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# **Modeling and Simulation for Emergency Management and Health Care Systems: Workshop Summary**

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Mark Sullivan, Mark Sullivan Architects

### A Dedication To Mark Sullivan (1950-2009)

The work I have done on the NIST symposium would never have been possible without the knowledge, enthusiasm, and support of Mark Sullivan, principal and founder of Mark Sullivan Architects. Mark died quite suddenly before he could be properly cited as the champion he was for furthering the integration of architecture as a critical patient care variable. When I began working for him in 1993, he had a vision that together we could improve the way patient care spaces were designed, not only for the patients, but for the nurses and other staff working in those spaces.

Mark always pushed to make sure architecture was represented in an evidenced-based and regulatory manner in our simulation models. He helped us shift paradigms with his work on space commissioning and his futuristic thinking and planning on how to combine the architectural software with modeling software. He was my colleague, friend, and husband. The work behind the scenes to make the symposium successful would not have been accomplished without him. I hope I have represented his work in the field of architecture in the best possible way.

Susan O'Hara

## PREFACE

The National Institute of Standards and Technology (NIST) is working with the U.S. Department of Homeland Security (DHS) to establish modeling and simulation (M&S) technical interest groups (TIGs) with technical experts from the various M&S domains associated with homeland security. The TIGs will share information, promote cross-fertilization of ideas, identify community research and standards needs, review plans, and help to establish consensus on a number of technical issues. The proposed objectives of the TIGs are listed below.

- Refinement and/or expansion of definition of the technical scope for each TIG within the general guidelines that have been established
- Specification/ratification of simulation user needs and modeling requirements
- Recommendation of appropriate modeling techniques for specific domains
- Identification of:
  - subject matter experts
  - relevant existing models and tools
  - data sources and reference data sets
  - guidelines, methods, specifications, and standards
  - best practices
- Recommendations for M&S evaluation approaches such as verification, validation, and accreditation

The initial set of M&S TIG domains include:

- Incident Command
- Hazardous Material Release
- Critical Infrastructure
- Health Care

A workshop on “Modeling and Simulation for Emergency Management and Health Care Systems” was held from July 24 to July 25, 2008, sponsored by the National Institute of Standards and Technology (NIST). The workshop is the first TIG meeting on Health Care.

This document provides a summary of the talks and working sessions during the “Modeling and Simulation for Emergency Management and Health Care Systems” workshop that was held on July 24 and July 25, 2008. We elected to provide a summary including the key points of the talks instead of including the presentation materials. We believe the readers will find this more useful.

For the six working sessions, we have included the summaries as provided by the group representatives for the sessions. Care has been taken to capture the presenters’ material as it was presented, and we have refrained from adding any new material. Presenters were invited to submit other relevant material for this report. A number of acronyms have been expanded in this material for better readability. The acronyms and abbreviations are also listed in Appendix D for reference.

While we have made every effort to summarize the talks and working sessions without losing the key message, readers and presenters are invited to send their comments, and/or suggestions for improvement of this document to *simresponse@cme.nist.gov* by September 30, 2010.

Appendix A of this document identifies organizations with a stake in health care simulation. Appendices B and C identify relevant existing and evolving standards. The information on standards has been collected using Internet searches and information provided by attendees of the workshop. The information presented for each standard has been adapted from referenced websites. Readers are invited to send information on additional standards, and suggested revisions on the information currently included to *simresponse@cme.nist.gov* by September 30, 2010. An updated version of this report may be prepared by December 31, 2010, if the feedback received warrants such a revision.

We would like to thank all the speakers who shared their valuable knowledge and time, all the participants in the workshop for providing their contribution through the working sessions, and the facilitators of the working sessions for capturing the discussions and presenting them to all attendees. We thank the vendors who provided displays of relevant tools and techniques during the workshop. We would also like to thank all the sponsors of this workshop including: NIST, DHS, SPARTA, Inc, and AEgis Technologies. Many people contributed to the success of the workshop and it will be hard to list everyone. We would specifically like to acknowledge the efforts of the workshop organization committee who worked with the authors including: Swee Leong, Sanjay Jain, and Mark Sullivan. Additional persons we need to thank include Jim Fackler, MD, Holger Hansen, MD, MPH, DrPH, F.A.C.E., and Joshua Kilbridge.

Susan O'Hara  
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# 1 EXECUTIVE SUMMARY

The “Modeling and Simulation for Emergency Management and Health Care Systems” workshop brought together people from different backgrounds including health care clinicians, health care administrators, health care facility architects, modeling and simulation professionals, government agency personnel, and academicians. This provided an opportunity to explore opportunities that allowed implementation of ideas that capitalized on the potential synergy among the diverse backgrounds. Below are two perspectives on the value of the workshop.

## A. A perspective from health care professional

Modeling and simulation is a new frontier for most managers, providers, and architects working in the health care industry. Although successfully utilized in other industries, modeling and simulation is slowly gaining acceptance as a tool for health care process improvement, patient flow, and capacity planning and design. Barriers for utilizing simulation modeling within the three distinct but unified entities of health care, architecture, and simulation engineering have prohibited its standardization as both a tool and a trusted resource.

Our experience in simulation modeling began after we attended a lecture on the subject at a health care architectural design conference. We were sold on the process and the tool but encountered a number of barriers, such as data availability and quality, reluctance by health care managers and facility directors to use these innovative tools, and the ability of health care providers to allocate precious dollars for an “untested” process.

Our journey for innovation began by trying to understand the variety of software products, model building processes, and engineering approaches. The model we developed was very successful; however, along the way, we learned that not all software, processes, and engineers are alike, equal, or interchangeable. We are still searching for answers to questions such as:

- What standards exist for simulation models and engineers?
- How can I determine if a model built in one software package has the same results as one built in another?
- What data collection process should I expect to be universal to simulation model building?

Too often we adapt tools from other industries without truly understanding the commonalities and differences for application in health care. This can be seen today as the health care industry makes efforts to implement new technologies that “solve a problem” but add more work, cost, or frustration for the managers and providers required to use the technologies. The result is reluctance or refusal to use simulation modeling and reap its benefits.

Furthermore, new technologies often do not work with one another. For example, (1) data collection software often can not be integrated with the database software used for building simulation models; (2) capacity planning solutions arrived at by using simulation software may not meet minimum standards for health care architecture design; (3) simulation engineers may use different software packages and the end user must learn more than one software system. In other words, interoperability between health care systems and simulation software is as lacking as interoperability between simulation software packages and the engineers who use them. If tools such as simulation modeling are to find their place as the evidence-based phenomenon they can be, standards must be set for health care providers to embrace the process, the tools, and the engineers who build them.

This workshop brought together representatives from industries, technology providers, government agencies, and research institutions to discuss the challenges associated with the application of simulation technology in health care. The objectives of the workshop were to:

- Explore the issues, concerns, needs, and requirements relevant to the application of modeling and simulation technology to health care clinics and systems of clinics.
- To understand and identify the needs and requirements regarding information sharing, exchange, interoperability, and interface standards among the various information systems and simulation systems in health care.
- Explore future directions and roadmap proposals in research, development, and application of modeling and simulation technology in the health care industry.
- Explore ways to promote modeling and simulation technology in the health care industry.

The time has come for the movement to surge forward. This workshop marks a formal and systematic way to bring health care simulation modeling into its rightful and evidence-based place for patient flow and capacity planning.

## **B. A perspective from modeling and simulation professional**

Modeling and simulation techniques are a powerful means to analyze complex systems and support improvements in their planning and operations. While they are powerful techniques, they should not be used everywhere. The techniques are useful for complex scenarios where other decision analysis techniques cannot be applied due to infeasibility or very high computation infrastructure requirements. Application of modeling and simulation can require a large effort for the steps involved including data gathering, input analysis, model building, verification and validation, output analysis and providing recommendations. Potential opportunities for application of modeling and simulation have to be carefully assessed based on detailed input and discussions with experts from the domain that is being targeted. This workshop provided an excellent forum to discuss the opportunities for application of modeling and simulation to health care, the potential use of a standard framework for reducing the effort required for such implementations, and the challenges going in to the future.

Modeling and simulation has been employed at the National Institute of Standards and Technology (NIST) in multiple areas for several decades. The Manufacturing Modeling and Simulation Group at NIST has contributed to the growth of modeling and simulation implementations in manufacturing through leading edge applications and promotion and development of standards that facilitate such efforts. Most recently, the group has spearheaded the development of the Core Manufacturing Simulation Data (CMSD) standard under the auspices of the Simulation Interoperability Standards Organization (SISO) (<http://www.sisostds.org/index.php?tg=fileman&idx=list&id=49&gr=Y&path=Specifications>.) Modeling and simulation has helped manufacturing become more efficient through a wide range of applications in analysis, planning, operations, and system acquisitions. The modeling and simulation professionals are looking to bring the same benefit to the health care industry through the application of these techniques.

Simulation technology can be used to improve facilities and services within the health care industry. To realize this vision, it must be possible to integrate simulation models and data that were developed using different simulation tools and other software applications. Because such integration and interoperability is not currently possible, the goal of this workshop was to identify barriers to that vision and efforts needed to attain that vision. The key focus of the workshop was to promote the development of a simulation framework to allow distributed, integrated execution of a broad range of simulation systems and presentation of results that captures the interdependencies among the systems modeled.

The workshop explored:

- Simulation opportunities and requirements for health care.
- What is needed to develop, demonstrate, and deploy a framework to enable simulations to share information within the industry?

We believe this workshop provided a strong foundation for collaboration among government agencies, the emergency response community, health care industry, and academia.

This document provides brief summaries of the presentations and workshop sessions. The summaries are arranged in the sequence of the workshop agenda. The appendices provide related information on modeling and simulation, standards associated with health care systems for emergency management, and related medical and health care organizations collected by the authors.

## **2 OPENING REMARKS: CHARGE TO THE GROUP - MODELING AND SIMULATION FOR EMERGENCY PREPAREDNESS: A NEEDS ANALYSIS OVERVIEW**

**Charles McLean**

**Group Leader, Manufacturing Simulation and Modeling Group, Manufacturing Engineering Laboratory,  
National Institute of Standards and Technology**

There exists a burgeoning need for coordination of modeling and simulation (M&S) activities between sponsoring government agencies. To-date, M&S efforts have been largely ad hoc. In response, the National Institute of Standards and Technology (NIST) has undertaken a needs analysis to determine what types of M&S efforts are required, and, ultimately, to develop M&S standards for governmental agencies, communities, and private organizations.

The current problem is that numerous federal, state, and local agencies share responsibility for aspects of emergency response, and each may have different needs for and perspectives on M&S techniques. There exists no common framework or definition for potential M&S applications, and little interoperability between M&S products and datasets.

Leaders at NIST have articulated a vision for the future, in which integrated M&S and gaming techniques could be used to support education and training, research and development, system and process improvement, and planning for the emergency response community. This vision relies on the development, testing, and deployment of interoperable systems through the identification or creation of interface standards.

Accomplishing this vision will require establishing order through a common taxonomy to categorize potential and existing uses of M&S applications. Such a classification scheme would incorporate the objectives, target organizations and mission areas, context, and implementation characteristics of M&S applications. Major categories of objectives include decision support, planning levels, systems engineering, training and performance measurement, and intelligence and risk analysis. Target organizations vary by type (international, federal, private, etc.), level or scope, and persistency (permanent versus temporary). The contexts for M&S include different modeling domains; types of incidents, events, and activities; emergency support functions; and life cycle phases. Implementation characteristics include techniques for representation, modes of interaction, interfaces, standards, data sets, and planning scenarios.

The needs for M&S in emergency response include examples of social behavior; physical phenomena; environmental, economic, and organizational factors; infrastructure systems; and other aspects of emergency response (see Figure 2-1.) The NIST needs analysis will also identify categories of data set requirements for M&S.

The scope of the health care domain includes patients, medical personnel and hospitals, pharmaceutical companies, and other health care organizations. There are important use case scenarios and uses for M&S in this domain. The use case describes who is involved, what their roles are, what data are needed, and other features of M&S. The uses of M&S in health care include system applications, physiological processes, simulator facilities, and devices.

The charge to the workshop prompted participants to help identify experts, information sources, and existing applications for M&S in the health care domain; to specify needs for M&S in health care, and to validate those needs; to define needed M&S functions, data, and integration capabilities; and to determine which existing standards are relevant, and what gaps exist in current standards.

# Simulation System Needs

## ***Realistic role playing user interfaces for:***

- *first responders*
- *incident management*
- *support personnel*
- *civilian population*
- *opposing forces*
- *live elements*



## ***Technically-correct simulations of:***

- *physical phenomena*
- *the environment*
- *social behaviors*
- *organizations*
- *infrastructure systems*

*Computing and  
communications  
infrastructure*

*Modular  
simulation  
and gaming  
reference  
architecture*

*Standard  
information  
models,  
databases, and  
message formats*

*Validated  
scenarios and  
sample data  
sets*

Acknowledgment: The building fire screenshot has been adapted from Sim City 4 website.

**Figure 2-1: Simulation System Needs**

### **3 KEYNOTE ADDRESSES**

#### ***3.1 KEYNOTE ADDRESS – DAY 1: MERGING COMMUNITY, EMERGENCY PLANNING WITH EMERGENCY DEPARTMENT HEALTH CARE SYSTEMS: THE FUTURE OF SIMULATION***

**Duane C. Caneva, MD**

**Director, Medical Preparedness Policy, White House Homeland Security Council**

The approach undertaken by the Department of Homeland Security (DHS) to emergency preparedness includes understanding the meaning and needs of preparedness, and the taxonomy and ontology of creating a national preparedness framework. Questions that drive this process include what it means to be “ready”, what is “preparedness”, how to manage risk, what responses are sustainable, how does current status impact other plans and programs, how visible are resources, and what is the best use of resources?

The National Response Framework, released in early 2008, was discussed. This document outlines an overall strategic approach to disaster response. There is a need for a national preparedness framework, which would describe the taxonomy and ontology of disaster preparedness in a “system of systems” approach. The goals of a model for preparedness include measuring readiness, providing root cause analysis for degrees of readiness, and allowing for optimization of response (see Figure 3-1.) In creating the model, it is important to identify the types of complexity that it must accommodate, including structural complexity (number of parts in system), interactive complexity (behavior of parts in system), and the perspective of complex adaptive systems, which exhibit coherence under change.

The ontologic character of the model is not a hierarchy per se, but a system in which all nodes have relevance and centeredness. Determining the connections between these nodes, and how they are formed, is an important consideration in creating models for preparedness. The model for national preparedness will be highly complex, capturing the dimensions, layers, spectra, and quanta of the preparedness framework. A “system of systems” architecture is created capturing relevant organizations, programs, types of incidents, capabilities, and system components.

The model should capture a readiness factor (statistical representation of readiness), resource utility function (statistical representation of likelihood of success), and preparedness factor (statistical representation of stage of preparedness). These factors help to determine the preparedness of a given unit or other entity. Other important factors in the model include a responsiveness factor, deployability factor, and resource donor impact factor. Together these and other factors provide a means to gauge and manage operational risk. Modeling and simulation play a key role in helping to determine these factors and their relationships in specific incidents.

A national preparedness model should also provide for the visibility of layers of command structure and resource node capabilities, as well as allowing for appropriate sharing of data across a national hierarchy. The layers of response – local, regional, national – may each have their own set of best practices, and their own characteristics (e.g., urban, suburban, rural) and potential disaster scenarios (e.g., earthquake, hurricane). A strong national preparedness framework, therefore, must be dynamic, multidimensional, and pragmatic; it should allow for analysis of preparedness, best deployment of resources, and the efficiency of resource utilization; it should provide for views across the framework to examine current status, hazards and vulnerabilities, risk management, strengths, and trends.

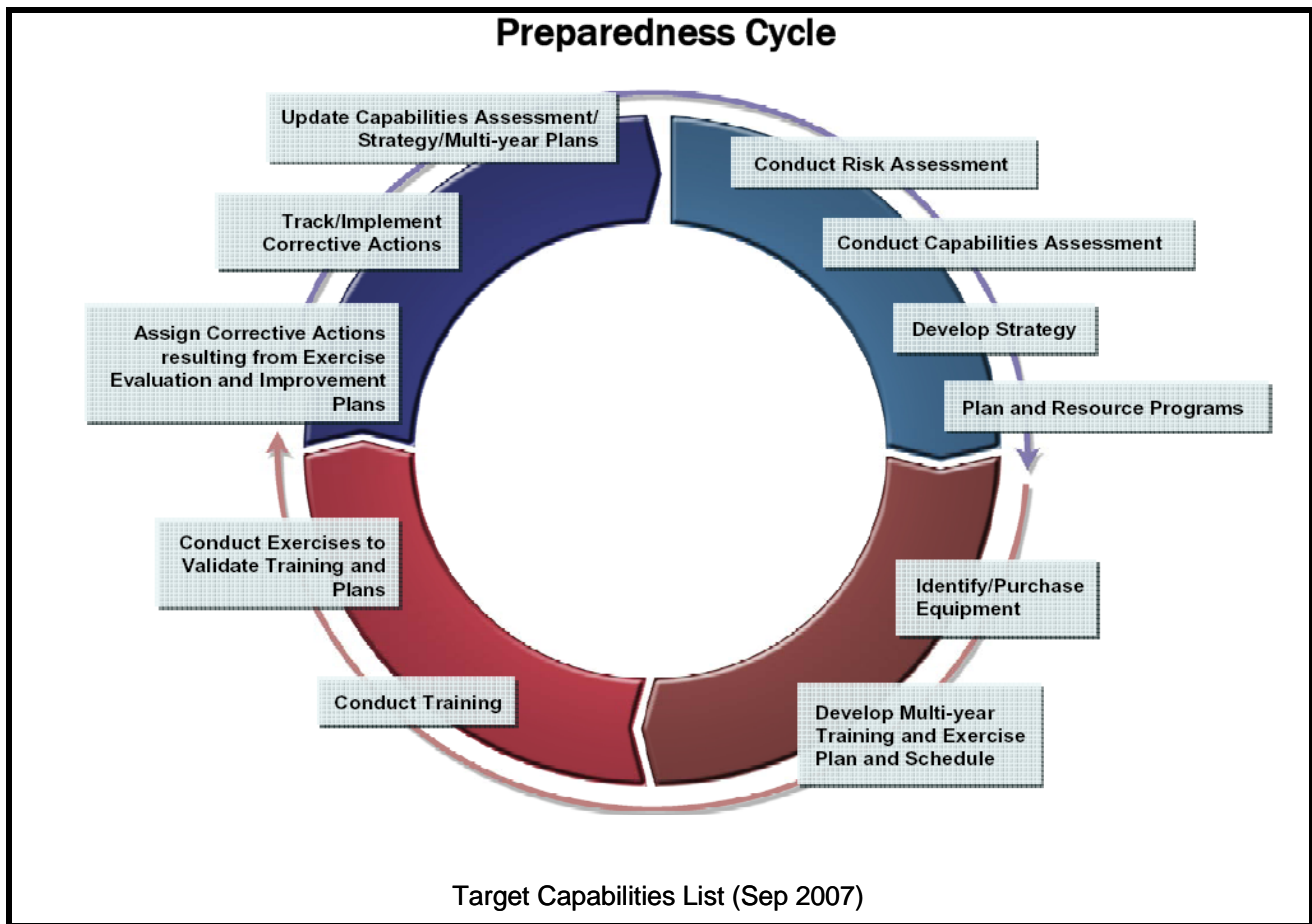


Figure 3-1: Preparedness Cycle

## **3.2 KEYNOTE ADDRESSES – DAY 2**

### **3.2.1 KEYNOTE ADDRESS – DAY 2, PART 1: THE TIME AND MOTION STUDY: HOW DO MEDICAL-SURGICAL NURSES SPEND THEIR TIME?**

**Marilyn Chow, RN, DNSc, FAAN**  
**Vice President, Patient Care Services, Kaiser Permanente**

There is currently a pressing need for change to the hospital work environment, as well as a unique opportunity for change. Results of a recent Time and Motion study provide direction for potential improvements to the hospital work environment. The worsening nursing shortage dictates the need for changes to the nurse work environment so that hospitals can maintain necessary staffing levels. An ongoing, unparalleled building boom in hospital construction and renovation provides an opportunity to affect the design of hospitals for the next generation. The Time and Motion study was undertaken to better understand how nurses spend their time, and to identify environmental variables in the nursing workplace that can be altered to improve the efficiency of nursing care, and ultimately, patient safety.

The study included 36 diverse hospitals across the U.S. A total of 763 medical-surgical nurses participated, accounting for more than 2200 work shifts and nearly 22000 hours of nursing time. The methods employed four study protocols that assessed, in brief, a sampling of nurse activities through a personal digital assistant; nurse location and movement through radio frequency identification (RFID) tags; and nurse physiologic response through the use of specialized armbands that collected basic physiologic data (see Figure 3-2.)

The results showed that nurses divided their time similarly between the patient room, nurse station, and other locations on and off the unit. In all, nurses spent 30.8 % of their time in the patient room. By activity category, nurses spent 77.7 % of all time on nursing practice activities, and only 6.6 % on activities considered to be waste. When nursing practice time was broken down into subcategories, the data demonstrated that nurses spent most of this time on activities other than patient care. Documentation (35.3 %), care coordination (20.6 %), and medication administration (17.2 %) consumed the majority of all nursing practice time, compared to 19.3 % for patient care activities, and only 7.2 % for patient assessment and surveillance; this last category is the reason that patients are in the hospital in the first place.

Nurses traveled long distances, a median of 4.8 km (3.0 miles) per 10 hour daytime shift. Distance traveled varied widely between nurses, from 1.6 km to 8.0 km (1 mile to 5 miles) per shift. This finding was one of the most surprising of the study; factors that may affect inter-nurse variation include nurse assignments (which patients in which rooms), adaptability, and approach to organization of work.

The results illustrate the complex and demanding hospital work environment, and suggest opportunities to improve the efficiency of nursing care. Changes to the processes and technologies of documentation, medication administration, and care coordination could affect nursing efficiency and the safe delivery of care.



# Data Collection Overview

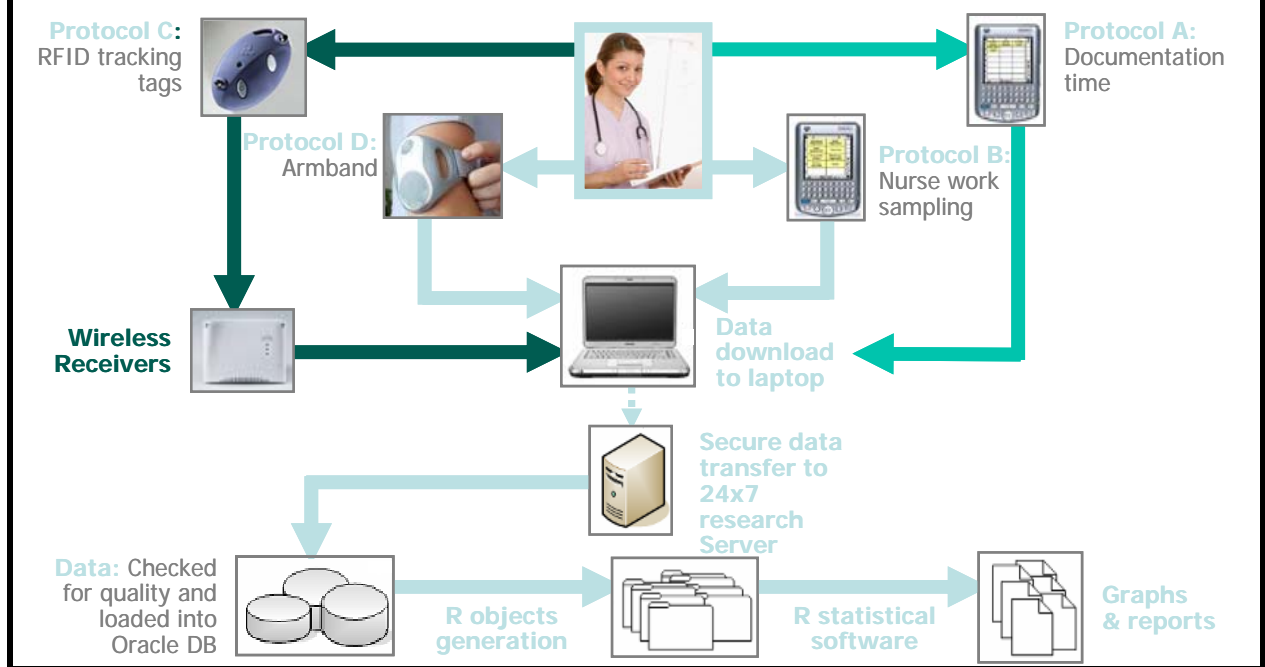


Figure 3-2: Data Collection Overview

### **3.2.2 KEYNOTE ADDRESS – DAY 2, PART 2: MODELING THE TIME AND MOTION STUDY**

**Susan O'Hara, RN, MPH**

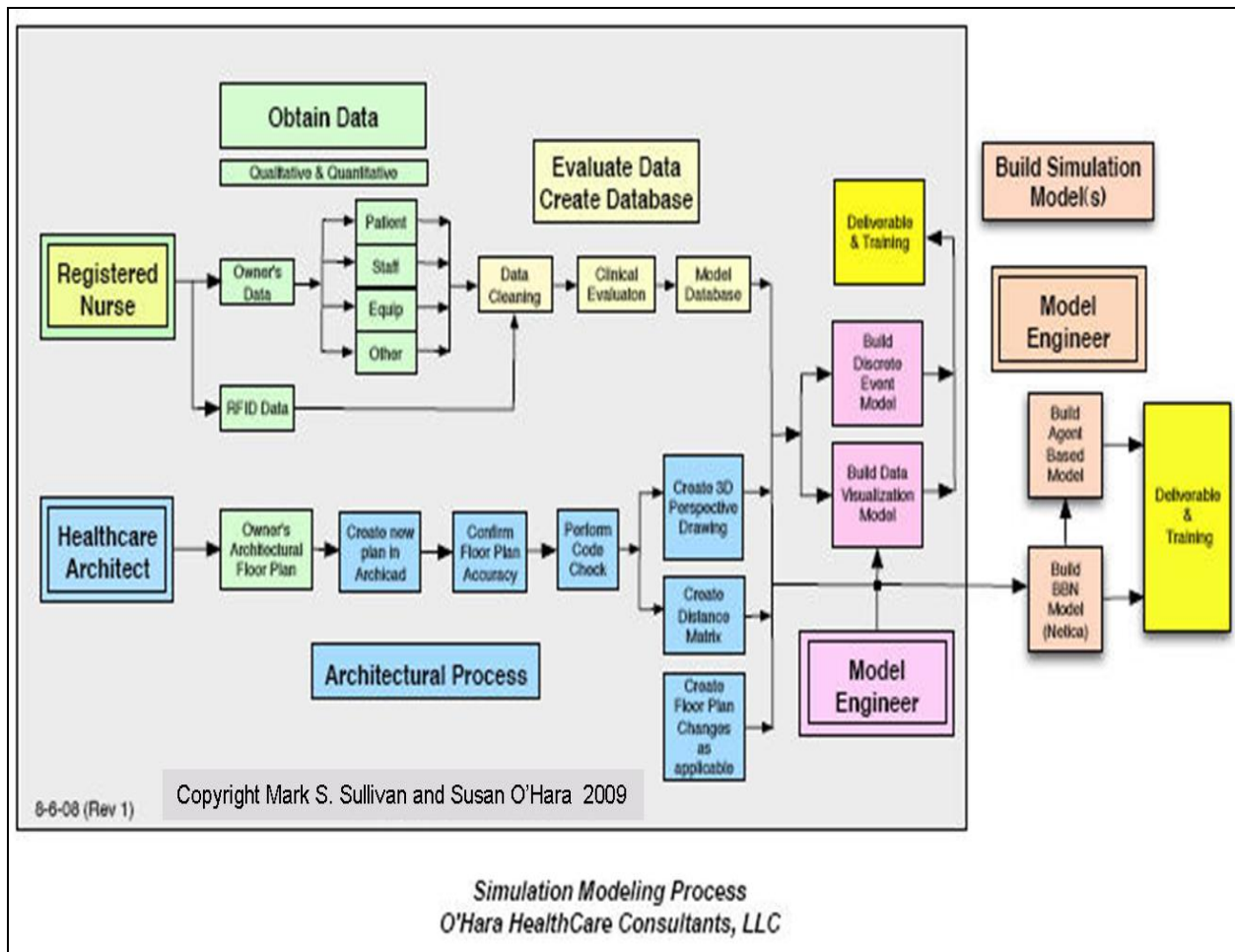
**President, O'Hara HealthCare Consultants, LLC**

M&S tools were employed on a subset of data from the Time and Motion study with the goal of identifying features of nurse practice or unit architecture that affect the movement and performance of nurses. To do so, experts developed a modeling approach based on both qualitative and quantitative data, including nurse assignments, patient characteristics, policies and processes, and architectural floor plans. The approach incorporated clinical, architectural, and engineering components. The model development process included a Bayesian Belief Network (BBN) to model nurse behavior, a probability movement and time spent model, and distance matrices, among other features; the results were incorporated into a data visualization model. Data visualization was used to obtain a real picture of what goes on in a nurse's day. A "typical" day could be mapped out on an influence diagram of nurse performance metrics and factors.

The goal is to form models that can provide answers regarding nursing policies and procedures and unit architecture, and to evaluate scenarios such as surge, different admissions processes, and so forth (see Figure 3-3.) Modeling the admission-discharge process, for example, has implications for surge response, as well as day-to-day operations. Modeling the process allows operations managers to identify the sequence of response to surge, to understand the difficulties that arise, and to test what-if scenarios for how to improve unit performance.

Suggestions for improving surge capacity include a reverse-triage approach – identifying which inpatients could be discharged to increase capacity in case of a surge – which, if performed daily, may help units prepare for potential surges. The use of a dedicated admissions nurse also drastically reduces the time committed by unit nurses to admission processes, and could ease throughput during a surge. The addition of a dedicated admissions nurse was evaluated in a model of a unit from the Time and Motion study. In this model, the use of an admissions nurse can increase patient care time. However, this finding is dependent upon nurse-to-patient ratios. At a 1:5 ratio, time with the patient increases with an admissions nurse; at a 1:6 ratio, patient care time improves little, while distance traveled increases; at 1:7, these results are further exaggerated.

M&S tools have significant utility in relation to nursing practice. Nurses must be engaged in the process, and process maps should be introduced as a part of clinician training. Finally, models should not be limited to the Emergency Department (ED) or an inpatient unit; they should encompass the whole hospital.



**Figure 3-3: Architecture + Clinicians + Engineering = Whole System Design**

## **4 ENHANCING OPERATIONAL READINESS BY LEVERAGING MODELS, SIMULATION, AND DECISION-MAKING TOOLS: PERSPECTIVES FROM THE FIELD**

### **4.1 DEFINING THE BUSINESS CASE**

**Paul Hewett**

**Deputy Director, Center for Integrated Emergency Preparedness, Decision and Information Sciences Division, Argonne National Laboratory**

Experts at the Center for Integrated Emergency Preparedness have taken M&S tools to users at state and local levels to encourage their integration into the planning process. M&S tools must be useful, usable, and used; tools without all three characteristics will not help end users. The usage rate with current models is only about 30 % to 50 %. The question is why these tools are not more widely adopted.

One part of the answer is defining where M&S tools fit. Across mission areas, operational phases, and domains, M&S and decision-support tools are used to support the planning process (see Figure 4-1.) Models are used to formulate plans for operations in terms of training, organization, planning, people, leadership, equipment, and facilities. By using models, emergency planners attempt to better understand emergency situations by generating assumptions (not facts), visualizing disaster dimensions, evaluating the evolution of hazards, and identifying needs and demands. Knowing these features of a disaster allows planners to assign appropriate capabilities, which may be defined as “the ability to take a course of action.” M&S and decision-support tools, therefore, inform incident action plans (tactical level), emergency operations plans (operations level), and concept plans (strategic level). They also define the range and scale of operations by predicting the assets that will be required. The foundation that M&S provide can be described by the acronym, GRRRS: Goals, Roles, Relationships, Resources, Structure.

Other reasons that M&S tools are not used include characteristics of the planning team and the tools themselves. Members of planning teams are rarely full-time and often only one-deep at the local level. They may be uncomfortable with basic information technology (IT), have little time to devote to M&S, and have unrealistic expectations of what M&S can accomplish. Common complaints describe M&S tools as inaccessible, complicated, expensive, and insufficiently reflective of local conditions or the domain in question. An example of a model that practitioners like is the hurricane evacuation model HUREVAC. Users note that it is free and easy to access and use, requires no data input, and provides easily understood output in a variety of useful formats. It is also important for users to practice using the tools to ensure proper interpretation of output, and the full use of model capabilities.

Good M&S tools, therefore, should have a familiar and simple layout; data input should be easy, such as drag-and-drop, rather than a large data grid. Practitioner-defined needs suggest that M&S tools should be customizable based on local data and demographics, and contain decision tools that address GRRRS. Tools should be robust and comprehensive, while keeping the technical aspects of the tool out of view. Ease-of-access is important; models may be hosted centrally or locally, and could be accessible by laptop or personal digital assistant (PDA). Tools should also account for the full range of hazards relevant to the user.

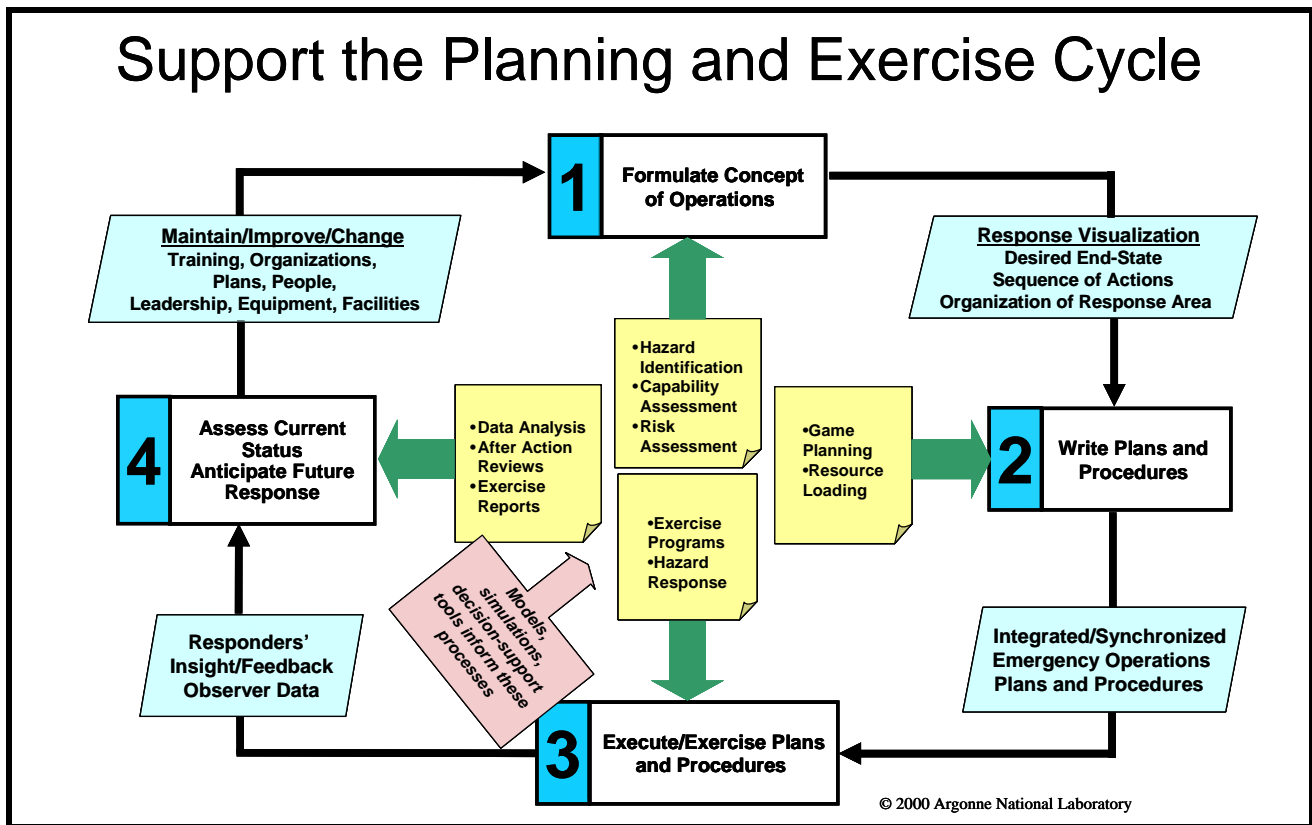


Figure 4-1: Support the Planning and Exercise Cycle

## 4.2 EXPLORING A SOLUTION

**W. Chris Metz**

**Lead Software Engineer, Center for Integrated Emergency Preparedness, Argonne National Laboratory**

The approach to bringing together M&S and emergency planning is to create a combined solution – a tool or set of tools – that is scalable to and usable in the typical community (see Figure 4-2.) Several of the challenges to this process include difficulties in bringing key stakeholders together (travel costs, schedule conflicts, hard to maintain team momentum), integrating technologies (many disparate M & S tools exist, most tools have limited scenario support), and tracking multiple simulation outputs in one place.

Optimally, the process begins with a face-to-face planning meeting to exchange information and build strong relationships. However, it can be a challenge to bring everyone to the table. When in-person meetings are not possible, distance planning methods can be used. Such methods are easily scaled to large teams, and allow for easy dissemination of information. If the plan is created using an online solution, it is easier to reuse the profiles and plan data for the exercise. Distant exercises (DISTEX) allow for leverage of existing profiles from the distance planning team, and live video feed can be incorporated into the exercise. Finally, data is captured and correlated providing the team with an analysis for review. This gives the team the advantage of capturing and correlating the analysis.

The creation of an emergency response plan should answer questions such as what should happen, when, and at whose direction. After the scenario is defined it is important to identify the associated departments' resources used over a scale of time. The departments are guided to filter the plan to show 'their' responsibilities.

Mass collaboration technology that supports distance planning is fast becoming widely accepted. Examples include Microsoft SharePoint, O3 spaces, and E-GroupWare. Each of these support document management, version control, discussion boards, email alerts, and other features, and do so out of the box. Mass collaboration technology also supports workflows, which control information flow either by individual (who needs to know) or time (when it needs to be known). Workflows may be sequential (linear) or state (more fluid). Workflows support decision making by disseminating appropriate information to the right people in real-time.

The goals of employing mass collaboration technology include incorporating outputs from disparate M&S tools, establishing trusted electronic contacts, and generating increased visibility of decision criteria, thereby contributing to higher quality plans. These tools can increase the confidence of decision makers, enhance the buy-in of participants, and maintain the momentum of the planning team.

A key concept is the creation of the emergency response plan. This plan defines the scenario in question, dictates what should happen, when, and at whose direction; and associates' departments and resources.

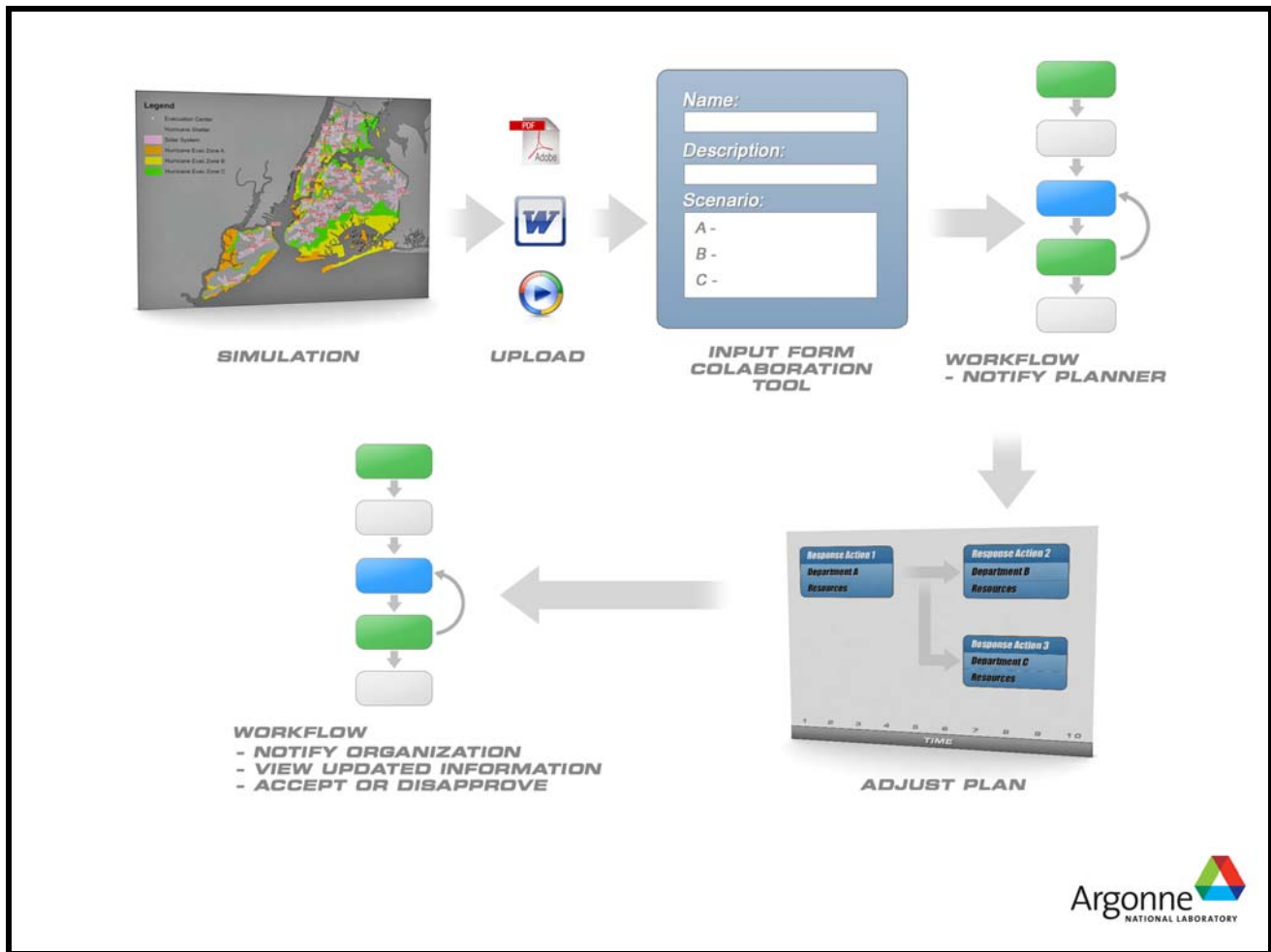


Figure 4-2: Opportunity for Integration with M&S

## 5 THE USE OF HI-FIDELITY SIMULATION FOR PEDIATRIC EMERGENCY TRAINING FOR MASS CASUALTY INCIDENT EXERCISES

**Phillip Jacobson, MD**

**Pediatric Critical Care, Rush University Medical Center and John H. Stronger Jr. Hospital of Cook County**

The Rush Simulation Laboratory is a patient simulator lab established early this decade. High-tech simulators are used in medicine for teaching and assessing psychomotor skills. The central advantage of simulation in this setting is that clinicians can gain experience, while no harm can come to patients.

While simulators are not well established in pediatric medicine, they may be of even greater utility in this setting since life-threatening emergencies are relatively rare with children, meaning that clinicians do not gain as much hands-on experience. Children also have unique physiology and disease processes, and interventional procedures can be more difficult.

The Rush Simulation Laboratory employs life-sized (adult, child, infant), hi-fidelity, computerized mannequins. Because they simulate pulse, breath, heart tones, vital signs, and pupil changes, the mannequins allow for physical examinations and interventions (see Figure 5-1.) The simulation lab runs monthly life-threatening emergency simulations for pediatric residency programs. The lab is also used to train licensed physicians and nurses (as opposed to students and residents) for disaster preparedness. Pediatric disaster training is important because children have unique characteristics, including airway differences, thinner skin (that absorbs more toxins), less blood and volume reserve, and greater risk of hypothermia due to larger surface-to-mass ratio, among other features.

Using the simulation lab, different pediatric disaster scenarios can be simulated, such as chemical or blast events. Mass casualty training is particularly important. Physicians are not trained to handle mass casualties, as real events are relatively rare. The design of mass casualty simulation is based on overwhelming medical staff with victims, and limiting time and resources. This scenario reveals the interrelationship between the care of each patient; time given to one patient is time taken from another victim. The use of the hi-fidelity mannequins forces clinicians to perform actual interventional procedures. Live actors are combined with simulation mannequins to create a life-like scenario that demands clinicians' interaction and challenges their decision making.

The results of a simulation of a mass casualty scenario run at the laboratory were described. Regarding participant actions and victim outcomes, four of five medical teams resuscitated an infant that should have been assessed as "expectant," meaning that the victim should have been passed over in triage. Four of five teams also ran out of Type O negative blood, resulting in the death of some victims. Some teams also ran out of ventilators, meaning that a team member had to hand ventilate. Organizers noted that the participants "thought on their feet" throughout the exercise, and noted the importance of this ability in disaster response.

When simulation participants were surveyed for feedback, all respondents said that this type of exercise should be required for disaster training, and would recommend the exercise to colleagues.



# Lifelike Mannequin Functions

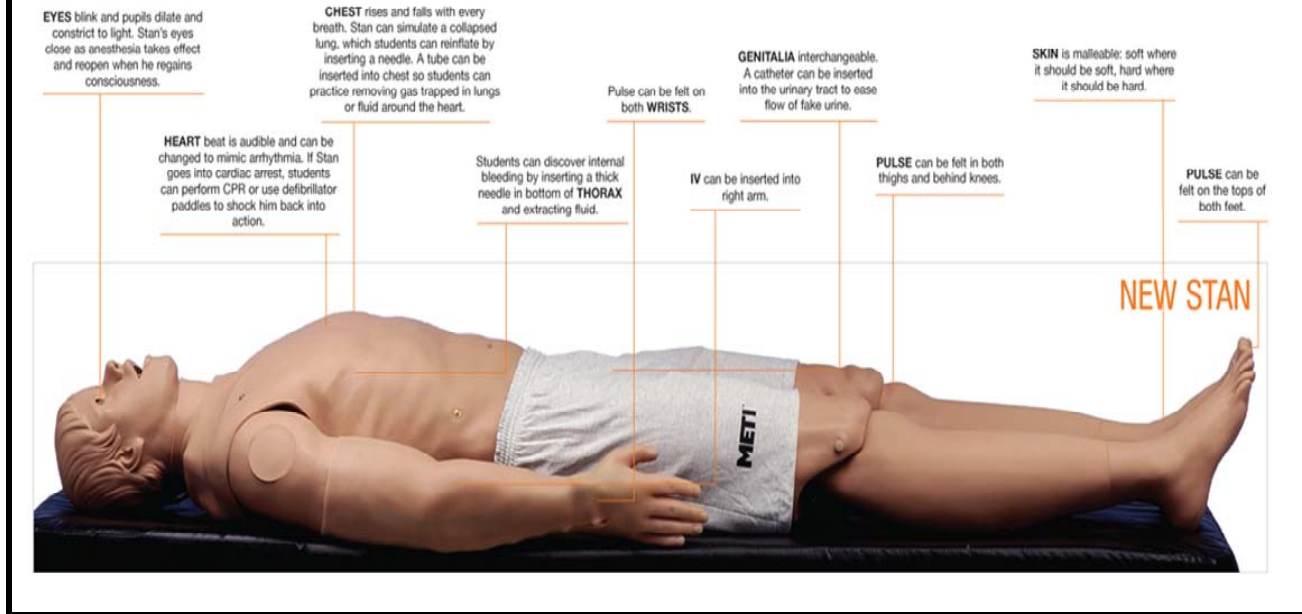


Figure 5-1: Lifelike Mannequin Functions

## 6 MODELING AND SIMULATION INTEROPERABLE TOOLSET FOR HEALTH CARE SYSTEMS ANALYSIS

**James Walsh**

**Research and Development Division Manager, SPARTA, Inc.**

Model interoperability can be defined as the ability to use tools together to solve a problem or meet an overall modeling need. An example would be using a queuing model to derive a statistical distribution for use in a discrete event simulation. Interoperability stands in contrast to integration of models, which is also important for the efficiency of the modeling effort.

The domain tool set can be understood as a “pyramid” construct. Component models form the base of the pyramid; these models have scope and detailed component representation. System models comprise the middle of the pyramid, building on the performance of lower level models to simulate the behavior of a system, such as an emergency department. The tip of the pyramid consists of system of systems (SoS) models, which are broad in scope, and involve the overall effectiveness of a system, such as an emergency management system (see Figure 6-1.) Building an SoS model can be accomplished through interoperation of two system models, or by developing an integrated SoS model.

Different levels of interoperability range from the level of data (“my model can use your data”), to the file level (“my file can be read by your application”), to the application level (“my model can work directly with your model”). The specific interoperability requirements emerge from analysis of the modeling need and type of models selected. Certain functions are key to model interoperability, including data formatting and sharing, model synchronization, display and animation, and data storage and analysis. Interoperability standards are needed in these functions to facilitate the tool set approach.

Agent-based models differ from process models by focusing on behavior and interactions, rather than activities and queues. An example of an agent-based model is the Health Care Efficacy Architectural Analysis Tool (HEAT), developed with O’Hara HealthCare Consultants, LLC and Mark Sullivan Architects, which uses a data-driven approach to create new “what if” scenarios by changing only data input, eliminating the need for developing a new model. The HEAT model incorporates architectural, movement, process, and capability data to simulate nurse behavior.

The HEAT model is also extensible to play a SoS modeling role, which requires the ability to interoperate at different levels of abstraction. In terms of interoperability, the HEAT model demonstrates several key functional requirements. HEAT employs Bayesian Belief Networks (BBN) to model nurse behavior, and XML schema as a mechanism to format modeling data and to describe model meta data. The BBN’s utilize an interface – an opportunity for standardization – so that different BBN’s can be employed without reconstructing the interface.

# Pyramid Construct to Organize Domain Tool Set

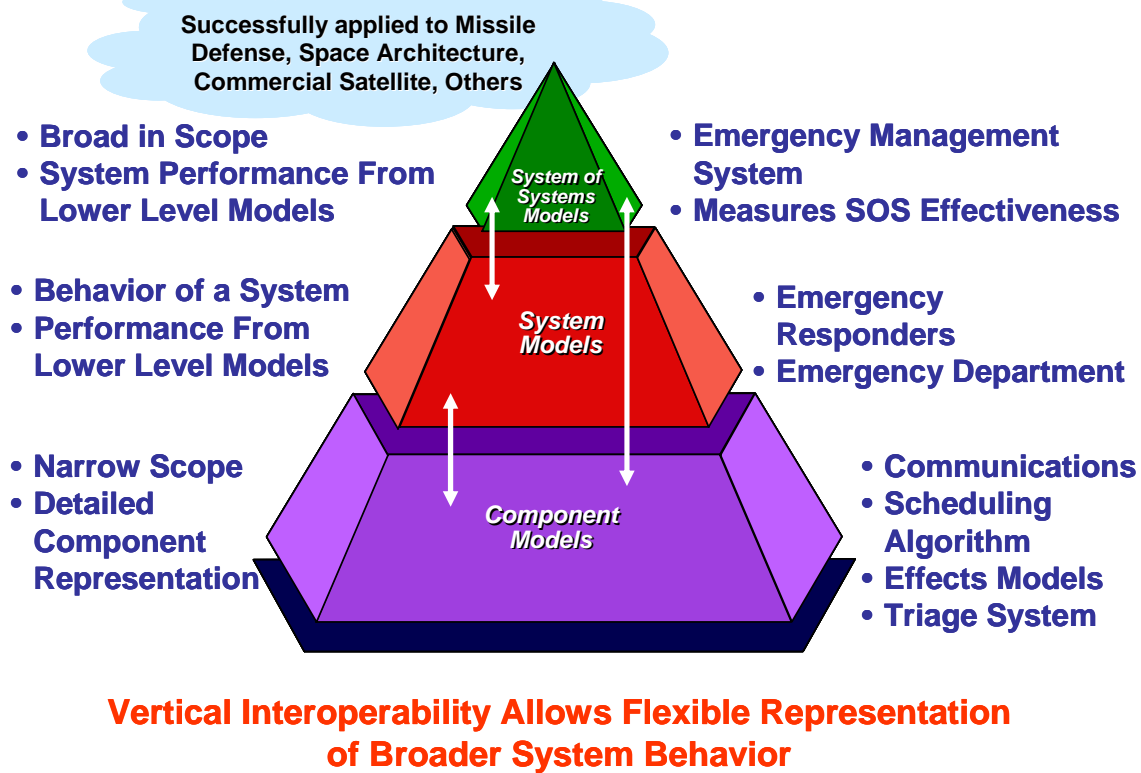


Figure 6-1: Pyramid Construct to Organize Domain Toolset

## 7 THE NEXT INFLUENZA PANDEMIC AND MODELING: THE NEED TO KEEP IT SIMPLE

**Martin Meltzer, PhD, MS**

**Division of Emerging Diseases and Surveillance Systems, Centers for Disease Control and Prevention**

Mathematical modeling tools have been used to inform planning for the next influenza pandemic. In terms of models, policy makers want answers, options (“what if” scenarios), and solutions that relate to their specific domain (e.g., state, and city). What policy makers do not need is a black box; they must understand the “mixing bowl” that is the model. In the case of public health, mathematical models mix epidemiological and other data related to the disease, and in this case, influenza and its dynamics.

Influenza is a viral disease that has a short incubation period (1 day to 5 days) and is highly communicable (1 day to 2 days before onset of symptoms, and 4 days to 5 days after onset). The short incubation period and communicability are a public health challenge, meaning that approaches to disease control such as quarantine most likely would not work. New strains of influenza arise through the close interaction between poultry, pigs, and people. Many influenza viruses derive from avian origins, but most avian viruses are not well adapted to human infection. In areas where poultry and pigs are kept in close proximity (such as Southeast Asia), however, the viruses shed from poultry are taken up by pigs. Pigs become infected with a wide range of viruses, including strains that are better adapted to humans, which allows for the resorting of avian flu viruses to become infectious to humans. It is possible that rare avian flu strains could cross directly to humans; the 1918 pandemic virus may be an example.

The epidemiology of influenza describes who gets sick, how many people get sick, when they get sick, and what happens when they get sick. Each strain of influenza (even those with similar phenotypes) is associated with different epidemiologic characteristics, including mortality. In general, individuals over the age of 65 years are at greatest risk for death. Pre-existing medical conditions also confer high risk for hospitalization with influenza-associated health problems. Evaluating the potential impact of influenza, therefore, involves accounting for age, risk (high versus low), and the virus itself.

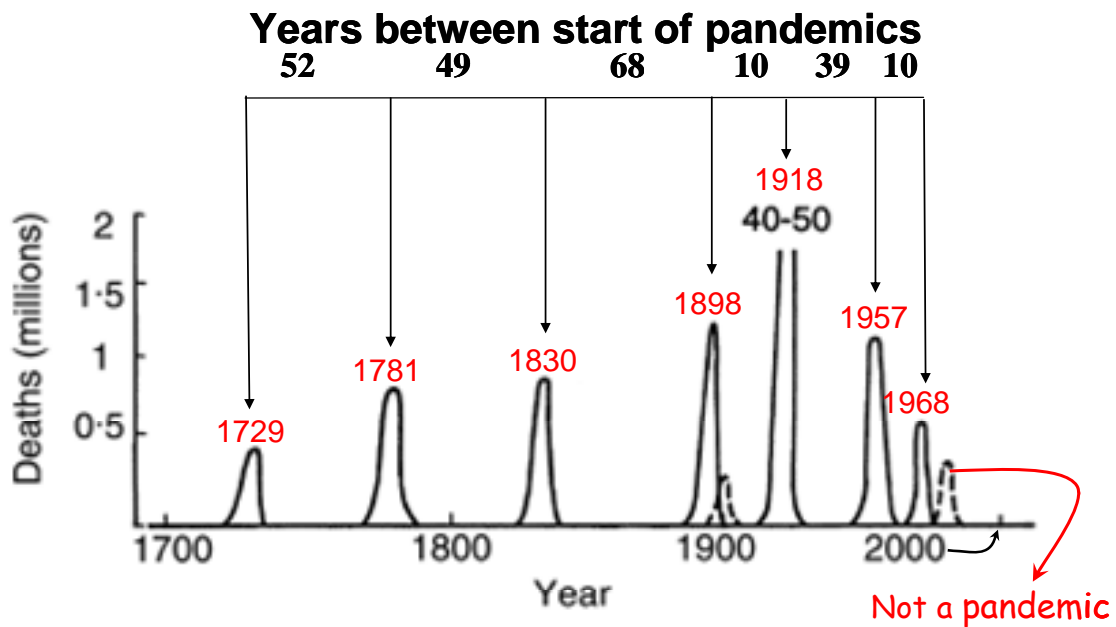
Estimates of the number of deaths for the next influenza pandemic range from 7 millions to 100 millions, based on extrapolations from previous pandemics (see Figure 7-1.) The questions for public health policy makers include: how to estimate which scenario is most probable, when it may occur, and how to respond. A key policy problem is to decide who to vaccinate first during the next influenza pandemic. One way to solve this problem is first vaccinate all those at the highest risk of death or vaccinate those who would provide the greatest economic return to vaccination. If risk of death is used as the criterion, then people over 65 years of age are the first in line to be vaccinated; if return on investment is the priority, and then the young, productive members of society are the first to be vaccinated.

Four pandemic flu planning models are available from the Centers for Disease Control and Prevention (CDC) for free on-line ([www.pandemicflu.gov/plan/tools.html](http://www.pandemicflu.gov/plan/tools.html)): FluAid, FluSurge, Instructions, and FluWorkLoss. Each is simple, and addresses one question. FluAid, for example, provides state-level estimates of pandemic impact. The output is a simple graph showing impact by gross attack rate (a measure of infectivity), with maximum, minimum, and mean rates of death and hospitalization. It does not describe the spread of disease or costs of impact. FluSurge estimates surge in demand for hospital-based resources. It depends on knowing the features of specific sites, such as numbers of physicians and hospital beds. The results estimate hospitalizations by week of pandemic. FluWorkLoss calculates work days lost to illness in a pandemic. The inputs include proportion of population in different age groups (e.g., 0-19, 20-64, and 65+ years). The output estimates proportion of lost workdays by day of outbreak. Finally, there is also a set of instructions that a user can follow to aid calculating 1968-type and 1918-type impact scenarios.

These models and associated manuals have been downloaded approximately 85000 times since 2000. They have been used by most, if not all, U.S. State health departments, U.S. Federal government agencies, as well as several other national governments. Although these models are undeniably simple, simple does not mean that these models are automatically simplistic. These models do not provide “the answer” or a complete pandemic plan. Rather, they aim to provide data to aid decision makers as they make plans for responding to the next influenza pandemics. For planners and policy makers unfamiliar with mathematical models, simple models and tools have a great deal of utility.

# When will the next 'flu pandemic occur?

## Time between start of pandemics



**Fig. 2** History of influenza pandemics 1700–2000. Not to exact scale

Source: Adapted from: Potter CW. J Applied Microbiol. 2001;91:572-579

**Figure 7-1: When Will the Next 'Flu Pandemic Occur? Time between Start of Pandemics**

## 8 APPROACHES TO MODEL AND SIMULATION DEVELOPMENT AND EVALUATION IN FEDERAL AGENCIES

**Charles W. Hutchings, PhD**

**Deputy Director, Modeling & Simulation Department of Homeland Security, Science & Technology Directorate/Test & Evaluation and Standards Division**

Federal agencies are actively exploring the need for guidelines, standards, and best practices in M&S, and what considerations are important when acquiring M&S capabilities. Definitions of “model” and “simulation” are important to provide a common language base. The Institute of Electrical and Electronics Engineers’ (IEEE) definition of a model is an approximation, representation, or idealization of selected aspects of the structure, behavior, operation, or other characteristics of a real-world process, concept, or system. A simulation is a model that behaves or operates like a given system when provided a set of controlled inputs. Other federal agencies use other definitions of these terms, highlighting the need for standards.

The importance of guidelines for M&S is multifaceted. Audits of M&S efforts by government agencies have indicated a need for improved management planning, coordination, and commitment. Guidelines for M&S would contribute to accountability for funds, confidence in M&S results, and the integration and interoperability of tools. Guidelines would also help to promulgate best practice, and facilitate private sector and commercial partnership in developing government tools, products, and services. Policy also holds the potential to advance the maturity of M&S as a field of technology.

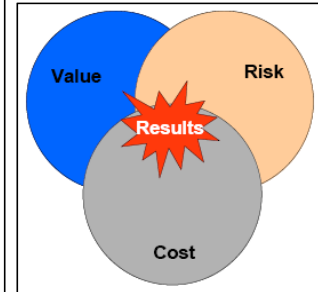
Considerations in acquiring M&S capabilities include economic, development, data, and evaluation factors. Guidelines and means for assessing each consideration would aid in the creation and adoption of M&S tools. Economic analyses question the relationship between results, cost, risk, and value (see Figure 8-1.) Development procedures include flow charts that incorporate steps for needs assessment, communication, design, peer-review, and application. The reliability and accessibility of data can be stumbling blocks to model development, and a process should be in place to vet data and identify its source. Evaluation procedures are critical to validate and verify the model.

The results of an extensive review of existing federal guidelines for M&S describes pockets of expertise in M&S in various government organizations, as well as specific M&S tools. The U.S. Department of Defense (DoD), for example, has an acquisition M&S master plan to provide policy and guidance, enhance technical framework for M&S, improve M&S capabilities, improve M&S use, and shape the workforce. The U.S. Environmental Protection Agency (EPA) has produced guidance for an iterative approach to the development, evaluation, and application of environmental models. The U.S. Government Accountability Office (GAO) issued guidelines for model evaluation, which expands upon the verification and validation of models, with recommended procedures for each step. The National Aeronautics and Space Administration (NASA) issued standards for M&S that delineate uses of M&S for which standards are required or not required. The standards apply to basic research in critical applications.

The U.S. Department of Homeland Security (DHS) is attempting to develop training, establish a community of interest, and develop policies, guidelines, and standards. It is also initiating strategic planning regarding M&S development, evaluation, and use.

# Economics of Modeling & Simulation

Step 1: Develop a Decision Framework	Step 2: Alternatives Analysis	Step 3: Pull the Information Together	Step 4: Communicate and Document
<b>TASKS</b>	<b>TASKS</b>	<b>TASKS</b>	<b>TASKS</b>
<ol style="list-style-type: none"> <li>1) Identify and define value structure</li> <li>2) Identify and define risk structure</li> <li>3) Identify and define cost structure</li> <li>4) Begin documentation</li> </ol>	<ol style="list-style-type: none"> <li>1) Identify and define alternatives</li> <li>2) Estimate value and cost</li> <li>3) Conduct risk analysis</li> <li>4) Ongoing documentation</li> </ol>	<ol style="list-style-type: none"> <li>1) Aggregate the cost estimate</li> <li>2) Calculate the return on investment</li> <li>3) Calculate the value score</li> <li>4) Calculate the risk score</li> <li>5) Compare value, cost, and risk</li> </ol>	<ol style="list-style-type: none"> <li>1) Communicate value to customers and stakeholders</li> <li>2) Prepare budget justification document</li> <li>3) Satisfy ad hoc reporting requirement</li> <li>4) Use lessons learned to improve processes</li> </ol>



Source: Value Measuring Methodology: A How-to-Guide, Federal CIO Council, Best Practices Committee, 2004

Figure 8-1: Economics of Modeling & Simulation

## 9 SIMULATION'S POTENTIAL ROLE IN EMERGENCY MEDICAL CARE SYSTEMS AND MEDICAL EMERGENCY PREPAREDNESS

**David Marcozzi, MD, MHS-CL, FACEP**

**Director, Emergency Care Coordination Center, Office of the Assistant Secretary for Preparedness and Response, Department of Health and Human Services**

A range of federal structures are responsible for emergency medical preparedness and response, beginning with the Assistant Secretary for Preparedness and Response (ASPR) within the U.S. Department of Health and Human Services (DHHS) (see Figure 9-1.) The mission of ASPR is to lead the nation in preventing, preparing for, and responding to the adverse health effects of public emergencies and disasters. The office serves as a coordination point for all processes, overseeing the spectrum of care from countermeasure development to administration.

Three reports have been published by the Institute of Medicine regarding emergency care in the U.S.; these reports reviewed hospital-based emergency care, pediatric emergency care, and pre-hospital emergency care. The reports note that the nation's emergency care has not kept pace with demand, and that there is a nationwide problem of emergency department (ED) overcrowding. In response to ED challenges, Congress established the Emergency Care Coordination Center (ECCC), which is mandated to promote and fund research in emergency medicine and trauma health care, among other tasks. The ECCC is still being developed. Its primary goal is to enhance operation efficiency and effectiveness of the delivery of emergency care.

The use of M&S is key to the research component of this mission. The concepts of M&S apply to the input, throughput, and output aspects of emergency care. The first step in this process is to identify the type of data needed, where the data will come from, and what methods should be used to analyze the data. Currently, ASPR is reviewing data standards and existing methods of data collection and modeling. A strategic plan and approach is now in progress, with the goal of developing best practices.

Daily emergency care and emergency preparedness are related, but require different approaches from the planning perspective. There are few existing data regarding emergency preparedness. Among the priorities of ASPR dictated by the Pandemic All Hazards Preparedness Act (PAHPA) are advanced research on countermeasures, and the development of preparedness priorities and evidence-based benchmarks and objective standards for measuring levels of preparedness.

To address these research goals, ASPR is undertaking an emergency preparedness response simulation project. The concept is to create a simulation and analysis device for medical response along the lines of the SimCity application. The tool would have to account for federal, state, and local response capabilities. The main challenges include data collection, and the modeling of relationships, events, environments, and other features of emergency response. The goal is to use the tool for planning, training, and real-time decision support. Desired outcomes include improved medical response, the ability to direct and improve medical operations, the definition and refinement of metrics, identification of bottlenecks in response, and to perform a cost-benefit analysis.



# Federal Emergency Preparedness

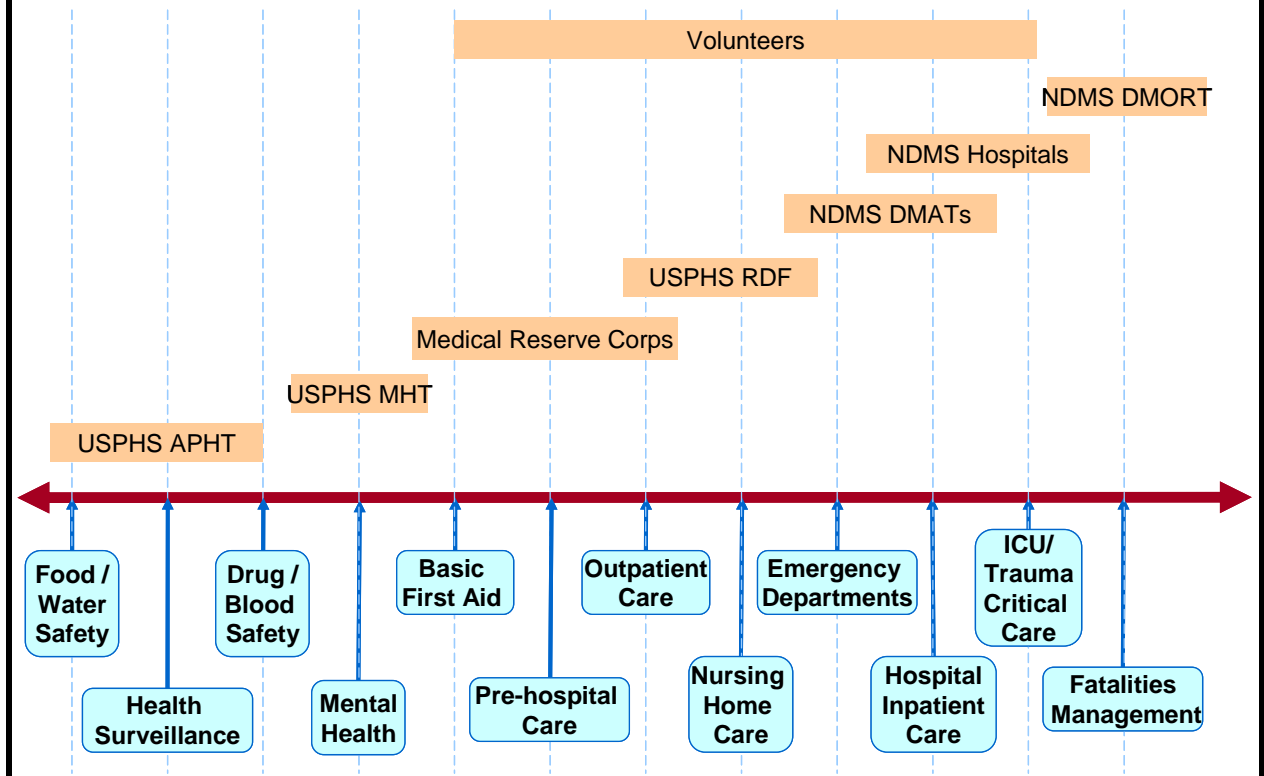


Figure 9-1: Federal Emergency Preparedness

## 10 SUSTAINABLE MODELING? SELECT FOR SUCCESS

**Terry P. Young, Professor**

**Chair of Healthcare Systems, School of Information Systems, Computing and Mathematics, Brunel University, Uxbridge, UK**

Providing health care services requires health care systems, as well as drugs, technology, and infrastructure; developing drugs and technologies depends on basic science research. All of these aspects then inform policy. Defining where within this framework modeling and simulation (M&S) can be applied can be challenging.

Each layer of this system has its own characteristics. For example, at the bottom of this schema – basic research – the impact of work on patients is often hard to define; intellectual property rights, however, are easily determined, and invention is favored over improvement. The higher regions – services and policy – have a clearer impact on patients, and improvement plays a key role. The question is where along this continuum the innovation interface is located, the interface line that bonds higher-level services (i.e., improvement) and technology (i.e., innovation). At the policy level, for example, the value concept is difficult to define, metrics are hard to assess, and improvement methodologies emphasize management and leadership. At the level of intervention development, the path to the marketplace is easily defined, metrics are easily quantified, but product value to service providers may be difficult to articulate (see Figure 10-1.)

The RIGHT program uses M&S to model policy- and service-level decision making. The question is how to mesh projects such as RIGHT, which works at higher levels, with M&S projects at the technology research and development level, where the goal is to coordinate efforts from research through to the delivery of care. Through the Multidisciplinary Assessment of Technology Centre for Healthcare (MATCH), several such tools have been developed for product development. An example is a value tool for early product assessment that helps to analyze the cost-benefit ratio of product development, and where the product fits in with other existing products. At other times, the team has applied Markov models, which have been used to evaluate the utility of procedures such as total knee replacement based on different health states. M&S methods at this level are concerned with linking technology to outcomes.

At higher levels of policy and services, M&S methods need to link processes to metrics. A wide variety of methods have been explored for this purpose, creating a need for a classification of methods. An early goal of the RIGHT program was to create a means of selecting an appropriate M&S tool, given the characteristics of a particular service-related decision. The preliminary interface that was created allowed for input such as price, time, expertise, available data, and type of output. This tool is the first step toward creating a seamless set of M&S tools that bridge the gap between policy and basic science, especially across the innovation interface. The issues going forward with this quest are community engagement (such as involving the right stakeholders; field work; and knowledge transfer), the data conundrum (what and how to collect; analysis; taxonomy; and policy), method development (new methods; hybrid methods; and ‘method-of-methods’), and tool development (software engineering; and potential for new markets).

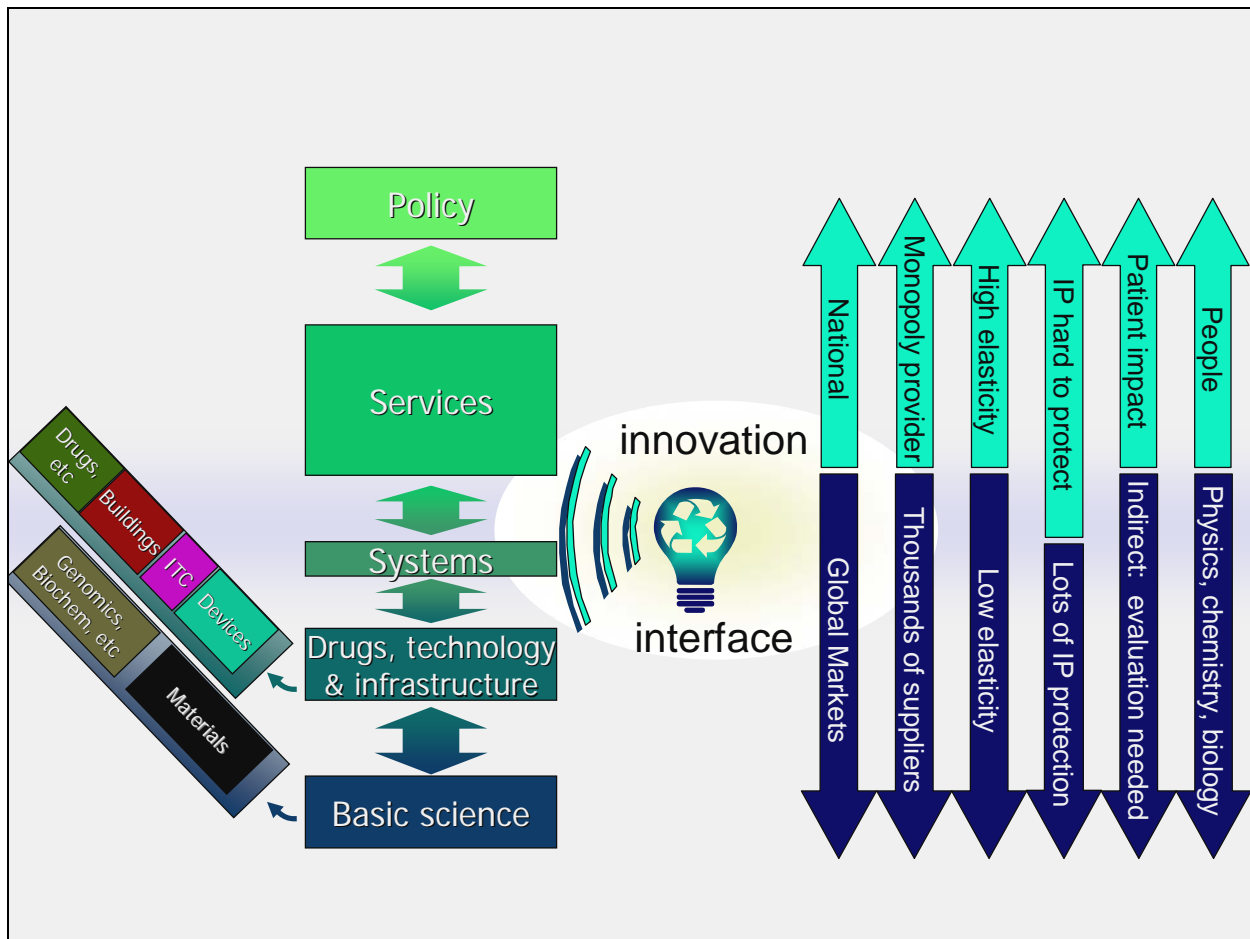


Figure 10-1: RIGHT – On Latest Thinking

## **11 MODELING AND OPTIMIZING THE PUBLIC HEALTH INFRASTRUCTURE FOR EMERGENCY RESPONSE**

### **11.1 OPTIMIZING HEALTH CARE RESOURCES FOR EFFICIENT USAGE, AND INTEGRATION WITHIN an EMERGENCY RESPONSE CONTEXT FOR LARGE-SCALE POPULATION PROTECTION**

**Eva K. Lee, PhD**

**Director, Center for Operations Research in Medicine and HealthCare; Professor, Industrial & Systems Engineering, Georgia Institute of Technology; Co-Director, NSF I/UCRC Center for Health Organization Transformation; Co-Director, Biomedical Informatics Program, NCRR-Atlanta Clinical and Translational Science Institute, Emory – Morehouse – Georgia Institute of Technology**

Multi-level strategic planning of the public health infrastructure is an essential element of city readiness and emergency response for biodefense, radiological response, and infectious disease outbreaks. The first level involves optimizing the existing health services, assessing current surge capability and capacity, and optimizing patient flow, efficiency and clinic throughput. The second level involves the protection of the regional population through large-scale dispensing of prophylaxis medication. The challenges to this process include the stockpiling and distribution of medication, locations of dispensing facilities, optimal facility staffing and resource allocation, as well as logistics, transportation, and dispensing modalities. Modeling, simulation, and large-scale optimization play an important role in addressing some of these challenges and in helping in the decision making process. Mass dispensing requires a smooth supply-demand operational infrastructure. It involves the flow of medication from stockpiles and managed inventory sites to dispensing sites for distribution to individuals, and the flow of population from their respective homes to checkpoints and to the dispensing locations.

Researchers at Georgia Tech created a software enterprise system called RealOpt that allows for the study, training, and enhancement of emergency response and planning for biologic threats, infectious disease outbreaks, and radiological population monitoring (<http://www2.isye.gatech.edu/realopt-regional/RealOptRegionalManual/Preface.html>). The tool is a decision support system for population and medication flow planning and real-time resource allocation (see Figure 11-1.) It couples fast optimization algorithms and large-scale simulation into one single software decision-support system. The system accommodates both regional and federal strategic and operation planning and assessment. It assists local/state emergency managers in determining optimal setting up of regional points of dispensing (PODs) and its regional stockpile/distribution planning to prepare for emergency situations. Given a regional population, the system helps determine where and how many PODs are needed for optimal operations, the optimal assignment of individuals/households to various PODs, and the optimal staffing and allocation of resources at each POD. RealOpt has been used in dispensing exercises for anthrax and smallpox, as well as real vaccination events for flu, Hepatitis A, and H1N1.

The computational challenges are two-fold: 1) To determine the network of PODs in a region, an optimization model with strategic planning considerations was designed. It addresses how to direct residents to PODs by minimizing average distance and travel time to the closest POD and how to minimize facility set-up costs. 2) For labor resource allocation, the problem involves multiple objectives such as minimizing labor costs, maximizing throughput, equalizing utilization at each POD, and minimizing wait time, while assigning staff with appropriate skills to serve in each station within the POD. The effectiveness of RealOpt was first validated in 2005 when it was used for planning and decision making for a large-scale anthrax drill. In this exercise, one county used RealOpt for planning, while seven other counties used other models. The county modeled with RealOpt processed the highest throughput of all 8 counties; 50 % more individuals were processed compared to the second-place county. External evaluators determined that RealOpt produced the most efficient floor plan, the most cost-effective dispensing (smallest labor versus throughput ratio), and the smoothest operations. The exercise also revealed many areas that need attention during operations planning and design of dispensing centers. The tool is free and widely used in public health agencies; it can be run on any computer or personal digital assistant.



**Figure 11-1: Infrastructure of RealOpt – A Tool for Emergency Operational & Strategic Planning**

## **11.2 EMERGENCY DEPARTMENT AND HOSPITAL THROUGHPUT MODELING**

**Tanner Flynn**  
**Principal, FDI-Simulation**

**David Ferrin, FHIMSS**  
**Principal, FDI-Simulation**

The basic elements to be considered in hospital throughput modeling for the emergency department (ED) and operating room (OR) include input (emergency admits, transfers, direct admits, post-operative admits), admissions and discharge times, business rules, and outcomes (optimizing numbers of beds, higher occupancy, lower surgery cancelations, etc.). Key performance indicators include volumes (of admissions, transfers, etc.), resources (beds, staff, hardware), cycle times (length of stay, boarding time, turn around time), and others (occupancy, bed utilization, etc.) (see Figure 11-2.)

Best practices for patient throughput simulation are numerous, but must be individualized by institution. Sources of best practices include the Institute for Healthcare Improvement, Healthcare Advisory Board, Sg2, and the Robert Wood Johnson Foundation.

Using key performance indicators and best practices, models can be constructed of ED, OR, or other facility throughput. In one example from a model of a hospital with 32 ED beds and 370 inpatient beds, the administrators wanted to know how many visits their ED could handle without increasing ED length of stay beyond 3 hours. The model estimated that the ED could handle approximately 40000 visits per year while maintaining a 3 hour length of stay. More visits led to a rapid increase in length of stay; 4 hours at 41000 visits, over 5 hours at 42000. The key message for surge capacity is that the difference between 40000 and 41000 visits is 3 patients per day; in other words, once capacity is reached, any further increase results in a dramatic change in length of stay. This is an example of how M&S can help managers understand how changes in different input parameters affect throughput, length of stay, and other outcomes.

Other features that throughput modeling can evaluate include bed availability, discharge patient flow, inpatient discharge time of day, bedside registration, use of a discharge lounge, and staffing levels, among many others. Using M&S to understand current status is invaluable in the context of emergency preparedness, as the models can be used not only to assess features of hospital design and organization to maximize daily throughput and value proposition, but also to judge the effects of surge on hospital functions.

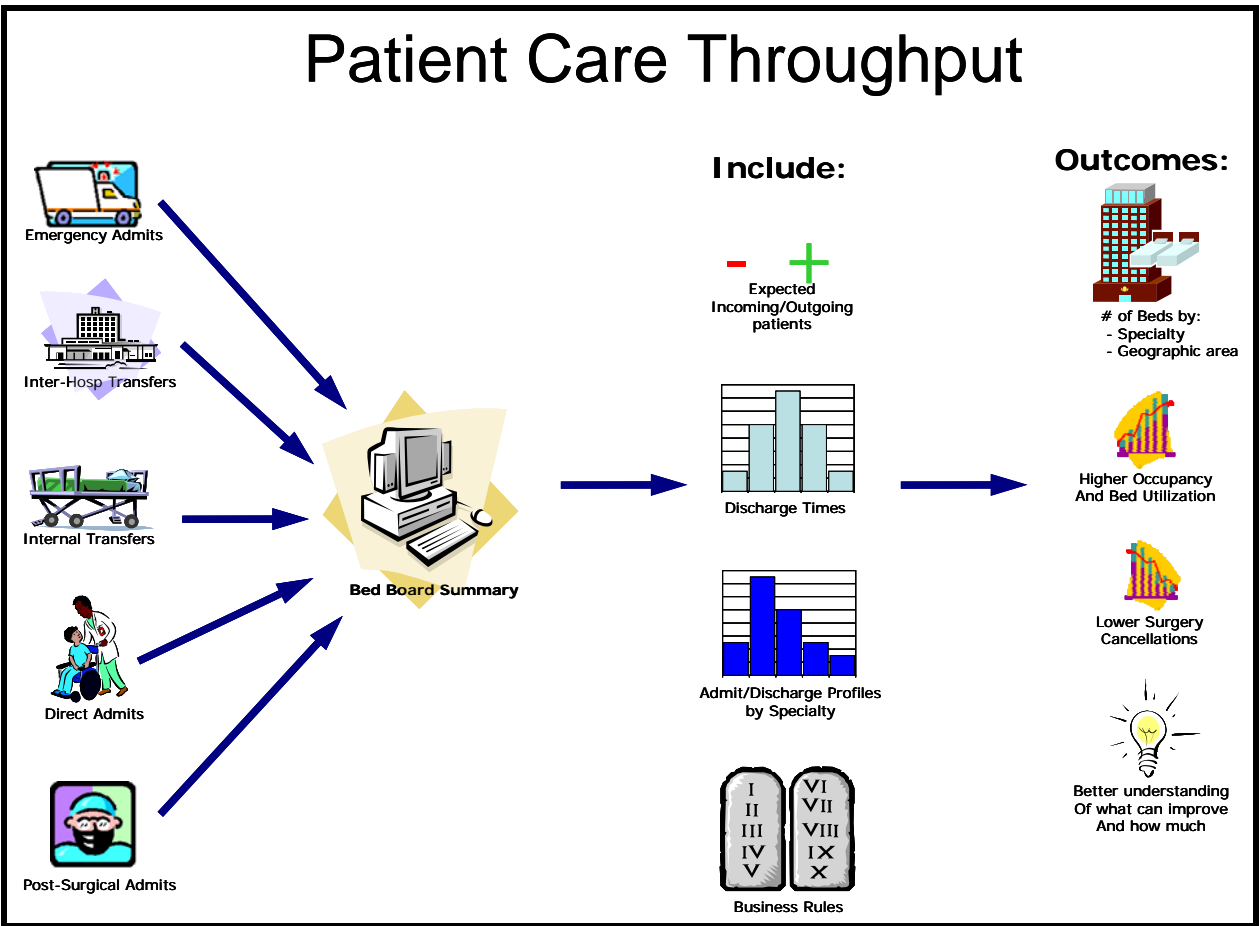


Figure 11-2: Patient Care Throughput

## 12 EMERGENCY MANAGEMENT

### ***12.1 TOWARDS A SIMULATION AND GAMING FRAMEWORK FOR INCIDENT MANAGEMENT***

**Sanjay Jain, PhD**

**Assistant Professor, School of Business, George Washington University**

Potential applications of M&S in incident management include training, systems engineering, vulnerability/risk analysis, and operational planning and decision support. The challenge is that developments in M&S for this application area are ad-hoc and fragmented. For M&S to be effective, a coordinated approach is required.

A vision for integrated M&S for incident management includes realistic role-playing game interfaces and technically correct simulations. The game interfaces include first responders, incident management, support personnel, civilian population, opposing forces, and live elements. The simulations model the major aspects of incident management including physical phenomena, the environment, social behaviors, organizations, and infrastructure systems. The overarching principals in this vision include modular simulation and a gaming reference architecture, computing and communications infrastructure, standard information models, databases and message formats, validated scenarios and sample data sets, conformance testing procedures, and systems.

There is a need to identify and/or develop the standards needed to achieve data exchange, module interoperability, and software re-use. M&S needs in incident management include tools that can be rapidly configured to support different scenarios; validated tools and data sets; data-driven simulations; scenario data available in standard formats; interoperable tools to allow for rapid integration; and a communication and computing infrastructure. Currently, ad-hoc M&S tools are used to analyze multiple aspects of a selected incident type with different, overlapping scopes. The input data for these tools exist in proprietary formats. The resulting 'custom developed' models are generally stand alone and cannot be integrated. A framework is needed to help integrate M&S tools in incident management.

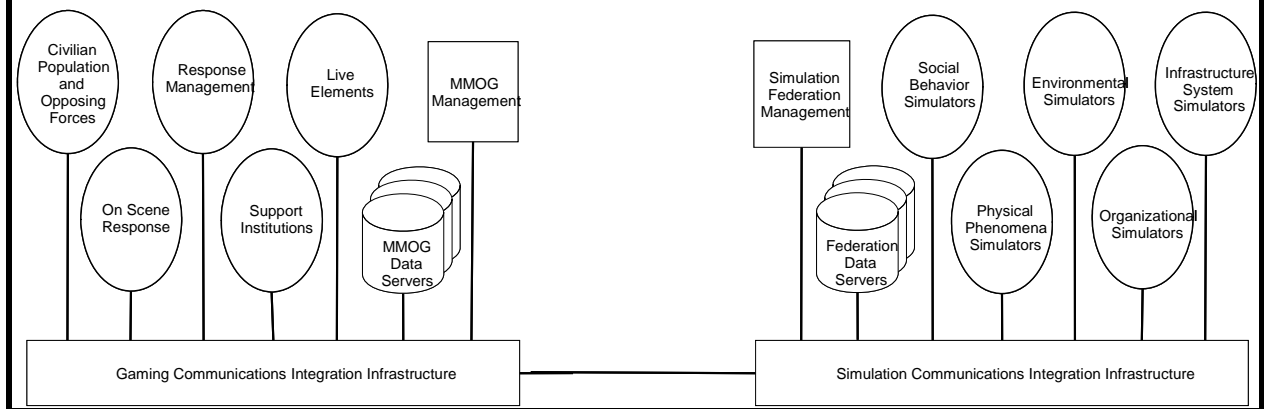
The recommended framework includes three dimensions: incident, lifecycle/phase, and domain. Incidents include man-made and natural incidents. The lifecycle/phase dimension ranges from prevention and preparedness to response, recovery, and mitigation. Domains include civilian population, critical infrastructure, environment, government agencies, private sector, and others. Each cell of the framework represents a potential M&S application. For example, an application may be developed to model fire (incident) prevention (lifecycle/phase) in the private sector (domain). Each cell may require multiple models, or individual models could simulate one aspect of multiple cells. A software architecture is needed for the integration of standard component models that cover the solution space.

A proposed system reference architecture concept was outlined that divided modules into gaming and simulation (see Figure 12-1.) Gaming subsystem modules include live elements, support institutions, response management, on-scene response, and civilian population. Simulation subsystem modules include social behavior simulators (crowd, traffic, epidemic, consumer and other behaviors), physical phenomena simulators (earthquake, explosion fire, plume disease and bioagents, and biotic agents), environmental simulators (weather, watershed, indoor climate, ecology), organizational simulators (fire, law enforcement, health care, government agencies, military, terrorists), and infrastructure system simulators (food supply, power distribution, water supply, transportation, communications, computers and networks).

Health care system simulations, by way of example, are an integral part of integrated incident management simulations. Health Care simulations include social behaviors (such as might influence epidemic spread), physical phenomena (such as spread of a bio-agent), and organizational simulations (such as response to anthrax attack). Gaming examples include emergency vehicle driver training and on-scene response and triage by emergency medical personnel.



# System Reference Architecture Concept



**Figure 12-1: System Reference Architecture Concept**

## ***12.2 Walking on Broken Glass – A Case for Developing Standards in Emergency Preparedness***

**Joseph L. Cappiello**  
**President & CEO, Simulation Education Services**

From the perspective of the hospital, organizations prepare for disasters for several reasons, including requirements (federal, state, insurance, etc.), geographical realities, history of past situations, public expectation, and moral imperative. Influences over preparation are equally diverse, including accreditation and regulatory requirements, financial limitations, workforce shortages, capacity constraints, operational disruption, corporate influence, and lack of standardized performance metrics, among others. Factors that impact preparedness range from the infrequency of events, to a lack of taxonomy and baseline data. Further, competing priorities, competition between hospitals, and a heavy focus on critical infrastructure also impacts preparedness.

The emphasis is typically on response rather than resiliency. Resiliency encompasses the continuity of operations planning. Unlike preparedness, resiliency can be easily and concretely defined. Definitions of resiliency describe it as the ability to rebound from stress or catastrophe. Resiliency as a concept has certain advantages. It creates a language and goals that “preparedness” cannot, broadens the dialogue, includes the continuity of operations planning, creates public-private partnerships, and lends itself to effective M&S scenarios. Resiliency describes a cycle from preparation to response, recovery, and mitigation. Elements of resiliency include robustness (continuing to function during disruption), resourcefulness (managing response to disruption), rapid recovery (get back to normal), and reflection (absorb new lessons).

The major issues from past disasters include failure of communications, inadequate utility plans and strategies, lacking incident command systems, and minimal involvement with the community’s Emergency Operations Center. Furthermore, hospital planning is often dictated by the most recent significant disaster. Finally, few organizations could withstand events that last for days and separate them from community support. During a disaster, hospitals experience increased admissions, decreased discharges, and ever-increasing pressure on limited resources. Outpatients and chronically ill patients seek support and medications at hospitals and citizens even seek non-health care services and shelter. Significant disasters are sustained, affect multiple communities simultaneously, overwhelm federal response, impact public services, and threaten the entire health care infrastructure.

There are six critical components for hospital resiliency: communications, resources, safety and security, staff responsibilities, utilities, and clinical activities. Models of hospital preparedness should incorporate these features. The “96 hour rule,” which is really a principle to guide planning, takes into account the fact that federal response to a large scale disaster may require 72 or more hours. Disaster response strategies derived by this rule include conservation of resources; curtailment of services; consolidation of patients; supplies and staff; staged or limited evacuation; and full evacuation. Modeling could help facilities determine what strategy to pursue; for example, what point should they elect to shelter in place versus initiate a full evacuation (see Figure 12-2.)

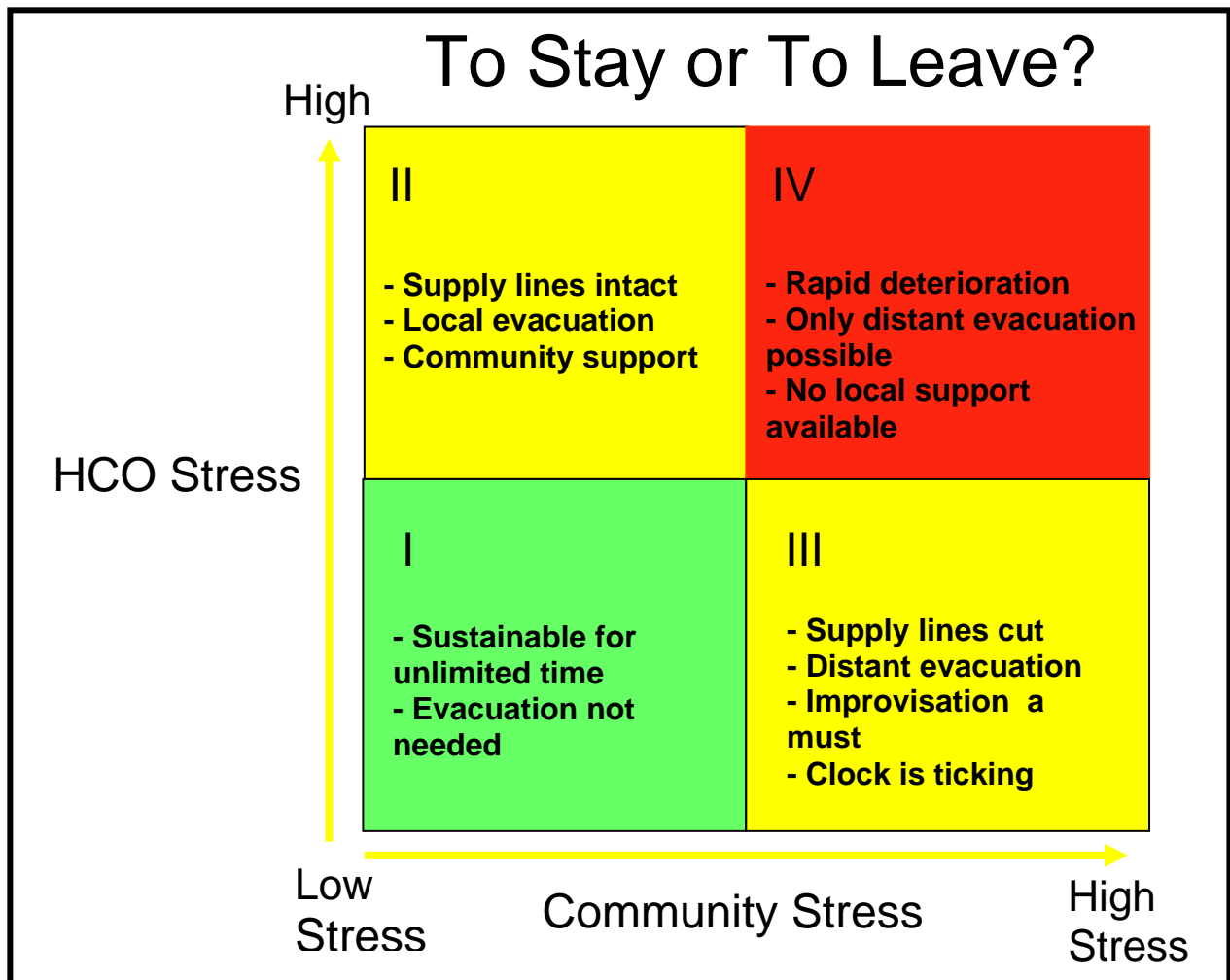


Figure 12-2: To Stay or Leave?

## ***12.3 Leveraging Ubiquitous Technologies for Real-Time Disaster Simulation***

**Ryan Scott Bardsley**

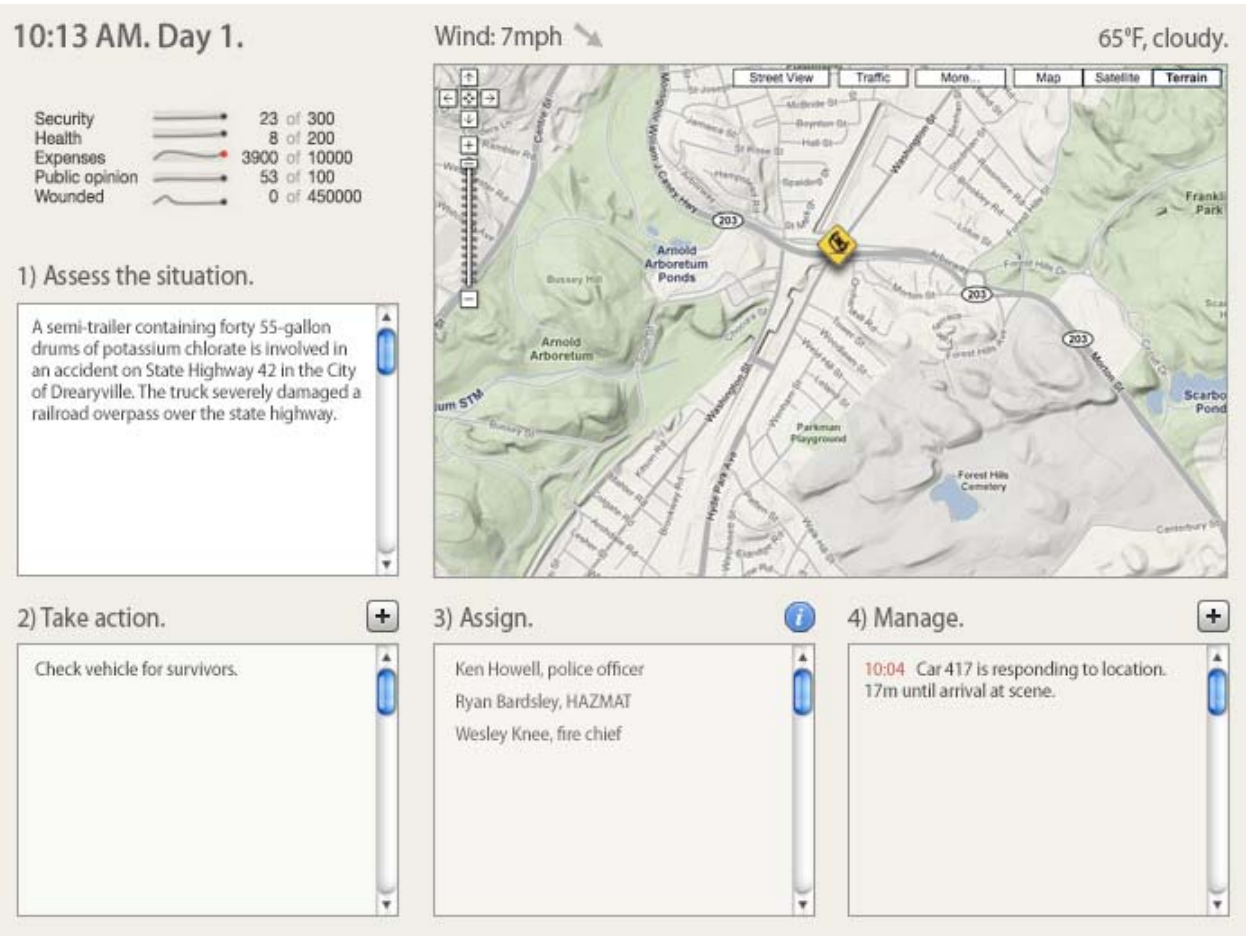
**Senior Systems Manager, Massachusetts General Hospital/ Center for Integration of Medicine and Innovative Technology (CIMIT)**

CIMIT's applied research in simulation ranges from fundamental technologies for medical simulation to intelligent tutoring systems. CIMIT has focused on integrating two M&S projects: a real-time incident preparedness (RIPS) simulation effort and a next-generation trauma mannequin called COMETS or Combat Medic Training System (<http://www.cimit.org/about-stories-simulation.html>.)

RIPS is designed to facilitate storytelling during tabletop training exercises, the most commonly used form of disaster response training. RIPS supports both rural and urban areas by automatically making the content relevant by pulling locale-specific content from web sources such as Google Maps. This architecture allows content to be freely shared and modified by users, a model successfully employed by the gaming industry. Certain areas of the narrative, such as place names, street names, and weather patterns, are customized to match those of the area where the simulation is being conducted. RIPS can therefore take any scenario and tailor it to provide a relevant training environment without the need to end user customization (see Figure 12-3.) Current RIPS scenarios include a slow-onset flood, conventional explosive device, release of a chemical agent, a smallpox outbreak, radiological spill in transit, response to suspicious packages, and HAZMAT (hazardous material) level B training.

COMETS is a multi-year research effort to develop a fully-autonomous and ruggedized casualty simulation for training of combat medics in battlefield hemorrhage control and tactical combat casualty care (TC3). It will initially take the form of a 183 cm (6 ft) tall, 75 kg (165 lb) male soldier that bleeds, screams, and writhes in pain. The mannequin is powered by a hybrid architecture of pre-computed physiologic models and real-time detection and response to medic intervention. The units will be completely autonomous, capable of operation outside of the line-of-sight of an instructor; once the program is initiated, the mannequin will "die" unless treated appropriately. This enables a single COMETS mannequin to be used from point-of-injury, through transport, to definitive care. While advanced technologically, the system is designed from the outset to be simple and intuitive to operate. All data are stored onboard to facilitate after-action review by an instructor allowing COMETS to provide the Army with a new tool for casualty data-collection and medic performance assessment.

The Comprehensive Emergency and Disaster Response Simulation (CEDRS) is an effort to integrate these two simulation approaches. CEDRS will integrate in-field data from medic intervention via the self-contained mannequin simulators with the RIPS virtual incident command simulation. The program will use a gaming approach to encourage suspension-of-disbelief, increase effectiveness of team training, and better simulate the complexities of actual disaster response.



## 13 HEALTH CARE SYSTEMS

### ***13.1 Trends in ED Design – Architectural Planning and Simulation Modeling Integration***

#### **13.1.1 From Feasibility Studies to Programming to Post-Occupancy – Patient Safety Perspective (Patient Safety and the Need for Simulation Modeling)**

**Kenneth N. Dickerman, ACHA, AIA, FHFI**  
**Patient Safety Design Consultants, LLC**

This is part one of a two-part presentation on the use of modeling and simulation to improve patient care in the physical space. This presentation features patient safety in the Emergency Department (ED). Patient safety is a significant problem in medical care. Estimates of deaths due to injury and hospital acquired infections range from 100000 to 250000 per year. Indeed, medical errors and accidents are one of the leading causes of death in the U.S.; a trip to the hospital is more risky than flying on a scheduled airline, working in a nuclear power plant, or serving on an aircraft carrier. Unfortunately, ED design has not kept up with the need to improve physical environments to enhance safety. The emergency department is a major patient “portal.” Patient safety, already tenuous, is put at the knife’s edge by challenges such as changing patient demographics (e.g., obesity), financial pressures, and the need to cope with major man-made or natural disasters.

This presentation discusses some important background material relating to safety and to concepts used to create better design, including standardization, forcing functions, natural mapping, visibility, and “knowledge in the world.” These concepts have been developed by environmental psychology researchers such as Donald Norman and apply to building environments as well as other systems. Charles Perrow has also contributed by describing how the complexity and connectivity of systems impacts the severity of accident events. Health care is a tightly connected, highly complex system. The “Swiss Cheese Model,” crafted by safety researcher James Reason, shows how safety is a systems problem in which many small failures, some due to latent defects in various system components, contribute to the chain of events that leads to accidents (see Figure 13-1.)

Simulation can, and should, play an important part in the process of health care building design. In fact, no part of the hospital has a greater need for better design than the ED. Unfortunately, a defective, incomplete design process has the same results in the quality of the building environment as poor systems design does for medical care. Inadequate environments contribute to errors, usually in small ways, but sometimes more dramatically. For example, hospital-acquired infections, a portion of the safety problem, sometimes result from air distribution and filtration problems. Falls frequently have an environmental component, and patient handling, which can lead to caregiver injuries, also has building design solutions.

Is it possible to model safety? There are challenges in following and mapping aberrant processes, including the lack of useful statistics, caregivers’ reluctance to cooperate, and potential legal concerns. However, these problems are not insurmountable and pale in comparison to the potential benefits of better ED design derived from and supported by simulation modeling.

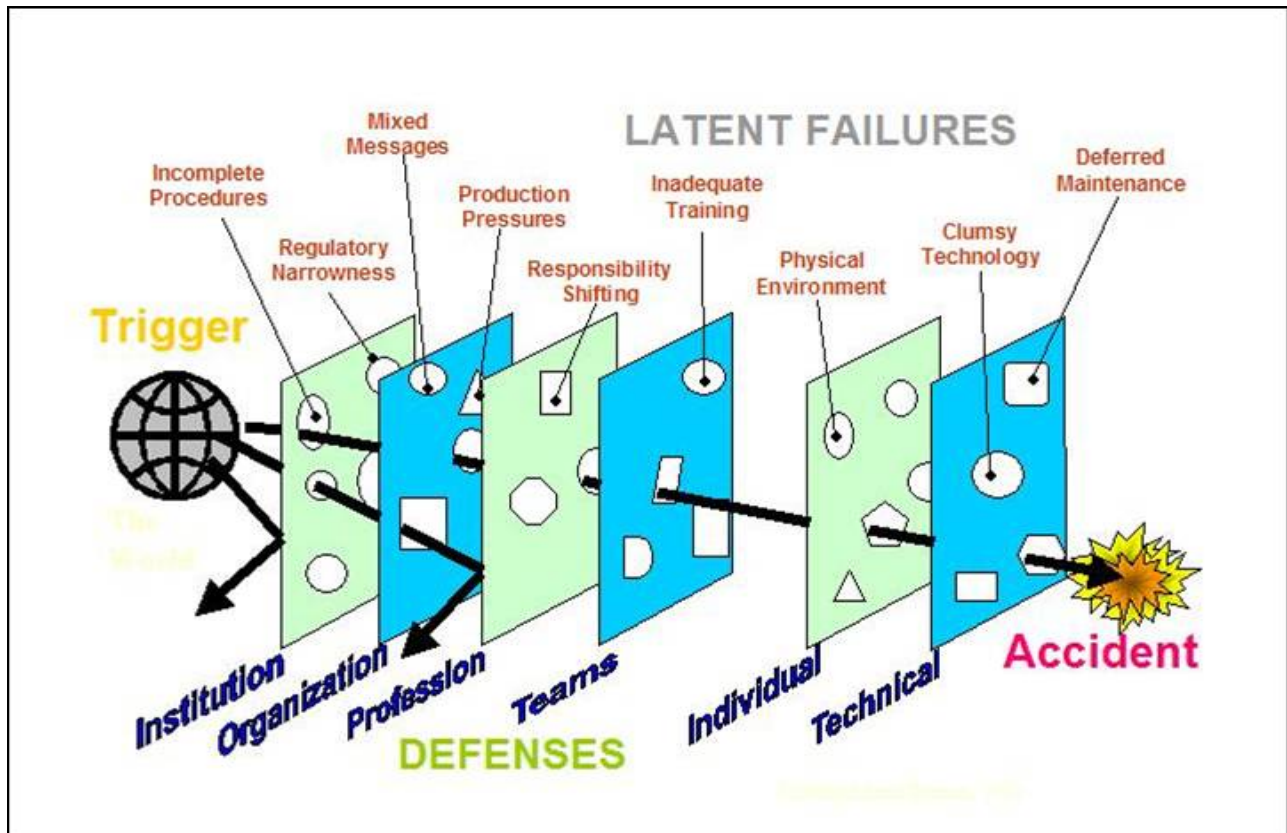


Figure 13-1: Swiss Cheese Model

### **13.1.2 FROM FEASIBILITY STUDIES TO PROGRAMMING TO POST-OCCUPANCY – BUILDING DESIGN AND TECHNOLOGY PERSPECTIVE**

**Mark Sullivan, AIA, NCARB**  
**President, Mark Sullivan Architects**

M&S can be used to inform the architectural approach to health care design. Modeling in health care design is an evidence-based approach that forces a closer analysis of flow process and space utilization. The steps to building a simulation model are analogous to the architectural design process. The purpose must be defined, data collected, precision of the model determined, and the model built. Then it must be verified, tested, and validated. The advantages of M&S in the design process are numerous. M&S allows for better assessment of operations and productivity opportunities, evaluation of staffing needs and space utilization, and examination of surge capacity, among other advantages.

Modeling is not new to architecture. Architects have long used 2D floor plans, scale models, and 3D virtual models for education and presentation. Newer technologies and applications now allow for the study of building design in the context of the surrounding environment using modeling and animation. By way of example, Mr. Sullivan presented a 3D animation that modeled the events of September 11, 2001, when an airliner struck the North Tower of the World Trade Center (Refer to the top left graphic of Figure 13-2.) The animation was created by computer scientists at Purdue University who developed an application to link computer simulation and visualization systems using detailed finite element analysis (FEA) models of the top 20 floors of the building. The goal of this work was to translate collected data into visual events in a scientifically accurate manner. The translator accomplishes this goal by discarding simulation data that have little visual relevance and enhancing details with high visual relevance. The result was a powerful, scalable, and generalizable tool for visualizing FEA simulations with physical and visual fidelity.

Similarly, evidence-based architectural models can be used to simulate the impact of new hospital design on work processes, patient flow, and the surrounding environment. For ED design, architectural models can be combined with M&S tools such as patient flow process maps to evaluate the movement of patients or staff through the proposed unit. Such models, based on real-world data, can also help to predict walking distances for staff (Refer to the top right graphic of Figure 13-2,) and the revenue lost due to when rooms are closed for procedures (Refer to the bottom graphic of Figure 13-2.) Codes, regulations, and guidelines can be incorporated into models to prevent later conflicts or violations.

Mr. Sullivan posed some important questions regarding M&S from an architect's perspective: Why is data collection so complicated and time consuming; why are M&S models often difficult to understand; why do many clients lack confidence in M&S; why are models not more interactive for client users; and why are simulation models not interconnected to the 3D model of the architectural environment? These questions apply to all components of the architectural process, programming, design and construction and should be addressed in feasibility studies on through post-occupancy evaluations. Each of these questions represents an important area for future research and innovation.





## ***13.2 Best Practices for Semantic Discovery and Leverage of Enterprise Data in Simulations***

**Alan McCutchen**

**Vice President, Products, Modus Operandi (MO), Inc**

High quality data is extremely important for successful M&S applications in health care. The completeness, relevance, and accuracy of data directly impact the quality of simulation results and decisions made. To provide simulators and decision makers with the highest quality data requires strong data integration and correlation. The use of semantic technology can improve data and event integration, and the interoperability of simulations.

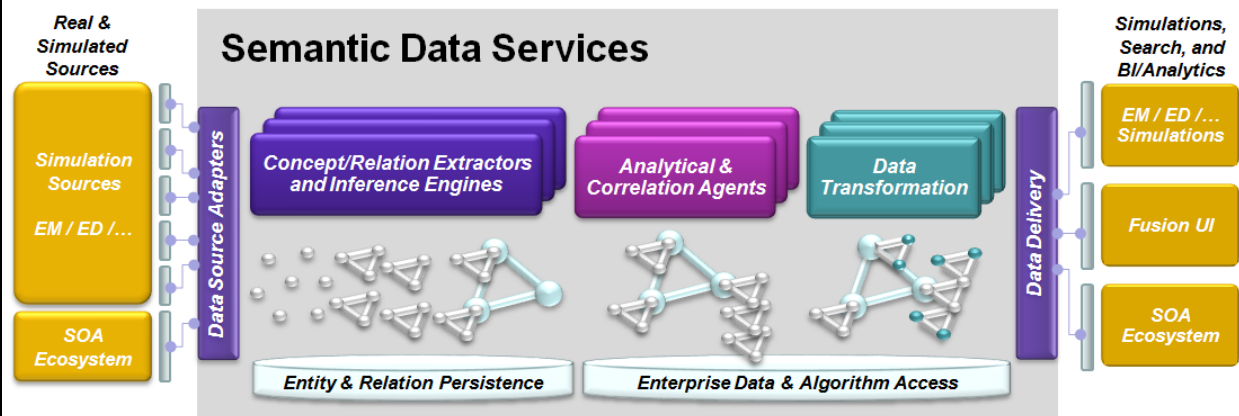
Issues that can limit the ability to leverage data are numerous, including lack of interoperability of data, inability to locate or retrieve data, trouble making sense of data, and others. Challenges to users reflect the difficulty in integrating data from complex systems. Barriers to integration and mediation include human consensus barriers, enablement barriers, and integration and sharing barriers. Human consensus barriers revolve around the lack of mission consensus and shared vocabulary, strong information architecture, and consistent representation. Often there is limited political 'mindshare'. Lack of consistent knowledge representations, inadequate technology to implement in a consistent manner and limited technology mindshare are typical of enablement barriers. Integration and sharing barriers are often a result of privacy constraints and concerns as well as the lack of unified access.

Semantic data services were designed to improve integration, create vocabulary-driven data discovery and access, enhance the mediation and interoperability of simulators, and align business processes and workflow. The impacts of semantic technology include smarter data (discoverable, relevant), smarter infrastructure (rule-, data-, and event-driven software), and improved interoperability (between simulators and communities of interest). Connecting simulators with semantic data services provides a better data and event integration framework (see Figure 13-3.)

Key software architectural considerations include flexible data source adapters, multi-channel messaging, best-of-breed infrastructure component support, enterprise data access, and Service Oriented Architecture (SOA) interfaces. Data source adapters accelerate integration of legacy systems while multi-channel messaging facilitates event-driven data and application integration. Best-of-Breed component support enables optimal solutions such as Declarative /Pluggable entity extractors (Apache UIMA (Unstructured Information Management Architecture) compatible), reasoners (Jena compatible), analytical algorithms and correlation agents, and finally pluggable security mechanisms and policies. SOA web service endpoints facilitate composable integration with Enterprise Service Buses and the broader enterprise ecosystem.

Best practices for semantic data services fall into four key dimensions: human consensus, semantic knowledge representations, enablement infrastructure, and simulation integration. The first dimension, human consensus, establishes management sponsorship and clear success criteria; this requires management buy-in and authority. The simulators and work products to be integrated should be identified as early in the project as possible. And there must be a focus on alignment of tasks with project success criteria. The second dimension, semantic knowledge representations, focuses on capturing subject matter expertise in a form that can be easily processed. Ontology and belief networks must be identified and refined. A minimum set of cross-ontology relationships should be specified. The third dimension, enablement infrastructure, aims for runtime functionality that is reusable, interoperable, and compliant with key standards. As part of the enablement infrastructure, it is important also to integrate and comply with security policies and mechanisms. We've seen best results where the process is iterative from pilot to production, keeping success criteria in mind throughout. The last dimension, simulation integration, builds on the previous three best practices. The simulators that need to leverage the data delivery infrastructure must be integrated, preferably using standard web services interfaces. The performance and accuracy of the other dimensions should also be validated, and the underlying ontology, mediation, and data mappings must be sustained. Enterprise business processes may also be used to orchestrate and monitor the process.

# Connecting Simulators with Semantic Data Services



## Event-driven Semantic Processing and Propagation of Simulation Data

- ⌚ Provides a data and event integration framework
- ⌚ Supports vocabulary-driven data discovery & access
- ⌚ Acts as a workflow propagation engine
- ⌚ Enables interoperability and mediation

Figure 13-3: Connecting Simulators with Semantic Data Services

### ***13.3 Back to the Future: The Ongoing Need to Promote Simulation Modeling to Health Care Decision Makers***

**Dave Eitel, MD, MBA**

The application of M&S tools to the modeling of emergency department (ED) capacity is an example of how these techniques can be used to improve health care delivery. There is a tremendous need to improve the effectiveness of patient handling in health care. One example of improved customer handling is the altered check-in processes at some airlines, which drastically reduced waiting times. This example illustrates the potential of re-thinking work processes in the ED. Indeed, “no wait” EDs do exist. Both improved airline check-in and no-wait EDs share in common the use of queuing. The ED represents a queuing (waiting in line) system, which consists of arriving entities – patients – and one or more “servers” providing service.

Queuing and lean engineering are about eliminating the waste of waiting. The core principles of queuing include matching demand (prediction of service load) and capacity (the ability to deliver service over a particular time period). Demand for services in the ED is random, or “stochastic,” but it is not unpredictable. For example, the patterns of physician staffing and patient arrivals are distinct on weekdays and weekends. Distinct patterns can also be demonstrated for individual days of the week: Sundays look like Sundays, Tuesdays like Tuesdays.

Capacity is a major issue for many hospitals. More specifically, the problem is hospital service capacity. Variation in arrivals and/or processes has a profound effect on service capacity. The interdependency of the many features of the hospital or ED requires application of M&S tools to describe the impact of variability on service capacity (see Figure 13-4.) Answering questions such as, “How long will patients spend in the ED for their visit?” requires predictive analysis: how many beds, physicians, nurses, and other resources will be needed and when will they be needed to handle any particular service load (demand) with current system design, physical plant, and staffing plans (capacity). The most important concept in queuing theory is the bottleneck, a stage or number of stages in a system that cannot process service quickly enough to prevent backlogs. Improving system performance requires identifying and minimizing the performance of bottlenecks.

Process modeling is used to model queuing systems (service systems). Queuing systems consist of entities being processed through a series of service stages, with the opportunity for queues to form between each stage when there is insufficient processing capacity at server units. Process modeling helps health care managers understand and manage the variation and interdependencies of their world. There are two forms of process modeling. The first is dynamic process modeling (Discrete Event Simulation), which handles the need to describe variation over time. This type of model is complex, work intensive, and time consuming, but it is powerful and can model anything. The second option is static process modeling, which allows for capacity and resource planning at a given service load.

Simulation provides the ability to model events that occur over time, as well as all variability associated with these events. Simulation permits decision makers to visualize the operation through animation of a new or existing system under a variety of conditions, and allows users to draw inferences about a new system’s behavior without actually building it, or an existing system’s behavior without disturbing it. For example, simulation can be used effectively to test major changes to patient flow processes.

The advantages of simulation tools include the ability to test major changes in patient flow processes. They allow for the evaluation of “what-if” scenarios before investing capital and without disrupting hospital operations. Simulation can contribute to an understanding of how various system components interact and affect overall performance, allows for real-world variability to be included in system analysis, can represent complex real-world behavior that cannot be captured analytically, captures logic and policies that do not exist or cannot otherwise be tested, and allows for analysis over time.

# Impact of Variability

How does variability impact system performance measures?

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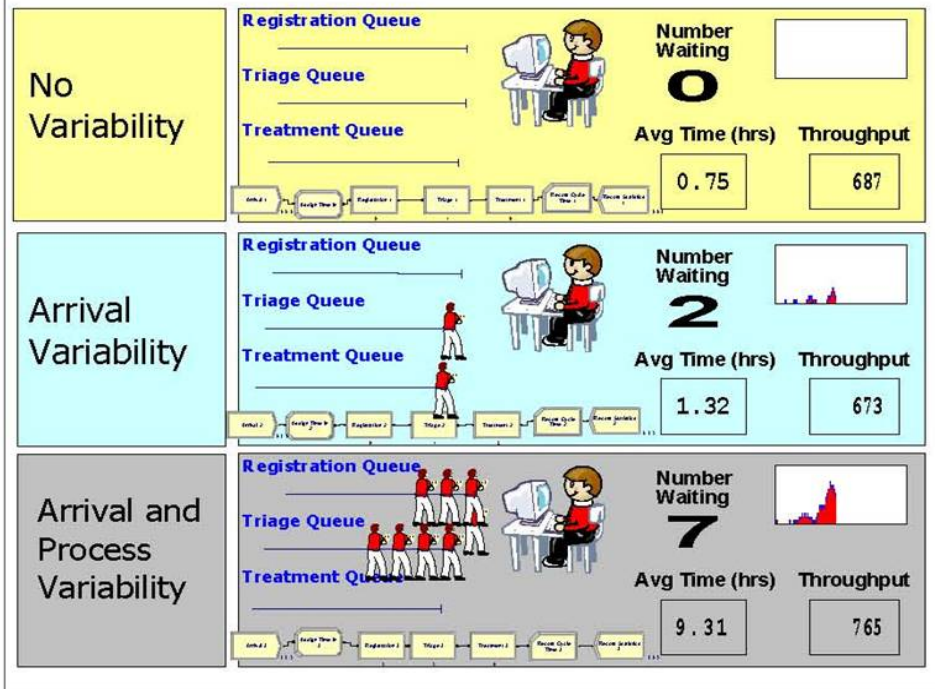


Figure 13-4: Impact Variability

# **14 PREPARING FOR WHEN THE RUBBER MEETS THE ROAD: ALIGNING SIMULATION AND TECHNOLOGY FOR DISTRIBUTED HIGH-ACUITY PATIENT CARE**

**Julian M. Goldman, MD**

**Director, CIMIT Program on Interoperability and the Medical Device Plug-n-Play Program, Massachusetts General Hospital, Harvard Medical School**

Emergency health care management use cases for M&S can be used to support effective planning and development. Applications of M&S include patient flow within or between institutions. One need to support M&S applications is the real-time transfer of data. High-acuity distributed systems do exist, but not yet in health care. Examples include air control, satellite tracking, and others. An essential requirement for such systems is interoperability, which must extend all the way to medical devices and the patient. Medical devices are key data sources in health care, and can be better utilized to deliver care. Many improvements in patient safety and health care efficiency require systems solutions that cannot be implemented due to lack of interoperability of medical devices and systems, especially in high-acuity settings. The ability to integrate the clinical environment is an essential step toward creating error-resistant systems.

At CIMIT (Center for Integration of Medicine and Innovative Technology), researchers have developed a prototype “Operating Room (OR) of the Future,” which is designed to study workflow and process. One conclusion from this prototype was that comprehensive integration of data from clinical and environmental systems can prevent errors and inefficiencies (see Figure 14-1.) Certain clinical scenarios demonstrate the potential benefits of interconnected medical devices. During cardio-pulmonary bypass, for example, the patient is switched from the anesthesia machine ventilator to the bypass machine, and then back again. There have been cases where the team forgot to turn on the ventilator after the patient was transitioned off the bypass machine. A smart system would provide a warning if the ventilator was off and bypass pump flow was zero. The use of patient-controlled analgesia (PCA) – pumps that deliver opioid – is another example. The problem with these devices is that patients or family members may press the delivery button by accident, potentially leading to overmedication and adverse effects such as respiratory depression. PCA devices could be linked to patient monitors that would detect respiratory depression and limit opioid delivery.

Two capabilities of medical device interoperability are required to mitigate these hazards. One is bi-directional medical device data communication. The second is medical device control capability to permit the integration of medical devices into networks that produce “error resistant” systems. The CIMIT Program on Interoperability and the Medical Device Plug-n-Play was established to lead the adoption of open standards to support medical device interoperability; to define a regulatory pathway in partnership with the U.S. Food and Drug Administration (FDA) and other regulators; to elicit clinical requirements for the proposed interoperable solutions to maintain focus on patient safety; and to use the vendor-neutral laboratory to evaluate standards and solutions, and model clinical use cases.

Standards for the Integrated Clinical Environment (ICE) have been drafted by the Program. The standard is for management of a network of medical devices in support of a single patient in the ICE. The standards establish general principles for design, verification, and validation of a model-based integration system that enables the creation of an Integrated Clinical Environment.

# Movement of Patients and Data Within an Institution

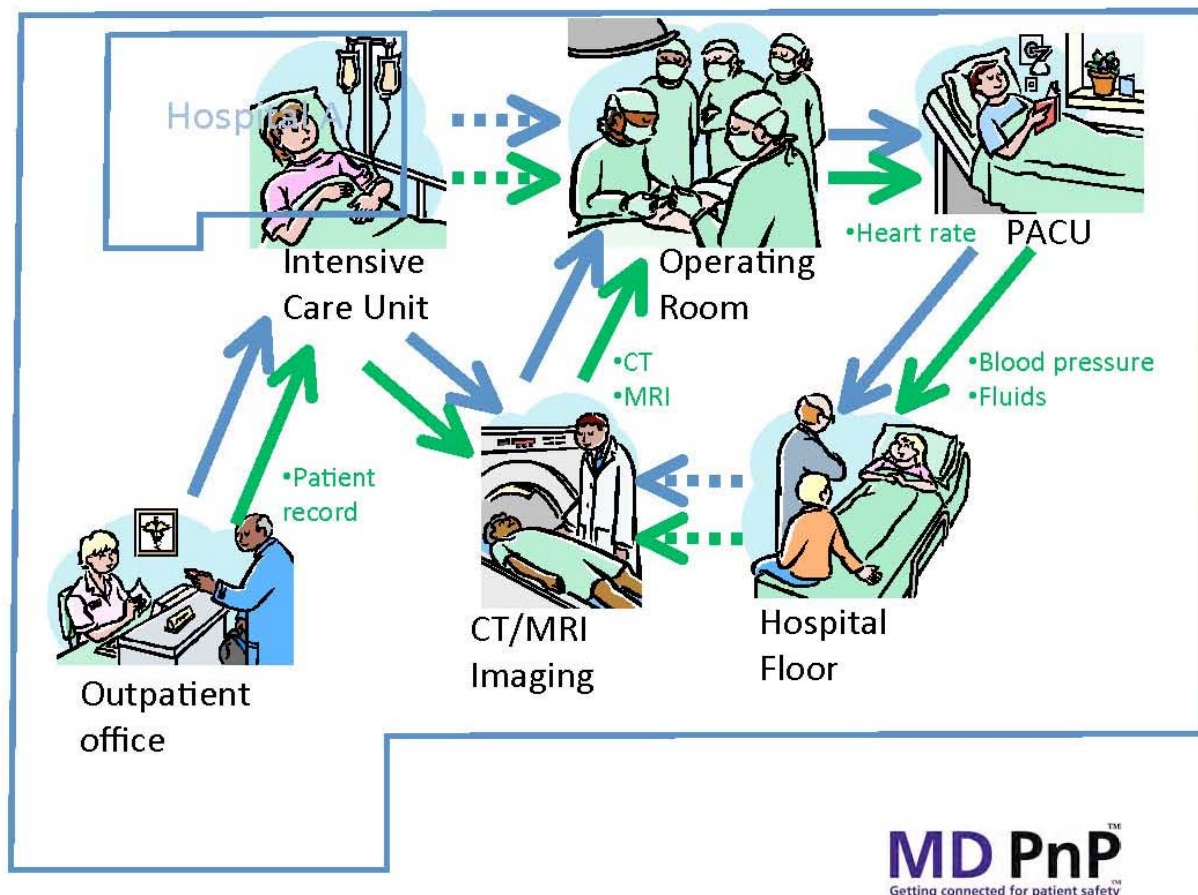


Figure 14-1: Movement of Patients and Data within an Institution



## **15 BREAKOUT SESSIONS/CHARGE TO THE GROUP: CASE STUDY GROUP REPORTS AND RECOMMENDATIONS**

Workshop participants broke into six groups to discuss specific features of M&S in emergency management and health care systems, and to suggest a starting place for the development of standards and guidelines. The six topics were determined by the workshop organizing committee to fill the most prominent needs for standards and guidelines. These six topics are:

- public health data requirements for modeling and simulation
- data requirements for modeling and simulation in emergency management and health care systems
- facilities-based modeling and simulation planning for disaster preparedness
- specifications for modeling, simulation, and gaming
- modeling and simulation needs assessment for health care systems – clinical needs
- modeling and simulation needs assessment for health care systems – engineering needs

The results of these work groups, summarized below, represent a starting point, a foundation for continuing discussion and research into the development of standards and guidelines for M&S in emergency management and health care systems.



## **15.1 PUBLIC HEALTH DATA REQUIREMENTS FOR MODELING AND SIMULATION**

Group 1 was asked to consider what data would be needed for M&S by public health departments when developing emergency response plans. Public health departments are charged with detecting changes in the need/demand for health care services, and making sure that need/demand is met with appropriate response. M&S can provide direction for designing systems to determine need/demand and response capacity, to examine what-if scenarios and to add predictive capabilities. (Planners should distinguish between objective need and subjective demand.)

In terms of charting the ability of public health systems to respond to a surge, necessary inputs include detailed demographics of the population and morbidity patterns by time and place. These data are generally available. On the response side of the public health equation – focusing on pre-hospital and hospital care – data sets exist but vary widely from state to state. Some states have county level data of hospital admissions which include primary and secondary diagnoses. However, the data generally do not describe the specialty services patients received. To accommodate M&S requirements, tags should be added to patient data that include information on specialty services and admission and discharge times.

On the capacity side, data exist describing the number of hospitals in an area and whether they have emergency departments. What services are available within a hospital and how many beds each facility has is generally not known. For M&S, public health departments need accurate, timely information on number and types of available beds. In terms of workforce, the number of physicians, nurses and other health care providers is unknown too in many cases. Physicians who do not practice fulltime should be identified for modeling purposes, perhaps through licensure registries. Each state should have a center where these data are housed, and staff who oversees the data and accommodates data retrieval.

While the list below shows M&S data requirements from a public health perspective, data needs may vary depending on the specific nature of the modeled emergency. Also, it should be recognized that M&S dealing with health emergencies typically involves collaboration of multiple public and private agencies.

### Demographics

- Current age and sex distribution
- Population density across target area

### Health patterns

- Disease specific morbidity rates
- Health care utilization statistics

### Emergency event

- Characteristics of targeted health threat
- Presumptive community reaction

### Response capacity

- Characteristics of health care facilities
- Size and capabilities of health care workforce

## **15.2 DATA REQUIREMENTS FOR MODELING AND SIMULATION IN EMERGENCY MANAGEMENT AND HEALTH CARE SYSTEMS**

The task of Group 2 was to create an initial set of data requirements for modeling and simulating emergency management and health care systems. The group discussed the topic in relation to a proposed scenario: a hospital nurse receives a pamphlet in the mail regarding M&S, and (s)he becomes interested in creating a simulation for handling an emergency at their hospital or unit; what data does the hospital need to give the engineers to create and run a simulation?

The goals of M&S identified by the group for this scenario include capacity analysis, and determining the hospital's needs from outside entities. Data requirements were divided into inputs and outputs. The inputs required from the hospital include data from:

- Admissions
- Discharge
- Insurance
- Social Services Office
- Management
- Operations manager

Defining the roles of personnel was also considered important, including:

- Nurses
- Doctors
- Emergency managers
- Security personnel
- Volunteers
- Technicians
- Administrators
- Transportation personnel

Existing data should be identified, and the format of existing data is critically important to the creation of M&S tools. Data types must be defined. These include data from admissions, patient treatment, and management.

Admissions office:

- Patient types
- Number of patients
- Time of arrive – should be further normalized for model

Patient treatment:

- Time patient leaves
- Total duration of day (waiting time, examination time, treatment time)
- Location of patient
- Staff responsible

Management:

- Number of hospital beds (Emergency Department (ED), Intensive-care Unit (ICU), general)
- Hospital layout
- Capacity of waiting area
- Capabilities and services

- Equipment (medical, such as CT, X-ray, MRI; transportation, such as ambulance, wheel chair)
- Blood supply (type and amount available)
- Operations (call list, on-duty personnel, incoming shifts/personnel, shift schedule)
- Alternative facility resources

The output data requirements were divided into the categories of throughput, utilization rate, patient acceptance rate, and bottlenecks.

Throughput:

- Patients per time unit
- Total patients treated
- Patients successfully discharged

Utilization rate:

- Staff
- Beds
- Equipment

Bottlenecks also include the exhaustion of resources. For example, what happens if the hospital runs out of blood during an emergency response?

## **15.3 FACILITIES-BASED MODELING AND SIMULATION PLANNING FOR DISASTER PREPAREDNESS**

Group 3 discussed an approach to developing a plan to deal with a major disaster from the perspective of facilities and design. Each of the concepts they developed could be evaluated with M&S to test different scenarios, and the impact of choices. For example, one could model the impact of resource utilization on the surrounding area. The features of developing an emergency preparedness plan for facilities include:

- Defining goals of the plan
- 
- Reaching agreement among participants on a glossary of terms
- 
- Isolating specific types of disasters that the plan would consider
  - Different types of disaster have highly specific characteristics
  - Need specialist on team for each type of disaster to be included
- 
- Identify decision makers up front
  - For creating the plan, for adopting the plan, and for implementing the plan
- 
- Identify major decision points
  - On a timeline, schedule or budget
- 
- Identify data required, depending on the complexity and scope of problem
- 
- Identify codes, and agencies that monitor codes that may impact elements of the plan
  - For example, repurposing of spaces may be necessary, and this must be done in compliance with codes and regulations
- 
- Identify resources
  - Internal resources in terms of staff and equipment
  - Dual-purpose equipment
  - In-house reserve resources over which the facility has control
  - Resources and collaborators outside facility
- 
- Create a database of all potential care space within a certain zone– facility, city, region, state
  - E.g., Outpatient surgical clinics could be identified and incorporated into response plan to serve trauma centers
- 
- Determine how all collaborators will work together and communicate
- 
- Within a specific facility, identify fall back positions
  - For example, what other space within the facility can be repurposed if ED is overwhelmed
  - Parking garage, ambulatory care spaces, and other clinical spaces or facilities which are not utilized on a 24/7 basis.

## **15.4 SPECIFICATIONS FOR MODELING, SIMULATION, AND GAMING**

The task of Group 4 was to create an initial set of specifications for modeling, simulation and gaming in the context of emergency management and health care systems. In other words, what should expectations be of the M&S process? The group divided specifications into user and developer categories. These categories encompass both needs and deliverables: what can users expect to get, and what do they need to provide; what do developers expect to get, and what do they need to provide.

User responsibilities and requirements include:

- Requirements:
  - Problem and intended use for model
    - Is it intended for decision support, optimization, etc.
  - Budget and schedule
  - Who will use the model
  - Level of user interaction: live, virtual
  - Run time
  - Extensibility/lifecycle
- Data
  - Availability
  - Accessibility
- Management buy-in (critical)
  - Physicians
  - Nurses
  - Administrators
  - Subject matter experts commitments
    - Testers
    - Continuing user group
- Analysis output
  - Form/field

Developer responsibilities and requirements include:

- Scope of work
  - Milestones
    - Conceptual model
    - Prototype
    - First data sets
    - Other key events
- Articulate modeling approach
  - Supports dialogue with customer
  - Alternative approaches, pros and cons
- Conceptual model: set of materials to describe the model
  - Set up
  - Algorithms
  - Fidelity
  - Interaction of elements
- Outputs to generate
- Risk assessment
- Data requirements
  - What's available, what's achievable
- Validation
- Deliverables:

- User interface
- One or more data sets
- Training
- Licensing
- Support plan
- Assumptions, extrapolations

Expectations:

- The rationale underlying these specifications is that many M&S projects fail due to differences between expectations of the client and what is achievable by a model.
- Specifying expectations allows M&S to achieve small successes throughout the process.
- Other key considerations
  - The challenge of attempting to create a model that works in real time or reacts quickly due to complex considerations, expectations of “real-time” responsiveness should be discussed
  - Major underlying factors always include the visualization of output and the availability of data.

## **15.5 MODELING AND SIMULATION NEEDS ASSESSMENT FOR HEALTH CARE SYSTEMS – CLINICAL NEEDS**

Group 5 considered the question of what clinicians want from M&S teams.

The group settled on three main categories of goals:

- imparting cultural change
- multi-patient simulation
- “med-arch-sim,” or medical-architecture-simulation.

Changing current medical culture will be key driver of improving patient safety and the efficiency of care delivery.

- One way to approach this problem is through multiple patient simulations to help clinicians shift from tactical thinking (their individual patient) to strategic thinking (multiple patients).
- Cognitive task analysis will aid the process of redesigning the hospital environment and organization.

“Med-arch-sim” is a term the group created to describe an ultra-high quality model of future state(s) to show the next generation of clinicians the possibilities of a new environment.

There are three domains that emerged during the group discussion:

- facilities (or architecture)
- simulation
- medical (or clinical)

Each domain has its own tools, but no tools exist to bring all three domains and correlating needs together.

- Architecture Tools
  - 2D Plans
  - 3D Renderings
- Simulation Tools
  - Conceptual diagrams and models
  - Mathematical models
  - Dynamic models
  - Programming paradigms
  - Analysis techniques
- Medical Tools
  - Patients
  - Medical simulations
  - Virtual reality
  - Tools for training

Value of multi-domain tool:

- architects could leverage both quantitative M&S and clinical aspects of design
- clinicians could draw on facilities and simulation data
- the simulation modelers could bring both architectural and clinical aspects to bear on their work.

The need for such a tool represents an opportunity for future development. The group issued a high-level charge to M&S for the development of a “med-arch-sim” real-time animation model to bring together these different cultures and environments.

The group determined that M&S tools should support multiple clinical goals:

- Team training
- Support task and skill training – from a systems perspective, modeling the interaction between tasks and devices
- Enable analysis of clinical pathways to support quantitative analysis
- Assess the physical environment in relation to delivery of care
- Create tools to assess the potential patient safety and error-resistance that could be achieved with systems integration, safety interlocks, and closed workflow loops
- Tools should be useful, useable, and used by the appropriate trained clinicians.



## **15.6 MODELING AND SIMULATION NEEDS ASSESSMENT FOR HEALTH CARE SYSTEMS – ENGINEERING NEEDS**

Group 6 considered the M&S needs assessment from an engineering perspective.

The participants considered this task in a phased approach:

- Short term (less expensive)
- Medium term (intermediate expensive)
- Long term (expensive).

Complexity increases from short- to long-term in relation to model development.

The terms and use of M&S applications for health care systems:

- Short Term
  - Complexity: Low; small problems with isolated scope
  - Analysis: Parametric
  - Design: Conceptual
  - Training: Familiarization
  - Operations: None
- Medium Term
  - Complexity: Intermediate; multiple components of system and mutual dependencies; semantic interoperability
  - Analysis: Quantitative analysis
  - Design: Evaluation of alternatives
  - Training: Task training and process refinement
  - Operations: Limited
- Long Term
  - Complexity: High; distributive enterprise dynamic level representations
  - Analysis: Predictive credibility
  - Design: Detailed system design (level of floor, instrumentation)
  - Training: Team and distributed collaborator training
  - Operations: Provide real-time operations support (suite of M&S tools, different levels of representation)

### **The enterprise business practice view**

The group's intention was to provide for any given activity the expected processes and deliverables. The group did not consider the table completed or thorough; it represents a framework for considering an analysis of M&S needs, and a starting place in this process.

- Task (activity): Deduce stakeholder needs
  - How (processes): Collaborate with stakeholder
  - Results (deliverables): Initial systematic M&S needs elicitation process and result
- Task (activity): Document conceptual mission space
  - How (processes): Semantically correct models, interoperability; challenging to accomplish
  - Results (deliverables): Practices, strong cultural commitment
- Task (activity): Suggest enterprise best practice for investment, development, qualification, and use
  - How (processes): Research existing standards, etc.
  - Results (deliverables): Best practices for enterprise system

## 16 CONCLUSION

Mr. Charles McLean concluded the workshop with thanks to the participants for their contributions and recommendations. NIST will endeavor to follow-up on the next steps recommended by workshop breakout groups (listed earlier in the description of the breakout sessions).

This workshop provided a strong foundation for collaborative follow-on efforts among government agencies, the response community, health care industry, and academia to:

- identify information sources, simulation systems, and data requirements
- develop a health care simulation framework
- develop standards for interoperability and integration
- develop and demonstrate distributed simulations using commercial simulation software and the simulation framework

The workshop brought together a number of people from government agencies, academia, and industry. Based on the discussions and feedback received from the attendees, the workshop succeeded in promoting the concept of the simulation framework.

It is too early to determine the strength of collaborative relationships established at the workshop, but the workshop did succeed in creating a network of people working in the area of modeling and simulation for emergency response health care applications. Some follow-up meetings have already taken place and more are being arranged. It is hoped that tangible collaborations will be established in the future to address the critical steps toward building a simulation framework for emergency response and developing necessary simulation standards for interoperability and integration of emergency response requirements.

As mentioned in the Preface of this document, this “Modeling and Simulation for Emergency Management and Health Care Systems” workshop is the first technical interest group (TIG) meeting on health care. With the strong interest expressed by the participants of this workshop, NIST is planning the next TIG workshop on this topic in 2010.

## APPENDIX A. MEDICAL AND HEALTH CARE ORGANIZATIONS

The following is a partial list of medical and health care organizations that support different levels of emergency response responding to unanticipated events that may result in injury and/or loss of human lives.

Entity Type:

- Multinational bodies:
  - World Association for Disaster and Emergency Medicine
  - World Health Organization (WHO)
- Governmental agencies or departments:
  - Centers for Disease Control and Prevention (CDC)
    - Bioterrorism Preparedness and Response
    - Emergency Preparedness and Response Branch
    - Environmental Health Services Emergency Planning Site
  - National Institutes of Health (NIH)
    - National Institute of Allergies and Infectious Diseases
  - U.S. Department of Health and Human services
    - Office of the Assistant Secretary for Preparedness and Response Emergency Operations
    - Agency for Health Care Research and Quality (AHRQ)
    - Health Insurance Portability and Accountability Act (HIPAA)
    - Healthfinder.gov
    - Administration for Children and Families
    - National Disaster Medical System
  - U.S. Food and Drug Administration (FDA)
  - U.S. Public Health Services (PHS)
  - State Departments of Public Health (<http://www.phppo.cdc.gov/phtn/sites.asp>)
- Military services:
  - Defense Threat Reduction Agency
  - Military Vaccine Agency
  - Modeling and Simulation Information Analysis Center
  - U.S. Department of Veterans Affairs
    - Emergency Management Strategic Health Care Group
- Private sector organizations:
  - Academic Center for Public Health Preparedness
  - American Academy of Emergency Medicine
  - American Academy of Pediatrics, Bioterrorism, Terrorism Resources
  - American College of Contingency Planners
  - American Hospital Association
    - Association for Healthcare Resources & Materials Management
  - American Medical Association
    - Center for Public Health Preparedness and Disaster Response
  - American Red Cross
  - American Society of Professional Emergency Planners
  - Center for Public Safety Excellence (CPSE)
    - Commission on Fire Accreditation International
    - Commission on Professional Credentialing
  - Center for Integration of Medicine and Innovative Technology (CIMIT)
  - Greater New York Hospital Association
  - Louisiana Hospital Association
  - Massachusetts Hospital Association
  - National Association of County and City Health Officials
  - National Associations of State EMS Directors

- National Bioterrorism Civilian Medical Response Center
- National Nurse Emergency Preparedness Initiative
- Nevada Hospital Association
- The RAND Center for Domestic and International Health Security
- Yale New Haven Health Center for Emergency Preparedness & Disaster Response
- University of Pittsburgh Medical Center, Center for Biosecurity
  
- Selected healthcare facilities and systems:
  - Caritas Christi Healthcare System
  - Catholic Health Initiative
  - Johns Hopkins Hospital and Healthcare System
  - Intermountain Healthcare
  - Kaiser Permanente

Public Regulatory:

- The Joint Commission Resources
- State and local Departments of Health

Public Advisory:

- Healthcare Advisory Board
- Institute for Healthcare Care Improvement (IHI)
- Institute of Medicine (IOM)
- Robert Wood Johnson Foundation
- The Leapfrog Group

## APPENDIX B. RELEVANT HEALTH CARE STANDARDS AND EFFORTS

The following table is a partial list of established standards and specifications that may be relevant to modeling and simulation for emergency management with focus on health care. The name, information category, description, standardization status, and responsible organization of each specification or standard are included in the table.

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
The International Classification of Diseases	Operational guidelines	An official system of assigning codes to diagnoses and procedures associated with hospital utilization.	Standard: Ninth Revision, Clinical Modification (ICD-9-CM)	The National Center for Health Statistics (NCHS), and Centers for Medicare and Medicaid Services.
Digital imaging and communications in medicine (DICOM)	General purpose integration interfaces	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.	Industry specification: DICOM 3.0	American College of Radiology (ACR), and National Electrical Manufacturers Association (NEMA)
Health Level Seven (HL7) Standards	Domain-specific integration interfaces	A specification for the exchange, management, and integration of electronic healthcare information.	Standards: 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	Health Level Seven (HL7), and American National Standards Institute (ANSI)

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Introductory resource guide for implementing the Health Insurance Portability and Accountability Act (HIPAA) Security Rule	Operational guidelines	Standards for the security of electronic health care information. It specifies a series of administrative, technical, and physical security procedures for covered entities to use to assure the confidentiality of electronic protected health information.	Standard: SP 800-66 REV 1	National Institute of Standards and Technology (NIST)
The Americans with Disabilities Act (ADA) Standards for Accessible Design	Operational guidelines	Guidelines for accessibility to places of public accommodation and commercial facilities by individuals with disabilities. These guidelines are to be applied during the design, construction, and alteration of such buildings and facilities.	Standards: ANSI A117.1-1980, and ADA Standards for Accessible Design	U.S. Department of Justice, and American National Standards Institute (ANSI)
Interim Life Safety Measures (ILSM)	Operational guidelines	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.	Standard: ILSM	The Joint Commission Resources

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Infection Control Risk Assessment (ICRA)	Operational guidelines	Guidance with general information on risks and possible mitigation strategies for remote use of and access to (EPHI) Electronic Protected Health Information.	Standard: ICRA	Department of Health and Human Services (DHHS)
Emergency management drills	Operational guidelines	A plan that describes a hospital's approach to conduct drills to test emergency management.	Standard: EC.4.20	The Joint Commission Resources
Emergency management planning	Operational guidelines	A plan that describes a hospital's approach to emergencies in the hospital or in its community.	Standard: EC.4.10	The Joint Commission Resources
Emergency electrical power source	Operational guidelines	A plan that describes the requirements of a hospital's emergency power system.	Standard: EC.7.20	The Joint Commission Resources
Maintenance, testing, and inspection requirements for hospital emergency power system	Operational guidelines	A plan that identifies how a hospital maintains, tests, and inspects its emergency power system.	Standard: EC.7.40	The Joint Commission Resources
Business continuity/disaster recovery plan	Operational guidelines	A plan that describes a hospital's continuity of information when information systems are interrupted.	Standard: IM.2.30	The Joint Commission Resources

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Patient flow management	Operational guidelines	Plans that identify and mitigate impediments to efficient patient flow throughout the hospital.	Standard: LD.3.15	The Joint Commission Resources
Infection control	Operational guidelines	A plan that manages an ongoing influx of potentially infectious patients over an extended period.	Standard: IC.6.10	The Joint Commission Resources
Disaster privileges	Operational guidelines	A plan that identifies the option to grant disaster privileges.	Standard: MS.4.110	The Joint Commission Resources
Drawing Interchange File (DXF) Formats	General purpose integration interfaces	A specification for exchange of radiology images and other medical information between computers.	Industry specification: AutoCAD, v.u.22.1.01	Autodesk, Inc.
WMD, Emergency Management and Medical Websites ( <a href="http://www.ynhhs.org/emergency/US_DHHS_web_sites.pdf">http://www.ynhhs.org/emergency/US_DHHS_web_sites.pdf</a> )	Reference resource	A comprehensive list of internet sites of use for emergency planning and in particular Weapons of Mass Destruction (WMD) and medical emergency planning.	Reference resource: Yale New Haven Health System	Yale New Haven Center for Emergency Preparedness and Disaster Response
Standard Guide for Hospital Preparedness and Response	Operational guidelines	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.	Standard: ASTM E2413 – 04 (2009)	ASTM International



## APPENDIX C. RELEVANT ARCHITECTURE STANDARDS AND EFFORTS

The following table is a partial list of established standards and specifications that may be relevant to modeling and simulation for architectural design for health care facilities. The name, information category, description, standardization status, and responsible organization of each specification or standard are included in the table.

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
The Industry Foundation Classes (IFC)	Domain-specific Integration Interfaces	A product data model to facilitate interoperability in the building industry. Its data requirements include disciplines involved, life-cycle stages, level of detail required, and software application used.	Industry specification: The IFC2x, Edition 3	The International Alliance for Interoperability (IAI)
The CIMSteel Integration Standards Release 2 (CIS/2)	Domain-specific Integration Interfaces	A product model and electronic data exchange file format for all parties of the steel supply chain involved in the construction of steel framed structures.	Industry specifications: SCI-P265:2003; SCI-P266:2003; SCI-P268:2003; SCI-P269:2003	The Steel Construction Institute (SCI)
National Building Information Model (NBIM) Standards	Domain-specific Integration Interfaces	A specification that supports business processes and information exchanges of information employed during all phases of the facility lifecycle. Nomenclature specific to North American business practices is used.	Industry specifications: SCI-P265:2003; SCI-P266:2003; SCI-P268:2003; SCI-P269:2003	National Institute for Building Sciences (NIBS)

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
International Building Code, 2003	Operational guidelines	A specification on structural and fire- and life-safety provisions covering seismic, wind, accessibility, egress, occupancy, roofs, etc.	Industry specification: ICC IBC-2003	International Code Council
CityGML	Domain-specific Integration Interfaces	A specification for exchange and storage of Virtual 3D city models.	Industry specification	The Open Geospatial Consortium, Inc (OGC)
The Americans with Disabilities Act (ADA) Standards for Accessible Design	Operational guidelines	Guidelines for accessibility to places of public accommodation and commercial facilities by individuals with disabilities. These guidelines are to be applied during the design, construction, and alteration of such buildings and facilities.	Standards: ANSI A117.1-1980, and ADA Standards for Accessible Design	U.S. Department of Justice, and American National Standards Institute (ANSI)
Interim Life Safety Measures (ILSM)	Operational guidelines	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.	Standard: ILSM	The Joint Commission Resources
Emergency electrical power source	Operational guidelines	A plan that describes the requirements of a hospital's emergency power system.	Standard: EC.7.20	The Joint Commission Resources

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Maintenance, testing, and inspection requirements for hospital emergency power system	Operational guidelines	A plan that identifies how a hospital maintains, tests, and inspects its emergency power system.	Standard: EC.7.40	The Joint Commission Resources
Governmental Unit Boundary Exchange Standard	Domain-specific Integration Interfaces	A specification for establish the content requirements for the collection and interchange of Government unit and legal entity boundary data.	Government Specification: Governmental Unit Boundary Data Exchange Standard (January/2003)	Federal Geographic Data Committee (FGDC)
Drawing Interchange File (DXF) Formats	General purpose integration interfaces	A specification for exchange of radiology images and other medical information between computers.	Industry specification: AutoCAD, v.u.22.1.01	Autodesk, Inc.
ESRI Shapefile Technical Description	Document formats	A geospatial vector data format for geographic information systems software.	Industry specification	Environmental Systems Research Institute (ESRI)
Spatial Data Transfer Standard (SDTS)	Document formats	A standard for the exchange of spatial data between different computing platforms.	Standard: FIPS 173	National Institute of Standards and Technology (NIST), and U.S. Geological Survey (USGS)
Standard for a United States National Grid (USNG)	General purpose Integration Interfaces	A system of geographic grid references for developing location-based services within U.S.	Government specification	Federal Geographic Data Committee (FGDC)
Green Guide for Health Care (or Green Guide)	Operational guidelines	The Green Guide for Health Care is a best practices guide for healthy and sustainable building design, construction, and operations for the healthcare industry.	Green Guide for Health care, Version 2.2	gghc.org

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
GeoTIFF	Document formats	A metadata format, which provides geographic information to associate with the image data.	Industry specification	GeoTIFF community (over 160 different remote sensing, GIS, cartographic, and surveying related organizations.)
OpenGIS Specifications	General purpose Integration Interfaces	Technical documents that detail interfaces and encodings to enable geoprocessing technologies to interoperate.	Industry specification	The Open Geospatial Consortium, Inc (OGC)
Vector Product Format (VPF)	General purpose Integration Interfaces	A format, structure, and organization for large geographic databases that are based on a georelational data model and are intended for direct use.	Military standard: MIL-STD-2407	National Geospatial-Intelligence Agency
Content Standard for Digital Geospatial Metadata (CSDGM)	General purpose Integration Interfaces	A specification that provides a common set of terminology and definitions for the documentation of digital geospatial data.	Standard: FGDC-STD-001-1998	Federal Geographic Data Committee (FGDC)
Computer Graphics Metafile (CGM)	Document formats	A specification for storage and exchange of virtual two-dimensional static pictures.	Standard: ANSI/ISO 8632-1992	International Standardization Organization (ISO), and American National Standards Institute (ANSI)

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Extensible Markup Language (XML)	Document formats	A simple, flexible text format derived from SGML for exchange of a wide variety of data on the Web and elsewhere.	Industry specification: XML 1.0 and XML 1.1	World Wide Web Consortium (W3C)
Flexible Image Transport System (FITS)	Document formats	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.	Government specification	National Aeronautics and Space Administration (NASA)
Graphics Interchange Format (GIF)	Document formats	A data stream-oriented format for the storage and transmission of raster-based graphics information.	Industry specification: GIF89a	CompuServe, Incorporated
Hierarchical Data Format (HDF)	Document formats	A set of file formats designed to facilitate sharing of scientific data. HDF4 - a file format that supports raster image, array, palette, group, annotation, and multidimensional table. HDF5 - a file format and library, includes 2 primary objects, dataset (a multi-dimensional array of records ) and group (a structure for grouping objects.)	Industry specification: GIF89a	National Center for Supercomputing Applications (NCSA), and The HDF Group (THG)

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Joint Photographic Experts Group (JPEG)	Document formats	An image compression format used to transfer color photographs and images over computer networks.	Standard: ISO/IEC IS 10918-1   ITU-T Recommendation T.81	International Organization for Standardization (ISO), and Joint Photographic Experts Group (JPEG)
Portable Network Graphics (PNG)	Document formats	An extensible file format for the lossless, portable, well-compressed storage of raster images. It supports online viewing applications.	Standard: ISO/IEC 15948:2003	International Organization for Standardization (ISO), and World Wide Web Consortium (W3C)
Tagged Image File Format (TIFF)	Document formats	A public domain tag-based file format for storing and interchanging raster images.	Industry specification: TIFF6.0	Adobe Systems
The Collaborative Design Activity (COLLADA)	Document formats	A public domain, Digital Asset schema for interactive 3D applications that contain features including programmable shader effects and physics simulation.	Standard: ISO/IEC 15948:2003	International Standardization Organization (ISO), and The Khronos Group
Truevision TGA File Format or Truevision Advanced Raster Graphics Adapter (TARGA) File Format	Document formats	A format for defining raster or bitmap images.	Industry specification: TGA, Version 2.0	Truevision (now Pinnacle Systems)

Standard/Specification Name	Information Category	Description	Standardization	Responsible Organization
Web Feature Service (WFS)	General purpose Integration Interfaces	An interface service for data access and manipulation operations on geographic features, using HTTP as the distributed computing platform.	Industry specification: OGC 04-094, Version 1.1.0	The Open Geospatial Consortium, Inc (OGC)
Web Map Service (WMS)	General purpose Integration Interfaces	An interface service in support of the creation and display of registered and superimposed map-like views of information that come simultaneously from multiple remote and heterogeneous sources.	Industry specification: OGC 03-109r1, Version 1.3.0; ISO/DIS 19128	The Open Geospatial Consortium, Inc (OGC)
X3D	General purpose Integration Interfaces	An is an open standard for 3D content delivery. It 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.	Industry specification: ISO/IEC 19774 (Humanoid Animation); ISO/IEC 19775 (the abstract specification); ISO/IEC 19776 (X3D XML and VRML encodings)	International Standardization Organization (ISO), and The Web3D Consortium
Guidelines for Design and Construction of Health Care Facilities	Operational guidelines	A specification referenced by architects, engineers, and health care professionals who are planning new or renovated health care facility construction.	Guidelines for Design and Construction of Health Care Facilities, The 2006 Edition	American Institute of Architects (AIA)
Massachusetts Department of Public Health	Operational guidelines	Mirrors AIA Guidelines for Design and Construction of Health Care Facilities	Based on AIA Guidelines	Massachusetts Department of Public Health

Life Safety Code (NFPA 101)	Operational guidelines	A specification provides the rules for sprinklers, alarms, egress, emergency lighting, smoke barriers, special hazard protection--the complete range of construction, protection, and occupancy features that impact lives every day.	The 2009 NFPA 101: Life Safety Code	National Fire Protection Association
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## APPENDIX D. ACRONYMS AND ABBREVIATIONS

ADA	Americans with Disabilities Act
AHRQ	Agency for Health Care Research and Quality
AIA	American Institute of Architects
ANSI	American National Standards Institute
ASPR	Assistant Secretary for Preparedness and Response
BBN	Bayesian Belief Network
CDC	Centers for Disease Control and Prevention
CEDRS	Comprehensive Emergency and Disaster Response Simulation
CGM	Computer Graphics Metafile
CIMIT	Center for Integration of Medicine and Innovative Technology
CIS	The CIMSteel Integration Standards
CMSD	Core Manufacturing Simulation Data
COLLADA	The Collaborative Design Activity
COMET	Combat Medic Training System
CSDGM	Content Standard for Digital Geospatial Metadata
DHHS	Department of Health Human Services
DHS	U.S. Department of Homeland Security
DICOM	Digital Imaging and Communications in Medicine
DISTEX	Distant Exercises
DoD	U.S. Department of Defense
DXF	Drawing Interchange File Format
ECCC	Emergency Care Coordination Center
ED	Emergency Department
EPA	U.S. Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FDA	U.S. Food and Drug Administration
FEA	Finite Element Analysis
FGDC	Federal Geographic Data Committee
FITS	Flexible Image Transport System
GAO	U.S. Government Accountability Office
GGHC	Green Guide for Health Care
GIF	Graphics Interchange Format
GRRRS	Goals, Roles, Relationships, Resources, Structure
HAZMAT	Hazardous Material
HCO	Health Care Organization
HDF	Hierarchical Data Format
HEAT	Health Care Efficacy Architectural Analysis Tool
HIPAA	Health Insurance Portability and Accountability Act
HL7	Health Level Seven
HUREVAC	Hurricane Evacuation
IAI	The International Alliance for Interoperability
IC	Infection Control
ICE	Integrated Clinical Environment
ICD	The International Classification of Disease
ICRA	Infection Control Risk Assessment
ICU	Intensive-Care Unit
IEEE	Institute of Electrical and Electronics Engineers
IFC	The Industry Foundation Classes
IHI	Institute for Health Improvement
ILSM	Interim Life Safety Measures
IOM	Institute of Medicine

ISO	International Standardization Organization
IT	Information Technology
JPEG	Joint Photographic Experts Group
MATCH	Multidisciplinary Assessment of Technology Center for Healthcare
M&S	Modeling and Simulation
NASA	National Aeronautics and Space Administration
NBIM	National Building Information Model
MMOG	Massively Multiplayer Online game
NCHS	The National Center for Health Statistics
NCSA	National Center for Supercomputing Applications
NFPA	National Fire Protection Association
NIBS	National Institute of Building Sciences
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
OGC	The Open Geospatial Consortium, Inc.
OR	Operating Room
PAHPA	Pandemic All Hazards Preparedness Act
PCA	Patient-Controlled Analgesia
PDA	Personal Digital Assistant
PNG	Portable Network Graphics
POD	Point of Dispensing
RFID	Radio Frequency Identification
RIPS	Real-time Incident Preparedness
SCI	The Steel Construction Institute
SDTS	Spatial Data Transfer Standard
SOA	Service Oriented Architecture
SoS	System of Systems
TARGA	Truevision Advanced Raster Graphics Adapter File Format
TC3	Tactical Combat Casualty Care
THG	The HDF Group
TIFF	Tagged Image File Format
TIG	Technical Interest Group
UIMA	Unstructured Information Management Architecture
USGS	U.S. Geological Survey
USNG	Standard for a United States National Grid
VPF	Vector Product Format
WFS	Web Feature Service
WHO	World Health Organization
WMS	Web Map Service
W3C	World Wide Web Consortium
XML	Extensible markup Language

## Disclaimer

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