The Role of Integrated Modeling and Simulation in Disaster Preparedness and Emergency Preparedness and Response: The SUMMIT Platform

Jalal Mapar
Department of Homeland Security
Science and Technology Directorate, Washington, DC
Jalal.Mapar@dhs.gov

Keith Holtermann
Justin Legary
Federal Emergency Management Agency,
Washington, DC
Keith.Holtermann@fema.dhs.gov
Justin.Legary@fema.dhs.gov

Karim Mahrous, Katherine Guzman, Zach Heath,
Charles J. John, Steven A. Mier, Stephen Mueller,
Carmen M. Pancerella, Andrew Rothfuss, Nerayo
Teclemariam, Lynn I. Yang, Ann Yoshimura
Sandia National Laboratories, Livermore, CA
{kmmahro|kguzman|zheath|cjjohn|samier|snmuell|
carmen|arothfu|nptecle|liyang|asyosh}@sandia.gov

Gabriel R. Elkin
Adam S. Norige
Lars Fiedler
MIT Lincoln Laboratory, Lexington, MA
{gabee|anorige|lars.fiedler}@ll.mit.edu

***Abstract*—The Department of Homeland Security, Science and Technology Directorate (DHS S&T), in partnership with the Federal Emergency Management Agency (FEMA), and in collaboration with Sandia National Laboratories, has developed the Standard Unified Modeling, Mapping, and Integration Toolkit (SUMMIT) as a geo-agile platform that enables users to discover and reuse models, integrate them quickly and economically, and apply them in analyses to improve the planning and execution of large and small exercises, planning efforts, and eventually response operations. The SUMMIT technology is innovative and promises to reduce the exercise cycle time by more than an order of magnitude. SUMMIT has been deployed to support National Level Exercises, regional exercises, and international exercises in Sweden, revolutionizing how exercises are designed and conducted. SUMMIT is now in the transition stage, from DHS S&T to the FEMA National Exercise and Simulation Center (NESC), where it will become available to the emergency management community. It will support the National Preparedness System[1] and integrate with the NESC Technology Platform in support of local, state, regional and national level exercises.**

Keywords- modeling and simulation, exercise planning, disaster preparedness, emergency preparedness, SUMMIT, National Preparedness System, NESC Technology Platform.

I. INTRODUCTION

As jurisdictions continue to improve their level of preparedness and enhance their ability to respond to emergencies, there is an increasing reliance on drills, exercises and training to maintain and improve response planning and readiness, especially as funds continue to be less available.[1] [2] In recent years, the use of modeling and simulation (M&S) technologies has become a valuable asset in providing scientific data in the conduct of training and exercises. Additionally, many models, information management tools, and devices are being used both in exercise environments, and to support response and recovery operations (e.g., by improving situational awareness). Today, many nations and organizations have technology initiatives underway that are targeted at improving the entire preparedness and response cycle.

The Department of Homeland Security, Science and Technology Directorate (DHS S&T), in partnership with the Federal Emergency Management Agency (FEMA), and in collaboration with Sandia National Laboratories (Sandia), has developed the Standard Unified Modeling, Mapping, and Integration Toolkit (SUMMIT) as a geo-agile platform that enables users to discover and reuse models, integrate them

[1] Presidential Policy Directive 8 (PPD-8), which describes the Nation's approach to national preparedness, calls for a comprehensive approach to build and assess national preparedness through the National Preparedness System.[1] The National Preparedness System states: "By highlighting strengths and revealing gaps, exercises facilitate the Nation's ability to validate capabilities and evaluate progress toward meeting the National Preparedness Goal."

Co-sponsored by Department of Homeland Security, Science & Technology Directorate, Infrastructure Protection & Disaster Management Division and FEMA National Exercise and Simulation Center (NESC)

quickly and economically, and apply them in analyses to improve the planning and execution of large and small exercises, planning efforts, and eventually response operations. The SUMMIT technology is innovative and promises to reduce the exercise cycle time by more than an order of magnitude. SUMMIT is now in the transition stage, from DHS S&T to the FEMA National Exercise and Simulation Center (NESC)[3], where it will become available to the emergency management community.

II. SUMMIT VISION & ARCHITECTURE

SUMMIT is an integrated visualization and modeling and simulation software environment that allows users—including emergency planners, responders, and decision makers—to seamlessly access and visualize integrated suites of modeling tools and data sources for planning, exercise and eventually operational response. Specifically, SUMMIT can be used to easily and rapidly discover, integrate, configure, execute, view and reuse the results of the nation's modeling and simulation resources and related data. These capabilities can greatly enhance the quality, cost and efficiency of exercises and planning. For example, utilization of science-based models helps ensure a realistic grounding for exercises and other emergency management activities. Reuse of models and data (e.g., reusing a model that previously has been vetted in a different locale or another exercise) can greatly reduce the cost and time required for the exercise and planning cycles. In addition, the ability to rerun models enables "what-if" trade-off analyses that are crucial for effective response during an actual event. Figures 1 and 2 show example input and output screens from SUMMIT.

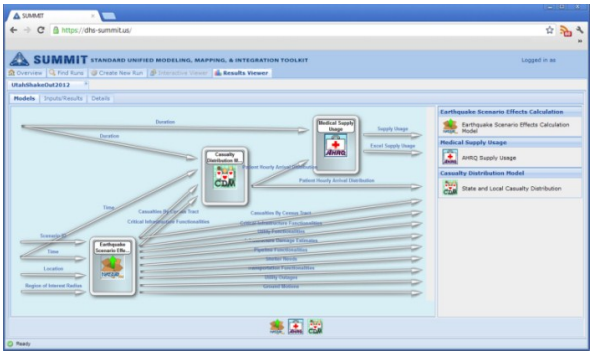

Figure 1. Example SUMMIT Input. SUMMIT template

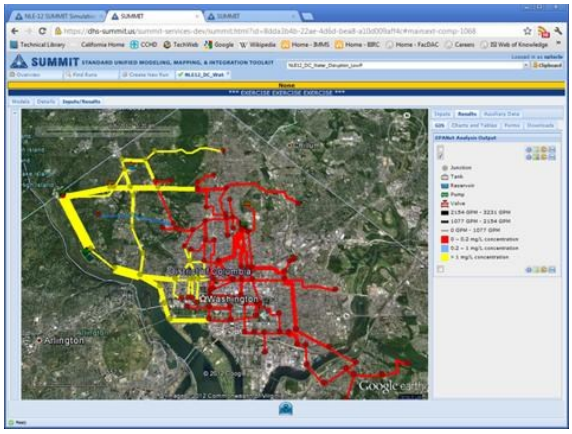

Figure 2. Example SUMMIT Output. Critical infrastructure network disruptions following an emergency incident

The SUMMIT framework is platform-neutral; users will be able to access models from most web browsers, and models can execute on a number of hardware platforms. With this type of framework, results can be delivered easily to a collaborating set of users to inform the scenario, and serve as exercise injects or data for decision-makers during exercise play.

The SUMMIT architecture (depicted in Figure 3) has three main components: the SUMMIT web-based clients, the SUMMIT server, and SUMMIT-accessible data and models.

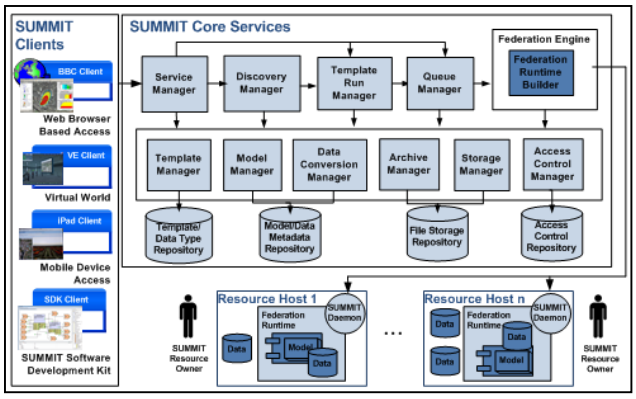

Figure 3. SUMMIT Architecture.

SUMMIT web-based clients allow users to connect to, configure, execute, and access the results of modeling and simulation runs on the SUMMIT system. The SUMMIT server maintains a repository of simulation templates and model results. A template is an abstract representation of an incident to be simulated. It provides a pattern or workflow for linking together and rendering interoperable

models and data to address that incident. The SUMMIT-accessible data and models are resources provided by model contributors that users can access through SUMMIT. The data and model components are the property of the model contributors and typically run on hosts that are remote to the SUMMIT server.

Additional customized clients can be created that make use of SUMMIT to provide exercise support, emergency response, and visualization capabilities to users. For example, mobile applications have been developed that access the SUMMIT server for scenario ground truth to support exercise play. Further details on this architecture can be found in [4] and [5].

III. SUMMIT Architectural Innovations

The SUMMIT architecture development strategy utilizes a spiral development process to draw upon emerging research and information in order to continually refine the SUMMIT framework. Thus, SUMMIT has been used to support exercises while the architecture has continued to mature. [6][8] A goal of SUMMIT is to provide a flexible service-oriented architecture by providing access to the proper set of utility services (see Figure 3) that enable users to discover modeling and simulation resources, configure and execute template runs, visualize and review results, and create what-if scenarios. A key design benefit of the SUMMIT architecture that enhances reusability is its ability to provide for separation of concerns (SoC) in the model development process. Traditionally when creating a computer simulation, the model designers need to develop for all parts of the process, spanning data type design, model development, model execution provisioning, and data visualization. SUMMIT breaks up this process into individual pieces, allowing developers to make use of existing capabilities or examples and interfaces when available, and provides a means to improve upon or replace existing implementations when they can be done better. This allows users to avoid being locked into a specific implementation. When a new capability is added to SUMMIT, it is often applicable and can be made use of by many resources that are already in the SUMMIT ecosystem.

The client-server nature of SUMMIT and the adoption of common, open web standards allows light-weight clients, for example, clients that execute within a web browser or on a mobile device, to make use of heavy-weight services and compute-intensive models making these models broadly accessible across a wide variety of platforms. This also cuts down on installation and sustainment costs.

IV. Deployments

SUMMIT has been deployed in exercises at the regional and national levels, and internationally. These deployments both illustrate SUMMIT's application and value to exercise planning and execution, as well as help identify new requirements.

National Level Exercise 2012 (NLE 12)

SUMMIT was deployed in conjunction with the FEMA NESC to support the National Level Exercise 2012, a cyber-attack scenario. SUMMIT provided scientifically-grounded data to scope, construct and enhance the scenario, drive exercise play, and inform exercise evaluation. Exercise controllers and evaluators in the Master Control Cell requested specific products, such as new scenario data and visualization of ground truth, which SUMMIT would then generate in real-time to dynamically drive exercise play. These products enhanced both the common operating picture and realism of the exercise scenario. SUMMIT templates were run repeatedly to rapidly produce critical infrastructure effects and economic impact data that supported the play of five states and the federal government including the President of the United States.

This deployment demonstrated SUMMIT's ability to drive many aspects of an exercise, from exercise planning through evaluation, and for dynamic exercise play from first responders up through the highest level policy-makers.

US-Sweden exercise planning

In an on-going collaboration between DHS S&T and the Swedish Civil Contingencies Agency (MSB)-Department of State, SUMMIT has been and continues to be used to support planning and conduct of response exercises in Sweden. These efforts are demonstrating SUMMIT's capability to rapidly integrate models to generate and visualize scenario data. In January 2012, SUMMIT was used

to drive a chemical release response exercise, providing scenario ground truth data. Most recently, flooding, infrastructure, and population models are being developed for a region near Stockholm and for integration in SUMMIT. SUMMIT will produce data such as flood contours based on rising water levels, infrastructure damage and population effects, and visualize this data in a 3-dimensional display on a tablet computer. This SUMMIT output will be used to support an exercise for Swedish responders.

These efforts demonstrate how SUMMIT can be used to quickly and economically federate models and produce data. Additionally, they show the value of SUMMIT as a driver and means for collaboration in emergency preparedness, not just across jurisdictions and agencies, but also internationally.

National Level Exercise 2011 (NLE 11)

For National Level Exercise 2011, a catastrophic earthquake scenario, SUMMIT supported exercise planning, control and conduct. Using SUMMIT, simulated ground truth data was provided to the exercise planners from FEMA's HAZUS model (casualty counts and infrastructure damage)[10], and the Agency for Healthcare Research and Quality hospital surge model (hospital supplies usage). [11] The utilization of data generated through science-based models helped exercise planners develop a realistic ground truth scenario. In addition, a building damage adjudication tool, a customized client application to SUMMIT, was used by planners to modify the individual building damage model outputs to align with exercise objectives, creating scenarios that are both science-based and exercise-driven.

In addition to supporting exercise planning, SUMMIT was used to enhance realism in exercise control and conduct. A custom mobile application for SUMMIT, implemented on an iPad, was developed for usage in the field, so that exercise controllers and players could view simulated building damage in a virtual handheld display.

Utah ShakeOut 2012

SUMMIT was used to support a regional exercise—the Utah ShakeOut earthquake exercise—through engagement with FEMA Region VIII and various regional jurisdictions. This effort illustrated the value of SUMMIT in enabling reuse of pre-existing templates, models and tools. NLE 11 templates and models were applied to the Utah region to develop scenario data and exercise injects for dozens of counties and municipalities involved in exercise play. The building damage adjudication tool was used to display infrastructure effects and promote a common operating picture.

The reapplication of SUMMIT capabilities enabled the rapid delivery of a wide range of vetted scenario data, including medical, displaced populations, infrastructure damage, and utility functions. Reuse also gave the exercise controllers free access to a common operating picture control tool that otherwise would not have been available.

V. SUMMIT TRANSITION

SUMMIT is in its transition stage from DHS S&T to the FEMA NESC in support of NESC's objective to provide state-of-the-art modeling and simulation capabilities to support national, federal, state, local, and tribal exercise. Specifically, the software architecture is concurrently undergoing the Software Engineering Lifecycle (SELC), Security, and Compliance transition process through DHS S&T. Once transitioned to the FEMA NESC, the emergency management community will be able to utilize the SUMMIT environment to link "best-in-class" modeling and simulation tools and generate and view science-based data that enhance planning activities, training, exercise and eventually response operations. During this transition period, research and development efforts will continue to advance SUMMIT capabilities in preparation for future deployments to the FEMA NESC.

VI. SUMMIT INTEGRATION WITH NESC TECHNOLOGY PLATFORM

FEMA's Homeland Security Exercise and Evaluation Program (HSEEP) is a capabilities-based exercise program that serves to standardize policies and methodologies for all phases of exercise design.[9] Fundamentally, HSEEP consists of two primary components: one being exercise doctrine, and the second being the "HSEEP toolkit", which is currently a small collection of web-based tools for exercise planners. The HSEEP toolkit is intended to help exercise planners plan, design, conduct, evaluate, and learn from proper HSEEP exercises. Currently, FEMA is building the next generation of the HSEEP toolkit, named the NESC Technology

Platform, which will significantly expand the capabilities of the HSEEP toolkit. In general, the NESC Technology Platform will serve as an information sharing backbone that will greatly increase information exchange, user collaboration, data security, and content modularity. Furthermore, it will serve as the foundation for an improved set of HSEEP tools, which will streamline HSEEP specific tasks, enable dynamic exercises and improve the analysis and evaluation capabilities of exercises.

Central to the design of the NESC Technology Platform is "plug-and-play"-like modularity, which will enable FEMA and 3rd party developers to easily integrate content and applications with the platform, creating limitless opportunities for information exploitation and the development of novel exercise capabilities. Due to the anticipated impact that modeling and simulation can have across the phases of HSEEP exercises, SUMMIT is one of the first systems to integrate with the NESC Technology Platform.

In late 2011, SUMMIT was integrated with a preliminary prototype of the Technology Platform. This integration consisted of enabling a new map-based collaboration tool, intended to support exercise development activities, to configure a SUMMIT model template and retrieve the associated model results through the Internet. The NESC Technology Platform collaborative maps tool then displayed a spatial representation of the SUMMIT model results where users could collaboratively "whiteboard", annotate, and discuss the model results. A screenshot of model results used within technology platform's collaborative map display is shown in Figure 4.

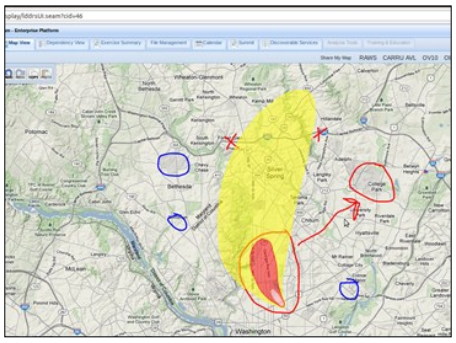

Figure 4. Plume model results generated by SUMMIT, displayed in a collaborative maps tool within the NESC Technology Platform

Integrating SUMMIT with NESC Technology Platform was accomplished through the use of web services. Both are networked systems that have access to the Internet and SUMMIT exposes a web service API that provides access to its capabilities. When the NESC Technology Platform needs to communicate with SUMMIT (e.g. for the retrieval of model data), it sends a message using SOAP over HTTP to SUMMIT's exposed web service interface. SUMMIT responds by returning an XML message that the NESC Technology Platform understands how to parse. Once the information from SUMMIT is obtained, the requesting tool within the NESC Technology Platform is able to use this information as desired, in this case displaying it on a collaborative map.

While modeling and simulation can support exercises in many more ways than just spatially viewing model data, this first integration effort demonstrated the ease at which this type of functionality can be included into the NESC Technology Platform. As it matures, additional SUMMIT-based HSEEP capabilities will be developed such as model-driven exercise event injects, model validated exercise scenarios, model guided "what-if" scenario exploration, and dynamic exercise scenario progression based on real-time model results.

It is envisioned that the NESC Technology Platform will provide capabilities that will span the wide spectrum of needs of a diverse set of stakeholders from Federal, state, local, and tribal governments, as well as non-governmental organizations and the private sector as appropriate. As such, widespread accessibility, information security, and ease of use and collaboration are important attributes. The system should enable more efficient and effective execution throughout the exercise life cycle. The inclusion of science-based modeling and simulation capabilities in the exercise process is a specific objective that will result in more realistic exercises. It is also recognized that as technology advances, there will be opportunities to improve the exercise system and its capabilities; therefore, flexibility and extensibility are important architectural goals. Finally, technology transition to operational use is a key objective.

Given initial system requirements, the NESC Technology Platform architecture is being designed

and prototyped to support local, state, regional and national level exercises. The initial focus of the architecture includes support for exercise conduct, exercise evaluation, and the introduction of science-based modeling and simulation tools into the HSEEP cycle.

SUMMIT is planned to be the M&S capability integrated in the NESC Technology Platform as one of its suite of tools in the improved toolkit. [7]

VII. Conclusions and Future Work

SUMMIT has been successfully deployed at FEMA National Level Exercises for the past 3 years, at small and large-scale regional exercises across the country, and in an international exercise with the Swedish Civil Contingencies Agency (MSB)-Department of State. It is being used to accelerate scenario planning, provide scientifically-grounded scenario data, and enhance the realism of the exercise environment. The availability of science-based data and models coupled with the ability to customize scenarios and make modifications during exercise play has had a major impact on how National Level Exercises are designed, planned, and conducted. With each subsequent exercise, exercise controllers are requesting additional modeling results to be computed in real-time with SUMMIT during exercise play, having an impact on real-time injects and player decision-making.

During NLE 12, SUMMIT provided the only common operating view for controllers/evaluators in the Master Control Cell focusing on the impact of disruptions to critical infrastructure. This supported exercise play of 17 Department/Agencies covering the National Capital Region and four FEMA Regions; over 20 private sector/critical infrastructure key resource entities, and four international countries. This was the first national level exercise for a cyber-attack catastrophic event, and the importance of this is evident by participation of the President of the United States of America.

By using SUMMIT, the emergency preparedness community is able to reuse both scenarios and model results in subsequent exercises, either by the same agency or other agencies. For example, the earthquake simulation template that was created for NLE 11 was reused in the Utah ShakeOut 2012 exercise.

Future work includes continuing support of regional, national and international exercises, completing transition of SUMMIT from DHS S&T to FEMA NESC, as well as plans to expand SUMMIT capabilities to support FEMA planning and response operations. [12]

References

[1] "National Preparedness System", Department of Homeland Security, November 2011. Retrieved July 2012 from http://www.fema.gov/pdf/prepared/nps_description.pdf.

[2] Obama, B. (2011), "Presidential Policy Directive/PPD-8: National Preparedness". Retrieved June 2011 from http://www.dhs.gov/xabout/laws/gc_1215444247124.shtm.

[3] Post-Katrina Emergency Management Reform Act (PKEMRA) Section 664 (2006). Press release January 12, 2009, retrieved from http://www.fema.gov/news/newsrelease.fema?id=47279.

[4] E. Friedman-Hill, T. Plantenga, and H. Ammerlahn, (2010). "Simulation templates in the SUMMIT system", in 2010 SISO Spring Interoperability Workshop, Orlando, FL, Apr 2010.

[5] T. Plantenga, E. Friedman-Hill, (2010). "Integrated Modeling, Mapping, and Simulation (IMMS) framework for planning exercises", in Interservice/Industry Training, Simulation, and Education Conferences (I/ITSEC), 2010.

[6] Mapar, J., et al. (2010), "Integrated Modeling, Mapping, and Simulation (IMMS) Framework for Exercise and Response Planning", Conference Paper, MODSIM World Conference, Hampton, VA, October, 2010.

[7] John, C., et al. (2011), "New Technologies and Processes for the Homeland Security Exercise and Evaluation Program Toolkit", Proceedings of the 2011 IEEE International Conference on Technologies for Homeland Security, Waltham, MA, November, 2011.

[8] Mier, S., et al. (2011), "The Use of Integrated Modeling and Simulation at FEMA for Emergency Preparedness Exercises", Proceedings of the 2011 IEEE International Conference on Technologies for Homeland Security, Waltham, MA, November, 2011.

[9] FEMA, "Homeland Security Exercise and Evaluation Program Volume 1: HSEEP Overview and Exercise Program Management", Washington, DC, 2007.

[10] HAZUS (2011). Retrieved June 2011 from http://www.fema.gov/plan/prevent/hazus.

[11] Agency for Healthcare Research and Quality (AHRQ) Hospital Surge Model (2011). Retrieved June 2011 from http://hospitalsurgemodel.ahrq.gov

[12] Threat and Hazard Identification and Risk Assessment Guide: Comprehensive Preparedness Guide (CPG) 201, First Edition April 2012. Retrieved July 2012 from http://www.fema.gov/library/viewRecord.do?id=5823.

Acknowledgements

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.