIP 2011]. **Standard Type:** NTCIP 1204, Version 03 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Document format
Object Definitions for Transportation Sensor Systems (TSS)	**Description:** The standard defines the user needs and features, functional requirements, and standardized data element and message dialog definitions for Transportation Sensor Systems (TSS) [NCTIP 2011]. It provides the vocabulary – commands, responses and information – necessary for traffic management and operations personnel to control, manage, and monitor transportation sensor system devices. These devices include smart inductive loop amplifiers, machine vision video detection, and microwave radar monitoring systems. **Standard Type:** NTCIP 1209:2005, Version 01.19; NTCIP 1209, Version 2 (Recommended standard) **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Document format
On-Board Land Vehicle Mayday Reporting Interface	**Description:** This standard addresses the responsibilities of a vehicle in detecting and reporting the event associated with either the intelligent vehicle itself or by the intelligent roadway of the vehicle that is disabled or involved. It proscribes a basic methodology to uniformly incorporate whatever level of data reporting the vehicle supports (containing information about both the vehicle condition and any occupant data), and transmits this data to the response management agency in a Nationally standardized format, regardless of the transmission media used

	to effect the communications [SAE 2011a]. The standard is intended for use by private industry (e.g., manufacturers) and public safety and emergency response agencies (at the receiving/dispatching point) at local, state, and national levels. Receiving devices are expected to be found at local public response dispatch points (primary safety answering points). **Standard Type:** SAE J2313 **Organization:** Society of Automotive Engineers (SAE) International **Classification:** Operational guidelines
Pandemic Phase Descriptions and Main Actions by Phase	**Description:** This document defines pandemic phases and main actions by phase. The pandemic phases include phases 1-6, post peak period, and post pandemic period [WHO 2011c] **Standard Type:** WHO specification **Organization:** World Health Organization (WHO) **Classification:** Operational guidelines
Practice for Metadata to Support Archived Data Management Systems	**Description:** This standard practice describes a hierarchical outline of sections and elements to be used in developing metadata to support archived data management systems. Specifically, the standard establishes the names of metadata elements and compound elements to be used in the metadata, the definitions of these metadata elements and compound elements, and suggested information about and examples of the values that are to be provided for the metadata elements. This standard is applicable to various types of operational data collected by intelligent transportation systems (ITS) and stored in an archived data management system. Similarly, the standard can also be used with other types of historical traffic and transportation data collected and stored in an archived data management system [ASTM 2011a]. **Standard Type:** ASTM E2468-05 **Organization:** ASTM International **Classification:** Domain-specific integration interface
Protocol for the Assessment of National Communicable Disease Surveillance and Response Systems: Guidelines for Assessment Teams	**Description:** This manual has been developed for World Health Organization (WHO) staff and partners carrying out assessments of national communicable disease surveillance systems with a national team. It will help WHO staff and consultants guide a group of national professionals through an assessment of the overall structure and performance of surveillance activities in a Member State. This assessment should lead to a standardized report and an agreed plan of action. The manual also outlines a suggested reporting format with tables for implementation plans [WHO 2011d]. **Standard Type:** WHO/CDS/CSR/ISR/2001/2/EN **Organization:** The World Health Organization (WHO) **Classification:** Operational guidelines; Document format

Public Health Emergency Response Guide for State, Local, & Tribal Public Health Directors	**Description:** The Public Health Emergency Response Guide is used for State, Local, and Tribal Public Health Directors. The guide is an all-hazards reference tool for health professionals who are responsible for initiating the public health response during the first 24 hours (i.e., the acute phase) of an emergency or disaster. It also contains guidance that is applicable to specific types of incidents, such as floods, earthquakes, and acts of terrorism [CDC 2011b]. **Standard Type:** Specification **Organization:** The National Center for Environmental Health (NCEH), Division of Emergency and Environmental Health Services (EEHS), the Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Radio Data System- Traffic Message Channel (RDS-TMC)	**Description:** The Traffic Message Channel (TMC) is a technology for providing traffic and travel delay information to drivers. The complementary Radio Data System (RDS) broadcasts digital information carrying TMC updates via FM radio waves. RDS-TMC is standardized under the EN ISO 14819-series [ETSI 2011]. **Standard Type:** Industry specification **Organization:** Traveler Information Services Association (TISA); ISO; European Committee for Standardization **Classification:** Document format
Road Transport and Traffic Telematics – Dedicate Short Range Communication (DSRC) – DSRC Application Layer	**Description:** The standard specifies the application layer core, which provides communication tools for applications based on dedicated short-range communication (DSRC) [ISO 2011c]. **Standard Type:** ISO 15628: 2007 **Organization:** ISO **Classification:** Domain-specific integration interface
SARS Risk Assessment and Preparedness Framework	**Description:** This document sets out a framework of activities, at national and international levels, that can be used to assess the risk that SARS might recur and to prepare appropriate contingency plans. Modeled on WHO's influenza pandemic preparedness plan, the framework adopts a phased approach in which recommended activities escalate in line with the evolving epidemiological situation. Phases are defined by distinct epidemiological criteria, such as the detection of sporadic cases with no secondary spread, the establishment of human-to-human transmission, and evidence of international spread [WHO 2011e]. **Standard Type:** WHO/CDS/CSR/ARO/2004.2 **Organization:** The World Health Organization (WHO) **Classification:** Operational guidelines
Sector-Specific Plans (SSPs)	**Description:** Sector-Specific Plans (SSPs) have been developed for each of the identified critical infrastructure sectors

	supporting the National Infrastructure Protection Plan (NIPP). The Sector-Specific Plans (SSPs) detail the application of the National Infrastructure Protection Plan (NIPP) risk management framework to the unique characteristics and risk landscape of each sector and provide the means by which the NIPP is implemented across all critical infrastructure and key resources (CIKR) sectors. Each Sector-Specific Agency developed an SSP through a coordinated effort involving their public and private sector CIKR partners [DHS 2011b]. **Standard Type:** The Sector-Specific Plans for Agriculture and Food; Banking and Finance; Communications; Defense Industrial Base; Energy; Information Technology; National Monuments and Icons; Transportation Systems; and Water. **Organization:** Department of Homeland Security **Classification:** Operational guidelines
Simple Transportation Management Framework (STMF)	**Description:** This standard describes the simple transportation management framework used for managing and communicating information between management stations and transportation devices. It covers integrated management of transportation networks, networking devices, and transportation specific equipment attached to NTCIP-based networks [NTCIP 2011]. It specifies a set of rules for processing, organizing and exchanging information between transportation centers (management applications) and transportation equipment (traffic signal controllers, message signs, etc.) so they can communicate with each other. **Standard Type:** NTCIP 1101:1996; NTCIP 1101 Amendment 1 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Domain-specific integration interface
Simple Transportation Management Framework (STMF) Application Profile	**Description:** This standard defines how to exchange data between a management system and a field device with the Simple Transportation Management Framework (STMF). This standard includes mandatory requirements for implementing the STMF, and optional and conditional requirements that may be applicable in specific environments [NTCIP 2011]. **Standard Type:** NTCIP 2301:2001 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Domain-specific integration interface
Smallpox Response Plan and Guidelines	**Description:** This document outlines the public health strategies that would guide the public health response to a smallpox emergency and many of the federal, state, and local public

	health activities that must be undertaken in a smallpox outbreak [CDC 2011c]. **Standard Type:** Smallpox Response Plan and Guidelines, Version 3.0 **Organization:** Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems	**Description:** This standard describes a medium access control (MAC) and physical layer (PHY) specification for wireless connectivity using dedicated short-range communications (DSRC) services. DSRC provides the foundation for a variety of applications including vehicle safety, automated tolling, enhanced navigation, traffic management and many others [ASTM 2011b]. **Standard Type:** ASTM E2213-03 (2010) **Organization:** ASTM International **Classification:** Domain-specific integration interface
Specifications for Archiving ITS-Generated Traffic Monitoring Data	**Description:** This specification describes data elements and schema for an archived data management system for intelligent transportation system (ITS)-generated traffic monitoring data, including conventional traffic monitoring data, data collected directly from ITS systems, and travel-time data from probe vehicles. It establishes the names of the data elements, their interrelationships, and their procedural definitions. These procedural definitions include data collection instrumentation and methodology as well as recommended procedures for calculating traffic statistics [ASTM 2011c]. **Standard Type:** ASTM E2665-08 **Organization:** ASTM International **Classification:** Domain-specific integration interface
Standard Classifications for Incident Reporting and Fire Protection Data	**Description:** The specification provides a common language and definitions for define and describe pre-incident environments, fire, and other emergency incidents, post-incident damage assessments, and fire service data [NFPA 2011]. **Standard Type:** NFPA 901: 2011 **Organization:** National Fire Protection Association (NFPA) **Classification:** Domain-specific integration interface; Operational guidelines
Standard for a Fire Service Vehicle Operations Training Program	**Description:** It specifies the minimum requirements for a fire service vehicle operations training program (except for aircraft and watercraft), including safety procedures for those members who drive or occupy fire service vehicles [NFPA 2011]. **Standard Type:** NFPA 1451: 2007 **Organization:** National Fire Protection Association (NFPA) **Classification:** Operational guidelines

Standard for Installation, Maintenance, and Use of Emergency Services Communications Systems	**Description:** The standard covers the installation, performance, operation, and maintenance of public emergency services communications systems and facilities [NFPA 2011]. **Standard Type:** NFPA 1221: 2010 **Organization:** National Protection Association (NFPA) **Classification:** Operational guidelines
Standard on Disaster/Emergency Management and Business Continuity Programs	**Description:** The standard provides a foundation for disaster/emergency management planning and operations and describes common elements, techniques, and processes [NFPA 2011]. **Standard Type:** NFPA 1600:2010 Organization: National Fire Protection Association (NFPA) **Classification:** Operational guidelines
Standard on Emergency Services Incident Management System Overview	**Description:** The standard defines and describes the essential elements of an incident management system that promotes coordination among responding agencies [NFPA 2011]. **Standard Type:** NFPA 1561:2008 **Organization:** National Fire Protection Association (NFPA) **Classification:** Domain-specific integration interface
Standard on Stored Electrical Energy Emergency and Standby Power Systems	**Description:** This Standard presents performance requirements for Level 1 and Level 2 stored electric energy systems providing an alternate source of electrical power in buildings and facilities in the event that the normal electrical power source fails. NFPA 111 also provides guidance for inspectors, designers, installers, manufacturers, and users of a stored emergency power supply system (SEPSS) and to serve as a basis for communication between the parties involved. Systems covered include power sources, transfer equipment, controls, supervisory equipment, and accessory equipment needed to supply electrical power to selected circuits [NFPA 2011]. **Standard Type:** NFPA 111-2010 **Organization:** National Fire Protection Association (NFPA) **Classification:** Operational guidelines
Traffic and Travel Information (TTI) – TTI via Transport Protocol Experts Group (TPEG) Extensible Markup Language (XML)	**Description:** ISO/TS 24530-1:2006 establishes the top-level "containers" for TPEG messages in XML and the common data types that are used by tpegML applications (e.g. tpeg-ptiML). ISO/TS 24530-2:2006 establishes the XML encoding of the method of Location Referencing used by TPEG applications. ISO/TS 24530-3:2006 establishes the XML encoding of the method of the Road Traffic Message application. ISO/TS 24530-4:2006 establishes the XML encoding of the method of the Public Transport Information application [ISO 2011b]. **Standard Type:** ISO/TS 24530-1:2006; ISO/TS 24530-2:2006; ISO/TS 24530-3:2006; ISO/TS 24530-4:2006 **Organization:** ISO **Classification:** Domain-specific integration interface

Traffic Management Center-to-Center Communications	**Description:** The standard for Traffic Management Center-to-Center contains both a functional level data dictionary and a message set and is designed to be independent of any specific communications protocol. The data dictionary defines a set of data elements (Des) necessary to support data exchange within and among traffic management systems. Specifically, it provides meta-attributes for each DE including definitions (semantics) and specific format (syntax) [IHS 2011]. **Standard Type:** AASHTO-ITE TM 2.1 **Organization:** U.S. Department of Transportation (DOT) **Classification:** Document format
Transit Communications Interface Profiles (TCIP)	**Description:** TCIP provides a library of information exchange building blocks, to allow transit agencies and transit suppliers to create standardized tailored interfaces [APTATCIP 2011]. The Transit Communications Interface Profiles (TCIP) standard specifies the rules and terms for the automated exchange of information in transit applications such as operations, maintenance, planning, management, and customer services. TCIP is an interface standard whose primary purpose is to define standardized mechanisms for the exchange of information in the form of data among transit business systems, subsystems, components, and devices. **Standard Type:** APTA TCIP-S-01 3.0.3 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Domain-specific integration interface
Transport information and control systems – Traffic Impediment Warning Systems (TIWS) – System Requirements	**Description:** This standard specifies system requirements for Traffic Impediment Warning Systems (TIWS). The purposes of the warning system are that information collected by the infrastructure is automatically and quickly provided to vehicles and reported to the traffic system operator, so vehicles can avoid secondary accidents. This Technical Specification focuses on closed circuit television (CCTV) cameras as the sensors, to detect traffic impediments using image processing and variable message signs as the communication method to provide information to drivers [ISO 2011b]. **Standard Type:** ISO/TS 15624:2001 **Organization:** ISO **Classification:** Operating guidelines
Transportation Management Protocols (TMP)	**Description:** This standard defines a set of rules and services for exchanging transportation management information between transportation management applications and equipment in an interoperable manner. TMP defines a composite application layer protocol for the management of transportation equipment.

	The composite protocol consists of three component protocols: the Internet-standard Simple Network Management Protocol (SNMP), the Simple Fixed Message Protocol (SFMP), and the Simple Transportation Management Protocol (STMP) [NTCIP 2011]. **Standard Type:** NTCIP 1103:2010 Version 02.17 **Organization:** American Association of State Highway and Transportation Officials (AASHTO); Institute of Transportation Engineers (ITE); National Electrical Manufacturers Association (NEMA) **Classification:** Domain-specific integration interface

D.4 – Incident Management Standards and Guidelines

This section identifies standards and guidelines that are potentially relevant to the development of M&S applications for incident management systems. 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 incident management M&S applications. Subsection 1 includes the standards that are specific to incident management 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), communications, and training respectively.

Standard Title	Overview
Advisory and Notification Markup Language (ANML)	**Description:** The Open Security Organization is developing an Advisory and Notification Markup Language (ANML). ANML is an XML-based specification for describing advisories and other types of notifications. ANML intends to solve the inconsistent use of terminology by software vendors in their advisories and make it easy for applications to read these advisories. Although ANML will have its biggest impact for security advisories, it can be used for any type of notification [OASIS 2010a]. **Standard Type:** Industry specification **Organization:** Open Security Organization **Classification:** Domain-specific Integration Interface
Common Biometric Exchange Formats Framework (CBEFF)	**Description:** The Common Biometric Exchange Formats Framework (CBEFF) describes the data elements necessary for biometric data interchange among proprietary application programs. It describes a set of data elements necessary to support biometric technologies in a common way. These data elements can be placed in a single file used to exchange biometric information between different system components or between systems themselves. The result promotes interoperability of biometric-based application programs and systems developed by different vendors by allowing biometric

	data interchange. Specifically, ANSI International Committee for Information Technology Standards (INCITS) 398 supports multiple biometric data types (e.g., fingerprint, face, and voice recognition.) and/or multiple biometric data blocks of the same biometric type. It also defines biometric data objects for use within smart cards and other tokens and describes common fields for biometric features and the validity period [ANSI 2010]. **Standard Type:** ANSI INCITS 398-2008 **Organization:** American National Standards Institute (ANSI) **Classification:** Domain-specific Integration Interface
Common Intrusion Detection Signatures Standard (CIDSS)	**Description:** The purpose of the Common Intrusion Detection Signatures Standard (CIDSS) is to define a common data format for storing signatures from different intrusion detection systems. CIDSS describes a common data format to represent information contained in signatures of intrusion detection systems, and explains the rationale for using this common format. The proposed format is a dialect of the Extensible Markup Language (XML) [OASIS 2010a]. **Standard Type:** CIDSS Version 05 **Organization:** CIDSS Development Group **Classification:** Domain-specific Integration Interface
Critical Infrastructure Protection Initiative (CIPI)	**Description:** The Open GIS Consortium (OGC) Critical Infrastructure Protection Initiative (CIPI) is an OGC Interoperability Initiative designed to test the application of interoperable technology to meet Critical Infrastructure Detection, Prevention, Planning, Response, and Recovery challenges. The Critical Infrastructure Protection Initiative Phase 1, Requirement Set 2 (CIPI-1.2) is a pilot project that leverages the success of previous and ongoing OGC initiatives to improve interoperability across communities that need to collaborate to detect, prevent, plan for, respond to, and recover from natural and human threats to telecommunications, water resources, oil and gas, government, transportation, emergency response, electric power and health services infrastructure. A collaborative effort, CIPI is being conducted in coordination with federal, state, local government, commercial, and non-government sponsors. CIPI will also identify requirements for new specifications to advance plug and play interoperability for critical infrastructure protection. The work on CIPI 1.2 has produced Draft Interoperability Reports [OGC 2010]. **Standard Type:** CIPI, Phase 1.2 **Organization:** Open GIS Consortium (OGC) **Classification:** Operational Guidelines
Emergency Alert System-Common Alerting Protocol (EAS-CAP) Implementation Guide	**Description:** Public warnings intended for transmission over the Emergency Alert System (EAS) can be encoded in Common Alerting Protocol (CAP) messages in various ways. The EAS-CAP Industry Group (ECIG) Implementation Guide (Version

	1.0) has been compiled in light of the draft OASIS CAP v1.2 specification and the Integrated Public Alert and Warning System (IPAWS) CAP-EAS Profile v1.0, as well as the results of a public comment period on the prior draft Implementation Guide. The guide is intended to further reduce areas of uncertainty in how an alert will be presented to the public via CAP-EAS, so that originators and distributors of alerts can deliver the intended message to the public, regardless of the vendors or platforms involved [ECIG 2010]. **Standard Type:** ECIG-IG-1.0 **Organization:** EAS-CAP Industry Group (ECIG) **Classification:** Operational Guidelines
Emergency Management Standard	**Description:** The Emergency Management Standard by the Emergency Management Accreditation Program (EMAP) is designed as a tool for continuous improvement as part of a voluntary accreditation process for local and state emergency management programs. EMAP makes no representation or guarantee as to the efficacy of any program as a result of use of or compliance with the standards contained herein. EMAP makes no guarantee or warranty as to the completeness of information in this document, and EMAP expressly disclaims liability for any personal injury or damages of any nature resulting from the publication, use of, or reliance on this document. Standard language has been developed through a series of collaborative workshops and committee and commission meetings [EMAP 2010]. **Standard Type:** EMAP Standard, September 2007 **Organization:** Emergency Management Accreditation Program (EMAP) **Classification:** Domain-specific Integration Interface
FEMA Comprehensive Preparedness Guide	**Description:** The Federal Emergency Management Agency (FEMA) Comprehensive Preparedness Guide provides general guidelines on developing Emergency Operations Plans (EOPs). It promotes a common understanding of the fundamentals of planning and decision making to help emergency planners examine a hazard and produce integrated, coordinated, and synchronized plans. This Guide helps emergency managers in State, Territorial, Local, and Tribal governments in their efforts to develop and maintain a viable all-hazard EOP [FEMA 2010a]. **Standard Type:** CPG 101 **Organization:** Federal Emergency Management Agency (FEMA) **Classification:** Operational Guidelines
Global Justice XML Data Model (GJXDM)	**Description:** The Global Justice XML Data Model (GJXDM) is an XML standard designed specifically for criminal justice information exchanges, providing law enforcement, public safety agencies, prosecutors, public defenders, and the judicial

	branch with a tool to effectively share data and information in a timely manner. There are three primary parts to the GJXDM: the Data Dictionary (identifying content and meaning), the Data Model (defining structure and organization), and the Component Reuse Repository [OJP 2010]. **Standard Type:** Global JXDM Version 3.0.3 **Organization:** U.S. Department of Justice (DOJ) **Classification:** Domain-specific Integration Interface
Incident Command System (ICS) Model Procedures Guide for Incidents Involving Structural Fire Fighting, High Rise, Multi Casualty, Highway, & Managing Large-Scale Incidents Using NIMS-ICS	**Description:** This manual combines the information from four existing National Incident Management System Consortium (NIMSC) Model Procedures Guides, plus new information on managing large-scale incidents, into one comprehensive, NIMS-compliant book. As with all NIMSC model procedures, this information was developed and approved by a broad group of national experts on these topics. The manual includes basic information on the National Incident Management System (NIMS) ICS and then detailed information on how to apply it to structure fires, high-rise fires, major EMS incidents, roadway incidents, and large-scale incidents of all types. This includes concepts such as unified command, area command, joint operations centers (JOC), multi-agency coordination centers (MACC) and much more. This is the definitive text on the application of NIMS ICS to common types of emergency incidents [NIMCS 2010a]. **Standard Type:** Incident Command System (ICS) Model Procedures Guide for Incidents Involving Structural Fire Fighting, High Rise, Multi Casualty, Highway, & Managing Large-Scale Incidents Using NIMS-ICS, Book 1 – First Edition **Organization:** National Incident Management System Consortium (NIMSC) **Classification:** Operational Guidelines
Incident Command System (ICS) Model Procedures Guide for Special Operations - Incidents Involving Hazardous Materials/WMD, Structural Collapse, Wildland, and Managing Large-Scale Incidents Using NIMS-ICS	**Description:** This manual combines the information from three existing National Incident Management System Consortium (NIMSC) Model Procedures Guides, plus new information on managing large-scale incidents, into one comprehensive, NIMS-compliant book. As with all NIMSC model procedures, this information was developed and approved by a broad group of national experts on these topics. The manual includes basic information on NIMS Incident Command System (ICS) and then detailed information on how to apply it to wildland, hazardous materials, urban search and rescue structural collapse, and large-scale incidents of all types. This includes concepts such as unified command, area command, joint operations centers (JOC), multi-agency coordination centers (MACC), and much more [NIMCS 2010b]. **Standard Type:** Special Operations - Incidents Involving Hazardous Materials/WMD, Structural Collapse, Wildland, and Managing Large-Scale Incidents Using NIMS-ICS, Book 2 – First Edition

	Organization: National Incident Management System Consortium (NIMSC) **Classification:** Operational Guidelines
Incident Object Description and Exchange Format (IODEF)	**Description:** The Incident Object Description Exchange Format (IODEF) is a format for representing computer security information commonly exchanged between Computer Security Incident Response Teams (CSIRTs). It provides an XML representation for conveying incident information across administrative domains between parties that have an operational responsibility of remediation or a watch-and-warning over a defined constituency. The data model encodes information about hosts, networks, and the services running on these systems; attack methodology and associated forensic evidence; impact of the activity; and limited approaches for documenting workflow [OASIS 2010a]. **Standard Type:** Industry specification **Organization:** Internet Engineering Task Force *(*IETF*)* Extended Incident Handling (INCH) Working Group **Classification:** Domain-specific Integration Interface
Intrusion Detection Message Exchange Format (IDMEF)	**Description:** The purpose of the Intrusion Detection Message Exchange Format (IDMEF) is to define data formats and exchange procedures for sharing information of interest to intrusion detection and response systems, and to the management systems, which may need to interact with them. The IDMEF data model is an object-oriented representation of the alert data sent to intrusion detection managers by intrusion detection analyzers. The data model defines support classes that accommodate the differences in data sources among analyzers. In particular, the notions of source and target for the alert are represented by the combination of Node, Process, Service, and User classes [OASIS 2010a]. **Standard Type:** IDMEF **Organization:** Internet Engineering Task Force *(*IETF*)* Intrusion Detection Exchange Format Working Group **Classification:** Domain-specific Integration Interface
Managing Hazardous Material Incidents (MHMIs)	**Description:** The Managing Hazardous Material Incidents (MHMIs) series was developed to provide emergency medical services (EMS) personnel and hospital emergency departments (EDs) with the necessary guidance to plan for, and improve their ability to respond to, incidents that involve human exposure to hazardous materials. The guidelines inform emergency personnel how to appropriately decontaminate, treat, and recommend follow-up care to exposed persons, as well as take measures to protect themselves. The MHMI series contain 3 volumes: “Emergency medical services: A planning guide for the management of contaminated patients;” “Hospital emergency departments: A planning guide for the management of contaminated patients;” and “Medical management guidelines

	(MMGs) for acute chemical exposures" [ATSDR 2010]. **Standard Type:** ATSDR MHMIs Version 2001 **Organization:** The Agency for Toxic Substances and Disease Registry (ATSDR) **Classification:** Operational Guidelines
Mass Casualty Event Preparedness and Response	**Description:** This document is an interim planning guidance for preparedness and response to a mass casualty event resulting from terrorist use of explosives. It includes a description of system-wide and discipline-specific challenges as well as recommended solutions to address these challenges. The proposed solutions for the discipline-specific challenges have been incorporated into easy to use templates that can assist various disciplines in managing surge needs for injuries. [CDC 2010]. **Standard Type:** Government document **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Model Procedures Guide for Highway Incidents	**Description:** Model Procedures Guide for Highway Incidents is a document that guides application of the Incident Management System (IMS) to events occurring on these high-volume roadways. The Guide addresses command structures for potential events ranging from parades to hazmat spills. Its idea is that the IMS is adaptable enough to handle incidents as small as a single-car breakdown and as large as a major winter storm. The guide discusses the factors involved in: providing emergency services and unblocking traffic as quickly as possible; protecting incident responders and those under their care from moving vehicles; protecting other motorists, passengers and cargo from incident hazards; facilitating the movement of emergency vehicles to and from the scene; and facilitating traffic flow past the incident and throughout the area [DOT 2010]. **Standard Type:** Government document **Organization:** National Fire Service Incident Management System Consortium (NFSIMSC), U.S. Department of Transportation **Classification:** Operational Guidelines
National Emergency Communications Plan	**Description:** The National Emergency Communications Plan (NECP) is a strategic plan that sets goals and identifies key national priorities to enhance governance, planning, technology, training and exercises, and disaster communications capabilities. The NECP provides recommendations including milestones to help emergency response providers and relevant government officials make measurable improvements in emergency communications over the next three years [DHS 2010b]. **Standard Type:** NEPC, July 2008 **Organization:** U.S. Department of Homeland Security (DHS)

	Classification: Operational Guidelines
National Incident Management System (NIMS)	**Description:** The National Incident Management System (NIMS) provides a systematic, proactive approach to guide departments and agencies at all levels of government, nongovernmental organizations, and the private sector to work seamlessly to prevent, protect against, respond to, recover from, and mitigate the effects of incidents, regardless of cause, size, location, or complexity, in order to reduce the loss of life and property and harm to the environment [FEMA 2010b]. **Standard Type:** National Incident Management System, December 2008 **Organization:** U.S. Department of Homeland Security (DHS) **Classification:** Operational Guidelines
National Preparedness Guidelines	**Description:** The Guidelines, including the supporting Target Capabilities List, supersedes the Interim National Preparedness Goal and defines what it means for the Nation to be prepared for all hazards. There are four critical elements of the Guidelines: National Preparedness Vision, National Planning Scenarios, Universal Task List (UTL), and Target Capabilities List (TCL) [FEMA 2010c]. **Standard Type:** National Preparedness Guidelines, September 2007 **Organization:** U.S. Department of Homeland Security (DHS) **Classification:** Operational Guidelines
National Response Framework	**Description:** The National Response Framework presents the guiding principles that enable all response partners to prepare for and provide a unified national response to disasters and emergencies - from the smallest incident to the largest catastrophe. The Framework establishes a comprehensive, national, all-hazards approach to domestic incident response [FEMA 2010d]. **Standard Type:** National Response Framework, January 2008 **Organization:** U.S. Department of Homeland Security (DHS) **Classification:** Operational Guidelines
National Strategy for Homeland Security	**Description:** The National Strategy for Homeland Security guides, organizes, and unifies our Nation's homeland security efforts. The 2008 Strategic Plan serves to focus the Department's mission and sharpen operational effectiveness, particularly in delivering services in support of Department-wide initiatives and the other mission goals. It identifies the goals and objectives by which we continually assess our performance. The Department uses performance measures at all levels to monitor our strategic progress and program success. This process also keeps the Department's priorities aligned, linking programs and operations to performance measures, mission goals, resource priorities, and strategic objectives [DHS

	2010c]. **Standard Type:** National Strategy for Homeland Security, September 16, 2008 **Organization:** U.S. Department of Homeland Security (DHS) **Classification:** Operational Guidelines
New Guide for School Preparedness and All Hazard Response	**Description:** The guide covers concepts, principles, and best practices for all-hazards integrated emergency management programs in preparedness, prevention, mitigation, response, and recovery for schools and school districts in preparation and response to a natural or man-caused incident [ASTM 2011]. **Standard Type:** ASTM WK8908 (Work Item) **Organization:** ASTM International **Classification:** Operational Guidelines
Preparing for a Terrorist Bombing: A Common Sense Approach	**Description:** This document focuses on common sense principles that will be useful in a bombing event [CDC 2010q]. **Standard Type:** Government document **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational Guidelines
Really Simple Syndication (RSS)	**Description:** Really Simple Syndication (RSS) is a family of web feed formats used to publish frequently updated works, such as blog entries, news headlines, audio, and video, in a standardized format. An RSS document includes full or summarized text, plus metadata such as publishing dates and authorship. Web feeds benefit publishers by letting them syndicate content automatically. They benefit readers who want to subscribe to timely updates from favored websites or to aggregate feeds from many sites into one place [RSSBOARD 2010]. **Standard Type:** RSS 2.0 **Organization:** RSS Advisory Board **Classification:** Domain-specific Integration Interface
Standard Classification for Search and Rescue Dog Crew/Teams	**Description:** The Standard Classification for Search and Rescue Dog Crew/Teams covers the aid of search and rescue managers in ordering resources for search and rescue incidents and to aid dog handlers in communicating the types of tasked for which they and their dogs have trained. This classification is intended as a supplement to the resource typing specifications of the Incident Command System and specifically as a means of typing search and rescue dog resources. This classification is suitable for classifying dog resources for a wide variety of emergency management purposes including both search and rescue and law enforcement incidents [ASTM 2011]. **Standard Type:** ASTM F1848-98 (2005) **Organization:** ASTM International **Classification:** Operational Guidelines

Standard for Installation, Maintenance, and Use of Emergency Services Communications Systems	**Description:** The Standard for Installation, Maintenance, and Use of Emergency Services Communications Systems covers the installation, performance, operation, and maintenance of public emergency services communications systems and facilities. It is not intended as a design specification manual or an instruction manual. The standard covers systems that receive alarms from the public, e.g., 9-1-1 services systems and communications centers, and retransmits those alarms to response agencies. It also provides requirements for dispatching systems and establishes a level of performance and the quality of installations for emergency communication systems. Elements of these systems may include communications centers, signal wiring, emergency response facilities, operations centers, telephones, dispatching systems, computer-aided dispatching, and public alerting systems. Other operations covered under this standard include system testing, record keeping, network security, and redundancy [NFPA 2011]. **Standard Type:** NFPA 1221-2010 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Standard Guide for Developing a Hazardous Materials Training Curriculum for Initial Response Personnel	**Description:** This guide summarizes the typical contents of a course to aid emergency response team training organizations in selecting important subjects for inclusion in existing or new training programs. It covers a format for a hazardous materials spill initial response team training curriculum [ASTM 2011]. **Standard Type:** F1011 - 07 **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Using the Incident Command System Framework in Managing Search and Rescue Operations	**Description:** This Standard Guide for Using the Incident Command System Framework in Managing Search and Rescue Operations covers the use of the Incident Command System (ICS), as developed in the National Incident Management System (NIMS) in 2004, as the management framework for search and rescue (SAR) operations. Except as otherwise specified herein, the methods and requirements of this standard also include NIMS, ICS, and National Response Framework (NRF) requirements, when required, for search and rescue personnel that deploy within the United States of America. The ICS may be used outside of the United States for managing SAR operations, users of this standard need to be aware of other incident management requirements, guidelines, policies, procedures, and protocols within the area of ICS SAR operations [ASTM 2011]. **Standard Type:** ASTM F1422 - 08 **Organization:** ASTM International **Classification:** Operational Guidelines

Standard on Disaster/Emergency Management and Business Continuity Programs	**Description:** This standard establishes a common set of criteria for disaster/emergency management and business continuity programs. Specifically, this standard provides disaster/emergency management and business continuity programs the criteria to assess current programs or to develop, implement, and maintain aspects for prevention, mitigation, preparation, response, and recovery from emergencies. This standard applies to public, nongovernmental, and private entities [NFPA 2011]. **Standard Type:** NFPA 1600 (2007) **Organization:** National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Standard on Emergency Services Incident Management System	**Description:** This standard establishes the minimum requirements for an incident management system to be used by emergency services to manage all incidents/planned events. Requirements are established for operating systems, implementation, and communications. Furthermore, the standard provides a description of key positions and roles within the incident management system, including the functions of the Incident Commander, Command Staff, Operations, Planning, Logistics, and Finance/Administration. The standard also addresses requirements for multi-agency coordination and training and staffing for Incident Management Teams [NFPA 2011]. **Standard Type:** NFPA 1561 (2008) **Organization:** National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Standard on Fire Department Occupational Safety and Health Program	**Description:** The Standard on Fire Department Occupational Safety and Health Program standard contains minimum requirements for a fire–service-related occupational safety and health program. The standard specifies safety requirements for those members involved in rescue, fire suppression, emergency medical services, hazardous materials operations, special operations, and related activities. It covers everything from training, vehicles, and equipment to protective clothing, emergency operations, and incident stress [NFPA 2011]. **Standard Type:** NFPA 1500 - 2007 **Organization:** National Fire Protection Association (NFPA) **Classification:** Operational Guidelines
Tsunami Warning Markup Language (TWML), Cyclone Warning Markup Language (CWML)	**Description:** The goal of the Tsunami Warning Markup Language (TWML) and the Cyclone Warning Markup Language (CWML) is to facilitate various kinds of automated processing, such as rapid dissemination to people in affected areas, aggregation of warning information, and interoperability with geo-spatial systems through the use of Geography Markup Language (GML) elements. The languages are also designed to be used in conjunction with OASIS standards such as the Emergency Data eXchange Language Distribution Element

	(EDXL-DE) and the Common Alerting Protocol (CAP) [OASIS 2010b]. **Standard Type:** CWML Version 1.0; TWML Draft **Organization:** National ICT Australia (NICTA) **Classification:** Domain-specific Integration Interface
Vehicular Emergency Data Set (VEDS)	**Description:** The Vehicular Emergency Data Set (VEDS) is an XML-based data standard that determines useful and critical elements needed to prove an efficient emergency response to vehicular emergency incidents. The Protocol identifies crash and medical data elements [OASIS 2010b]. **Standard Type:** VEDS Version 2.0 **Organization:** ComCARE Alliance **Classification:** Domain-specific Integration Interface

D.5 – Healthcare Systems Standards and Guidelines

This section identifies standards and guidelines that are potentially relevant to the development of M&S applications for healthcare systems. 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 healthcare M&S applications.

Standard Title	Overview
After a Terrorist Bombing: Health and Safety Information for the General Public	**Description:** A document contains "Immediately after the event" and "Hours or days after the event" for helping people who have been affected by the blast and will provide updated information as soon as they learn more [CDC 2010a]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Bioterrorism Readiness Plan: A Template for Healthcare Facilities	**Description:** A Bioterrorism Readiness Plan to serve as a reference document and initial template to facilitate preparation of bioterrorism readiness plans for individual institutions [CDC 2010r]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC), The Association for Professionals in Infection Control and Epidemiology (APIC) Bioterrorism Task Force **Classification:** Operational guidelines
Business Continuity/Disaster Recovery Plan	**Description:** The business continuity/disaster recovery plan is to identify the most critical information needs for patient care, treatment, and services and business processes, and the impact on the hospital if these information systems were severely interrupted. The plan identifies alternative means for processing data, providing for recovery of data, and returning to normal operations as soon as possible [JCAHOSTD 2010].

	Standard Type: IM.2.30 (2008) **Organization:** The Joint Commission **Classification:** Operational guidelines
Common Biometric Exchange Formats Framework (CBEFF)	**Description**: The standard specifies a common set of data elements necessary to support multiple biometric technologies and to promote interoperability of biometric-based application programs and systems by allowing for biometric data exchange. These common data elements can be placed in a single file, record, or data object used to exchange biometric information between different system components and applications. This standard specifies the biometric data elements [ANSI 2010]. **Standard Type:** ANSI INCITS 398-2008 **Organization:** American National Standards Institute (ANSI) **Classification:** Document Format
Communicating in the First Hours for Anthrax: Short and Extended Messages	**Description:** These messages can be used by public health officials 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
Community-Based Mass Prophylaxis: A Planning Guide for Public Health Preparedness	**Description:** Planning guide to help state, county, and local officials meet federal requirements to prepare for public health emergencies [AHRQ 2011a]. Outlines five components of mass prophylaxis response to epidemic outbreaks. Addresses dispensing operations using a comprehensive operational structure for Dispensing/Vaccination Centers (DVCs) based on the National Incident Management System (NIMS). **Standard Type:** N/A **Organization:** The Agency of Healthcare Research & Quality (AHRQ) **Classification:** Operational guidelines
Digital Imaging and Communications in Medicine (DICOM)	**Description:** A specification for exchange of radiology images and other medical information between computers. It enables digital communication between diagnostic and therapeutic equipment and systems from various manufacturers. DICOM is a global Information-Technology that is used in virtually all hospitals worldwide. Its current structure is designed to ensure the interoperability of systems to produce, store, display, process, send, retrieve, query or print medical images and derived structured documents as well as to manage related workflow [NEMA 2010].

	Standard Type: DICOM 3.0 **Organization:** American College of Radiology (ACR), and National Electrical Manufacturers Association (NEMA) **Classification:** General purpose integration interfaces
Disaster Privileges	**Description:** A plan that identifies the option to grant privileges during disaster situations to doctors and other licensed practitioners [JCAHOSTD 2010]. **Standard Type:** MS.4.110; HR.4.35 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Drawing Interchange File (DXF) Formats	**Description:** The DXF format is a tagged data representation of all the information contained in an AutoCAD drawing file. Tagged data means that each data element in the file is preceded by an integer number that is called a group code. A group code's value indicates what type of data element follows. This value also indicates the meaning of a data element for a given object (or record) type. Virtually all user-specified information in a drawing file can be represented in DXF format [AUTODESK 2010]. DXF can be used for exchange of radiology images and other medical information between computers. **Standard Type:** AutoCAD 2009, v.u.23.1.01 **Organization:** Autodesk, Inc. **Classification:** General purpose integration interfaces
Emergency Electrical Power Source	**Description:** A plan that describes the requirements of a hospital's emergency power system [JCAHOSTD 2010]. **Standard Type:** EC.7.20 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Emergency Management Drills	**Description:** A plan that describes a hospital's approach to conduct drills to test emergency management [JCAHOSTD 2010]. **Standard Type:** EC.4.20 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Emergency Management Planning	**Description:** An emergency management plan that comprehensively describes the approach to emergencies in the hospital or its community [JCAHOSTD 2010]. **Standard Type:** EC.4.10 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Environment of Care Crosswalk	**Description:** The Joint Commission Resources, a not-for-profit affiliate of The Joint Commission, released the Environment of Care Crosswalk. The 2012 Crosswalk of the Joint Commission Environment of Care Standards for Hospitals helps hospitals to

	simplify their compliance activities and recognize when there is a duplication of requirements between the complete 2012 Joint Commission Environment of Care , Emergency Management , and Life Safety (LS) standards and elements of performance for hospitals and their comparable Centers for Medicare & Medicaid, Occupational Safety and Health Administration (OSHA), National Fire Protection Association (NFPA), and the Environmental Protection Agency (EPA) regulations. [JCR 2011]. **Standard Type:** 2012 Crosswalk of the Joint Commission Environment of Care Standards for Hospitals **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
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 2010s]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Guidance for Public Health Departments and Clinicians Caring for Individuals Who May Have Been Recently Exposed to Polonium -210	**Description:** Clinical guidance recommendations for public health departments and clinicians to care people who may have been recently exposed to Polonium -210 (Po-210). Po-210 is considered to be one of the most hazardous radioactive materials known, but it must be inhaled or ingested to exert its toxic effects. It is found naturally in the environment, and the general population is internally contaminated with small but measurable amounts of it on a regular basis through food, water, and air [CDC 2010u]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Guidance on Initial Responses to a Suspicious Letter/Container With a Potential Biological Threat	**Description:** Guidelines for local responders, based on existing procedures, on the initial response to letters, packages, or containers containing suspicious powders, liquids, or other materials [DHS 2010e]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC), Federal Bureau of Investigation (FBI), Department of Homeland Security (DHS)

	Classification: Operational guidelines
Guidelines for Handling Decedents Contaminated with Radioactive Materials	**Description:** Detonation of a nuclear weapon or activation of a radiological dispersal device could cause radioactively contaminated decedents. These guidelines are designed to address both of these scenarios. They could also be applicable in other instances where decedents' bodies are contaminated with radioactive material (e.g., reactor accidents, transportation accidents involving radioactive material, or the discharge of a decedent from a hospital after injection or implantation of a radiopharmaceutical). These guidelines suggest ways for medical examiners, coroners, and morticians to deal with loose surface contamination, internal contamination, or shrapnel on or in decedents' bodies [CDC 2010v]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Health informatics – Genomic Sequence Variation Markup Language (GSVML)	**Description:** ISO 25720:2009 is applicable to the data exchange format that is designed to facilitate the exchange of the genomic sequence variation data around the world, without forcing change of any database schema. From an informatics perspective, GSVML defines the data exchange format based on XML. The scope of ISO 25720:2009 is the data exchange format, but the database schema itself is outside the scope of this International Standard. From a biological point of view, all genetic sequence variations are taken into consideration and are within the scope of this International Standard, while polymorphisms, especially single nucleotide polymorphism (SNP), are the main focus of this International Standard [ISO 2011b]. **Standard Type:** ISO 25720:2009 **Organization:** ISO **Classification:** Domain-specific integration interface
Health Insurance Portability and Accountability Act (HIPAA)	**Description:** The Health Insurance Portability and Accountability Act (HIPAA) is a federal law that provides rights and protections for participants and beneficiaries in group health plans. HIPAA includes protections for coverage under group health plans that limit exclusions for preexisting conditions; prohibit discrimination against employees and dependents based on their health status; and allow a special opportunity to enroll in a new plan to individuals in certain circumstances [DOL 2010]. The Administrative Simplification provisions of the Health Insurance Portability and Accountability Act of 1996 (HIPAA, Title II) required the Department of Health and Human Services (HHS) to establish national standards for electronic health care transactions and national identifiers for providers, health plans, and employers. As the industry has implemented these standards, and increased the use of electronic data

	interchange, the Nation's health care system will become increasingly effective and efficient [HHS 2010a]. **Standard Type:** HIPAA of 1996 (P.L.104 – 191) **Organization:** Department of Health and Human Services (HHS) **Classification:** Operational guidelines
Health Insurance Portability and Accountability Act (HIPAA) Security Rule	**Description:** The HIPAA Security Rule establishes national standards to protect individuals' electronic personal health information that is created, received, used, or maintained by a covered entity. The Security Rule requires appropriate administrative, physical and technical safeguards to ensure the confidentiality, integrity, and security of electronic protected health information [HHS 2010b]. **Standard Type:** HIPAA Security Rule 164.308 (a)(7)(i) **Organization:** National Institute of Standards and Technology (NIST) **Classification:** Operational guidelines
Health Level Seven (HL7) Standards	**Description:** Health Level Seven is one of several American National Standards Institute (ANSI) –accredited Standards Developing Organizations (SDOs) operating in the healthcare arena. Health Level Seven's domain is clinical and administrative data [HL7 2010]. HL7 standards are used for the exchange, management, and integration of electronic healthcare information. **Standard Type:** ANSI/HL7 V2 XML-2003; ANSI/HL7 V2.5-2003; ANSI/HL7 V3 DSR, R1-2005, ... ANSI/HL7 V3 PM, R1-2005; ANSI/HL7 V3 CR, R3-2005; ANSI/HL7 V3 MFRI, R1-2006 **Organization:** Health Level Seven (HL7); American National Standards Institute (ANSI) **Classification:** Domain-specific integration interfaces
Infection Control	**Description:** A plan that is used by the hospital to respond to an influx, or the risk of an influx, of infectious patients [JACHOSTD 2010]. **Standard Type:** IC.6.10 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Interim Guidelines for Hospital Response to Mass Casualties from a Radiological Incident	**Description:** The guidance focuses on six key areas: (1) notification and communication, which emphasizes the importance of hospitals working with their communities and public health agencies on developing emergency communication plans; (2) triage; (3) patient management, including decontamination, treatment, care of special populations, discharge and follow up, and patient mental health concerns; (4) healthcare provider protection, including staff training and practitioner mental health concerns; (5) surveillance, and (6)

	community planning [CDC 2010w]. **Standard Type:** N/A **Organization:** the Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Interim Life Safety Measures (ILSM)	**Description:** Guidelines for Design and Construction of Hospital and Health Care Facilities to minimize the possibility of injury or damage due to fire, smoke & fumes, or other threat. ILSM are health and safety measures that are put in place to protect the safety of patients, visitors, and staff who work in the hospital [BMET 2010]. **Standard Type:** ILSM **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Interim Recommendations for Firefighters & Other First Responders for the Selection & Use of Protective Clothing & Respirators Against Biological Agents	**Description:** This interim statement of selection and use of protective clothing and respirators against biological agents is based on current understanding of the potential threats and existing recommendations issued for biological aerosols. 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 [CDC 2010x]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
International Classification of Diseases	**Description:** The International Classification of Diseases (ICD) is designed to promote international comparability in the collection, processing, classification, and presentation of mortality statistics. This includes providing a format for reporting causes of death on the death certificate. The reported conditions are then translated into medical codes through use of the classification structure and the selection and modification rules contained in the applicable revision of the ICD, published by the World Health Organization. These coding rules improve the usefulness of mortality statistics by giving preference to certain categories, by consolidating conditions, and by systematically selecting a single cause of death from a reported sequence of conditions. The single selected cause for tabulation is called the underlying cause of death, and the other reported causes are the non-underlying causes of death. The combination of underlying and non-underlying causes is the multiple causes of death. The ICD has been revised periodically to incorporate changes in the medical field. To date, there have been 10 revisions of the ICD. [CDC 2010y]. **Standard Type:** ICD-10; ICD-10-CM (ICD-10 Clinical Modification)

	Organization: The National Center for Health Statistics (NCHS); Centers for Medicare and Medicaid Services **Classification:** Operational guidelines
Introductory Resource Guide for Implementing the Health Insurance Portability and Accountability Act (HIPAA) Security Rule	**Description:** A publication discusses security considerations and resources on security terms and concepts used and presented in the HIPAA security rule [NIST 2010a]. **Standard Type:** N/A **Organization:** National Institute of Standards and Technology (NIST) **Classification:** Operational guidelines
Maintenance, Testing, and Inspection Requirements for Hospital Emergency Power System	**Description:** A plan that identifies how a hospital maintains, tests, and inspects its emergency power system [JCAHOSTD 2010]. **Standard Type:** EC.7.40 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Managing Hazardous Material Incidents (MHMIs)	**Description:** The Managing Hazardous Material Incidents (MHMIs) series was developed to provide emergency medical services (EMS) personnel and hospital emergency departments (EDs) with the necessary guidance to plan for, and improve their ability to respond to, incidents that involve human exposure to hazardous materials. The guidelines inform emergency personnel how to appropriately decontaminate, treat, and recommend follow-up care to exposed persons, as well as take measures to protect themselves. The MHMI series contain 3 volumes: "Emergency medical services: A planning guide for the management of contaminated patients;" "Hospital emergency departments: A planning guide for the management of contaminated patients;" and "Medical management guidelines (MMGs) for acute chemical exposures" [ATSDR 2010]. **Standard Type:** ATSDR MHMIs Version 2001 **Organization:** The Agency for Toxic Substances and Disease Registry (ATSDR) **Classification:** Operational Guidelines
Mass Casualty Event Preparedness and Response	**Description:** This document provides information of preparedness and response for preparing for a terrorist bombing, after a terrorist bombing, coping with a traumatic event, emergency wound care, injuries, brain injuries, and burns, etc. [CDC 2010aa]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **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
NIOSH Pocket Guide to Chemical Hazards (NPG)	**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 2010cc]. **Standard Type:** N/A **Organization:** The National Institute for Occupational Safety & Health (NIOSH) **Classification:** Operational guidelines
Patient Flow Management	**Description:** Plans that identify and mitigate impediments to efficient patient flow throughout the hospital [JCAHOSTD 2010]. **Standard Type:** LD.3.15 **Organization:** The Joint Commission Resources **Classification:** Operational guidelines
Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners	**Description:** 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. Population monitoring is the process of identifying, screening, and monitoring people for exposure to radiation or contamination from radioactive materials [CDC 2010ee]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention

	(CDC) **Classification:** Operational guidelines
Preparing for a Terrorist Bombing: A Common Sense Approach	**Description:** This document focuses on common sense principles that will be useful in a bombing event [CDC 2010p]. **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
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 2010hh]. **Standard Type:** N/A **Organization:** The Centers for Disease Control and Prevention (CDC) **Classification:** Operational guidelines
Sheltering in Place during a Radiation Emergency	**Description:** A fact sheet, prepared by the Centers for Disease Control and Prevention, used during a radiation emergency to help protect individuals and family and to help prepare a safe and well-stocked shelter from exposure to radiation [CDC 2010ii]. **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:** The standard identifies the minimum levels of competence required by responders to emergencies involving hazardous materials/weapons of mass destruction (WMD). 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 hazmats/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 EMS Personnel Responding to Hazardous Materials/Weapons of Mass Destruction Incidents	**Description:** The standard includes qualifications for EMS responders to terrorism incidents that involve hazardous materials. It 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 [NFPA 2011]. **Standard Type:** NFPA 473-2008 **Organization:** The National Fire Protection Association (NFPA) **Classification:** Operational guidelines
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 2011]. **Standard Type:** E1429 – 91(2004) **Organization:** ASTM International **Classification:** Operational Guideline
Standard Guide for Hospital Preparedness and Response	**Description:** A guide intended to assist the leaders of hospitals in the design, planning, and response to be undertaken by hospitals and health care organizations to an event that necessitates the activation of an emergency operations plan [ASTM 2011]. **Standard Type:** ASTM E2413 – 04 (2009) **Organization:** ASTM International **Classification:** Operational guidelines
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. 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 2011].

	Standard Type: ASTM E2601-08 **Organization:** ASTM International **Classification:** Operational guidelines

Appendix E – Data Sources

This appendix lists databases and other sources of data that may be used to develop or run homeland security models and simulations. The appendices are organized as follows:

- E.1 – Hazardous Material Release Data Sources
- E.2 – Critical Infrastructure Data Sources
- E.3 – Incident Management Data Sources
- E.4 – Healthcare Systems Data Sources

The name of 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.

E.1 – Hazardous Material Release 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 2010]. **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

E.2 – Critical Infrastructure Data Sources

This section identifies databases and other sources of data that may be used to develop or run critical infrastructure system models, simulations, and training applications. The name of 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
American Community Survey (ACS)	**Description:** The American Community Survey (ACS) is a nationwide survey designed to provide communities a fresh look at how they are changing. It is a critical element in the Census Bureau's reengineered decennial census program. The ACS collects and produces population and housing information every year instead of every ten years. The ACS FTP Site contains data from the American Community Survey as they are released. The FTP site contains data tables from all years of the ACS, Public Use Microdata Sample (PUMS) Files, the ACS Summary Files, table shells, archived from the 1996 – 2004 ACS, and more [CENSUS 2011b]. **Data Source:** ACS FTP Site **Organization:** U.S. Census Bureau (USCS) **Format Used:** PDF; Excel **Classification:** Demographic and Behavioral
American FactFinder	**Description:** The American FactFinder, an on-line tool, provides data in the form of maps, tables, and reports from a variety of Census Bureau sources. Information provided by the American FactFinder includes basic demographic; social and economic data; popular statistics tables on people, housing, and business and government; censuses and surveys; etc. The Census Bureau conducts many censuses and surveys. The most well-known is the official population census of the United States, called the decennial census. It is conducted every ten years, most recently in April 2010. During each decennial census, the Census Bureau collects data from every household in the U.S. and its territories [CENSUS 2011c]. **Data Source:** American FactFinder **Organization:** U.S. Census Bureau **Format Used:** Shapefile; Excel; ASCII **Classification:** Demographic and Behavioral
American Hospital Association (AHA) Database	**Description:** American Hospital Association (AHA) Database contains data for every hospital in the U.S. The data is collected from AHA annually survey. Non-responding hospital data are estimated using advanced methods to approximate specific data elements. The AHA Annual Survey Database for Fiscal Year 2009 has more than 700 fields of data and information on 6,000+ hospitals. Included in the database are demographic information, organizational structure, facilities and services, utilization data, community orientation indicators, physician arrangements, managed care relationships, expenses and staffing [AHADATA 2011]. **Data Source:** American Hospital Association (AHA) Database; Hospital Detail Report Wizard; Hospital Market Analysis Wizard; Healthcare Systems and Networks Report

	Wizard **Organization:** American Hospital Association (AHA) **Format Used:** Excel; ASCII; PDF **Classification:** Resources; Demographic and Behavioral
American Hospital Directory's Data Services	**Description:** The American Hospital Directory (AHD) provides data and statistics about more than 6,000 hospitals nationwide. The database of information about hospitals is built from both public and private sources including Medicare claims data, hospital cost reports, and other files obtained from the federal Centers for Medicare and Medicaid Services (CMS). AHD is not affiliated with the American Hospital Association and is not a source for AHA Data. Users use their search tools to explore their database of hospital information. Key statistics may be summarized by hospital, state, and Nation. Statistics include bed size, discharges, patient days, and gross patient revenue [AHD 2011]. **Data Source:** AHD's Data Services, AHD's Quick Search; AHD's Advanced Search **Organization:** American Hospital Directory (AHD) **Format Used: .**CSV; ASCII; Excel **Classification:** Resources; Demographic and Behavioral
American Housing Survey (AHS)	**Description:** The American Housing Survey (AHS) collects data on the Nation's housing, including apartments, single-family homes, mobile homes, vacant housing units, household characteristics, income, housing and neighborhood quality, housing costs, equipment and fuels, size of housing unit, and recent movers. National data are collected in odd numbered years, and data for each of 47 selected Metropolitan Areas are collected currently about every six years. The national sample covers an average 55,000 housing units. Each metropolitan area sample covers 4,100 or more housing units. The Bureau of the Census conducts the survey for the Department of Housing and Urban Development (HUD). The Data Access includes three categories: National Data, Metropolitan Data, and Dates metropolitan Areas are Surveyed [CENSUS 2011d]. **Data Source:** AHS Data Access **Organization:** U.S. Census Bureau (USCS) **Format Used:** Excel; PDF **Classification:** Demographic and Behavioral
Automated Critical Asset Management System (ACAMS)	**Description:** Automated Critical Asset Management System (ACAMS) is a web-enabled information services portal that helps state and local governments build CIKR protection programs in their local jurisdictions. ACAMS is a secure, online database, and database management platform that allows for the collection and management of CIKR asset data; the cataloguing, screening, and sorting of this data; the production of tailored infrastructure reports; and the development of a variety of pre- and post-incident response plans useful to

	strategic and operational planners and tactical commanders [DHS 2011c]. **Data Source:** ACAMS **Organization:** Department of Homeland Security/Office of Infrastructure Protection **Format Used:** TXT; PDF; Keyhole Markup Language (KML) **Classification:** Resources; Controlling Documents
Bureau of Transportation Statistics(BTS) Data and Statistics	**Description:** Bureau of Transportation Statistics (BTS) is a part of U.S. Department of Transportation's Research and Innovative Technology Administration (RITA). BTS established itself with a focus in three key areas, each mandated by legislation: 1) compiling, analyzing, and publishing a comprehensive set of transportation statistics; 2) making statistics readily accessible; and 3) implementing a long term data collection program. BTS' data and statistics includes Airline Traffic Data, Airline Data, Airline On-Time Data, Border Crossing/Entry Data, Commodity Flow Survey, Freight Data and Statistics, Intermodal Passenger Connectivity Database, International Data, National Transportation Atlas Database, National Transportation Statistics, Passenger Travel Data Sources, TranStats – Multimodal Transportation Database, and others [BTS 2011]. **Data Source:** RITA Site **Organization:** U.S. Department of Transportation (DoT) **Format Used:** PDF; Excel; CVS; Table; Maps **Classification:** Demographic and Behavioral; Incidents
ChicagoMaps	**Description:** *ChicagoMaps* provides information on citizen services and physical infrastructure components in the city. Geographic Information Systems (GIS) is used to manage street and building inventories, dispatch services, and maintenance of underground utilities [CHICAGO 2011]. **Data Source:** Chicago GIS Portal **Organization:** City of Chicago **Format Used:** GIF **Classification:** Resources; Spatial
Community Collaborative Rain, Hail and Snow Observations (CoCoRaHS) Reports	**Description:** The National Weather Service (NWS) supports the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network. CoCoRaHS is a unique, non-profit, community-based network of volunteers of all ages and backgrounds working together to measure and map precipitation (rain, snow, and hail). The network has 20,000 active observers in all 50 states. CoCoRaHS provides reports on daily precipitation, significant weather, multiple day accumulation, drought impact, etc. [COCO 2011]. **Data Source:** CoCoRaHS **Organization:** CoCoRaHS network **Format Used:** KML **Classification:** Environment

Computer-Aided Management of Emergency Operations (CAMEO)	**Description:** CAMEO is a system of software applications used widely to plan for and respond to chemical emergencies. CAMEO can also be used to navigate between ALOHA (Areal Locations of Hazardous Atmospheres), MARPLOT (Mapping Applications for Response, Planning, and Local Operational Tasks), and the downloadable version of CAMEO Chemicals. All modules work interactively to share and display critical information in a timely fashion. The CAMEO system is available in Macintosh and Windows formats. CAMEO is a database application that includes eight modules (such as Facilities and Contacts) to assist with data management requirements under the Emergency Planning and Community Right-to-Know Act (EPCRA). The system includes a chemical database of over 6,000 hazardous chemicals, 80,000 synonyms, and product trade names. It provides a search engine to find chemicals instantly for support making plan for and respond to chemical emergencies [EPA 2011a]. **Data Source:** CAMEOfm Version 2.0 **Organization:** Environment Protection Agency (EPA); National Oceanic; Atmospheric Administration (NOAA) **Format Used:** ASCII **Classification:** Environment; Controlling Documents
Consolidated Database System (CDBS)	**Description:** The FCC Media Bureau is responsible for licensing broadcast services in the Unites States. The licensing information for broadcast radio (AM and FM) and television (TV, LPTV, and DTV) is contained in the Consolidated Database System (CDBS).The CDBS is used to track the filing and completion of broadcast construction permit, license, renewal, ownership, assignment of license (sale of station), transfer of control (change of ownership structure), and EEO (Equal Employment Opportunity) applications. The CDBS Public Access links access web pages that provide the ability to search and retrieve information from FCC Media Bureau databases for broadcast stations, and for certain EEO information for broadcast stations and Cable and MVPD (Multi-channel Video Programming Distributor) employment units [FCC 2011]. **Data Source:** CDBS Public Searches **Organization:** Federal Communications Commission (FCC) **Format Used:** PDF; HTML **Classification:** Resources
DC Atlas	Description: The DC Atlas is a web-based tool that contains over 150 map layers arranged in various overlay categories. Each overlay grouping is interactive, allowing users to zoom in and out, move to different places, and identify features for more information. The *DC Atlas* provides detailed maps with GIS functionality. The information can be retrieved from its All-in-One Service. Additionally, maps and information can be

	printed. The service provides access to a wide range of planimetric, cultural, environment datasets enabling users to create their own maps easily and quickly [DC 2011]. **Data Source:** DC Atlas All-In-One **Organization:** Government of the District of Columbia **Format Used:** TXT; CSV; Shapefile; MXD (ArcGIS Map Document) **Classification:** Incidents; Environment; Resources; Spatial, Demographic and Behavioral
Digital Terrain Elevation Data (DTED)	**Description:** Digital Terrain Elevation Data (DTED) is a uniform matrix of terrain elevation values. It provides basic quantitative data for systems and applications that require terrain elevation, slope, and/or surface roughness information. DTED is produced at three different levels of detail. The three classes of DTED are known as DTED Level 0, DTED Level 1, and DTED Level 2. DTED Level 0 elevation post spacing is 30 arc second (nominally one kilometer). DTED Level 0 may be of value to scientific, technical, and other communities for and applications that require terrain elevation, slope, and/or surface roughness information. DTED Level 1 is the basic medium resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or gross terrain roughness in a digital format. DTED Level 2 is the basic high resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or terrain roughness in a digital format. Distribution of DTED and the Digital Data Products catalog is authorized to the U.S. Department of Defense (DoD), DoD contractors, and to U.S. Government agencies that support DoD functions. [NGA 2011a]. **Data Source:** DTED Level 0; DTED Level 1; and DTED Level 2 **Organization:** National Geospatial-Intelligence Agency (NGA) **Format Used:** ASCII **Classification:** Spatial
Earth Observing System (EOS) Data Services	**Description:** The Earth Observing System (EOS) is a coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. EOS is a major component of the Earth Science Division of NASA's Science Mission Directorate. EOS enables an improved understanding of the Earth as an integrated system. The EOS Data Gateway (EDG) is the primary interface to all data available in NASA's Earth Observation System Data Information System, and related data centers. With EDG, a user can search for and acquire a large variety of earth, ocean, and atmospheric science data obtained from EOS instruments such as MODIS and MISR, as well as other satellites such as Landsat [NASA 2011].

	Data Source: EOS Data Gateway (EDG) **Organization:** National Aeronautics and Space Administration (NASA) **Format Used:** TXT **Classification:** Environment
Emergency Preparedness Resource Inventory (EPRI)	**Description:** Emergency Preparedness Resource Inventory (EPRI) is a Web-based tool allowing local or regional planners to assemble an inventory of critical resources that would be useful in responding to a bioterrorist attack. It can be customized for any region, state, or locality. EPRI creates automated reports for use in preparedness and planning as well as incident response [AHRQ 2011b]. **Data Source:** Emergency Preparedness Resource Inventory (EPRI) **Organization:** Agency for Healthcare Research and Quality (AHRQ) **Format Used:** ASCII **Classification:** Resources; Incidents
Energy Information Administration (EIA) Energy Information	**Description:** The U.S. Energy Information Administration (EIA) collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA provides a wide range of information and data products covering energy production, stocks, demand, imports, exports, and prices; and prepares analyses and special reports on topics of current interest. The EIA information is disseminated in different ways, including reports, web products, press releases, databases, and maps; it is issued weekly, monthly, annually, and periodically as needed or requested. EIA information covers data on coal, crude oil, diesel, electricity, gasoline, general energy, natural gas, nuclear, and renewable [EIA 2011]. **Data Source:** EIA Site **Organization:** U.S. Department of Energy (DoE) **Format Used:** RSS; ASCII; PDF; Table; Maps **Classification:** Environment; Resources
Envirofacts	**Description:** The Envirofact Multisystem Search allows the users to search multiple environmental databases for facility information, including toxic chemical releases, water discharge permit compliance, hazardous waste handling processes, Superfund status, and air emission estimates. Search the Envirofacts data using any combination of the following criteria: facility name, geography, facility industrial classification, or pollutant. Envirofacts offers several choices for downloading data: EZ Searcher, Custom Searches, and Geo-spatial Download. Through different search options, users can select data from EPA's Facility Registry System (FRS), Locational Reference Database, Toxics Release Inventory

	(TRI), Permit Compliance System (PCS), and RadNet (formerly the Environmental Radiation Ambient Monitoring System (ERAMS) and build reports or files [EPA 2011b]. **Data Source:** Envirofacts Multisystem Search **Organization:** Environmental Protection Agency (EPA) **Format Used:** Table; CSV; XML; KML; Shapefile; Environmental Systems Research Institute (ESRI) Feature Class **Classification:** Environmental; Resources
Federal Deposit Insurance Corporation (FDIC) Data and Statistics	**Description:** The Federal Deposit Insurance Corporation (FDIC) provides detailed information on an institution-level basis in their Institution Directory. Statistics at a Glance provides a view of the industry's overall picture. This includes the latest quarterly data (Current Snapshot) that defines the banking industry, as well as the most recent trends (Industry Trends). The FDIC Quarterly Banking Profile identifies the latest performance trends in the industry and the state (QBP State Tables - annual and quarterly data for large and small institutions go back to 1995). Branching and deposit market share information is available through Summary of Deposits and Deposit Market Share Report. These sites present aggregates of each institution's deposits in any combined choice of states, metro areas, cities, counties or zip codes. Statistics on Depository Institutions allows the user to create custom "ad hoc" Peer Groups, reports and downloads; analyze prospective mergers, classes of competitors; compare up to four columns of data. The Failed Bank List page has a separate Web page for each bank closed since October of 2000. The FDIC also has many historical studies that can be found on the Research & Analysis page [FDIC 2011]. **Data Source:** FDIC Site **Organization:** Federal Deposit Insurance Corporation (FDIC) **Format Used:** ASCII; PDF; Excel; CVS; Table; Maps **Classification:** Resources
Geodatabase	**Description:** The Geodatabase is a storage and management framework for geographic information systems (GIS) Data. It combines “geo” (spatial data) with “database” (data repository) to create a central data repository for spatial data storage and management. It is designed to store, query, and manipulate geographic information and spatial data. The Geodatabase Toolset (GDBT) 9.3/9.3.1 is available for monitoring, investigating, and reporting the performance of multiuser geodatabase [ESRI 2011b]. **Data Source:** GEODATABASE Toolset (GDBT) **Organization:** U.S. Geological Survey **Format Used:** SQL **Classification:** Environment; Spatial

Geospatial Intelligence (GEOINT)	**Description:** The National Geospatial-Intelligence Agency creates *Geospatial Intelligence (*GEOINT) products using imagery, geospatial and targeting analysis, image sciences and modeling for U.S. national defense and disaster relief. GEOINT Online (GO) is a grouping of web-based capabilities for an on-demand discovery of and access to GEOINT content, services, expertise, and support. The most important capability that GEOINT Online can provide is integrated discovery and access to GEOINT. The user will be able to browse and search all NGA holdings—whether they are intelligence reports, imagery, maps and charts, presentations, documents, or files—regardless of where they are stored. GO currently enables users to Customize communities of practice/interest pages, Share content and services through online communities of practice/interest, Notify users of domestic and foreign events, Use advanced visualization and analytics functionality with appropriate plug-ins, and Discover and access geospatial information [NGA 2011b]. **Data Source:** GEOINT Online **Organization:** National Geospatial-Intelligence Agency (NGA) **Format Used:** ASCII; PDF; Excel; CVS; Table; Maps **Classification:** Spatial; Investigative Intelligence
Geo-spatial Multi-Agency Coordination Group (GeoMAC)	**Description:** The Geo-spatial Multi-Agency Coordination Group (GeoMAC) is an internet-based mapping application originally designed for fire managers to access online maps of current fire locations and perimeters in the conterminous 48 States and Alaska. Using a standard web browser, fire personnel can view this information to pinpoint the affected areas. With the growing concern of western wildland fires in the summer of 2000, this application has also become available to the public. In order to give fire managers near real-time information, fire perimeter data is updated daily based upon input from incident intelligence sources, GPS data, infrared (IR) imagery from fixed wing and satellite platforms. The GeoMAC web site allows users in remote locations to manipulate map information displays, zoom in and out to display fire information at various scales and detail, and print hard copy maps for use in fire information and media briefings, dispatch offices and coordination centers. The fire maps also have relational databases in which the user can display information on individual fires such as name of the fire, current acreage and other fire status information [GEOMAC 2011]. **Data Source:** GeoMAC Group **Organization:** U.S. Department of the Interior; U.S. Department of Agriculture; National Interagency Fire Center; U.S. Geological Survey **Format Used:** Feeds; ASCII; XML **Classification:** Spatial; Environment

Global Terrorism Database (GTD)	**Description:** The Global Terrorism Database (GTD) is an open-source database including information on terrorist events around the world from 1970 through 2008 (with additional annual updates planned for the future). Unlike many other event databases, the GTD includes systematic data on domestic as well as transnational and international terrorist incidents that have occurred during this time period and now includes more than 87,000 cases. For each GTD incident, information is available on the date and location of the incident, the weapons used and nature of the target, the number of casualties, and–when identifiable–the group or individual responsible [UMD 2011]. **Data Source:** GTD online interface; "GTD Contact Form" request **Organization:** U.S. Department of Homeland Security; National Consortium for the Study of Terrorism and Responses to Terrorism **Format Used:** CSV **Classification:** Incidents; Demographic and Behavioral
Google Earth	**Description:** Offers maps and satellite images for complex or pinpointed regional searches [GOOGLE 2011]. **Data Source:** Google Earth 6.0; Google Earth Pro **Organization:** Google **Format Used:** KLM; KMZ; COLLADA **Classification:** Spatial
Government Datasets	**Description:** The purpose of Data.gov is to increase public access to high value, machine readable data sets generated by the Executive Branch of the Federal Government. Data.gov provides descriptions of the Federal data sets (metadata), information about how to access the data sets and tools that leverage government datasets. Data.gov includes searchable *catalogs* that provide access to "raw" data sets and various tools. *Catalogs* offers "*Raw" Data catalog*, *Tool Catalog*, and *Geodata Catalog*. "*Raw" Data Catalog* provides users with instant view/download of platform-independent, machine-readable data as well as a link to a metadata page specific to the respective dataset. *Tool Catalog* provides the public with simple, application-driven access to Federal data with hyperlinks and features widgets, data mining and extraction tools, applications, and other services. *Geodata Catalog* provides trusted, authoritative, Federal geo-spatial through links to download the datasets and a metadata page with details on the datasets, as well as links to more detailed Federal Geographic Data Committee (FGDC) metadata information. The categories used by "*Raw" Data Category* and *Tool Category* include Agriculture; Art, Recreation, and Travel; Banking, Finance, and Insurance; Births, Deaths, marriages, and Divorces; Business Enterprise; Construction and housing; Educations; Energy and Utilities; Federal Government

	Finances, and Employment; Foreign Commerce and Aid; Geography and Environment; Health and Nutrition; Income, Expenditures, Poverty, and Wealth; Information and Communication; International Statistics; Labor Force, Employment, and earning; Law Enforcement, Courts, and Prisons, national Security and Veterans Affairs; Natural Resources; Other; Population; Prices; Science and Technology; Social Insurance and Human Services; State and Local Government Finances and Employment; Transportation; and Wholesale and Retail trade. The categories used by *Geodata Category* include: Biology and Ecology; Administrative and Political Boundaries; Atmospheric and Climatic; Business and Economic; Elevation and Derived Products; Environment and Conservation; Agriculture and Geophysical; Human Health and Disease; Imagery and base Maps; Inland Water Resources; Military; Locations and Geodetic Networks; Oceans and Estuaries; Cadastral; Cultural, Society, and Demographics; Facilities and Structures; Transportation Network; and Utilities and Communication [DATA 2011]. **Data Source:** Data.gov Catalogs **Organization:** General Services Administration; Federal Chief Information Officer (CIO) Council **Format Used:** XML; Keyhole Markup Language (KML); Compressed Keyhole Markup Language (KMZ); Shapefile; PDF; CSV; TXT; XLS; Feeds; Chart **Classification:** Resources; Environment; Demographic and Behavioral
Integrated Common Analytical Viewer (iCAV)	**Description:** The Office of Infrastructure Protection's Infrastructure Information Collection Division (IICD) leads the Department's efforts to gather and manage vital information regarding the Nation's critical infrastructure and key resources (CIKR). Accurate CIKR data is essential to developing and executing infrastructure protection programs at all levels of government. IICD helps ensure needed infrastructure data is available to homeland security partners by identifying information sources and developing applications to use and analyze CIKR data. As part of this effort, IICD developed and maintains the Infrastructure Data Taxonomy, a common terminology for communicating about critical infrastructure. A suite of Web-based visualization tools available through IICD's Integrated Common Analytical Viewer (iCAV) provide this comprehensive perspective by enabling users to selectively view and analyze infrastructure data from multiple sources in a dynamic map [IICD 2011]. Data Source: iCAV Organization: DHS Format Used: KML **Classification:** Resources; Demographic and Behavioral; Environment; Incidents

Interactive GIS Web Mapping Applications	**Description:** The web applications, GIS-NET, SUB-NET, OVOV-NET, and Z-NET allow for interactively viewing and investigating zoning, land use policy, subdivision activity, aerial imagery, and many other features pertaining to land use within the unincorporated communities of Los Angeles County. GIS-NET provides geographic information regarding land use planning and zoning for the unincorporated areas of Los Angeles County. SUB-NET provides geographic information regarding subdivision activity in the unincorporated areas of Los Angeles County. OVOV-NET provides geographic information regarding land use planning and zoning for the incorporated areas of Santa Clarita Valley in the Los Angeles County. Z-NET provides basic zoning and land use information about properties in incorporate areas of Los Angeles County [LACOUNTY 2011]. **Data Source:** GIS-NET; SUB-NET; OVOV-NET; Z-NET **Organization:** Los Angeles County Department of Regional Planning **Format Used:** GIF; PDF **Classification:** Environment; Spatial
LandScan Dataset	**Description:** The Oak Ridge National Laboratory (ORNL) LandScan datasets contain global population distribution data. LandScan represents an ambient population (average over 24 hours) with approximately 1 km resolution (30" X 30"). The LandScan algorithm uses spatial data and imagery analysis technologies and a multi-variable dasymetric modeling approach to disaggregate census counts within an administrative boundary. Since no single population distribution model can account for the differences in spatial data availability, quality, scale, and accuracy as well as the differences in cultural settlement practices, LandScan population distribution models are tailored to match the data conditions and geographical nature of each individual country and region. [ORNL 2011]. **Data Source:** ACS FTP Site **Organization:** U.S. Census Bureau (USCS) **Format Used:** ESRI Grid **Classification:** Demographic and Behavioral; Spatial
Montgomery County Government Map Viewer	**Description:** Montgomery County Government Map Viewer contains over 17 thematic areas of data. It includes aerial photos, boundaries, census, economic development, education, environmental protection, grids, health and human services, housing, place of interest, public safety, public works and transportation, recreation, regional services centers, streets and zip codes, and other high accuracy base map data sets [MCMD 2011]. **Data Source:** Montgomery County Government Map Viewer **Organization:** Montgomery County, Maryland Government

	Format Used: GIF **Classification:** Environment; Resources; Demographic and Behavioral; Spatial
National Climatic Data Center (NCDC) Geodata	**Description:** NCDC, the world's largest active archive of weather data, produces numerous climate publications and responses to data requests from all over the world. NCDC supports a three tier national climate services support program – the partners include: NCDC, Regional Climate Centers, and State Climatologists. The online Climate data Directory includes Surface Data, Upper Air Data, Marine Data, Satellite Data, Important Notes, Climatology & Extremes, and Related Links. NCDC provides data access tools to retrieve climate and weather, satellite, and radar data [NCDC 2011]. NCDC's GIS Portal allows users to view, access, and utilize in situ station data through NCDC's Geographic Information System (GIS) portal. Interactive maps, associated metadata, and advanced Open Geo-spatial Consortium (OGC) services, such as Web Map Services (WMS) and Web Feature Services (WFS) are available. **Data Source:** National Climatic Data Center (NCDC) Geodata Portal **Organization:** NOAA **Format Used:** WMS; WFS;KML;KMZ **Classification:** Environment; Spatial
National Digital Forecast Database (NDFD)	**Description:** As the foundation of the NWS Digital Services Program, the National Digital Forecast Database (NDFD) consists of gridded forecasts of sensible weather elements (e.g., cloud cover, maximum temperature). NDFD contains a seamless mosaic of digital forecasts from NWS field offices working in collaboration with the National Centers for Environmental Prediction (NCEP) [NWS 2011a]. **Data Source:** NDFD Access Data (via File Transfer Protocol (FTP); HTTP; XML Web Service; Web Feature Service; Web Browser) **Organization:** National Weather Service (NWS) **Format Used:** Grids in Gridded Binary (GRIB2); XML; Shapefile **Classification:** Environment
National Emergency Medical Services (EMS) Information System (NEMSIS)	**Description:** The National Emergency Medical Services (EMS) Information System (NEMSIS) is the national repository that will be used to potentially store EMS data from every state in the Nation. The NEMSIS project was developed to help states collect more standardized elements and eventually submit the data to a national EMS database. The NEMSIS Technical Assistance Center (TAC) is the resource center for the NEMSIS project. The 2009 NEMSIS Public-Release Research Dataset is now available. This dataset includes 6,216,520 EMS events submitted by 26 states during

	the 2009 calendar year. The 2008 NEMSIS Public-Release Research Dataset will continue to be available through the NEMSIS TAC [NEMSIS 2010]. **Data Source:** NEMSIS Technical Assistance Center **Organization:** National Highway Traffic Safety Administration (NHTSA); Health Resources and Services Administration (HRSA); CDC **Format Used:** XML **Classification:** Demographic and Behavioral
National Fire Department Census Database	**Description:** The National Fire Department Census Database provides an online address listing of U.S. fire departments registered with U. S. Fire Administration (USFA) as well as some basic information about each fire department. The purpose of the census, which is ongoing, is to create a national database for use by USFA to conduct special studies that will guide program decision-making and to improve direct communication with individual fire departments. These files contain the following information: department name, headquarters address, department mailing address, headquarters telephone number, headquarters fax number, county, department type, organization type, Web site address, number of stations, number of active firefighters, the number of non-firefighting personnel, and a flag indicating the department's status as primary emergency management department [USFA 2011]. **Data Source:** National Fire Department Census Database **Organization:** U.S. Fire Administration (USFA) **Format Used:** CSV **Classification:** Incidents, Controlling Documents
National Geochemical Survey Database	**Description:** The online spatial data is provided by the National Geochemical Survey Database. The database contains information from the National-scale geochemical analysis of stream sediments and soils in the U.S., from existing data, reanalysis of existing samples, and new sampling. Goal for sample density is one per 289 square km. There are 3 ways to get information: 1) View: show in a web browser window, show in Google Earth or down load KML, and show in GIS using OGC WMS; 2) Download: download data for selected geographic areas; 3) Documentation: complete National Geochemical Survey report available on the web [USGS 2011b]. **Data Source:** National Geochemical Survey Database **Organization:** U.S. Geological Survey (USGS) **Format Used:** Shapefile; dBase; HTML; TXT; CSV; KML; KMZ **Classification:** Environment; Spatial
National Geophysical Data Center (NGDC)	**Description:** The National Geophysical Data Center (NGDC) Online Access Systems include *Interactive Map Services,*

	Space Physics Interactive Data Resources (SPIDR), G*eophysical Data System (GEODAS)*, *Seafloor Composition*, and *FTP Area*. *Interactive Maps* provides visually display for many NGDC data layers. *SPIDR* is designed to allow a solar terrestrial physics customer to intelligently access and manage historical space and physics data for integration with environment models and space weather forecasts. SPIDR is a distributed network of synchronous databases. *GEODAS* is an interactive database management system for used in the assimilation, storage, and retrieval geophysical data. The data included in the GEODAS are trackline marine geophysics, hydrographic surveys, coastal relief, multi-beam bathymetry, and aeromagnetic surveys. Download data directly, create custom CDs. *Seafloor Composition* is used to search for and download selected descriptions and analyses of marine sediment and rock samples. *FTP Area* is for browse data types available from NGDC [NGDC 2011]. **Data Source:** NGDC Online Access Systems **Organization:** National Oceanic and Atmospheric Administration (NOAA)/National Geophysical Data Center (NGDC) **Format Used:** GIF; PNG; XML **Classification:** Environment; Spatial
National Integrated Land System (NILS)	**Description:** GeoCommunicator is the publication site for the Bureau of Land management's (BLM's) National Integrated Land System (NILS). NILS' Land Survey Information System is the official Federal Government website for the distribution of the Public Land Survey System – PLSS of the United States and other survey-based data for the Federal Government. GeoCommunicator provides searching, processing, and dynamic mapping of many BLM activities, such as land use permits; Mineral materials, community pits; oil, gas, and geothermal leasing; mining claims; etc. It provides a centralized site for downloading NILS data and exporting survey points/lines and control points [BLM 2011]. **Data Source:** GeoCommunicator **Organization:** Bureau of Land Management (BLM) **Format Used:** Shapefile **Classification:** Environment; Resources
National Renewable Energy Laboratory (NREL) Geographic Information System (GIS) Data	**Description:** The National Renewable Energy Laboratory (NREL) Dynamic Maps, GIS Data and Analysis Tools Web Site provides dynamically generated maps of renewable energy resources that determine which energy technologies are viable solutions in national and international regions. Click on the download data link in the page to activate the File Archive Download Utility. Data are available for the U.S. and internationally, and for energy resources including biomass, hydrogen, solar, and wind. The NREL's Geographic Information System (GIS) team analyzes wind, solar, biomass,

	geothermal, and other energy resources and inputs the data into the GIS. NRFL has made some of their biomass, solar and wind datasets — in either high resolution or low resolution — available for download through this Web site. High-resolution datasets are available for specific states. Low-resolution datasets are available for Alaska, Hawaii, and the lower 48 states [NREL 2011]. **Data Source:** NREL's Geographic Information System Data **Organization:** The National Renewable Energy Laboratory (NREL) **Format Used:** SHP **Classification:** Resources; Spatial
National Weather Service File/Web Services	**Description:** The National Weather Service Telecommunication Gateway web site contains information on meteorological data exchange, communication standards, switching practices, and meteorological data codes. The File/Web Services allows user to access data and products filed on the Gateway central server resources using FTP and HTTP applications. The File/Web Services provide current data and product files of computer models, text products, text parsed data, observed data, radar products, and satellite products [NWS 2011b]. **Data Source:** File/Web Services **Organization:** National Weather Service **Format Used:** GRIB; FTP; HTTP; RPG/SPG; NESDIS; TXT **Classification:** Incidents; Environment
Public Utilities Commission Interactive Maps	**Description:** The Public Utilities Commission of Ohio's Interactive Maps Page was created to provide on-line access to the PUCO's Geographic Information System (GIS) maps and database. The various maps enable the user to search, identify, and print information on data layers including service area boundaries, exchanges, roads, school districts, county boundaries, cities, political districts, railroad crossings, etc. The maps types include telephone/electric/rail map; telephone service map, electric map, railroad cross accident maps, railroad map, water and waste water utilities map, telephone extended area service map, census boundary and zip code map, etc. [PUCO 2011]. **Data Source:** PUCO Interactive Maps **Organization:** The Public Utilities Commission of Ohio (PUCO) **Format Used:** PDF; Google Map **Classification:** Spatial; Environment; Incidents; Resources
QuickFacts	**Description:** QuickFacts is an easy access to facts about people, business, and geography. It includes data for all states and counties, and for cities and towns with more than 25,000 people. QuickFacts tables are summary profiles showing frequently requested data items from various Census Bureau

	programs. Profiles are available for the Nation, states, counties, and large cities [CENSUS 2011e]. **Data Source:** QuickFacts **Organization:** U.S. Census Bureau **Format Used:** ASCII **Classification:** Spatial; Resources; Demographic and Behavior; Environment
San Francisco Enterprise Geographic Information Systems (GIS) Program	**Description:** The San Francisco Enterprise GIS Program provides mapping expertise, data, and applications for the City and County of San Francisco. The Program provides four mapping services: SFViewer, SFParcel, SFProspector, and CrimeMaps. With SFViewer and SFParcel, users can find a location or an assessor parcel, view parcel information, view aerial photos, and print maps. SFProspector allows searching for properties and creating demographic or business report for an area of San Francisco. CrimeMaps provides the public with information about recent crime activity in their neighborhood [SFGOV 2011]. **Data Source:** SFViewer; SFParcel; SFProspector; CrimeMaps **Organization:** City & County of San Francisco **Format Used:** GIF; TXT; ASCII **Classification:** Resources; Spatial; Environment; Demographic and Behavioral
SEDRIS Environmental Data Sets	**Description:** SEDRIS includes the representation of environmental data and the interchange of environmental data sets. The SEDRIS environmental data sets are available free of charge from SEDRIS. The types of SEDRIS data sets include models (e.g., chair, communication console, space station gamma, and test), Terrain (e.g., Atlantis, Auto-generated Terrain, Bellevue Washington, and Lake Tahoe), and other domains (e.g., atmosphere, Master Environmental Library), and data achieves (e.g., 4.0-compliant SEDRIS Transmittal Formats) [SEDRIS 2011b]. **Data Source:** SEDRIS Environmental Databases **Organization:** Defense Advanced Research Projects Agency (DARPA) **Format Used:** SEDRIS Transmittal Format (SFT) **Classification:** Environment
The Federated Data System (DataFed)	**Description:** DataFed is web services-based software that non-intrusively mediates between autonomous, distributed data providers and users. The main goals of DataFed include to aid air quality management and science by effective use of relevant data, to facilitate the access and flow of atmospheric data from provider to users, and to support the development of user-driven data processing value chains. The main web application of DataFed is the generic Viewer of spatio-temporal datasets. The Viewer can be used for all the federated datasets in DataFed [DATAFED 2011].

	Data Source: DataFed Viewer **Organization:** National Science Foundation (NSF); National Aeronautics and Space Administration (NASA) **Format Used:** CSV; KML **Classification:** Environment
The National Map	**Description:** The National Map is a collaborative effort among the USGS and other Federal, State, and local partners to improve and deliver topographic information for the Nation. It has many uses ranging from recreation to scientific analysis to emergency response. The National Map includes several primary data viewers: the first viewer, The National Map Viewer, has the primary role of viewing distributed data sets from many contributing Federal State and Local Partners through dynamic web map services. The second viewer, The National Map Seamless Server, is the primary site for downloading USGS imagery, elevation and land cover data. Use the 'Best Practices' viewer to download the most up-to-date National Map road, boundaries, structures and other 'vector' data. Use the National Hydrography Data (NHD) viewer to download our full-featured National Hydrography data [NMAP 2011]. **Data Source:** The National Map **Organization:** U.S. Geological Survey **Format Used:** PDF; GeoPDF; GeoTIFF; SHP; JPEG **Classification:** Spatial
The North American Environmental Atlas	**Description:** The North American Environmental Atlas is a digital repository of maps and information that are available as downloadable map and data files without cost. It is an interactive mapping tool to research, analyze and manage environmental issues in Canada, United States and Mexico. It is designed to help understand continental-scale environmental issues. The Atlas offers basic cartographic and environmental data for the continent. It is intended for use by both environmental scientists and the citizens of the United States, Canada, and Mexico. Its maps and services are designed to help the public visualize environmental topics at a continental scale [CEC 2011]. **Data Source:** North American Environmental Atlas **Organization:** Commission for Environmental Cooperation (CEC) **Format Used:** Shapefile; PDF; ZIP **Classification:** Environment
Topologically Integrated Geographic Encoding and Referencing (TIGER) Database	**Description: The** Web browser is used to view and download Topologically Integrated Geographic Encoding and Referencing (TIGER) data. The design of the TIGER database adapts the theories of topology, graph theory, and associated fields of mathematics to provide a disciplined, mathematical description for the geographic structure of the United States

	and its territories [CENSUS 2011f]. **Data Source:** Tiger Map Server Browser **Organization:** U.S. Census Bureau **Format Used:** SHP; Tiger/Line; ASCII; XML **Classification:** Spatial
U.S. Board on Geographic Names Database	**Description:** The U.S. Board on Geographic Names serves the Federal Government and the public as a central authority to which name problems, name inquiries, name changes, and new name proposals can be directed. The U.S. Board on Geographic Names Database holds the Federally recognized name of each feature and defines the feature location by state, county, USGS topographic map, and geographic coordinates. Other attributes include names or spellings other than the official name, feature designations, feature classification, historical and descriptive information, and for some categories the geometric boundaries. Use "Search Domestic Names", "Download Domestic Names", "Search Foreign Names", and "Search Antarctic Names" to query or download information [USGS 2011c]. **Data Source:** Online Systems: Search Domestic Names, Download Domestic Names **Organization:** U.S. Geological Survey **Format Used:** XML; HTML; ASCII **Classification:** Controlling Document
United States-Mexico Demographic Data	**Description**: United States-Mexico Demographic Data Viewer is an interactive application that provides rapid, interactive data mapping, viewing, and analysis of more than 200 socioeconomic variables that are congruent between the United States and Mexico. It is a useful tool for browsing and visualizing patterns at geographic levels ranging from regions to counties/ municipalities, the U.S.-Mexico DDViewer may be used to map population, vital statistic, land area, and household data [CU 2011]. **Data Source:** DDViewer 3.1 **Organization:** Columbia University, International Earth Science Information Network (CIESIN) **Format Used:** **Classification:** Spatial; Demographic and Behavioral; Resources
Westchester County Geographic Information Systems	**Description:** The Mapping Westchester County of New York map service provides access to a large amount of facility, environmental, demographic, transportation, and large scale planimetric datasets. Links to other areas of the county's GIS website also enables users to download coverage and metadata [WCNY 2011]. **Data Source:** Westchester County Geographic Information Systems **Organization:** Westchester County, New York Government **Format Used:** GIF

	Classification: Incidents; Environment; Resources; Demographic and Behavioral; Spatial

E.3 – Incident Management Data Sources

This section identifies databases and other sources of data that may be used to develop or run incident management models, simulations, and training applications. The name of 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
Active Fire Mapping Program	**Description:** The MODIS (Moderate Resolution Imaging Spectroradiometer) Active Fire Mapping Program provides a near real-time geo-spatial overview of the current wildland fire situation at regional and national scales. Locations of current fires and the extent of previous fire activity are ascertained using satellite imagery acquired by the MODIS sensor. These fire data are integrated with various sources of contextual spatial data and information in a suite of geo-spatial data and mapping products. This information is utilized by fire managers to assess the current fire situation and serves as a decision support tool in strategic decisions regarding fire suppression resource allocation. The data and products provided by the program are also valuable for numerous other fire-related applications. MODIS fire detection data and products are continuously updated and published year round to provide temporal and spatial coverage for the variable fire conditions that occur year round on the North American continent. The MODIS Active Fire Mapping Program provides active fire detection and monitoring for the continental United States, Alaska, Hawaii, and Canada [USDA 2010]. **Data Source:** NASA Earth Observing System (EOS) Data Gateway (EDG) **Organization:** USDA Forest Service (USFS) Remote Sensing Applications Center, NASA, the University of Maryland, the National Interagency Fire Center **Format:** KML/KMZ **Classification:** Incidents, Environment
California Integrated Seismic Network (CISN) Display	**Description:** The California Integrated Seismic Network (CISN) is a partnership among federal, state, and university agencies involved in California earthquake monitoring. CISN Display is part of a Web-enabled earthquake notification system alerting users in near real-time of seismicity, and also valuable geophysical information following a large earthquake. CISN Display is a software package that rapidly receives earthquake information via the Internet distributed by seismic networks operating in the United States. It is a means of delivering graphical earthquake information to users at emergency operations centers, and other organizations. The CISN Display is

	the front-end of a client/server architecture known as the QuakeWatch system. It is comprised of the CISN Display (and other potential clients), message queues, server, server "feeder" modules, and messaging middleware, schema, and generators. Central to the CISN Display's role as a gateway to other earthquake products is its comprehensive XML-schema. Earthquake products deliverable to the CISN Display are ShakeMap, Ground Displacement, Focal Mechanisms, Rapid Notifications, OES Reports, and Earthquake Commentaries [CISN 2010]. **Data Source:** CISN Display Version 1.31 **Organization:** California Integrated Seismic Network **Format:** ShakeMap, CISN Display map **Classification:** Domain-specific Integration Interface
Centers for Disease Control and Prevention (CDC) Widgets	**Description:** CDC.gov provides content in several useful ways, via CDC e-mail updates, podcasts and RSS feeds. CDC widgets are online CDC.gov applications, built by one Web site that can be displayed onto another Web site. Available widgets include Adult BMI Calculator, H1N1 (Swine Flu), Fraudulent H1N1 Products, H1N1 School Guidance, Pet Health and Safety, Public Health Image Library Image of the Day, Five Minutes or Less for Health, Smoking and Tobacco Use, Flu IQ, Seasonal Flu Updates, National Environmental Public Health Tracking Program, and CDC Text Messages. [CDC 2010mm]. **Data Source:** CDC.gov **Organization:** Centers for Disease Control and Prevention **Format:** html, RSS **Classification:** Incidents, Demographic and Behavior, Environment, Controlling Document
Data Sets Available in the DataFerrett System	**Description:** DataFerrett is a unique data analysis and extraction tool—with recoding capabilities—to customize federal, state, and local data to suit the user's requirements. TheDataWeb is the infrastructure for intelligent browsing and accessing data across the Internet. TheDataWeb provides access across the Internet using the DataFerrett interface to use demographic, economic, environmental, health, and other databases housed in different systems in different agencies and organizations (Ferrett stands for Federated Electronic Research, Review, Extraction, and Tabulation Tool.) Some of the searchable data sets topics in the DataFerrett application are American Community Survey (ACS), Behavioral Risk Factor Surveillance System (BRFSS), National Ambulatory Medical Care Survey (NAMCS), and Census 2000 [CENSUS 2010g]. **Data Source:** DataFerrett system **Organization:** U.S. Census Bureau **Format:** XML/CAP 1.1, ATOM, RSS **Classification:** Controlling Documents, Demographic and Behavior, Resources

Disaster Management – Open Platform for Emergency Networks (DM-OPEN)	**Description:** Disaster Management – Open Platform for Emergency Networks (DM-OPEN) was created to establish information exchange and collaboration between existing emergency preparedness information systems. DM-OPEN is a non-proprietary operational interoperability backbone that provides a set of non-proprietary "level playing field" web services designed to enable disparate third-party applications, systems, networks and devices to share information using open interoperability standards. As a Federal infrastructure, DM-OPEN is designed to support the delivery of real-time data and situational awareness to public emergency responders in the field, at operation centers and across all levels of response management. The DM-OPEN mission is to enable a national network of systems that facilitates data sharing between software products serving the responder community. DM-OPEN also serves as a test bed to facilitate the development of open, non-proprietary consensus standards that support interoperable information sharing for the emergency responder community [FEMA 2010e]. **Data Source:** DM-OPEN 2.0 **Organization:** Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) **Format:** WSDL, Map, CAP, EDXL-DE, HTTPS Servlet, SOAP **Classification:** Incidents, Simulation Support, Controlling Documents, Resources, Demographic and Behavioral
FedStats	**Description:** FedStats provides access to the full range of official statistical information produced by the Federal Government without having to know in advance which Federal agency produces which particular statistic. With convenient searching and linking capabilities to more than 100 agencies that provide data and trend information on such topics as economic and population trends, crime, education, health care, aviation safety, energy use, and farm production [FEDSTATS 2010]. **Data Source:** www.fedstats.gov **Organization:** The Federal Interagency Council on Statistical Policy **Format:** HTML, spreadsheets **Classification:** Resources, Demographic and Behavioral, Environment, Controlling Documents
Geo-spatial Multi-Agency Coordination Group (GeoMAC)	**Description:** The Geo-spatial Multi-Agency Coordination Group (GeoMAC) is an internet-based mapping application originally designed for fire managers to access online maps of current fire locations and perimeters in the conterminous 48 States and Alaska. Using a standard web browser, fire personnel can view this information to pinpoint the affected areas. With the growing concern of western wildland fires in the summer of 2000, this application has also become available to the public. In order to give fire managers near real-time information, fire perimeter data

	is updated daily based upon input from incident intelligence sources, GPS data, infrared (IR) imagery from fixed wing and satellite platforms. The GeoMAC web site allows users in remote locations to manipulate map information displays, zoom in and out to display fire information at various scales and detail, and print hard copy maps for use in fire information and media briefings, dispatch offices and coordination centers. The fire maps also have relational databases in which the user can display information on individual fires such as name of the fire, current acreage and other fire status information [GEOMAC 2010]. **Data Source:** The GeoMAC web site **Organization:** U.S. Department of the Interior, U.S. Department of Agriculture, National Interagency Fire Center, U.S. Geological Survey **Format:** Map, Data **Classification:** Incident, Spatial, Environment
GIS Data Depot	**Description:** The GeoCommunity GISDataDepot is an online resource for GIS and Deospatial data. It provides GIS data from multiple sources. Data provided by the GISDataDepot include standard U.S. Geological Survey (USGS) digital raster graphic (DRG) data, USGS Digital Elevation Model (DEM) data, USGA orthoimagery data, and FEMA Flood Data. A DRG is a scanned image of a USGS standard series topographic map, including all map collar information. The USGS DEM data files are digital representations of cartographic information in a raster form. DEMs consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. The GeoCommunity has one of the largest online collections of orthoimagery available in the world [GEOCOMM 2010]. **Data Source:** GIS Data Depot **Organization:** MindSites Group, Niceville, FL **Format:** DEM, NWI, DLG, LU/LC, TIGER, E00, MIF **Classification:** Environment
Global Terrorism Database (GTD)	**Description:** The Global Terrorism Database (GTD) is an open-source database including information on terrorist events around the world from 1970 through 2008 (with additional annual updates planned for the future). Unlike many other event databases, the GTD includes systematic data on domestic as well as transnational and international terrorist incidents that have occurred during this time period and now includes more than 87,000 cases. For each GTD incident, information is available on the date and location of the incident, the weapons used and nature of the target, the number of casualties, and--when identifiable--the group or individual responsible. The National Consortium for the Study of Terrorism and Responses to Terrorism (START) makes the GTD available via this online interface in an effort to increase understanding of terrorist violence so that it can be more

	readily studied and defeated [START 2010]. **Data Source:** GTD **Organization:** U.S. Department of Homeland Security/National Consortium for the Study of Terrorism and Responses to Terrorism (START) **Format:** Chart, Table, CSV **Classification:** Incidents, Controlling Documents
Incident Information System	**Description:** The Incident Information System, InciWeb, is an interagency all-risk incident information management system. The system was developed with two primary missions: provide the public a single source of incident related information, and provide a standardized reporting tool for the Public Affairs community. A number of supporting systems automate the delivery of incident information to remote sources. This ensures that the information regarding active incidents is consistent, and the delivery is timely. Information posted on the website is for information purposes only [INCIWEB 2010]. **Data Source:** InciWeb **Organization:** Inciweb.org **Format:** Table, JPG **Classification:** Incidents
National Fire Department Census Database	**Description:** The National Fire Department Census Database provides an online address listing of U.S. fire departments registered with U.S. Fire Administration (USFA) as well as some basic information about each fire department. The purpose of the census, which is ongoing, is to create a national database for use by USFA to conduct special studies that will guide program decision-making and to improve direct communication with individual fire departments [USFA 2010a]. **Data Source:** USFA's National Fire Department Census Database **Organization:** U.S. Fire Administration (USFA) **Format:** Report/Online Table **Classification:** Resources
National Fire Incident Reporting System (NFIRS)	**Description:** The National Fire Incident Reporting System (NFIRS) has two objectives: to help State and local governments develop fire reporting and analysis capability for their own use, and to obtain data that can be used to more accurately assess and subsequently combat the fire problem at a national level. To meet these objectives, the USFA has developed a standard NFIRS package that includes incident and casualty forms, a coding structure for data processing purposes, manuals, computer software and procedures, documentation and a National Fire Academy training course for utilizing the system [USFA 2010b]. **Data Source:** USFA NFIRS 5.0 Client Software Version 5.7.0 **Organization:** U.S. Fire Administration (USFA)

	Format: NFPA 901 **Classification:** Incidents, Controlling Documents
National Incident Management System - Incident Resource Inventory System (NIMS-IRIS)	**Description:** National Incident Management System - Incident Resource Inventory System (NIMS-IRIS) is a database management tool that allows emergency responders to enter typed resources and select specific resources for mutual aid purposes based upon mission requirements, capability of resources, and response time. NIMS-IRIS tracks equipment, communications, contracts, facilities, responders, services, supplies, and teams [FEMA 2010f]. **Data Source:** NIMS-IRIS Version 2.2 **Organization:** Federal Emergency Management Agency (FEMA) **Format:** EDXL **Classification:** Resources
National Response Center (NRC) Data Query Page	**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, which 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 [NRC 2010]. **Data Source:** NRC DOWNLOAD DATA **Organization:** National Response Center **Format:** XLS, HTML **Classification:** Incidents, Environment, Controlling Documents
National Situation Updates	**Description:** National Situation Updates are compiled for use in emergency management planning and operational activities. Updates include information and graphics gathered from a variety of sources including other federal agencies and departments, state and local government, and the news media. Updates are published daily, Monday through Friday, by the Information Coordination Unit, Response and Recovery Directorate at FEMA Headquarters [FEMA 2010g]. **Data Source:** FEMA Emergency Managers **Organization:** Federal Emergency Management Agency (FEMA) **Format:** Report **Classification:** Incidents, Controlling Documents

RAND Database of Worldwide Terrorism Incidents (RDWTI)	**Description:** The RAND Corporation has developed and maintained a database of terrorism incidents stretching back to 1972, which contains comprehensive information on international and domestic terrorism. Over the years, many public and private sponsors have contributed to the maintenance of the RAND Database of Worldwide Terrorism Incidents (RDWTI). The new subscription-based RDWTI, launched in January 2009, is a fully searchable and interactive database [RAND 2010a]. **Data Source:** RDWTI **Organization:** RAND Corporation, Department of Health and Human Services (HHS) **Format:** txt, pie charts, and chronological graphs **Classification:** Incidents
Rand Public Health Preparedness Exercise Database	**Description:** The Rand Corporation RAND assessed existing public health preparedness exercises and developed a database of those exercises that met the quality criteria for use by state and local public health departments. It is primarily intended for state and local public health officials. The database provides a list of possible exercises performed along with criteria rating the success of each exercise. There are fourteen design criteria used to rate each exercise. These criteria are: 1) clearly stated goals; 2) clearly stated objectives; 3) the objectives are appropriate given the goals; 4) each objective is addressed during the exercise; 5) objectives are measurable; 6) the scenario is appropriate given the goals and objectives; 7) the scenario is internally consistent; 8) scenario is "a realistic depiction of the capabilities and resources likely to be available to a participating health jurisdiction;" 9) clear guidance about participants; 10) all participants are engaged; 11) exercise can be replicated; 12) results in action items; 13) feedback is solicited from participants; 14) can be completed within the given timeframe. The goal of this database is "to identify the best exercises to help local and state public health departments prepare for public health emergencies" [RAND 2010b]. **Data Source:** Rand Public Health Preparedness Exercise Database **Organization:** RAND Corporation, Department of Health and Human Services (HHS) **Format:** XLS, Pie charts, Chronological graphs **Classification:** Training, Resources
Responder Knowledge Base (RKB)	**Description:** The Responder Knowledge Base (RKB) is a decision support infrastructure for the responder community that provides information on commercial equipment and technology to the state, local, and tribal homeland security community to assist them with their purchasing and operational equipment decisions. RKB provides emergency responders, purchasers, and planners with a trusted, integrated, online source of information on products, standards, certifications, grants, and other equipment-related information. The RKB hosts the online

	interactive version of the FEMA Authorized Equipment List (AEL), which is provided in an interactive format and linked to relevant information such as applicable standards. The RKB also provides the official online version of the InterAgency Board's Standardized Equipment List (SEL). The RKB is the only site in existence that provides an integrated display of the AEL and SEL. The AEL is the generic list of equipment items allowable under several Department of Homeland Security (DHS) grant programs, including the Homeland Security Grant Program. This choice displays only the official AEL items. The SEL includes recommended features and operating considerations. This choice displays only the SEL. The RKB site has added special features such as *Mission Critical Hints,* the ability to display side by side comparisons of products, and an *Ask an Expert* feature [RKB 2010]. **Data Source:** RKB Version 3.9 **Organization:** Federal Emergency Management Agency **Format:** Report/Online table **Classification:** Incidents, Resources, Controlling Documents, Investigative Intelligence, Demographic and Behavioral, Environment, Training
Storm Prediction Center (SPC) Forecast Products	**Description:** The Storm Prediction Center (SPC) of the National Weather Service (NWS) is providing tornado/severe thunderstorm watches, mesoscale discussions, convective day 1-3 outlooks, fire weather outlooks, and watch, warning and advisory display through Really Simple Syndication (RSS) [NOAA 2010f]. **Data Source:** SPC Products RSS Feeds **Organization:** National Oceanic and Atmospheric Administration (NOAA) **Format:** RSS, XML **Classification:** Incidents, Demographic and Behavior, Environment
Texas Natural Resources Information System (TNRIS)	**Description:** TNRIS was established by the Legislature in 1968 as the Texas Water-Oriented Data Bank. In 1972, after four years of growth and diversification, it was renamed the Texas Natural Resources Information System. The mission of TNRIS is to provide a "centralized information system incorporating all Texas natural resource data, socioeconomic data related to natural resources, and indexes related to that data that are collected by state agencies or other entities." TNRIS's data storehouse comprises the most comprehensive set of geographic data for the State of Texas. It contains over 1,000,000 frames of Aerial Photography and over 50 unique datasets that add up to over 500 gigabytes of data. Access digital datasets directly through the online *Data Search & Download*, or go to *Ordering Services* to work with TNRIS staff on a custom order [TNRIS 2010]. **Data Source:** TNRIS Data Catalog

	Organization: Texas Water Development Board **Format:** USGS DEM, Mr SID **Classification:** Resources
Unified Incident Command and Decision Support (UICDS)	**Description:** UICDS is the "middleware foundation" that enables information sharing and decision support among commercial, government, and academic incident management technologies used to support the National Response Framework (NRF) and the National Incident Management System (NIMS), including the Incident Command System (ICS), in order to prevent, protect, respond, and recover from natural, technological, and terrorist events. UICDS links homeland security and emergency management organizations, from incident command at the scene of an emergency to local and state operations centers to federal departments and agencies, from intelligence fusion centers to transportation management centers to health service organizations, and many other groups [UICDS 2010]. **Data Source:** UICDS Technology Provider **Organization:** Science Applications International Corporation (SAIC) **Format:** NIEM-based data exchange, Multiple data communication standards **Classification:** Incidents
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. WISER is available for download as a standalone application on Windows Mobile devices, Palm OS PDAs, Apple iPhone and iPod Touch, BlackBerry devices, Microsoft Windows PCs, and via WebWISER [WISER 2010]. **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

E.4 – Healthcare Systems Data Sources

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

Data Source Title	Overview
Ambulatory Health Care Data	**Description:** The National Ambulatory Medical Care Survey (NAMCS) is a national survey designed to meet the need for objective, reliable information about the provision and use of ambulatory medical care services in the United States. Findings are based on a sample of visits to non-federal employed office-based physicians who are primarily engaged in direct patient care. The National Hospital Ambulatory Medical Care Survey (NHAMCS) is designed to collect data on the utilization and provision of ambulatory care services in hospital emergency and outpatient departments. Findings are based on a national sample of visits to the emergency departments and outpatient departments of non-institutional general and short-stay hospitals [CDC 2010jj]. **Data Source:** NAMCS/NHAMCS **Organization:** National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC) **Format:** Report **Classification:** Demographic and Behavior, Resources
American Hospital Association (AHA) Database	**Description:** American Hospital Association (AHA) Database contains data for every hospital in the U.S. The data is collected from AHA annually survey. Non-responding hospital data are estimated using advanced methods to approximate specific data elements. Multiple data sets power this database, including the latest edition of the AHA Annual Survey of Hospitals, primary research into the organizational structures of Systems and Networks conducted by Health Forum, and information from Health Forum subscriber lists [AHADATA 2011]. **Data Source:** American Hospital Association (AHA) Database. Five tools are provided: Hospital Statistics Wizard; Hospital Market Analysis Wizard; Health Care Systems and Networks Wizard; Hospital Detail Report Wizard; Mailing List Wizard **Organization:** American Hospital Association (AHA) **Format Used:** PDF, Excel table, Chart **Classification:** Resources, Demographic and Behavior
American Housing Survey (AHS)	**Description:** The American Housing Survey (AHS) collects data on the Nation's housing, including apartments, single-family homes, mobile homes, vacant housing units, household characteristics, income, housing and neighborhood quality, housing costs, equipment and fuels, size of housing unit, and recent movers. National data are collected in odd numbered years, and data for each of 47 selected Metropolitan Areas are collected currently about every six years. The national sample covers an average 55,000 housing units. Each metropolitan area sample covers 4,100 or more housing units. The Data Access includes three categories: National Data, Metropolitan Data, and Dates metropolitan Areas are Survey [CENSUS 2010d]. **Data Source:** AHS Data Access

	Organization: U.S. Census Bureau (USCS) **Format Used:** Excel; PDF **Classification:** Demographic and Behavioral
Behavioral Risk Factor Surveillance System (BRFSS)	**Description:** The Behavioral Risk Factor Surveillance System (BRFSS) is a state-based system of health surveys that collects information on health risk behaviors, preventive health practices, and health care access primarily related to chronic disease and injury. For many states, the BRFSS is the only available source of timely, accurate data on health-related behaviors [CDC 2010kk]. **Data Source:** BRFSS Maps, BRFSS GIS Data, BRFSS Datasets **Organization:** Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion/Division of Adult and Community Health **Format:** SHP, RTF, SAS, XPT, PDF, TXT, CSV, SAS7BCAT, SAS7BDAT, ZIP **Classification:** Demographic and Behavior, Controlling Documents, Incidents
CDC Wide-ranging Online Data for Epidemiologic Research (WONDER)	**Description:** The Centers for Disease Control and Prevention (CDC) WONDER – Wide-ranging Online Data for Epidemiologic Research – is an integrated information and communication system for public health. It speeds and simplifies access to public health information for state and local health departments, the public health service, and the academic public health community. CDC WONDER allows accessing statistical research data and reports published by CDC and querying numeric data sets on CDC's computers [CDC 2010ll]. **Data Source:** WONDER Online Databases **Organization:** The Centers for Disease Control and Prevention (CDC) **Format:** HTML, chart and map images (bitmaps), ASCII, spreadsheet **Classification:** Resources, Controlling Documents, Demographic and Behavioral
CDC.gov Widgets and Gadgets	**Description:** CDC.gov provides content in several useful ways, via our e-mail updates, podcasts and RSS feeds. Our newest features are the Flu Updates, Emergency Text Messages and the CDC Data and Statistics Widget. Widgets are online applications built by one Web site that can be displayed onto another Web site. A widget is a CDC.gov application that displays the featured content directly on your web page. You can embed content in personalized home pages, blogs, and other sites. Once you've added the widget, there's no technical maintenance. CDC.gov will update the content automatically. Available widgets include Adult BMI Calculator, H1N1 (Swine Flu), Fraudulent H1N1 Products, H1N1 School Guidance, Pet Health and Safety, Public Health Image Library Image of the Day, Five Minutes or Less for Health, Smoking and Tobacco Use, Flu IQ, Seasonal Flu Updates, National Environmental Public Health Tracking

	Program, CDC Text Messages, etc. [CDC 2010mm]. **Data Source:** CDC.gov **Organization:** Centers for Disease Control and Prevention **Format:** TXT, RSS **Classification:** Incidents, Demographic and Behavior, Environment, Controlling Document
Clinical Data Repository (CDR)	**Description:** The Clinical Center installed a hospital-wide, real-time computerized medical information system (MIS) in 1976. This system supports the Clinical Center's dual responsibilities of providing quality patient care and collecting research data. The Clinical Data Repository (CDR) is a new facility that will house all electronic data collected at the clinical center from the time MIS was installed (1975) until today. The CDR will be continually updated with current data and will be the single place to find information for clinical, research, and administrative use [NIH 2010d]. **Data Source:** CDR Version 1.4, CCMIS (Mac/MIS, Web/MIS 3.0) **Organization:** National Institute of health (NIH) **Format:** Clinical Data Repository (CDR) **Classification:** Demographic and Behavior
Directory of Information Resources Online (DIRLINE)	**Description:** DIRLINE (Directory of Information Resources Online) is the National Library of Medicine's online database containing location and descriptive information about a wide variety of information resources including organizations, research resources, projects, and databases concerned with health and biomedicine. DIRLINE contains over 8,500 records and focuses primarily on health and biomedicine, although it also provides limited coverage of some other special interests. These information resources fall into many categories including federal, state, and local government agencies; information and referral centers; professional societies; self-help groups and voluntary associations; academic and research institutions and their programs; information systems and research facilities. Topics include HIV/AIDS, maternal and child health, most diseases and conditions including genetic and other rare diseases, health services research and technology assessment. Each record may contain information on the publications, holdings, and services provided [NIH 2010e]. **Data Source:** DIRLINE **Organization:** The National Library of Medicine (NLM) **Format:** Report **Classification:** Resources, Controlling Documents
Drug Information Portal	**Description:** The Drug Information Portal, a free web resource, provides an informative, user–friendly portal to current drug information for over 15,000 drugs. Links to sources span the breadth of the National Library of Medicine (NLM), the National Institutes of Health (NIH) and other government agencies.

	Current information regarding consumer health, clinical trials, AIDS–related drug information, MeSH pharmacological actions, PubMed biomedical literature, and physical properties and structure can be retrieved by searching on a drug name. A varied selection of focused topics in medicine and drug–related information is also available from displayed subject headings [NIH 2010f]. **Data Source:** Drug Information Portal **Organization:** The National Library of Medicine (NLM) **Format:** Report **Classification:** Resources, Controlling Document
FedStats	**Description:** FedStats provides access to the full range of official statistical information produced by the Federal Government without having to know in advance which federal agency produces which particular statistic. With convenient searching and linking capabilities to more than 100 agencies that provide data and trend information on such topics as economic and population trends, crime, education, health care, aviation safety, energy use, and farm production [FEDSTATS 2010]. **Data Source:** www.fedstats.gov **Organization:** The Federal Interagency Council on Statistical Policy **Format:** HTML, spreadsheets **Classification:** Resources, Demographic and Behavior, Environment, Controlling Documents
Haz-Map	**Description:** Haz-Map is an occupational health database designed for health and safety professionals and for consumers seeking information about the health effects of exposure to chemicals and biological agents at work. Haz-Map links jobs and hazardous tasks with occupational diseases and their symptoms. It is one of the products and services made available by the National Library of Medicine's (NLM) Toxicology and Environmental Health Information Program. Haz-Map includes three categories: hazardous agents, occupational diseases, and high risk jobs [NIH 2010g]. **Data Source:** Haz-Map **Organization:** The National Library of Medicine (NLM) **Format:** Report **Classification:** Demographic and Behavior, Environment, Controlling Documents
Healthcare Cost and Utilization Project (HCUP) Databases	**Description:** Healthcare Cost and Utilization Project (HCUP) databases bring together the data collection efforts of State data organizations, hospital associations, private data organizations, and the Federal Government to create a national information resource of patient-level health care data (HCUP Partners). HCUP includes the largest collection of longitudinal hospital care data in the United States, with all-payer, encounter-level information beginning in 1988. These databases enable research

	on a broad range of health policy issues, including cost and quality of health services, medical practice patterns, access to health care programs, and outcomes of treatments at the national, State, and local market levels [AHRQ 2010]. **Data Source:** Nationwide Inpatient Sample (NIS), Kids' Inpatient Database (KID) , Nationwide Emergency Department Sample (NEDS), State Inpatient Databases (SID), State Ambulatory Surgery Databases (SASD), and State Emergency Department Databases (SEDD) **Organization:** The Agency for Healthcare Research and Quality (AHRQ) **Format:** PDF, HTML **Classification:** Demographic and Behavior, Resources, Controlling Documents
Healthy People 2010 Database	**Description:** DATA2010 is an information system developed by staff of the division of Health Promotion Statistics of the National Center for Health Statistics, CDC, and contains the most recent monitoring data for tracking Healthy People 2010. With this system, world-wide users have the ability to view the data collected to track Healthy People 2010 objectives, with national baseline and monitoring data for each Healthy People 2010 objective. Users can select data options to create and browse real-time tables and graphs of the baseline and tracking year data for all 28 health focus areas, as well as the leading health indicators. This interactive system allows users to query an updated database and construct tables. Tables can be constructed for specific objectives, or objectives identified by focus areas, data source, or by select population [CDC 2010nn]. **Data Source:** DATA2010 **Organization:** National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC) **Format:** Table and Graph **Classification:** Controlling Documents, Demographic and Behavior
Hospital Compare	**Description:** Hospital Compare is used to find information on how well hospitals care for patients with certain medical conditions or surgical procedures, and results from a survey of patients about the quality of care they receives during a recent hospital stay. The data provided includes process of care, mortality, and readmission quality measures. The collection period for the measures is generally 12 months. However, some measures may be based upon fewer than 12 months. Generally, the Hospital Compare quality measures are refreshed the third month of each quarter [CMS 2010]. **Data Source:** Medicare Hospital Compare **Organization:** Centers for Medicare and Medicaid Services (CMS) of Department of Health and Human Services, Hospital Quality Alliance **Format:** CSV, dbf

	Classification: Resources, Controlling Documents
Hospital Electronic Health Records (HER) Adoption Database	**Description:** The Hospital HER Adoption Database 2010 is based on a survey of U.S. hospitals tracking the adoption of electronic health records (HER), also known as electronic medical records (EMR). The data included are hospital specific. The database is used to determine where hospitals are along the technology adoption curve regarding electronic clinical documentation, results viewing, computerized provider order entry, decision support, and bar coding; find out where these functions are implemented in the hospital: emergency department, ICU, general medical/surgical, specialty, onsite ambulatory practices, and offsite ambulatory practices; and understand the capabilities of hospital's electronic systems [AHADATA 2011]. **Data Source:** Database **Organization:** American Hospital Association (AHA) **Format:** PDF, Microsoft Excel file **Classification:** Demographic and Behavior, Resources, Controlling Documents
National Emergency Medical Services (EMS) Information System (NEMSIS)	**Description:** The Hazardous Substances Emergency Events Surveillance (HSEES) system was established 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. The HSEES system data and prevention outreach are critical for identifying, preventing, and mitigating the consequences of terrorist threats against our chemical infrastructure. Fourteen state health departments currently have cooperative agreements with ATSDR to participate in HSEES: Colorado, Florida, Iowa, Louisiana, Michigan, Minnesota, New Jersey, New York, North Carolina, Oregon, Texas, Utah, Washington, and Wisconsin [NEMSIS 2010]. **Data Source:** NEMSIS NHTSA Dataset Version 3 **Organization:** National Highway Traffic Safety Administration (NHTSA); Health Resources and Services Administration (HRSA); CDC; University of Utah; University of North Carolina **Format Used:** XSD **Classification:** Demographic and Behavioral
National Incident Management System – Incident Resource Inventory System (NIMS-IRIS)	**Description:** National Incident Management System – Incident Resource Inventory System (NIMS-IRIS) is a database management tool that allows emergency responders to enter typed resources and select specific resources for mutual aid purposes based upon mission requirements, capability of resources, and response time. NIMS-IRIS tracks equipment, communications, contracts, facilities, responders, services,

	supplies, and teams [FEMA 2010f]. **Data Source:** NIMS-IRIS Version 2.2 **Organization:** Federal Emergency Management Agency (FEMA) **Format:** EDXL **Classification:** Resources
Rand Public Health Preparedness Database	**Description:** The Rand Corporation database, funded by the U.S. Department of Health and Human Services, provides access to numerous public health preparedness exercises. It is primarily intended for state and local public health officials. The database provides a list of possible exercises performed along with criteria rating the success of each exercise. There are fourteen design criteria used to rate each exercise. These criteria are: 1) clearly stated goals; 2) clearly stated objectives; 3) the objectives are appropriate given the goals; 4) each objective is addressed during the exercise; 5) objectives are measurable; 6) the scenario is appropriate given the goals and objectives; 7) the scenario is internally consistent; 8) scenario is "a realistic depiction of the capabilities and resources likely to be available to a participating health jurisdiction;" 9) clear guidance about participants; 10) all participants are engaged; 11) exercise can be replicated; 12) results in action items; 13) feedback is solicited from participants; 14) can be completed within the given timeframe. The goal of this database is "to identify the best exercises to help local and state public health departments prepare for public health emergencies." [RAND 2010c] **Data Source:** Rand Public Health Preparedness Exercise Database **Organization:** RAND Corporation, Department of Health and Human Services (HHS) **Format:** **Classification:** Training, Resources
Risk Group Database for Risk Group Classification for Infectious Agents	**Description:** In many countries, including the United States, infectious agents are categorized in risk groups based on their relative risk. Depending on the country and/or organization, this classification system might take the following factors into consideration: pathogenicity of the organism, mode of transmission and host range, availability of effective preventive measures (e.g., vaccines), availability of effective treatment (e.g., antibiotics), and other factors. The Risk group classifications used in the Risk Group Database are primarily used in the research environment as part of a comprehensive bio-safety risk assessment. The Risk Group database provides four search engines: search bacteria, search virus, search fungi, and search parasites [ABSA 2010]. **Data Source:** ABSA Risk Group Database **Organization:** American Biological Safety Association (ABSA) **Format:** **Classification:** Controlling Documents, Demographic and

	Behavior
The Emergency Response Safety and Health Database	**Description:** The Emergency Response Safety and Health Database is a rapidly accessible occupational safety and health database developed by NIOSH for the emergency response community. The ERSH-DB contains accurate and concise information on high-priority chemical, biological and radiological agents that could be encountered by personnel responding to a terrorist event. The information contained in the ERSH-DB represents a compilation of material from a diverse array of sources, and is intended to address the safety and health information needs of a wide range of emergency response personnel, including, but not limited to, the fields of fire and rescue, emergency medicine, law enforcement, emergency management, public health, safety and health, and mortuary and funeral. As a central source of information, the ERSH-DB allows diverse segments of the emergency response community to share a wealth of information that is not readily accessible and to avoid duplication of effort [CDC 2010oo]. **Data Source:** ERSH-DB **Organization:** The Centers for Disease Control and Prevention (CDC); The National Institute of Occupational Safety & Health (NIOSH) **Format Used:** text, table **Classification:** Controlling Documents
TheDataWeb Browser	**Description:** TheDataWeb is a network of online data libraries that the DataFerrett accesses the data through. DataFerrett is a unique data analysis and extraction tool—with recoding capabilities—to customize federal, state, and local data to suit the user's requirements. (FERRETT stands for Federated Electronic Research, Review, Extraction, and Tabulation Tool.) Data topics of TheDataWeb include census data, economic data, health data, income and unemployment data, population data, labor data, cancer data, crime and transportation data, family dynamics, vital statistics data, etc. [CENSUS 2010g] **Data Source:** BetaDataFerrett **Organization:** U.S. Census Bureau **Format:** XML/CAP 1.1, ATOM, RSS **Classification:** Controlling Documents, Demographic and Behavior, Resources
Weapons of Mass Destruction (WMD), Emergency Management and Medical Websites	**Description:** A comprehensive list of internet sites of use for emergency planning and in particular Weapons of Mass Destruction (WMD) and medical emergency planning [YNHHS 2010]. **Data Source:** Yale New Haven Center for Emergency Preparedness and Disaster Response Yale New Haven Health System **Organization:** Yale New Haven Health System **Format Used:** N/A

	Classification: Controlling Documents
Web-based Injury Statistics Query and Reporting System (WISQARS)	**Description:** The Web-based Injury Statistics Query and Reporting System (WISQARS) is an interactive database system that provides customized reports of injury-related data. The database includes fatal injury data (from the National Vital Statistics System), nonfatal injury data (from the National Electronic Injury Surveillance System), and violent deaths (from the National Violent Death Reporting System (NVDRS) [CDC 2010pp]. **Data Source:** WISQARS **Organization:** Centers for Disease Control and Prevention (CDC) **Format:** CSV **Classification:** Incidents

Appendix F – Breakout Group Notes

This appendix contains notes from each of the four parallel breakout groups. The information is generally presented in bullet form and for the most part is self-explanatory. The presentation summaries for the different technical groups have had minor editing for the purpose of achieving improved consistency and clarification. The appendices are organized as follows:

- F.1 – Hazardous Material Release Breakout Group Notes
- F.2 – Critical Infrastructure Breakout Group Notes
- F.3 – Incident Management Breakout Group Notes
- F.4 – Healthcare Systems Breakout Group Notes

F.1 – Hazardous Material Release Breakout Group Notes

The discussions in HMR breakout group had good involvement from the participants reflecting their past interactions on the topics. Many in the group appeared to have been involved in various forums over the years that include discussions related to the topics covered in the pre-workshop reading materials. The notes included below are based on the summary presentation provided at the end of the workshop by the HMR breakout group chair and co-chair, Drs. Sugiyama and Miller respectively. Please also note that the content included in this section was primarily provided by the attendees of the breakout session and may not reflect the opinions of the editors. The editors did consider all the input carefully to identify the content to be included in appropriate parts of the report and modified the report accordingly.

Summary of Key Points from Debrief Presentation

- Different models are needed/used to:
  - Answer different questions
  - Address different space and temporal resolutions
  - Provide results on different response time scales
- Appropriate M&S tools depends on
  - User (technical expertise, SME support, etc.)
  - Level of detail needed varies with the application
  - Key caveat: M&S providers have no control over the user base
- Most of the HMR focus is on airborne releases
  - Focus on preparedness and response phases
  - Separate water modeling discussion

HMR Breakout Group Approach

- Workshop discussion based on recognition:
  - Broad spectrum of M&S users
  - Range of releases to be considered: airborne, waterborne, food/water distribution systems
  - Full range of hazmat sources (e.g., CBRNE, toxic industrial chemicals (TICs) and toxic industrial material (TIMs), some natural hazards – volcanic ash or emissions, wildfire)
  - Differences between models for preparedness, response, and longer-term recovery / forensics
  - Large number of available models that cover different parts of scenario space
- Simplified the range of topics that we would consider w/primary focus on federal level M&S

Users of Hazmat M&S

- Decision makers (tactical and strategic)

  - Non-technical emergency responders
  - Emergency operations centers
  - State and local agencies
  - Federal agencies
- Commercial/private sector
- Trained users (minimal, expert)
- Subject matter reach-back staff (provide services and M&S products to users)
- Public / media

Range Of User Products

- Key impacts of interest
  - Population health effects to inform shelter/evacuation, relocation decisions
  - Worker protection
  - Contaminated areas
  - Economic and environmental
  - Affected infrastructure
- Graphical products
  - Geographical referencing
  - Animations to communicate time-evolution
- Interagency briefing products to communicate Hazmat M&S results to non-technical decision makers (Homeland/National Security Council tasking):
  - Interagency development, review, and approval
  - Radiological Dispersion Devices (RDD), Improvised Nuclear Devices (IND) initial versions (DOE-led)
  - Underway: Nuclear Power Plant - DOE/DHS, chemical/biological (CB) - DHS-led

Preparedness Applications

- Hazard assessments
  - Large number of simulations typically required to capture range of possible scenarios
  - Probabilistic methods often used to sample source / meteorological variability
  - Regulatory modeling (e.g., EPA, NRC)
- Training / exercise support to provide realistic-enough scenarios for players
  - After-action reviews and reports; implementing fixes
  - Need to train on same tool you'll use in real life situations
- Sensor placement
  - Need to carefully design criteria for optimization
  - Different (spatial/temporal) data resolution needed for detection vs. characterization of impacts

Response Applications

- Consequence management
  - Near real-time provision of actionable information
  - Initial fast estimation for immediate response (e.g., rules of thumb developed from M&S, simple Gaussian models)
  - M&S scoping of potential range of impacts (e.g., release characteristics are typically least known in the early stages of a response)
  - Detailed complex analyses via subject matter experts (e.g., reach-back support to federal resources)

- Situational awareness
- Guidance for monitoring and sampling planning

Use (and Misuse) of Hazmat M&S Tools

- Use the right model(s) for the application
  - Users and developers need to understand the applications for which the M&S tool should be used
  - Based on fidelity, resolution, and performance requirements
- Best practices
  - Design M&S tools to meet usability requirements and to minimize user errors
  - Provide an appropriate level of VV&A needed for all M&S tools (currently no practical way forward to develop common guidance and standards for all applications)
  - Provide appropriate training and documentation
  - Span the appropriate scenario space for the question of interest
  - Convey uncertainty of the product (how to do this is a key gap!)
  - Sustain appropriate maintenance of M&S tool and process for user feedback
  - Promote data exchange formats to facilitate data sharing
- Proper interpretation of M&S critical in communicating results to users
  - Interpretational information (Hazmat M&S results are highly technical and prone to mis-interpretation)
  - Documentation of assumptions
- Decisions should not be based solely on M&S results
  - M&S results need to be confirmed by data
  - Reduction in uncertainty as data is incorporated needs to be communicated
  - Examples of Key Scientific Needs
- Urban modeling (urban parameterizations, empirical urban, CFD)
- Complex flow conditions (e.g., land-sea breeze, complex topography)
- Complex physics process (e.g., wet and dry deposition on different surfaces, weathering, re-suspension)
- Improved source term / release mechanism models
- Methods for source term estimation and reconstruction
- Data at the appropriate spatial and temporal resolutions required for M&S tool(s)
- Integration and coupling of M&S calculation for multiple impacts (e.g., different media, scales / regimes of applicability, resolution temporal/spatial mismatches)

Water Modeling Considerations

- Range of models
  - River / watershed
  - Coastal
  - Long-range ocean transport
  - Man-made systems (e.g., pipeline system)
- Differences from airborne modeling
  - Data density much lower than in atmosphere
  - Longer time-scales
  - Actionable levels of concern are limited
- Key needs
  - Improved water M&S tools
  - Development of re-locatable M&S tools

Key Need: Coupling of M&S and Decision Support Tools

- Coupling of Hazmat models
  - Indoor-outdoor, including sheltering/shielding corrections
  - Subway-outdoor
  - Airborne-water
- Agreed-upon data exchange to enable connectivity to other decision support tools, for example:
  - GIS systems used by local, state, federal agencies
  - Critical infrastructure impacts
  - Response asset planning models

Key Need: Product and VV&A Standards

- Standard presentation of customer products would be beneficial
  - Use of same contour levels and colors for chemical effects
  - Use of federal protective action guideline levels for radiological impacts
  - Common interpretative information
- VV&A approaches are not standardized across community
  - Difficult to define given the range of agency needs, applications, users
  - Difficult to enforce due to the wide range of multiple model providers (government and commercial)
  - Cost for formal implementation across the community
  - Limited interagency standards for chemical and biological releases

Key Issue: Interpretation of M&S Products is Critical in Communicating Results

- M&S output provided to users should provide
  - Interpretational information (Hazmat M&S results are highly technical and prone to misinterpretation)
  - Documentation of inputs for the particular product
  - Document assumptions and limitations of the chosen M&S tool
- Use of M&S products for informing the public / media is controversial but critical
  - M&S products should be used to inform and help decision makers and Public Affairs Officers (PAOs) craft public action messages
  - Many agencies' policy is that raw M&S products should not be directly released to the public due to the risk of misunderstanding
  - Briefing Products are a step forward but are not really stand-alone

Key Issue: Understanding and Communicating Uncertainty

- No standard approach for incorporating all types of uncertainty in Hazmat M&S
  - Traditional subject matter expert-based worst case and most likely case analyses
  - Multiple simulations to determine M&S sensitivity / range
  - Ensembles (weather)
- Rigorous statistical methods needed to incorporate all sources of uncertainty (e.g., source, meteorological, and physical processes)
- Communicating uncertainty to the user is a major (unsolved) challenge

Final Perspective

- General guidance to developer and user community on M&S tools is needed (to which the workshop will contribute)
- Addressing this part of an-ongoing long-term discussion in the community

- Communicating the complex information provided by and the limitations of M&S tools to the complete range of users is a developing new challenge

Additional Reports of Interest that were Identified by Participants

- DOT, 2008: Emergency Response Guidebook (Orange Book) – updated ~3 years, next version 2012
- NAS/NRC, 2003: Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases
- NRC, 2006: Successful Response Starts with a Map: Improving Geo-spatial Support for Disaster Management
- OFCM, 2004: Federal R&D Needs and Priorities for Atmospheric Transport & Diffusion Modeling + semi-regular updates
- OFCM 2007(?): Report of Joint Action Group for Joint Urban Test Beds (JAG/JUTB)
- OFCM JAG/ATD(R&DP), 200?: National Research and Development (R&D) Plan for Atmospheric Transport and Diffusion (ATD) modeling systems
- Federal Research and Development Needs and Priorities for Atmospheric Transport and Diffusion Modeling (FCM-R23-2004). September 2004
- Other:
  - DoD Technical Panel 9 of the Technical Cooperation Program (TTCP) Chemical, Biological, and Radiological Defense (CBD) Group, annual reports: information exchanges between US, Canada, UK, Australia
  - DHS, 2007: Aquatic Fate and Effects Workshop
  - IMAAC Interagency VV&A Workshop, 2009: OUO draft only (POC: Joe Chang)
  - EU COST reports: EU approach to standardize M&S

Recommended Changes to Pre-Read Materials by Section

- Introduction and guidance
  - Incorporate corrected language on IMAAC
  - Include discussion of National Contingency Plan (oil and hazardous substances)
  - International agreements (e.g., IAEA / Comprehensive Test Ban Treaty (CTBT) monitoring, NOAA volcanic aviation hazards)
  - Focus on Federal Level aspects
- Perspectives on Methodologies, M&S
  - Simplify the detailed discussion on M&S process
- Capabilities and requirements specification
  - Details of revised bullets provided in notes below
- Review of tools and standards
  - Refer to existing compendiums of M&S tools (e.g., OFCM, NAS/NRC report)
- Issues and recommendations section
  - Replace sections on Best Practices and Limitations with material discussed at workshop
  - R&D and Science Gaps are based on high-level needs and limitations identified by participants

Data Output Requirements

- Change “User Interface Requirements” to “Data output requirements”
- Dependent on the user – ALOHA vs. NARAC
- Need to drive by user domain analysis
- A/B: move to performance requirements (input); usability section. Add “on the fly” to B
- C: add appropriate legends, documentation, standardized action levels of color.

  - C1 – legends (2D)
  - C2 – 3D, depending on your user; caveat: if 3D required.
- D: change to animations
- E: standardization. Change to different products for different types of releases & different users; graphical and data files
- F: being able to generate different output files, KMLs, shape files to input GIS systems
- MISSING: uncertainty communication
- Disclaimer, legal coverage, indemnification
- Associated metadata; standardized data format
- Interpretation of the output products and what it means; also input assumptions used in model run

Data Input Requirements

- A: add: anthropogenic heating
- B & C: morph into source description data to define the scenario in the source model (where, when, what, how much)
- D: chemical and physical properties; material properties
- E: geo-spatial data
  - Add/include critical infrastructure data
- F: demographic data very important; population is separate enough to call out; attributes by time of day critical data
- G: separate bullet on "health action level"

Recommendations for Future Work

- Needs analysis
  - Reorganize by phase (Preparedness, Response, Recovery)
  - Subset by type of release and scale of response
- Review of tools and standards
  - Develop criteria for inclusion of M&S tools to provide a consistent level of detail
  - Group by application (vs. current alphabetical listing)
  - Identify tools with unlimited and/or free availability

F.2 – Critical Infrastructure Breakout Group Notes

The discussions in critical infrastructure (CI) systems breakout group have been summarized using topic areas roughly aligned with sections of the draft report on critical infrastructure that was shared with the workshop participants. The bullets under each topic area generally identify suggested additions and occasionally questions raised by the participants in the CI breakout. An additional topic area of document organization has been included at the end to capture such comments such as those suggesting additional sections. Discussions relevant to one topic have been collected in one place even when some of it may have happened at different times during the two days. Please also note that the content included in this section was primarily provided by the attendees of the breakout session and may not reflect the opinions of the editors. In fact, there are occasional contradictory comments but they are included in the interest of capturing all the contributions. The editors did consider all the input carefully to identify the content to be included in appropriate parts of the report.

Needs Analysis

M&S should meet the following additional needs of the decision makers:

- Predict damage to infrastructure primarily affected by incident

- Predict cascading damage to other infrastructure
- Predict impact on human populace affected by the incident and damage to the infrastructure (including evacuation models)
- Predict situation following the incident before information for situational awareness becomes available.
- Analyze trade-offs between investments and risks to improve resiliency in disasters.
- Provide predictions across the whole range from micro and macro scale, for example, models that predict cracks in individual building to models that address impact of a hurricane on all the infrastructure systems in a region.

Requirements

- Include cyber-security aspects
- Include capability for geographic models to utilize raster and elevation data
- Need to define prioritized list of questions relevant to each CI sector – the list can be improved through discussions with involved organizations including private sector
- The scope of models should be driven by the intended use and that should be captured in the request for proposals

M&S Resources: Simulation Models and Tools

- Department of Transportation's (DoT's) subway environmental simulation that models smoke movement around tunnels during fires
- Finite element analysis tools including ABAQUS, ANSYS, LS-DYNA,DYSMAS, and CTH
- Isight process modeling tool
- Emergency and Disaster Modeling simulation (EDMsim)
- Functional Dependency Network Analysis (FDNA) for interdependency analysis

M&S Resources: Projects, Facilities, and Capabilities

- CEMSA
- High Performance Building project
- Decision support system for risk assessment and managing floods (RAMFlood)
- M&S for emergency planners: FEMA Project #7 M&S RCPGP (Regional Catastrophic Preparedness Grant Program) contracted with DMAPS, AHC, CSC (project planning)
- HiTRAC for estimating national level risks for supply chains
- MELCOR for nuclear reactor modeling
- Wide Area Recovery & Resiliency Program (WARRP) program

M&S Resources: Relevant Standards and Guidelines

- Add Open Geo-spatial Consortium's (OGC's) OpenGIS City Geography Markup Language (CityGML)

M&S Resources: Data Sources

- DoT/Bureau of Transportation Statistics – TranStats online data base
- Data from DHS Office of Infrastructure Protection's (OIP's) Infrastructure Information Coordination Division (IICD) such as Homeland Security Infrastructure Program (HSIP) Gold
- Energy Information Administration that includes lot of data on energy infrastructure
- Federal Deposit Insurance Corporation for aggregate data on banking sector
- Population Dynamics – LandScan datasets
- Data from National Geo-spatial-Intelligence Agency (NGA) available on a need to know basis
    - Geo-spatial Intelligence (GEOINT) data

    - Digital Terrain Elevation Data (DTED)
- Aggregate economic data from diverse sources:
    - Publications such as the International Air Travel Association (IATA) quarterly newsletter
    - Commercial services such as IHS Global Insights for industry and country forecasts, SRI Consulting's Chemical Economics Handbook for chemical production, supply, demand, etc.

Best Practices

- Results dissemination
    - Pre-hurricane damage assessment to coastal infrastructure from NISAC available on DHS internal network on official use only (OUO) basis
- Implementation
    - Update predictions based on real data from field
- Development process
    - Involve user as early as possible in development, starting from requirements development
    - Avoid requirement creep by having a formal change request process
    - Clearly defined data dictionary and taxonomy
    - Document the model follow standard practices in user's manual and technical manuals
    - Share accreditation guidelines with developers
    - Configuration management and tracing to results
    - Leverage best practices from systems engineering and software engineering
- Data inputs
    - Best practices for building data to collect for building automation systems (similar to John Deere collecting data through smart tractors?)
- Verification, Validation, and Accreditation (VV&A) practices
    - Validation based on real data that becomes available post incident
    - Test cases for validating model
    - A very well defined integrated model development process overlaid with VV&A such as that used in High Level Architecture (HLA) Federation Development and Execution Process (FEDEP)
    - Mandatory process should be implemented as such for validation. Do not follow the practice in case of HLA where too many waivers were allowed.
    - VV&A approaches used by U.S. Navy
        - Demonstrations and/or live event
        - Data collection and experimentation at multi-scales running in parallel with code development and benchmarking of models against data early in development cycle used in Dynamic System Mechanics Advanced Simulation (DYSMAS) project
        - Scenario driven development process used in Navy's Combat weapon system (AEGIS)
    - Focus on "Big V" versus "little v," i.e., focus on validation throughout the development process starting from requirements validation up front
    - DoD's M&S Use Risk Methodology (MURM)
    - Round Robins (akin to the ensemble approach) – prediction from a number of models compared to experimental results
    - "Hindcasting" – comparing against historical data
    - Data validation by user experts through comparison with field experience
    - Build parallel model for validating another model- especially for scalability

Limitations, Cautions, and Warnings

- Communication to decision makers:

    - In M&S literature, highlight information on limitations so that they are actually read.
    - Highlight: “all models are wrong, some are useful.”
    - Highlight: focus on understanding not on numbers.
    - Need better ways to communicate critical information on limitations to decision makers to avoid erroneous extrapolations since tools don’t have automated means to stop application in inappropriate situations.
    - All decision makers should clearly understand the intended use of subject model and simulation.
    - Need to provide objective ways to go beyond biased views.
    - Input and assumptions should be made clear to decision makers. Model designed for one situation applied to another can impact the outputs to affect credibility.
    - Simulation will not make the decision, decision-maker needs to include other knowledge particularly for real-time decisions; use only after sufficient experience with the tool.
    - Avoid overselling a capability.
    - Proceed with caution in case of one shot scenarios where all the information is from a model with no benefit of comparison with real or experimental data.
- Communication to developers:
    - For CI models, clearly define the system boundaries during development and use and identify critical factors, such as interdependencies, that may impact the results.
- Model use:
    - Appropriate “simple” models may be used for understanding, generalizing, and capturing system complexity but may not be suitable for predicting specifics.
    - Warnings to users on range of applicability of models
    - Make clear what model is not intended for.
    - Don’t apply models beyond their intended domains of use, e.g., improper attributes.
    - If applicable, specify that models must be used with analysis support and not in standalone mode by decision makers.
    - Differentiate between predictive, exercise and real-time models. Exercise support requirement less stringent than real-time models, hence, models meant for exercise support may generally not be usable for incident management.
    - Need to develop experience with simulation tools to avoid using them as black box
    - Simulation development and use process, objectives, and models should be aligned else the results may not be credible.
    - Need model documentation, reference data sets, and access to experts (or knowledge), otherwise there may be significant risk in the use of the model.
- Data availability and collection methods
    - Data limitation should be described since data is not available generally, costs a lot to get, not at the desired level of detail, and the validity of data at times is questionable.
    - Counterpoint: Models can be useful for general understanding even with inaccurate data. Example provided of use of earthquake models without knowing the exact location of the undersea cables
    - Model parameter measured with different methods can lead to different input data and hence different results.
- Sources of variation
    - Add warnings if applicable related to hardware platforms, software language (e.g., for single versus double precision problems), code not optimized.
    - When integrating models make sure that models are compatible.
- VV&A
    - Validation of multiple integrated models will require multiple experts.
- Model outputs

  - Not including estimates of uncertainty or quality of data and/or models is risky when applying results.
  - When assumptions significantly affect model output, perform sensitivity analysis.
- CI sector specific input:
  - Health care/fire facilities models are generally outdated soon after construction since modifications are not captured in the model. Ensure updates are communicated to first responders in case of an incident.
  - There are known differences between model design/building code information and reality.
  - Limitations on the quantity or existence of data to address problems, e.g., food security models limited by lack of data.
  - Chemical and other KR suppliers moving off shore and that is limiting knowledge of supply chain to inform model development. That is particularly a concern for critical manufacturing sector.
  - There is unbounded complexity in (computer) networks.
  - Telecom technology is dynamically changing and hence need to ensure that current technology in use is captured in the simulation models being used.
  - Lack of access to commercial data for understanding and model development since there is no CVI type process for strategic materials such as metals.
  - For dams, there is uncertainty in materials data related to modeling characteristics and survivability to threats.
  - Lack of understanding of interdependencies in transportation systems and of the shift among modes due to economic factors.

Issues: Research & Development

- Conceptual understanding
  - Develop theory and algorithms for complex systems in CI and understanding of involved phenomenology and people aspects, e.g., people afraid to come to work for pandemic flu
  - Develop understanding of interaction of decision makers with simulation tools
  - Recognizing common threads across sectors that can be leveraged
  - Suite of persistent authoritative consistent conceptual models associated with each sector to facilitate collaboration between technical community and users
  - What threats to worry about specific to the sector
  - Different kind of uncertainties, epistemic versus aleatory, involved in modeling various infrastructure systems should be understood together with their impact on results.
- Data input capabilities
  - Dealing with dynamic and streaming data
  - Capturing data for models based on reality such as 3D image capture for urban and terrain at the desired fidelity level
- New modeling capabilities
  - Modeling of building collapses. A report from National Institute for Building Sciences has concluded that it is too difficult to predict building collapses due to lack of data on properties of particular infrastructure. A need was identified for the models to identify places where people may be trapped in collapsed buildings and to understand the toxic or other hazardous risks within the collapsed structure. The attendees from Singapore shared that they are able to collect data for buildings from existing systems. However, the U.S. attendees felt that it will be a challenge to do something similar in the U.S.A. due to much larger scale and variety of ways of capturing building data.
  - Pedestrian evacuation dynamics
  - Commercial facilities including modeling of crowds and individuals psychology, variation in occupancy, and use of real-time information

- Response of structures to explosives
- Model, analyze, and manage risks and uncertainties
- Modeling of damaged infrastructure and the following evacuation and shoring up
- Cross sector interdependency modeling and analysis and cascading effects
- Vulnerability and consequences
- Real time tools to help decision making
- Extend models to include Geo-spatial Concept of Operations (GeoCONOPS) capabilities
- Models that adapt the behavior dynamically to match the configuration updates
- Air support for emergency services including capture of required data, and guidance for selecting appropriate aircraft based on urban and natural terrain
- Linkages within and outside the Energy sector
- Simulation of all hazards, including individual and simultaneous multiple events, at nuclear plants such as, earthquakes, tsunamis, tornadoes, aircraft impact, etc.
- Granular data sets required to support nuclear plant location analysis
- Upates to fire models due to changes to resilient and green buildings
- Tie owner-operation to test analysis clinical data to locations and facilities in healthcare sector
- Model healthcare as an enterprise rather than individual facilities; identify data needed for modeling as an enterprise
- Cyber attacks at application level
- Socio-economic impact of overlapping CI sectors (from systems to System of systems)
- Individual firm behavior in banking and finance
- International goods movement including implications for customs and security
- Deterioration of water supply networks to predict maintenance and replacement needs; abstract to all infrastructure

- VV&A
  - Develop benchmarking data sets for models for each CI sector. Navy tried something like this and that went a long way towards developing models and supporting tools.
  - Validate actual performance of buildings and large structures against expected performance based on the design codes, e.g., performance under scenarios of earthquake, floods, etc. There may be some related work in a new DHS or NIBS resiliency program. Similar work is happening for sustainability under the DHS High Performance building program.
  - Validation of models – methodology and results
  - Build experimental set-ups that can be shared and replicated to support validation of simulation models; provide ancillary and auxiliary tools
  - Need to understand the limitations of test set-up since some aspects may not be replicated in reality
  - Develop techniques to validate models of systems involving human behavior. At times, these models use agent-based paradigms. Also, need lot more data and statistics on such systems.
  - Flood plain data and model validation
- Uncertainty quantification
  - Comparison of models looking at uncertainty and intended use to help selection of models
  - Enhanced capability to capture uncertainty in inputs and its impact on outputs
  - Develop scenario specific trustworthy measures and metrics on model outputs that take into account the uncertainties in data and model
  - Representation and visualization of uncertainty in large data sets

- Analysis capabilities

    - Guidance for drawing conclusions based on a combination of uncertain and accurate input data.
    - Determine impact on synthesis due to heterogeneity of component models
    - Develop metric to capture trustworthiness of the model outputs based on input data quality and fidelity of the model – link to VV&A
    - Define the procedures for different fidelity level models to determine the parameters in fire simulations
    - Develop mechanism that help increase understanding of key issues from simulation outputs
    - Best way to communicate model results/forecast to the public
- M&S economics
    - Analyze trade-offs between risk and investment and identify point of diminishing return
    - Build vs. buy decisions before developing a new solution
- Multi-resolution modeling
    - Link response models to systems to understand how would micro benefit macro
- Development process
    - Enable collaborative model development, from data to execution (different from distributed execution)
    - Keep to defined requirements for R&D
    - Stick to agreed assumptions and constraints
    - Follow code development practices such as ISO9001
    - Elevate coding principles, styles, platforms, and tools to domain specific applications
    - Determining appropriate life cycle methodology for intended use – model-based (systems engineering) or simulation based (currently used) or component-based
- Model execution performance
    - Exa-scale computing – parallel processing in simulation needs to be further developed

Issues: Standards

- Standardization for domain specific models
- Standards for volunteered geo-spatial data (from sensors, tweets, utilities etc) and streaming data to populate databases and rapid injects into infrastructure interdependency models
- Standard output formats for infrastructure models
- Metadata standards for models and data for interoperability
- Virtual representation of National Monuments and Icons
- Code of ethics for M&S professionals

Issues: Implementation

- Data availability and sharing
    - Accurate, timely, and legitimate data will be critical for all types of models; however, such data is generally hard to find for all the parameters needed by the models.
    - In some cases, data collected decades ago is being used. Crowd models are based on data collected in 1970s even though the demographics have changed with population now having a higher percentage of overweight people who do not move as effectively.
    - Lack of data should not be a barrier to building good models. It was suggested that representative distributions might be used where accurate data is not available.
    - Need higher fidelity terrain data and 3D data
    - Catalog of relevant data sources including agencies of U.S. Department of Commerce
    - Identify responsible contacts for each infrastructure and places one can get help on a particular infrastructure

- Disseminate guidance on data identified under Protection of Critical Infrastructure Information (PCII), i.e., not classified but protected as critical;
    - How to get access to such data for M&S yet keep it secure; figure out the needs and ways to sanitize?
    - Mandatory training and protocol
    - Currently limited guidance available on use of data
    - Recommend using the same model for PCII as is being used for Chemical Vulnerability Information (CVI) including the training requirement
- Develop central directory of databases including private sector data. Need to address proprietary issues, perhaps by developing guidelines for sanitizing data for sharing similar to PCII and CVI.
- Define the kind of data required for modeling for the 18 identified CI systems and the potential sources for such data.
- Define data required for selected scenarios. As an example, the group captured the data requirements for a hurricane scenario in Louisiana as below:
    - Levee data: age, deterioration, etc.
    - Geo-spatial locations, getting the aspects of vulnerabilities of the different infrastructures, e.g., above ground transfer systems have a known level of wind tolerance.
    - What was damaged before, as they are most likely to be damaged again.
    - Evacuation data of who went where last time. Also population attributes (demographics- age, community). These will help define the evacuation areas.
    - Interactions among characteristics – wind, water, demographics
    - Understanding what's happening during the event. To build real-time scenario, need to know what's happening during the event, and releasing it to whom and at what time.
- Procedures for acquiring information from private sector organizations. A specific case of difficulties in acquiring data from a phone company for some earthquake models was mentioned. It was also surmised that insurance companies would have lot of relevant data, but it is not sure if they'd be willing to share it.
- Provide a matrix relating sectors with regards to data affecting model use including common data that can be reused, and other data that is specific to scenario
- Reuse of the local knowledge and documentation (permits, fire codes, inspections)

- Model availability and guidance
    - Central repository/ directory/ authoritative source of models and tools with related information such as guidance on use and quality.
    - Consumers report kind of guidance on tools with quantified confidence in analysis outputs
    - Identify the models that are available for use free of cost.
    - Identify organization(s) that will maintain benchmark problems and models for each of the sectors (e.g., computational analysis benchmarks)
    - Some users or support organizations may require access to code and model blueprint. Should open source software be used? How does one develop deep understanding of simulation engine without such access? Build access to simulation code in contract?
    - Establish model validation databases – include meta-analysis of validation that has been conducted
    - Infrastructure to manage families of models (PLM/SLM tools avail. in commercial world used for software)

- Model outputs:
    - Develop a mechanism to relate results to models similar to the National Science Foundation funded scheme for Agent-based Models for keeping tools and results together

- M&S Economics
    - Develop M&S effort guidelines that provide realistic picture and set reasonable user expectations
    - Define economics of M&S, that is, cost benefit analysis guidelines that help bring rigor to M&S process
- Partnerships for model development and use
    - Greater information sharing and interoperability
    - Partnerships between national labs
    - Academic partnerships, Centers of Excellence and private sector
    - Establish consortiums for sharing knowledge and development of common tools (similar to DoD and industry)
    - Collaborative enterprise environment establishment and cultivation

Document Organization

- Add a section on relevant organizations, such as those listed below, to the document with respective expertise areas:
    - National Labs
    - Academia
    - Virginia Modeling And Simulation Center (VMASC)
    - DoD labs
    - NIST Engineering Laboratory
    - U.S. Nuclear Regulatory Commission reports
    - International research centers – particularly in EU, Japan, Singapore
    - Johns Hopkins University/ Applied Physics Laboratory (JHU/APL)
    - Professional organizations in the area of simulation such as, Society for Computer Simulation, SimSummit, and Simulation Interoperability Standards Organization (SISO)
    - University Research Centers on M&S such as, ACIMS, MOVES, Alabama Center for M&S, Georgia Tech, and University of Central Florida
    - Universities offering M&S graduate programs – ASU, ODU, UCF, NPS, etc.
    - CIMNE (International Center for Numerical Methods in Engineering), Spain

Recommendations for Future Work

- Orient the document towards DHS personnel and not include research and development community.
- Present simulation in larger framework of analysis tools.
- Define a structure of the document that allows frequent refreshing of contents to stay updated.
- Add a section for web services for M&S, e.g., for distributed execution DEVS/SOA
- Consider expanding the definition of CI sectors to include commerce supply chains to international customers, ports, shipping and national waterways and their socio-economic and ecological impact

F.3 – Incident Management Breakout Group Notes

The discussions in incident management (IM) breakout group sessions have been summarized using topic areas aligned with sections of the draft report on incident management that was shared with the workshop participants. The bullets under each topic area generally identify suggested additions and occasionally questions raised by the participants in the IM breakout. An additional topic area of document organization has been included at the end to capture such comments such as those suggesting additional sections. Discussions relevant to one topic have been collected in one place even when some of it may have happened at different times during the two days. Please also note that the content included in this section

was primarily provided by the attendees of the breakout session and may not reflect the opinions of the editors. The editors did consider all the input carefully to identify the content to be included in appropriate parts of the report.

Needs Analysis

- Timely accurate information and better assessment on quality of the raw data that is available
- Standard ways to define incident management problems
- A searchable on-line index of models appropriate to given situation, like "experts book" used by journalists
- Guidance for command & control
- Provide best added value for on-the-spot responders first, and then for senior decision makers

Requirements

- Response plans need to comprehend the possibility that intended responders are among the victims
- Agile and adaptable models that can be used for a wide variety of situations. Such models are preferred over perfectly designed ones that cater only to a specific scenario.
- Integrated all-purpose models for training, analysis and real-time management
- Documentation including intended use, known limitations, indicators and warnings of violation of assumptions
- Ability to translate scale, scope, units of measurement
- Geographic portability

M&S Resources: Simulation Models and Tools

- Degree of trust required depends on intended use (support for critical decisions requires much high standard than for "what-if")
- Include information on the following:
    - HSEE
    - MSEL Builder
    - Evacuation modeling tools developed by Redfish Group under Homeland Security Institute (HIS) sponsorship
    - Hazmat
    - DTRA CAT (consequence assessment tool set)

Best Practices

- Model inputs
    - Resolve conflicts that arise from different data sources yielding different results
    - Use of a common data translator in the absence of a data standard as practiced by the Department of Defense
    - Appropriate assumptions, appropriate scope, appropriate level of detail, and readily accessible
- Results dissemination
    - Defined timelines for successive M&S results with increasing levels of accuracy similar to that done by National Atmospheric Release Advisory Center (NARAC)
    - Provide quantified confidence levels with M&S results (such as satisfaction/regret curves provided by Critical Infrastructure Protection Decision Support System – Decision Model (CIPDSS-DM))
- Implementation
    - Translational and searchable capability better than trying to drive everyone to one standard
    - Used in exercises, realistic tests before inclusion in crisis response
    - Use of reach-back centers to support use of M&S by incident managers and responders

Limitations, Cautions, and Warnings

- Should be included in any "catalog" of M&S tools
- Policy makers and decision makers can't assume away limitations

Issues: Research & Development

- Conceptual understanding
  - Study local incident managers - do they know what response times and approaches are? Is their knowledge all subjective judgment?
  - Organizational behavior research effort to determine how different levels use information and M&S, how to measure benefits
  - Dimensions of M&S applicability and use, may include such attributes as:
    - Level within organization
    - Stage of event -- time criticality
    - Component / environment of event
    - Type of event
  - Use of models when data is inaccurate/ has uncertainty
- New modeling capabilities
  - Model interdependency issues (e.g. health effects, HAZMAT from building collapses, interacting crises)
  - Exploit information available from public sources such as CNN and other news channels
- Analysis capabilities
  - Develop guidelines to determine how well a model will work in situation you never anticipated
  - Define guidelines to identify patterns in incidents
  - Provide robust pre-positioning of resources versus highly detailed plans
- VV&A
  - Determine when we know enough, either in validation or in decision-making; Use the determination to optimize the validation effort
  - Processes to validate usability of M&S tools
- M&S economics
  - Determine M&S efforts needed at various levels of response
- Include R&D needs identified in 2004 workshop (LLNL Report UCRL-CONF-208718 "Computer Simulation for Emergency Incident Management):
  - Scalability of software solutions
  - Integration of multiple simulation paradigms
  - Software environment for federated computing
  - Visualization for insight
  - Modeling human behavior
  - Understanding complex adaptive systems
  - Resource constrained computing
  - Relevance of non-police/fire/EMS communities to the design of effective incident management simulation

Issues: Standards

- Data structures
- Data interfaces
- Geo-spatial / visualization
- Standard nomenclature
- Ways to assess and label the validity of models

Issues: Implementation

- Data availability and sharing:
  - Address the major constraint of organizational resistance to sharing data -- biggest obstacle is policy and culture, not technology
  - In real-time, good data more critical than analytical modeling
  - Models should integrate the latest field data available and should not be seen as competing with data
- Model availability and guidance:
  - Develop a well-grounded decision-making process and structure to provide basis for mission requirements that in turn drive assessments of models; DHS needs clearer mission / problem definitions as prerequisite for model requirements and evaluation
  - On-line searchable information about approved models available for specified purposes, including assumptions, limitations, indicators and warnings of inappropriateness; S&T needs a "librarian" to keep track of what has already been done -- searchable
  - Better sharing of information on how models are chosen to integrate into SUMMIT framework at the National Exercise Simulation Center (NESC)
- Model outputs:
  - Consider new information channels (e.g. social media) as part of the communications processes
- Process recommendations:
  - Have dedicated staff associated with the most important models, checking them
  - Have frameworks to commission a run from a reach-back center
  - Can use analytical tools (simpler than simulation) to look at whether you have the needed people, training, resources
  - A clearer decision-making process and structure to support the kind of requirements development sought here; DHS needs to devote analytical effort to improving its own decision processes
  - M&S goals identified need to be continuously updated, not one-time efforts -- DHS needs a mechanism for continuously updating information like these documents
  - Lessons learned activity should include considering what did people fail to recognize and act on

Recommendations for Future Work

- For the M&S tools listed include information on:
  - Evaluations and quality
  - Intended uses (training, decision support, level of organization)
  - Limitations of models
  - Availability
  - Currency
  - Validity
  - Complexity
  - Ease of use

F.4 – Healthcare Systems Breakout Group Notes

The Healthcare Systems breakout group had extended discussions. There was so much enthusiasm and interest in the topic that it was difficult to fit everything into the allotted time period. The discussions have been summarized using topic areas aligned with sections of the draft report on healthcare systems that was shared with the workshop participants. The bullets under each topic area generally identify suggested additions and occasionally questions raised by the participants in the IM breakout. An number of

additional topic areas were discussed by the group and have been included after the sections corresponding to the pre-workshop reading document. In particular, the group found the idea of developing a healthcare model exemplar quite important and spent some time developing it further as captured near the end of this section. Please also note that the content included in this section was primarily provided by the attendees of the breakout session and may not reflect the opinions of the editors. The editors did consider all the input carefully to identify the content to be included in appropriate parts of the report.

Needs Analysis

- Continuous automated knowledge capture
- Infrastructure-less response
- Data intensive cumulative continuous analysis
- Preventative and predictive modeling
- Best practices benchmarks
- Situational awareness (county, regional, state, national)
- Focused innovation environment
- Dynamic data translation
- Continuous and dynamic patient state vector
- Data dictionary
- Command, control, and communication (CCC) vs. outcomes
- Business enterprise
- Facility design
- Capacity demand management
- Conceptual modeling

Intended Use

- Consensus building and collaboration
- More integration communication planning increase data and use
- Focus innovation
- Predictive element
- Real time dynamic
- Mission integration (reflect real message/issue)
- Community live, thrive, survive
- Mission support
- Neutralize politics
- Architects (AIA)
- Audit traceability
- Deploy gracefully
- Learn subjective things
- Process
  - Mission
  - Function
  - Conceptualization
  - Data
  - Performance credibility

Functional Requirements

- Identify and specify the system state for different health care domains across integrated health emergency Area of Operations (AOO) over time

- Define functional requirements
- Integration with law enforcement plans and authority
- Health department oversight
- Definition of steady state conditions
- Scoping implications generic
- Fully cross-barred model of relationships between population and individuals: an end to end approach.
- Protect against cognitive bias
- Theoretical model

Data Requirements

- Resources state: prevalence vs. incidence
  - Examples ancillary departments
  - Population profiles
  - Displaced (housing, residents)
- HIPAA-compliant patient-specific data over consistent period of time (exclude rare and outliers)
- Data types
  - Predefined data sets
  - Capture systems pre-incident protocols
  - Injury analysis
  - Trauma types
  - Treatment plans

User Interface Requirements

- Tools for integrating multiple models
- Scenario generation tools

Performance Requirements

- No 'negative training'
- Implementations and applications should interoperable and distributed

Credibility and Evaluation

- Set the expectation early to have VVA for best practice guidance
- Need VVA standards

Other Projects, Facilities, and Capabilities

- National Center for Collaboration in Medical Modeling and Simulation at Eastern Virginia Medical School
- National Intrepid Center of Excellence (NICOE)
  - Traumatic Brain Injury

Simulation Models and Tools

- Evaluations by user (disclaimer/instructions)
  - Availability
  - Hardware/software requirements
  - Support offered by distributor
- Other simulation tools used for healthcare simulation (included but not limited to)
  - Flexsim HC – discrete event simulation for healthcare
  - ACSLX – biomedical modeling

Limitations, Cautions, and Warnings

- Need VVA standards
- User responsibilities
- Certification of model champions
- Political view
- Database issue – multiple; no continuity
- Decentralize model building and implementation with integrity

General Research, Development, Standards, and Implementation Issues

- Data translators are needed for healthcare data - More important than standards
- Need VVA standards
  - Discussion
    - Totally lacking
    - Pitfall
    - Avoided
  - VVA cannot be treated as a separate deliverable.
  - Modelers need to tell what they did
- Overall philosophies
  - Discovery
  - Imperfect science
  - Risk assessment
  - Must be contextualized – risk always there. Constantly overlaying and experimenting because they are discovery processes - not exact processes
  - Sliding scale of trustworthiness of model based on data
    - Human
    - Finite element models
  - Think about models multi-applicability
  - Include all domains (architecture, health care)
  - HIPAA disaster (identity lost, stolen, categorized missing)
  - Human behavior and communication patterns
  - Training requirements for public health officials
  - Community education
- Simulation Documentation
  - Requirements
  - Does it meet specs – 'of course' (because there are no specs!)
  - Need a CMMI-type (Capability Maturity Model Integration) for M&S
  - Levels of documentation – the standard minimum
  - Ways of recognizing managing data integrity
- VV&A an inherent part of contract with client
  - We need to provide appropriate VV&A techniques consistent with the needs for the project
- Types, cost, time
  - Risk or confidence based
- Did you do enough? Need to know baseline
- Initiatives - we need to know what DHS is doing
- Tools
  - Modeling
  - Support tools (statistical)

  - Ad hoc health care support
- Technical issues
- Policies
  - Codification of legal responsibilities (modelers and analysts)
  - Error representation reporting
    - Define the meaning of error
    - Research issues on how to incorporate into sim mod
    - Healthcare response
- Standards
  - representing the criticality of model
    - Is this just a game?
    - Or is it predicting deaths or collapse of buildings
- Information access – destruction, backup access
- Vulnerable populations: aged; language and culture barriers; multiple-use facilities;

Healthcare Specific Research, Development, Standards, and Implementation Issues

- Standard models pros and cons
  - Encourage widespread model development vs. single source development
  - Stimulate the market so that the community is not dependent upon a single or a few entities (not all eggs in one basket)
  - Need standards so that models don't require system integrators
  - Development of portfolio of healthcare models
  - Market/technology is immature (lots of development will mature the market)
  - Find mechanisms for encouraging innovation
    - Contests
    - Competitions
- Research or further investigation to search for existing models
  - Need to be studies that characterize the uniqueness of the healthcare responses in disaster
    - Distributed highly sensitive, interdependent (some interdependencies not inherently known)
  - Fatalities: Which people die?
    - Population (civilians)
    - Families/communities profile /health status
    - Front line staff (first responders)

Simulation Engineers/Analysts

- Licensing/certification of simulation analysts
- Accountability/certification of models (sign-off on models)
- Need to establish internal Q&A practices for models
  - What are the practices?
  - When are they to be performed?
    - After process modeling
    - After baseline (review process modeling and approve)
    - Design of experiments (DOE)
    - Preliminary results

Healthcare Model Exemplar

Need to develop a comprehensive supply-chain disaster model for healthcare systems that includes:

- Determine characteristic models for this event: heterogeneous

  - System dynamics
  - Agent-based modeling
  - Discrete event
  - Physics
- Mission driven model (vs. technology driven)
  - For whom
    - Stakeholders
    - Patient centric
  - Disaster Outcomes
    - process flow (according to disaster protocols), health state, treatments
- Model input and output: achieved through evidence based metrics
- Model according to event status by phases of events
  - Pre-event
    - Vaccine acquisition and administration, distribution
    - Training
      - Post trauma exercise systems
    - Alternate resource planning (facility, staff)
    - Interagency coordination
      - Health department, Emergency Operation Centers (EOCs)
      - Behavioral support (mental health case managers, faith-based support)
      - Non-governmental organizations (NGOs), e.g. American Red Cross
      - Logistical support
      - Utilities and transportation
      - Alternate infrastructures
      - Communication systems (all types)
  - Event
  - Post- event/ long term recovery
    - Living response
    - Fatality response
    - Patient
    - Responders
    - After trauma – exercise value; how to live
- Prioritization of multiple roles for individual responders (teams)
- Loss of capabilities
  - Facilities
    - Loss of main hospitals and healthcare facilities, e.g., building structure
    - Key systems or critical infrastructure; e.g., contamination of heating, ventilation, and air conditioning (HVAC)
  - Medical records (paper and online/computer)
  - Laboratory storage of contaminants (biological radiation, nuclear hazards)
  - Incapacitation or loss of frontline staff and emergency medical technicians (EMTs)
  - Mutiny, refusal to work or show up for work by responders
  - Use of an emergency health reserve corps
  - Supplies (medications, medical)
- Regulatory components/policies and SOP's
  - Mandatory infrastructure
  - Legal documentation (evidence /forensics)
  - Prioritization reallocation for disaster purposes
  - Altered standards of care during emergency/disaster situations

- Must maintain control for data integrity

Recommendations

- Pharmaceutical approach (already have good processes in SOP) and medical equipment
  - Modeling supply chain safety
- Healthcare simulation training and education
  - Nursing, medical schools, ancillary health programs
  - Engineering programs
  - Architectural
  - Business
- Certification of healthcare professionals in simulation
- Certification of users
- Improve publicly-available:
  - Data sets
  - Models (example: disaster arrival model)
  - Tools
  - Training
- Find success stories
- M&S expectations (schedule, phases, costs, time, internal staff (model champions) technology and/or data experts)
- External review panels for publicly funded projects
- Establish staff configurations of modeling teams for different types of modeling projects (identify which types of experts are required to solve each type of problems)