

4.5 Integrated Modeling, Mapping, and Simulation (IMMS) Framework for Exercise and Response Planning

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Abstract. Emergency management personnel at federal, state, and local levels can benefit from the increased situational awareness and operational efficiency afforded by simulation and modeling for emergency preparedness, including planning, training and exercises. To support this goal, the Department of Homeland Security's Science & Technology Directorate is funding the Integrated Modeling, Mapping, and Simulation (IMMS) program to create an integrating framework that brings together diverse models for use by the emergency response community. SUMMIT, one piece of the IMMS program, is the initial software framework that connects users such as emergency planners and exercise developers with modeling resources, bridging the gap in expertise and technical skills between these two communities. SUMMIT was recently deployed to support exercise planning for National Level Exercise 2010. Threat, casualty, infrastructure, and medical surge models were combined within SUMMIT to estimate health care resource requirements for the exercise ground truth.

1.0 INTRODUCTION

1.1 Exercise Management

Exercises provide a way to assess and validate the speed, effectiveness and efficiency of emergency management capabilities, and test the adequacy of policies, plans, procedures, and protocols of emergency response in a risk-free environment. In 2002, the U.S. Department of Homeland Security (DHS) and Federal Emergency Management Agency (FEMA) developed policies, incorporated into the Homeland Security Exercise and Evaluation Program (HSEEP) [1], to guide the design, development, conduct, and evaluation of exercises. This served as an opportunity to standardize the language and concepts used in the exercise planning and evaluation process for the homeland security community.

Under DHS leadership, the National Exercise Program (NEP) [2,3] provides a

framework for prioritizing and coordinating federal, regional and state exercise activities, without replacing any individual department or agency exercises. NEP defines four tiers of exercises:

Tier I: White House directed, U.S. Government-wide Strategy & Policy Focus, Full Participation

Tier II: Federal Strategy & Policy Focus, Significant Simulation

Tier III: Other Federal Exercises, Operational, Tactical or Organizational Focus, Simulation

Tier IV: State, Territorial, Local, Tribal or Private Sector Focus

Typically, Tier I and II are supported by the FEMA's National Exercise Division (NED). Each year one exercise is designated as the National Level Exercise (NLE), a Tier I event requiring senior level participation among the Federal interagency community. NLEs are full-scale exercises that are typically scheduled five years prior, and are

planned for up to two years in advance. A full-scale exercise is a multi-agency, multi-jurisdictional, multi-discipline exercise involving functional and "boots on the ground" response.

The role of modeling and simulation (M&S) in HSEEP exercises is still evolving. Though dozens of federally-funded modeling efforts have been identified that are relevant for emergency response to hazards and threats and that could greatly enhance exercise planning and conduct, there is no formal mechanism for the emergency management community to discover, access and use these M&S capabilities. Furthermore, the wide range and disparity of M&S capabilities for emergency management necessitates a way to integrate and run models.

1.2 IMMS Program

Realizing the opportunities to enhance exercises and planning through modeling and simulation, the Department of Homeland Security Science and Technology Directorate (DHS/S&T) spearheaded the Integrated Mapping, Modeling and Simulation (IMMS) program.¹ IMMS is a research and development effort to develop a common framework for integrating incident-related M&S tools to enhance situational awareness and operational efficiency of emergency managers and exercise planners. Among the many applications are support to exercises, including Tiers I-IV. Recognizing that the modeling and simulation community is large and highly diverse, DHS/S&T is providing, through IMMS, the M&S and exercise communities a way to discover models, integrate them quickly and economically, and apply them in analyses to improve exercise, planning, and response

¹ "High-Priority Technology Needs", Department of Homeland Security Science and Technology Directorate, Version 2.0, June 2008. The Incident Management Integrated Product Team (IPT), led by FEMA and the Office of Emergency Communications, identified an integrated modeling, mapping and simulation capability as a high-priority technology.

efforts. The central technological component of IMMS is the Standard Unified Modeling and Mapping Integration Toolkit (SUMMIT), which connects users such as emergency planners and exercise developers with modeling resources in an easy-to-use format. This paper provides a high-level overview of the SUMMIT architecture, and a description of IMMS support to National Level Exercise 2010 (NLE10). NLE10 lessons learned from M&S support of exercises are being incorporated as requirements and concepts of operation (ConOps) for SUMMIT, and are being used to develop and refine the IMMS vision.

2.0 BODY

2.1 SUMMIT

To create a capability for linking together M&S tools, SUMMIT is being iteratively designed and prototyped. SUMMIT provides a platform-neutral framework that brings together distributed M&S codes and a wide range of users. The framework makes it easier to discover and integrate models, provision them for a specific scenario, execute models on available resources, and deliver results to a collaborating set of users.

The SUMMIT architecture allows for considerable flexibility, placing few restrictions on federated models, but still providing necessary capabilities for integration. Model owners decide who has permission to use their code, and where it is hosted. Exercise planners and other emergency response users link models as needed to address specific scenarios.

For example, suppose the exercise scenario is the release of chlorine gas from a railcar in an urban setting, and the emergency responder wants to know if there are sufficient medical supplies for first response. A computational approach (Fig. 1) might incorporate a finite element model that computes the chemical gas dispersion plume for given weather conditions, another model that quantifies casualties in the

population at risk, and a third model that tallies available medical resources. SUMMIT makes it possible for the planner to link these three models, execute them, and view results, all from a single client interface.

Figure 1 depicts a SUMMIT simulation template, an abstraction that shows how models are connected to address a specific scenario. Although the template displays only a high level view, “under the hood” there is sufficient detail to define a software federation of models that can execute automatically.

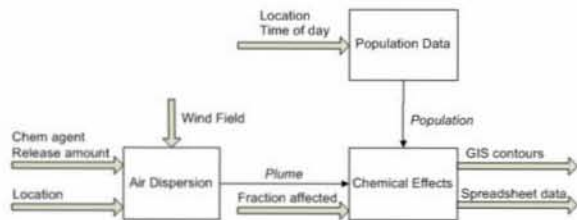


Figure 1. Example simulation template linking three models (boxes) via data flows (arrows).

Software components in SUMMIT are divided between a central server, user clients, and executable models that are often (but not always) hosted on the machines of model owners. Figure 2 shows the main components of the architecture. The “data” and “model” icons in the figure are components owned by model contributors. All other icons are part of the SUMMIT framework. A SUMMIT Client component allows for interaction with the user, and a SUMMIT Software Development Kit (SDK) provides tools for model owners to integrate their models and verify that they are SUMMIT-compliant. Components in the SUMMIT core server provide system functionality through a set of distributed services.

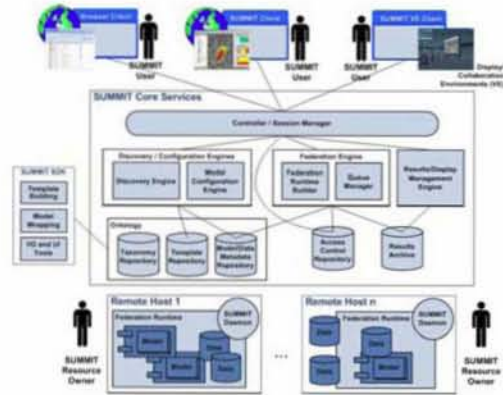


Figure 2. SUMMIT architecture.

SUMMIT provides for three types of users: emergency responders and exercise planners (the primary end user), model owners, and scenario planners. *End users* access content through a SUMMIT Client. They log into the system, discover an appropriate simulation template (such as Fig. 1), configure inputs, and then view results after SUMMIT automatically executes the models that compose the simulation template. *Model owners* use SUMMIT SDK tools to create a software wrapper that enables execution of their model as part of a SUMMIT-mediated federation of models. (Note that in this paper the term “federation of models” does not refer to a High Level Architecture [4] type of federation, but to a collection of models run consecutively with interconnected data.) For example, the three models in the chlorine gas scenario described earlier might be contributed by three different model owners and hosted at three different remote sites. *Scenario planners* use SUMMIT SDK tools to create simulation templates that specify inputs and needed outputs and bring together models for a specific incident scenario. In the chlorine gas example a scenario planner created the simulation template by linking three models at a conceptual level to produce the desired output.

Further details on the coordination and execution of models in the SUMMIT

framework are discussed in references [5] and [6].

SUMMIT has created a flexible external interface that allows for multiple client environments. These include a native rich client platform, a browser-based client, and interfaces to advanced commercial and government GIS technologies. Utilization of these environments allows users to grasp complex multivariate data quickly and intuitively. The IMMS team is also investigating the capabilities of virtual environment technology to bring telepresence and a heightened sense of situational awareness into exercises.

SUMMIT is also providing external interfaces so that its M&S integration capabilities can be leveraged by external tools. For example, exercise management tools will be able to access SUMMIT-archived data, allowing for even greater intra-exercise coordination.

2.2 National Level Exercise 2010

To better understand the potential utilization and role of IMMS in exercise, the IMMS team participated in NLE10 in May 2010 [7]. The objective of this first pilot was to apply the existing reference implementation of SUMMIT in a live exercise so that architecture requirements and concepts of operation (ConOps) could be evaluated and improved. The specific scenario for NLE10 was response and recovery from incidents involving an improvised nuclear device (IND) detonation in a U.S. city. The scenario was derived from National Planning Scenario 1: IND Detonation [8]. The major objectives of NLE10 were to exercise:

- Intelligence and information sharing and dissemination
- Incident Management
- Critical Infrastructure protection
- Medical Surge
- Public information
- Continuity of Operations (COOP)
- Economic and Community Recovery

NLE10 was conducted in the National Capital Region. Exercise players in NLE10 represented over 60 federal agencies, including U.S. Department of Defense, Central Intelligence Agency, Department of Energy, Department of Health and Human Services, DHS, Department of Justice, Department of State, Department of Transportation, and Environmental Protection Agency. Due to a late venue change, this NLE consisted of federal play only, and no local or state play; however, representatives from local and state governments and FEMA Regional Office V contributed to the planning process, and participated in the Simulation Cell (SimCell), providing “boots on the ground”, realistic scenario injects that drove the operations-based exercise play.

Exercise conduct consisted of a Master Control Cell (MCC) releasing injects from the Master Scenario Event List (MSEL) to exercise players. The MCC included:

- A control room acting as the key node of communication, hosting both exercise controllers (who plan and manage exercise play) and evaluators (who track action relative to evaluation criteria and analyze exercise results without disturbing exercise flow) from 62 federal departments and agencies.
- A SimCell hosting representatives from the region, state, local, international, private sector, law enforcement, etc., which provided injects to and answered requests for information from the exercise players.

MSEL injects were released via phone, email, fax and the DHS Lessons Learned Information Sharing (LLIS) portal [9].

2.3 How SUMMIT Supported NLE10

SUMMIT was one of several M&S providers for NLE10, supporting both exercise planning and execution. The IMMS team used SUMMIT to integrate multiple M&S tools contributed from different agencies. Threat, casualty, and infrastructure models

and data were provided by the DOE National Atmospheric Release Advisory Center (NARAC), and DHS Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) National Infrastructure Simulation and Analysis Center (NISAC). A medical surge model from the Department of Health and Human Services (HHS) Agency for Healthcare Research and Quality (AHRQ) provided health care resource surge requirements. SUMMIT was used for the pre-planned exercise ground truth, calculated prior to the exercise, and the real-time scenario injects, computed during the exercise execution.

A new SUMMIT simulation template was created specifically for the NLE10 scenario (Fig. 3). The template integrated M&S tools for nuclear effects, infrastructure effects and medical surge needs. The NLE10 template defines how models connect and the data flows between models. In the future, this template may be reused to support similar exercises at the federal, state or local level.

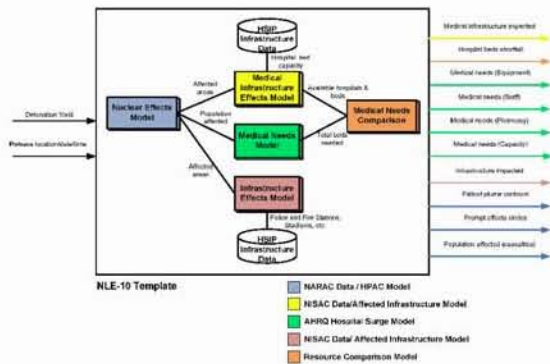


Figure 3. A representation of the NLE10 template depicting input parameters, models, and the data flow between models. Outputs are colored to match the model from which they are produced.

For exercise planning, SUMMIT was used to provide ground truth injects on the amount of surge equipment and staff that would be required in the medical response (Fig. 4). For exercise conduct, SUMMIT was used to provide real-time scenario injects on the equipment and staff needs estimated by on-scene responders.



Figure 4. Example output data from models and data federated in SUMMIT for NLE10.

3.0 DISCUSSION

The application and deployment of SUMMIT in NLE10 provided valuable lessons learned on M&S support to exercises. These lessons learned are being incorporated into SUMMIT requirements and ConOps, and will enhance SUMMIT’s support of NLE11, an earthquake scenario in the New Madrid Seismic Zone based on National Planning Scenario 9: Natural Disaster – Major Earthquake [8].

NLE10 lessons learned include:

SUMMIT can facilitate the use of M&S in exercise planning.

By having an integrated framework for M&S, exercise planners were able to more easily run various scenarios in order to generate the ground truth data. Exercise planners did not have to expend time to locate the individual models, execute a series of distributed M&S tools, and gather outputs. SUMMIT enabled multiple executions to be made easily so that exercise controllers could carefully plan and scope their exercise. Furthermore, the template may be reused by exercise planners who are using this same National Planning Scenario.

Exercise controllers require a common and consistent picture of the exercise.

Maintaining situational awareness of exercise events and a common exercise picture across the dozens of exercise controllers in the Master Control Cell and SimCell is vital for sustaining a realistic scenario. During NLE10, there were several instances in which a common exercise picture and improved situational awareness would have been valuable. For example, at one point the Master Control Cell released a scenario inject that provided incorrect ground truth data.

SUMMIT provided some enhanced situational awareness in NLE10 by integrating several M&S tools into a single conceptual simulation template. A more comprehensive common exercise picture can be provided through exercise management tools that link with SUMMIT. Exercise management tools provide timelines of exercise injects, expected player actions, and actual player actions. They show how player actions affect the ground truth scenario. The exercise management tools used in NLE10 provided a global view; however, according to feedback received from the exercise controllers, these tools were neither easy nor intuitive to navigate and query. Additionally, controllers reported that there was little to no feedback on player receipt of injects and player responses to injects. The SUMMIT architecture is being designed so exercise management tools can be integrated with M&S tools that generate ground truth. This will help ensure a common exercise picture, enabling exercise planners and managers to record and access exercise objectives, scenario ground truth data, expected and actual player actions, exercise management team actions, consequences of player actions, and scenario outcomes in one location.

Collaboration environments and visualization tools greatly enhance exercise planning and conduct, but must be user-friendly, intuitive and robust.

Visualization tools, such as GIS-based and virtual world technologies, can be used to display a common exercise picture of the exercise scenario data, release of injects, player actions and consequences of player actions. For exercise planners and controllers who are not techno-savvy (which several people stated about themselves during the hot wash feedback session immediately following NLE10), a virtual world or other visualization should make it much easier for them to interact and make changes to the scenario and common exercise picture. The SUMMIT architecture is providing a means for virtual world technologies to be federated with M&S and exercise management tools. Exercise data can be displayed in an immersive environment and accessed by distributed exercise planners, managers and players.

Scenario data coordination and consistency is imperative.

During the exercise planning phase, M&S was used to develop ground truth data and exercise injects. One of the benefits of using M&S for this purpose is to help ensure that the underlying scenario is consistent and realistic. It is much less likely for exercise planners or controllers to create conflicting scenario data when the ground truth data are calculated or derived from a physics-based model, objective data and a consistent set of assumptions. In NLE10 some inconsistencies in the ground truth data did appear because of the use of several models with different assumptions. For example, two of the data providers calculated casualty numbers which differed significantly due to the fact that different population databases were used. Through the use of a unifying M&S framework, discrepancies between models can be managed by following these guidelines:

- 1) Models with the same inputs and outputs should be managed in a single simulation template, making it easy to set up comparative runs. The same

template should be used to compute all ground truth data.

- 2) All assumptions and input parameters are documented, openly shared and used among the data providers.
- 3) All M&S tools (including databases) that are used to calculate scenario data are integrated.

To minimize inconsistencies and enhance coordination in scenario development, SUMMIT is providing an integrating framework through which multiple models and datasets can be used together to generate consistent data.

4.0 CONCLUSIONS

NLE10 provided important lessons learned on architecture requirements and ConOps for SUMMIT. These are being implemented in SUMMIT and will help enhance exercise planning and conduct in NLE11. Research on SUMMIT support to Tier II-IV exercises is underway and will build upon the lessons learned from support to NLEs.

The SUMMIT architecture has proven to be flexible enough to create simulations via model federation that allow for complex scenario construction in an intuitive manner. The flexibility and extensibility of the architecture also allows for evolutionary growth with participation of the M&S and exercise communities. Integration of data visualization tools and virtual environments allows M&S data and results to be readily accessed by the exercise community.

A SUMMIT *early adopter program* has been established to evaluate the integration process with the participation of model contributors in the M&S community. Information about SUMMIT and this program can be found at the SUMMIT web site (<http://dhs-summit.com>).

The current focus for SUMMIT is support for emergency response exercises; subsequent research will focus on emergency planning and response operations. Bringing modeling and simulation tools to emergency planning

and operations will allow for improved accuracy in exercise parameters, creating more realistic training exercises and better prepared emergency responders.

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6.0 ACKNOWLEDGMENTS

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