Greetings From
MSIAC
JOURNAL
"Gateway to M&S Discovery"
Postcards from the Road

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DEFENSE TECHNICAL INFORMATION CENTER
U.S. DEPARTMENT OF DEFENSE
READINESS THROUGH M&S
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The MSIAC, chartered by DoD, collects and disseminates information about all aspects of modeling and simulation (M&S) – policy, practice, technology, and applications. The MSIAC leverages past and existing M&S investments by storing and analyzing results and then offering its expertise and knowledge through mission-tailored services. MSIAC uses its existing strategic alliances to access a wide range of commercial, academic, U.S. Government, and foreign M&S information, and supports the DoD M&S community through its education courses, publications, help desk, and projects. Contact the MSIAC at 888-566-7672 or at http://www.dod-msiac.org

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Guest Editorial

Michael J. Sanders
Colonel, United States Army
Deputy Director
Modeling and Simulation Coordination Office
(M&S CO)

Let me welcome you to the 2009 Summer Issue of the MSIAC Journal. I am honored to be the Guest Editor and to grab some of your summer vacation reading time while introducing this issue's theme of "Gateway to M&S Discovery: Postcards from the Road."

America's highway system is an important part of the nation's infrastructure. It has always been important to the nation's defense. Almost exactly ninety years ago, the Army's Transcontinental Motor Convoy traveled from Washington, DC, to San Francisco to discover how quickly we could use our highways to move troops across the continent. Equally important, this highway system has helped define our national identity in the Twentieth Century. We have a great love affair with the open road and a need for self-expression (images of George Maharis's Corvette, strains of "that ribbon of highway" and "see the USA"). President Dwight Eisenhower fully understood the significance of our highways as part of the national infrastructure when he signed the Federal-Aid Highway Act of 1956 creating the Interstate System. Our national highway system has transformed the American cultural landscape as much as it has transformed the physical terrain.

Like the "Great American Highway," Modeling and Simulation (M&S) is changing our culture, touching each of our lives. It has become ubiquitous and pervasive, and will help define the Twenty-First Century. M&S systems enhance reuse, research, experimentation, and critical analysis. M&S provides transformational technology for the U.S. and for DoD operations by powering applications that save taxpayer dollars, save lives, and accelerate the search for solutions to our Nation's greatest challenges. M&S systems, like our highway system, offer many routes that lead from any given origin or that converge upon any given destination. Varying M&S routes provide different capabilities or offer distinct, but always interesting, stopovers. However, in navigating the M&S network, as in navigating our highway system, if you have a firm destination and a hard schedule, you're best off relying on a roadmap.

DoD M&S now has its own roadmap and this issue of the Journal offers some of the "postcard views" of interesting sights that can be found along the way. The roadmap, developed as a result of a major change to the DoD M&S management infrastructure, is titled "The DoD M&S Corporate and Crosscutting Business Plan." The roadmap indicates a valuable way ahead based on our strong vision for future DoD M&S efforts and supported by our responsive and representative management. We have a firm destination in providing support to our Warfighters and enhancing Warfighter operations. We have a hard schedule of strong goals and objectives across the full spectrum of the DoD M&S Community.

But this roadmap for DoD M&S offers more than just the destination; it also illuminates the journey. As we choose our path ahead, we are keeping a watchful eye for the signposts along the way by continuously introducing new M&S technologies, approaches, and standards that enhance future defense capabilities and that meet Joint and Service-unique requirements and needs. This Journal issue features five of these signposts. "Modeling Architecture for Technology Research and EXperimentation (MATREX): M&S Tools and Resources Enabling Critical Analyses" highlights the Army's use of M&S. "Discovery and Reuse of Modeling and Simulation Assets" presents our need first to discover M&S assets as a part of enabling effective reuse and reducing duplication. "Experimenting with Simulation and Stimulation" shows a new route leading towards reshaping simulation support for human-in-the-loop experimentation. "Adaptive Behavior Models for Asymmetric Adversaries" illustrates the view that a successful road trip requires preparing for the unknown by arguing that models of opponent behavior must become more dynamic and use adaptive threats consistent with those in modern asymmetric warfare. Finally, "Coast Guard

Team Completes Accreditation of New Modeling and Simulation Tool" shows the benefits of ensuring that your roadmap is correct.

In reality, the DoD M&S roadmap is like any other roadmap: sometimes we know what we will encounter, and sometimes we don't. One participant in that revolutionary 1919 Transcontinental Motor Convoy was a 29-year-old Army Lieutenant Colonel named Dwight Eisenhower, who wrote at the time that "the road is one succession of dust, ruts, pits, and holes," but, when given the opportunity 37 years later, prepared for the future by signing the Highway Act. We also need to prepare for the future of M&S and its "dust, ruts, pits, and holes." Now, we are doing this by accumulating knowledge of the terrain and developing a firm understanding of how to handle the unknown, what to do in an emergency, where we can refuel for the next generation of technology, and learning the rules/standards of the M&S road. This Journal's articles form a valuable part of this journey of discovery.

I know you will enjoy this summer issue. Think of us as you motor by those famous four faces fronting Mt. Rushmore. And write to us – as the Deputy Director of the Modeling and Simulation Coordination Office (M&S CO), I am earnestly looking forward to receiving, reading, and viewing your own "M&S Postcards from the Road."

Modeling Architecture for Technology Research and EXperimentation (MATREX):

M&S Tools and Resources Enabling Critical Analyses

Modeling Architecture for Technology Research and EXperimentation (MATREX):
M&S Tools and Resources Enabling Critical Analyses

Christopher J. Metevier
MATREX program at the STTC within US Army RDECOM

Chris Gaughan
MATREX program at the STTC within US Army RDECOM

Scott Gallant
Effective Applications

Lana E. McGlynn
McGlynn Consulting Group

Joseph S. McDonnell, Ph.D.
Dynamic Animation Systems

Gary Smith
MATREX with RDECOM
Orlando, Fl

Keith Snively
Dynamic Animation Systems

The Modeling Architecture for Technology Research and EXperimentation (MATREX) provides a unifying distributed Modeling and Simulation (M&S) architecture and supporting tools and resources that ease the integration and use of multi-resolution live, virtual, and constructive (LVC) applications. It enables full spectrum analysis of system designs and operational concepts while reducing risk and acquisition timelines. To provide this capability across the Army and the other Services, the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) and the Research, Development & Engineering Command (RDECOM) has funded development of the MATREX program. The MATREX environment, including the toolset and resources, is available as Government-Furnished Software (GFS) with support and training available.

M&S customers who require the use of distributed simulation[1] typically do not have a long life cycle for an experiment, analysis initiative or simulation-based event. To reduce cost, they need to use a well-established simulation architecture and robust models that are easy to integrate with other distributed simulations. This short lead time for system design, development, integration and execution forces the system definition and design to happen very quickly. This is where the various facets that compose MATREX can and do help.

For instance, one important aspect of MATREX is its capability to leverage many M&S resources developed at RDECOM laboratories, centers and activities. The world-class RDECOM team of M&S experts has utilized MATREX to identify issues, exercise requirements, align development efforts and conduct experiments that involve system of systems (SoS) technologies beyond the expertise of any one part of RDECOM. Figure 1 highlights the M&S contributions of each RDECOM component.

Additionally, the MATREX environment is used for a variety of purposes. These numerous and often generic uses of MATREX offer a difficult systems engineering challenge in linking system requirements to detailed system design and technical dependencies. To facilitate customization for a given user's goals, the MATREX systems design team has developed a highly flexible and configurable system design that will allow it to meet a wide breadth of user requirements.

To determine how your organization can best use the capabilities of the MATREX program to meet your analysis needs it is useful to begin with an understanding of the system design approach and the supporting toolset and resources.

The MATREX System Design Approach

The MATREX suite of models, tools and architecture allow for many different possible configurations of the system to achieve the user's functional requirements. The philosophy is to work with the users to develop a System Design Descrip-

[1] Simulation conducted over multiple host computers in a Local Area Network (LAN) or Wide Area Network (WAN)

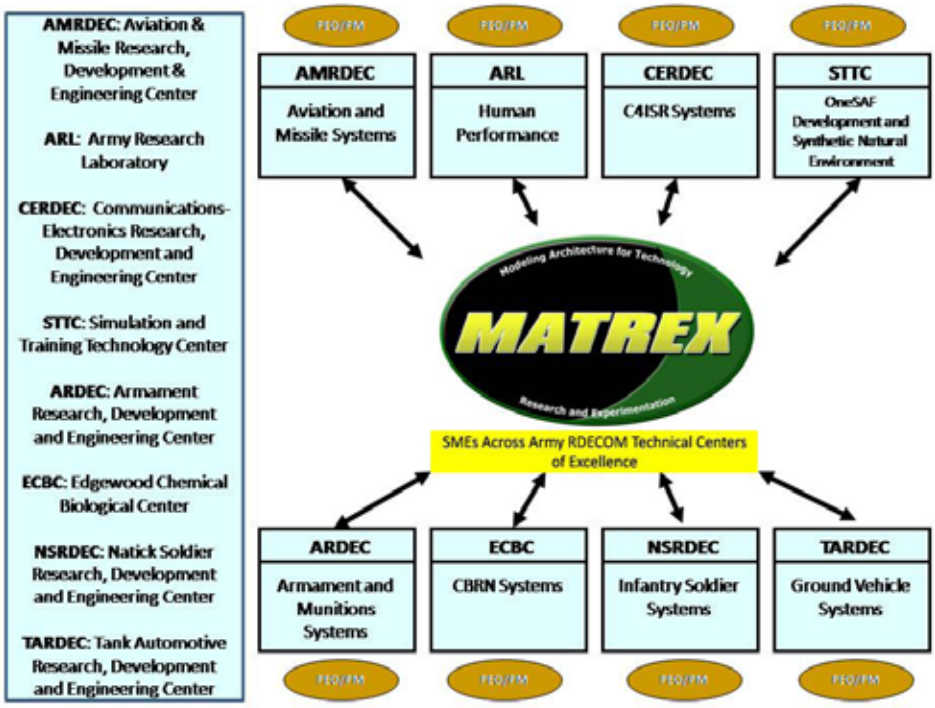

Figure 1: Contribution of the RDECOM Laboratories and Centers

tion (SDD) that meets their exercise requirements, data decomposition requirements, system architecture guidelines, scenario, configuration choices and model selection. The SDD includes the mapping between the data to be collected during the exercise, the initial exercise goals and the explanation of what the data means.

The MATREX environment consists of models of various fidelities and resolutions. These models can be combined within an architecture that is designed to scale, so that, when the model permits it, multiple instances of each model can operate in parallel within the system. This added level of complexity allows more design possibilities (and challenges) than most simulation architectures. Simulation requirements such as "fair fight" issues, scalability concerns and data element analysis force the design to have additional architectural strategies that must uniformly be followed. These architectural strategies are captured and enforced with the SDD.

The MATREX program has developed the SDD to capture the system design at a functional level and subsequently link the functional design to the technical design. This allows the functional requirements to be linked to system design and allocated to specific models. The low level requirements, object model and test cases can then be auto-generated based on model allocation to functions. The SDD is data-driven, easing information maintenance duties by linking the system engineering products and simplifying the editing of the system design. The SDD also allows for auto-generating low level specifications, certain DoDAF views and test cases.

The MATREX SDD exists within the MATREX Integrated Development Environment (IDE). The MATREX IDE is a content management system hosted on a secure server that provides various views into the MATREX system design. Since the SDD contains not only the object model information, but also the semantics of the data exchanges, test threads can be generated from the SDD and traced back to system requirements. In addition, the test generation process uses a transport abstraction layer to allow these tests to be translated into various protocols for distributed simulation, e.g. High Level Architecture (HLA), Test and Training Enabling Architecture (TENA), etc., ensuring portability of the tests along with the models. Therefore, the tests evolve and migrate to new transport protocols with the SDD.

Figure 2 shows the four core building blocks MATREX uses to describe what the system does and how it accomplishes. They are: (1) Requirements, (2) What, (3) How and (4) Who.

In the "Requirements" block, the SDD contains System and Systems of Systems Requirements that depict two types of requirements: functional requirements which pertain to the model, and technical requirements which pertain to the execution architecture, such as, "The execution middleware will be HLA". An example would be "The system shall implement Networked Fires" to include any relevant details from the source of the requirement.

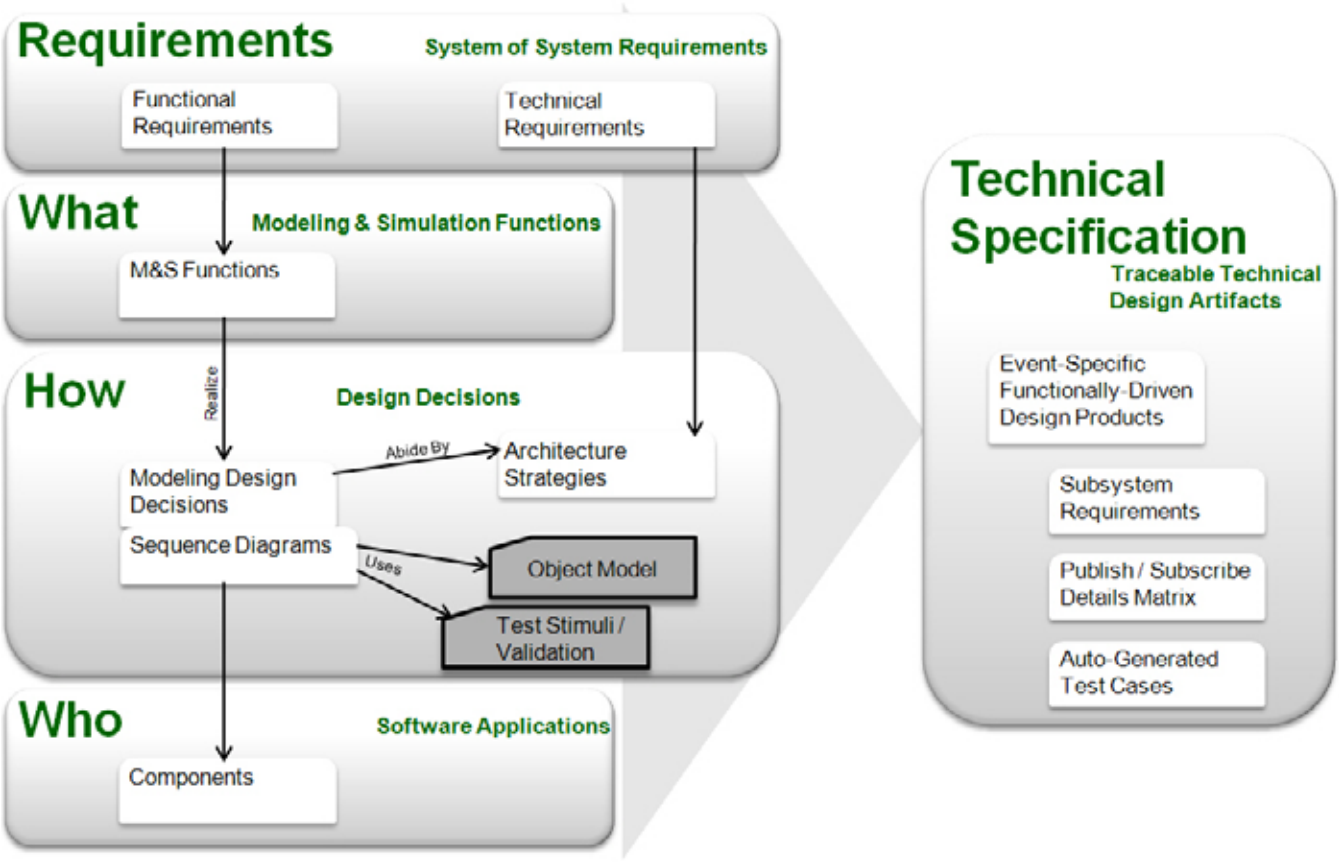

Figure: 2 System Design Information Architecture

The "What" block contains the modeling and simulation functions that link to the functional requirements. An example would be the detailed description of "Networked Fires" according to the source and required warfare-related capabilities.

The "How" block contains the design decisions that describe how the functions are realized in the modeling design decisions (MDD). The architecture strategies which point back to technical requirements also must abide by the MDD. This enforces that the architectural decisions should dictate what models and capabilities are used instead of the model dictating what capability is available. The sequence diagrams for how these design decisions can be realized are products which are then used by the object model and test stimuli/validation. For the Networked Fires example, the MDD would show the lower level functions like the fires request, fires adjudication, fire mission assignment, fires execution and reporting. It would include the sequence of events and information shared between those functions to accomplish the Networked Fires function described in the "What" block.

The "Who" block doesn't specify one model for one function but rather all of the models that have been evaluated, given the MDD, that fulfill that functionality. This allows for flexibility within events to use models based on fidelity or resolution requirements as well as political or monetary concerns, which unfortunately can dictate the architecture of an event despite gaps in capability. Examples of components within the "Who" block would be the models and applications necessary to accomplish derived functions within the "How" block.

The "Technical Specification" block contains all of the generated artifacts from the aforementioned design decisions and their allocation to solutions. Some examples of these products would be a publish/subscribe table showing the components' input and output requirements, detailed interface requirements and test cases verifying each compo-

nent abides by the design captured within the sequence diagram in the "How" block.

Outside of MATREX, these types of products are typically updated manually within spreadsheets or text documents causing a maintenance burden including version control, duplication of information causing copy and paste errors and the tedious time-consuming process of humans maintaining extensive documentation.

All of these elements are combined to make up the MATREX System Requirements Specification (SRS), System Design Description (SDD) and System/Subsystem Specification (SSS).

MATREX Supporting Toolset and Resources

The MATREX program strives to create a system and tool suite that will ultimately facilitate a quick, automated system design to match the unique situation for systems engineering. By having the long range goal of heavy automation in mind when designing the infrastructure and tool set, the important elements of the MATREX system were kept as generic as possible to allow for various object models, middleware protocols such as HLA and TENA, design decisions and architectural strategies. The following is a list of the tools and services available to MATREX customers.

MATREX RTI and FOM

HLA is one of the simulation protocols available for executing a MATREX federation. HLA is implemented by using a Run-Time Infrastructure (RTI) and a Federation Object Model (FOM). MATREX has an RTI that is based on RTI-NG v9.0 and our RTI is provided as GFS. The MATREX FOM is co-managed with Future Combat System (FCS) Lead Systems Integrator (LSI) and provides a basis for commonality in the FCS M&S community, RDECOM, TRADOC, ATEC, and beyond (we are currently investigating the role of I-BCT as the FCS program stands down). There are many users across all commands that are using the FOM which increases interoperability across those organizations. This saves times and money across the M&S community.

ProtoCore

MATREX offers an Application Programmer's Interface (API) that abstracts away the middleware protocols in order to allow the developers of models to focus on model behavior vice rewriting code to align with specific distributed simulation protocols. This API, known as ProtoCore, reduces reliance on middleware services, data management techniques and architectural design patterns. In turn, it allows a simulation event to be middleware agnostic as the automated tool suite helps set up and configure models based on the SDD. Because ProtoCore offers a forward path for legacy object models and component models, future users can leverage existing software investments and minimize expenditure in development cycle resources by using ProtoCore to port their models to current distributed simulation standards.

Advanced Testing Capability (ATC)

MATREX also offers a testing tool that generates test applications based on the design and over-the-wire communication distributed simulation requirements. The Advanced Testing Capability (ATC) allows for testing over the middleware layer based on a predefined sequence diagram including validation values. The ATC's primary purpose for MATREX integration testing is its ability to perform meaningful and repeatable "black box" level testing on any component being integrated into the MATREX environment. This allows a simulation to test interactions with other simulations without needing to run them in turn, reducing integration costs. ATC also performs the function of documenting specific test cases in order to provide reproducibility. The goal for the near future is to export sequence diagrams from the SDD into a standardized format for ingestion into the ATC tool. This will allow for testing components directly from the design and technical contracts linked to system requirements further reducing integration costs.

Battle Command Management Services (BCMS)

The MATREX offers a suite of models called the Battle Command Management Services (BCMS). The BCMS manages the Common Operating Picture (COP) and Local Operating Picture (LOP) for the force structure according to the information flow. It also provides interfaces for integra-

tion of external services including communication effects, fusion, human performance modeling and Command & Control devices; these services are highly configurable or replaceable according to information topologies and higher fidelity model availability. The BCMS enables the modeling of the propagation and maintenance of friendly and enemy situational awareness (SA) as it originates from the simulated battlefield. BCMS converts data from battlefield simulations into reported/detected information, models the reporting of that information from platform to platforms via defined reporting hierarchies, and maintains information about known entities (friendly & enemy) on behalf of the simulation(s) modeling the battlefield entities.

Configuration and System Administration Tool (CSAT)

A goal of MATREX is to initialize a simulation from a common, controlled, standardized format that describes a military scenario. MATREX uses the Military Scenario Development Environment (MSDE) to generate data in a Military Scenario Definition Language (MSDL) format. To accommodate the full set of data needed to initialize a distributed simulation, MATREX has developed a tool called the Configuration and System Administration Tool (CSAT). CSAT ingests a scenario produced in MSDL format and allows a user to supplement the scenario data with simulation configuration data. The output of CSAT is then used to initialize the models within a simulation. The MSDL offers a common, controlled, standardized format to describe a military scenario. CSAT simplifies configuration management and data consistency is ensured through this approach.

Distributed Virtual Laboratory (DVL)

The MATREX Distributed Virtual Laboratory (DVL) provides a closed classified distributed networking capability to all RDECOM laboratories and support centers. The DVL offers the capability to conduct experiments and make demonstrations of MATREX studies, concepts and capabilities. The MATREX DVL also peers with the Cross Command Collaboration Effort (3CE) Network allowing the MATREX community access to 51+ sites on the TRADOC Battle Lab Simulation Collaboration Environment (BLCSE) network, ATEC Test Integration network (ATIN) and the FCS LSI network. Services provided by the MATREX DVL include: systems engineering and architecture development; design and development; integration and test; performance analysis; operations and technical support; network security infrastructure; services: access to the classified FCS advanced collaborative environment (ACE) portal; voice of internet protocol (VoIP); and, virtual teleconference (VTC).

Integrated Development Environment (IDE)

The Integrated Development Environment (IDE) is the content management system (CMS) for the MATREX program. This system facilitates distributed systems engineering, configuration management and sharing of key information via the Internet.

Example Usage of MATREX

The US Army Operational Test Command (OTC) provides an example usage of the MATREX environment. MATREX and OTC developed a beneficial partnership through sharing technologies and capabilities. In particular, MATREX and OTC leveraged the feasibility of Cross Command solutions to modeling, simulation, testing, and validation of legacy, current and future systems and architectures. OTC met its near-term mission requirements for integration through a series of integration events utilizing an HLA approach in the form of the MATREX FOM and RTI enabled by porting OTC simulations to ProtoCore. These events, occurring regularly over the a number of years, have systematically increased in level of complexity and scope (35 enterprise members), culminating in a seamless integration of live, virtual and constructive entities made possible, in part, by a robust MATREX FOM and RTI.

The OTC Analytic Simulation and Instrumentation Suite (OASIS) integrates test technologies and weaves them into the live test environment by providing a family of integrated systems to support operational tests. It provides an acquisition strategy to adapt, buy or create the common components for a family of integrated, interoperable enterprise tools to support test technology "centers of gravity" which includes: live, virtual, constructive (LVC) environments of selected warfighting systems; tactical systems including system under test (SUT); test control and networks which is part of the environment; and data collection, reduction

and analysis (DCRA), which is critical in order to assess the SUT performance. There have been enumerations added to the FOM in order to better model/represent live entities on the battlefield – a benefit to all the members of this collaboration.

Perhaps the greatest example of this collaboration was demonstrated when components of OASIS integration effort particularly the Extensible C4I Instrumentation System (ExCIS) fire support simulation were integrated with simulations and simulation support tools from training and R&D applications to create a unique FCS Spin-out 1 (SO1) federation that satisfied the requirements of the four very different event stakeholders trainers, doctrine developers, material developers, and operational testers, which own phases of the SO1 event window. The SO1 simulation team was able to achieve, at least in one small but very visible way, the promise of shared common components and standards because each of the tool kit providers, regardless of domain, had worked during the previous year to integrate the MATREX FOM in support of other efforts.

Conclusion

To reiterate, the goal of the MATREX program is to develop a composable M&S environment wherein a collection of multi-fidelity models, simulations, tools and resources can be integrated and mapped to an established architecture for conducting analysis, experimentation and technology trade-offs for RDECOM and others. MATREX is both a concept and an environment, not a model. It is architected to integrate existing M&S into a robust representation of the battlespace, ultimately seeking to combine the capabilities of the Army's highest fidelity digital terrain, dynamic environmental effects and physics-based M&S. The unifying architecture of MATREX allows integrated models to pass data among themselves and share a common synthetic battlespace. The MATREX Team has developed a cross-cutting set of tools that facilitates interoperability and ease of use.

ABOUT THE AUTHORS

CHRISTOPHER J. METEVIER is the Technical Project Manager of the Modeling Architecture for Technology, Research, & EXperimentation (MATREX) program at the Simulation & Training Technology Center (STTC) within the US Army RDECOM. He has over 19 years of experience with the Navy and Army in his Modeling & Simulation (M&S) field. His M&S experience extends across the acquisition lifecycle and includes the research, development, adaptation, integration, experimentation, test, and fielding of numerous simulation technologies and systems. He received his Master of Business Administration degree from Webster University and his Bachelor of Science degree in Electrical Engineering from the University of Central Florida.

CHRIS GAUGHAN is the Deputy Technical Project Manager of the Modeling Architecture for Technology, Research, & EXperimentation (MATREX) program at the Simulation & Training Technology Center (STTC) within the US Army RDECOM. From 2004-2009 he worked at the Edgewood Chemical Biological Center (ECBC) where he served as the Configuration Manager of the CBRN Simulation Suite. During his tenure at ECBC, he has been the principal investigator for numerous Joint Science and Technology Office projects focused on CBRN Modeling and Simulation (M&S). He has provided M&S analytical support to the Joint Program Executive Office for Chem-Bio Defense and to the TRADOC Maneuver Support Battle Lab. He received his Master of Science and Bachelor of Science in Electrical Engineering from Drexel University in Philadelphia, PA.

SCOTT GALLANT is a Systems Architect with Effective Applications. He has over ten years experience in distributed computing including Army modeling and simulation. He has led technical teams on the MATREX program for distributed software and federation design, development and execution management in support of technical assessments, data analysis and experimentation. He is leading the Systems Engineering team for the implementation of the described product infrastructure. Scott Gallant also currently serves as the System Architect for the MATREX program.

LANA E. MCGLYNN, founder of McGlynn Consulting Group (MCG), has over 35 years of hands-on experience in technical and leadership positions. She offers comprehensive consulting in the fields of modeling and simulation (M&S), testing, logistics, acquisition, and studies and analyses. Prior to retirement from federal service, she served as the Special Assistant to the Deputy Under Secretary of the

Army for Operations Research (DUSA (OR)) for M&S. She is a member of the Army Acquisition Corps and was certified as an Acquisition Professional, Level III, in Program Management. She is a graduate of Harvard's JFK School of Government Senior Executive Fellows Program, and the resident course at U.S. Army War College.

JOSEPH S. MCDONNELL, Ph.D. is a Principal Scientist with Dynamic Animation Systems (DAS). Dr. McDonnell has over 15 years experience in Modeling and Simulation for DoD, DHS, FEMA and USFS programs, filling various technical and managerial roles, from development through program management. He is currently the MATREX Principal Scientist. Dr. McDonnell earned his Ph.D. in Mathematics at the University of Virginia.

GARY SMITH is the Technical Lead for Modeling Architecture for Technology and Research EXperimentation, (MATREX) with the Research and Development Command (RDECOM) in Orlando, FL. He has extensive software engineering and code development experience in the areas of modeling and simulation within the DoD community. He has a Bachelor's Degree in Mathematics from St. Mary's College of Maryland.

KEITH SNIVELY is a Senior Software Engineer with Dynamic Animation Systems Inc. He has over ten years experience in DoD modeling and simulation. His experience includes several years working on design and development of the DMSO RTI-NG. He has also worked on development for the TENA middleware. Recently Mr. Snively participated in the development of the HLA 1516 Evolved specification. Currently Mr. Snively serves as a software developer for the MATREX program and specifically supports design and development of the MATREX RTI-NG and ProtoCore.

Discovery and Reuse of Modeling and Simulation Assets

Discovery and Reuse of Modeling and Simulation Assets

Paul Gustavson
SimVentions
Fredericksburg, VA 22408
pgustavson@simventions.com

Ali Nikolai
DoD M&S Coordination Office
Alexandria, VA 22311
alberta.nikolai.ctr@osd.mil

Roy Scrudder
DoD M&S Coordination Office
Alexandria, VA 22311
Roy.Scrudder@osd.mil

Curtis Blais
MOVES Institute, Naval Postgraduate School
Monterey, CA 93943-5001
clblais@nps.edu

Richard Daehler-Wilking, Ph.D.
Space and Naval Warfare Systems Center
Charleston, South Carolina 29419
r.daehler-wilking@navy.mil

ABSTRACT

The ability to discover existing modeling and simulation (M&S) assets is a critical need for enabling effective reuse and for reducing the duplication of capabilities. Such visibility and accessibility is key to optimizing the investment of the estimated billions of dollars spent on M&S within the Department of Defense (DoD).

Key enabling technologies include an integrated search and discovery capability, and the specification of a consistent set of metadata that can be used to search across multiple registries and repositories. The objective of this paper is to familiarize the community with these enabling technology efforts. It will describe a common M&S discovery metadata specification and describe how it is related to DoD overarching specifications as well as M&S specific registry implementations. It describes how the schemas of these sources were integrated to formulate a concise, practical, and flexible schema, and how that schema can best be used. It also examines the M&S Catalog development effort, which offers a search and discovery capability using negotiated data exchange agreements with a variety of primary sources to respond to user queries about M&S. Additionally it discusses how data structures at each source are translated to the corresponding metadata specification, and then communicated to the M&S Catalog central search engine.

Disclaimer: The views presented in this paper are those of the authors and do not necessarily represent the views of the Department of Defense or its Components.

1. Introduction

Although their business models are different, the Simulation Interoperability Standards Organization (SISO) and the omnipresent Internet search engine Google have something in common. Part of SISO's mission is "to provide an open forum that promotes the interoperability and reuse of models and simulations [1]." Google's mission is "to organize the world's information and make it universally accessible and useful [2]." Clearly, both seek to promote the discovery and reuse of content.

In fact, the ability to discover existing M&S resources is a critical need for enabling effective reuse and for reducing the duplication of capabilities. Such visibility and accessibility is key to optimizing the investment of the estimated billions of dollars spent on M&S within the Department of Defense (DoD). Because Google has been so successful in its similar mission, it behooves us to consider for a moment how Google works.

Google got its start in January 1996 as a thesis project by graduate student Larry Page, after whom "PageRank" is named [3, 4]. Page's theory was that by tracking and crawling related hyperlinks on a web page, one could use such data to produce more relevant candidate search results as compared to a typical search engine at that time, which simply compared keywords of a web page to a search

string. From a user's perspective, the search string would still be the input, but searching data based on the merit of "associations" within a web page, which are citations and links to other resources such as web pages, images, and videos, is central to the modern Google Engine that we know today [5]. The search engine is just one part of the solution; the other part is making sense of the metadata within a page that provides these associations.

Thus, what the DoD M&S community needs is not just a search and discovery capability, but also specification of a consistent set of metadata that can be used to search across multiple registries and repositories.

2. Discovery Metadata

M&S resources are typically not described by HTML tags as are the web pages that Google and other web based search engines crawl and index daily. M&S resources are tagged and bagged in a number of different ways - if at all. Current web-based technologies based on the Extensible Markup Language (XML) permit more explicit markup of information on the Web. Such markup can be exploited to make search and discovery of M&S resources more efficient, particularly as the DoD moves toward the Global Information Grid (GIG) and its Net-Centric Data Sharing Strategy.

Of critical importance is determining what information is most useful for search and discovery of M&S resources. Consider for a moment if you walked into a grocery store to find it well-stocked with unmarked products and goods and none of the items were labeled. Would you be able to understand what products were on the shelf? Such a trip to a grocery store would be perplexing and frustrating. Perhaps you have experienced a similar frustration when shopping at a store where the prices are not clearly identified on the shelf or the product. The likelihood is that a product with no price presented to the consumer will remain on the shelf and not be purchased. In fact, customers with the intent to buy are interested in seeing several pieces of information to aid in their selection process, such as product name, manufacturer, size, weight, and nutritional content. What we learn from this is that metadata is vitally important.

Likewise, those of us that are producers and consumers of M&S assets need a common way to tag and understand M&S resources. This discovery metadata, which provides the labeling of a resource, is in many ways independent from the structural metadata that reveals the interior composition of a resource. Back to the grocery store analogy: the cereal that you might look for on the shelf can only be discovered if the box containing the cereal is decorated and annotated in a way that you can recognize. You probably do not need to know the chemical make-up of its ingredients. That structural metadata may be important to some stakeholders (e.g., mothers) BUT only after discovery.

A common discovery metadata labeling system for M&S resources has been a long need. The M&S Community of Interest (COI) Discovery Metadata Specification (MSC-DMS) has been developed in response to this need [6]. It provides a consistent schema for discovery, analogous to the nutritional labeling now common on foods marketed in the U.S. (See Figure 1.)

Figure 1: Tagging M&S Resources

The MSC-DMS specification was introduced previously at the 2008 Fall SIW, under paper 08F-SIW-043 [7]. In the current paper, we dive deeper to expose elements of the MSC-DMS that can be used to reveal useful associations to assist in the discovery of relevant candidate M&S resources. In many ways, we are attempting to follow Google's approach in identifying parts of a web page that could be used to reveal citation based associations matching the keywords entered by a person searching for relevant M&S assets, but with the advantage of greater contextual precision through the use of the Extensible Markup Language (XML).

2.1 MSC-DMS Internals

First, we quickly look at the overall structure of the MSCDMS XML language, and then we identify some of

the key aspects of the MSC-DMS that could be used to expedite the crawling, indexing and searching of M&S resource. Figure 2 offers a glimpse of the MSC-DMS structure.

Figure 2:
MSC-DMS Structure

Essentially only 8 root elements and 11 sub elements are required: Title, Type, Description, Date Created, Version, Releasability, POC, Keywords. We begin with these essential elements to first identify the core basic elements that can be used to support a simple search.

2.2 Simple Search

The common input device for searching for items of interest is a simple keyword text window illustrated in Figure 4. The simplicity offered to the user is that they have one spot to enter the keyword and values of interest. The engine then needs to be smart and know how to leverage those keywords. Likewise, the author or publisher of a resource needs to be aware of what element tags ought to be populated to aid in a search.

```
<?xml version="1.0" encoding="UTF-8"?>
<ms:Resource
xsi:schemaLocation="http://metadata.dod.mil/mdr/ns/MSCDM/1.1/ MSC-DM-v1_1.xsd"
xmlns:ddms="http://metadata.dod.mil/mdr/ns/DDMS/1.4/"
xmlns:ms="http://metadata.dod.mil/mdr/ns/MSCDM/1.1/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
      <ms:Title ms:value="battle sim sprocket model"/>
      <ms:Type ms:value="software"/>
      <ms:Description>
              <ms:Text>Battle Sim software that models space sprockets</ms:Text>
      </ms:Description>
      <ms:Dates>
              <ms:Date ms:type="created" ms:value="2007-08-13"/>
      </ms:Dates>
      <ms:Version ms:value="1.4"/>
      <ms:Releasability ms:value="A: Unlimited distribution "/>
      <ms:POCs>
              <ms:POC>
                      <ms:Role ms:value="publisher"/>
                      <ms:Person>
                              <ms:Name ms:first="Samuel" ms:last="Adams"/>
                              <ms:AddressInfo/>
                              <ms:Phone ms:type="work" ms:number="555.123.4567"/>
                              <ms:Email ms:type="work" ms:address="sadams@sprockets.sims"/>
                      </ms:Person>
              </ms:POC>
      </ms:POCs>
      <ms:Keywords>
              <ms:Keyword ddms:value="software"/>
      </ms:Keywords>
</ms:Resource>
```

Figure 3: Minimum Required MSC-DMS XML Structure

Not everything identified at the core level of the MSCDMS is mandatory; there are some common but optional elements that are used only if needed. The XML view in Figure 3 depicts a well-formed and valid XML document that adheres to the MSC-DMS based on the required fields.

Figure 4: Simple Search Screen

The core element tags that could be leveraged from the MSC-DMS metadata in a simple search would include the following:

- Title
- Type
- Description
- POC.Person.Name*, or
- POC.Organization.Name*
- Keywords.Keyword

*only one of these needs to be declared (person or organization)

Keep in mind these fields reflect the type of mine-able metadata that "simple search" criteria would likely use. This "simple search" approach has existed long before the Google engine came into existence. As an example, a good way to locate a high-probability candidate would be to enter a quoted phrase into the search window, then seek records whose Title and Description tags contain the quoted phrase. If such a match is found, then it would be elevated to the top of the search list as the best, most likely candidate. Typically, however, the "simple search" approach results in less than stellar discovery list of candidates.

There are several additional fields offered by the MSCDMS that are optional, but which can be extremely useful with the Simple Search method. They include the following:

- Usage
- Media
- Security
- Rights
- Releasability

The MSC-DMS specification gives further details for each of these MSC-DMS elements, and the reader is encouraged to explore these further.

2.3 Citation-based Associations

The next logical question is what other aspects of metadata can be leveraged for improving discovery beyond the simple search? There are several nonessential (not required) metadata elements provided by the MSC-DMS that can be used to reflect citation-based associations, which are used for identifying information of possible interest related to an M&S resource. The specific metadata elements that support this capability that we will examine further include the following:

- Resource Association (ID, value)
- POC Person/Organization (ID, URL)
- Usage.History (POC ID)
- Media (location)

2.3.1 Resource Association Citations

A few years ago the M&S acquisition community proposed a convention within their Product Development Metadata Specification (PDMS)specification for tagging resources with a unique ID. Additionally, the development teams for the Base Object Model (BOM) and High-Level Architecture (HLA) Evolved standards defined a means to reference external object model components either defined in other parts of the model, or found within external models. This capability is accomplished through the use of an ID tag. This concept was integrated into the MSC-DMS during its development so that M&S resources could be uniquely identified and referenced by other resources.

The Resource.ID is a unique identifier that can be associated to an M&S resource record. It is intended to be used to support cross referencing by other resources and also for the benefit of organizing data hosted by one or more repositories. Consider the example illustrated in Figure 5.

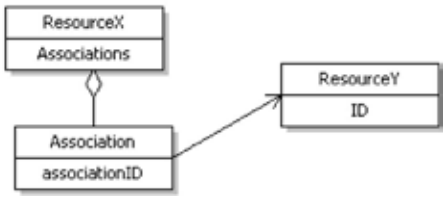

Figure 5: Resource ID Citation

In this example the *ID* for ResourceY is cited as an *Association* of ResourceX. The *Association* subcomponent offers a way to cite other sources, which may be either resource assets or support assets. Associations can be made

to various types of resource and support assets including software, tools, data models, documents, and more.

There are two ways the *Association* subcomponent can be used to reference external assets. One is the *associationID* tag, which we just described, and the other is the *value* field, which is used to identify an associated source that may be not be cataloged by an *associatedID*. Figure 6 provides an XML example of an *Association* subcomponent that employs the *value* field.

```
<Association
 qualifier="URL"
 value="http://www.simsrus.com/BMA1003.xml"
 schemaHref="http://www.simsrus.com/schemas"
 schemaQualifier="na"
 relationship="is-described-by"
 type="related documents"
</Association>
```

Figure 6: Association Value Example

In this example an *Association* within the resource metadata is made to an external XML document. The *qualifier* attribute specifies the reference format of the external source as a Universal Resource Locator (URL). The value attribute specifies the actual external source, in this case the file location and name. The *schemaHref* attribute identifies the schema type needed to parse/digest the cited source. And the *relationship* element identifies how the cited source is related to the principal resource, ResourceX.

The benefit in having an *Association* is that it provides more quality material for a search engine to crawl, index, and search. A cited *Association*, whether it is provided by an *association ID* or a by a reference *value,* likely offers additional metadata that can be canvassed against the search criteria entered by a user. This allows a page (a resource) to be weighted and sorted by the search engine.

2.3.2 POC Citations

Let us now turn our attention to the Point of Contact (POC) component of the resource metadata. Just as an M&S metadata resource can be uniquely identified by an ID, so can also a *POC,* such as a *Person* or *Organization.* And, much like the *Association* component of an M&S metadata resource, a POC can cite other *POC IDs* such as a sponsor, supervisor, or parent organization. Figure 7 provides an example illustration of how such *IDs* can be referenced by other *POCs.*

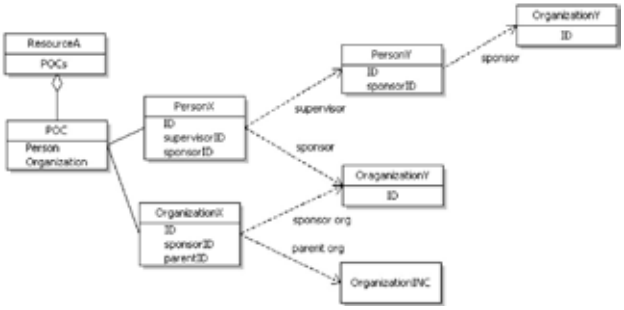

Figure 7: POC ID Citation

In this example, any POC sources linked to PersonX and OrganizationX become items of interests. As more relationships are identified through ID citations then more information can be leveraged by the search engine. The more sources that can be crawled, indexed and searched using the keyword criteria provided within the search request the greater the discovery competency. The higher the rate of search criteria keyword matches that are found within these additional sources will result in a greater a "PageRank" for the original resource for which these sources were cited. Consider again the example in Figure 7. PersonY, OrganizationY, and OrganizationNC have become resource items of interest due to the POC ID associations cited by ResourceA. Any other resource related to these POCs can be further interrogated by the search engine to determine if there is additional history for these POCs in matching with the keyword search criteria. The more matches that are found would elevate the original resource for which these POCs were cited as a probable search result candidate.

2.3.3 Usage History POC Citations

Usage History offers an additional means to explore how resources have been used and integrated. Much as Amazon.com provides user feedback on a product, so does the intent of the MSC-DMS. A repository that offers visibility to the discovery metadata of a resource should also allow integration use and experience of that resource to be captured and re-shared with the community. A POC that provides such experience as history can be identified within

the metadata. This is illustrated in Figure 8.

Figure 8: Usage History POC ID Citation

What this citation-based association offers is a means to investigate the POC. Has the person or organization garnered enough experience in the use (or development) of other related resources for their comments to be considered? If so this data is mined (crawled, indexed and searched) more strongly than others. And if their comments are valuable because of a rich history and there are significant key word matches with their other related resources, then that would elevate the original resource of interest to be higher on the candidate list.

2.3.4 Media Location Citations

Often *Media* properties may be associated to an M&S resource to identify the physical or digital manifestation of the M&S resource. The *Media* properties include F*ormat* and *Location*. The *Location,* as it name implies, provides a means to identify the location of the media. It is, in essence, an address that may be used to access the information resource content, e.g., a URI or file system location. At this point it should be clear that this field is a citation-based association, and that the potential exists to crawl, index and search the media content identified by the *Location* property.

Drilling into any of these citation-based associations and interrogating resources further can be accomplished using both "Simple Search" mechanisms described earlier and through further (next layer) "Citation-Based Association" mechanisms used to find additional mapped and related resources. The desired result is a well organized set of available candidate resources that support stakeholder needs.

2.4 Weighted-based Search

The fields of the MSC-DMS can also be weighted. Consider the previous discussion pertaining to the strength of a POC's shared experience of resources, which was based on *History* entries within a repository. The more experience a POC has the greater their comments should be weighed.

Consider again a web page. The philosophy of an engine like Google is that, "Words in a larger or bolder font are weighted higher than other words [5]." For example, the words in the *Header* of an HTML page means much more than the words within a set of *Paragraph* tags found on the same page. In the same way, some of the metadata tags provided by the MSCDMS can be and should be weighted differently when it is being crawled by a search engine.

A valuation of the MSC-DMS components as they relate to supporting weighted-based searches is reflected in Table 1.

MSC-DMS Component	Valuation Weight	Comment
Title	High	This is an extremely visible and important aspect of the metadata. If the words in the title of a resource match the search criteria, then it is highly probably that the resource is a top search candidate.
Type	Medium	The values for representing types may be coincidently reflected in a key words of the search criteria. But in most cases a match would be of great intrigue, but certainly less than Title.
Description	Medium	Unless the search criteria are provided in a quote string, then this field is medium.
Dates	Medium	Specific dates identified in the search criteria, if they match with the Dates of a resource would be of great intrigue. Dates however, are not often identified search values.
Version	Low	This is not a highly weighted search tag.
Security	Low	Security is important to an M&S resource, but it not typically a strong element of the search criteria.
Rights	Low	Rights is important to a M&S resource, but it is not typically a strong element of the search criteria.
Releasability	Low	Releasability is important to a M&S resource, but it is not typically a strong element of the search criteria.
Associations	Medium	Much can be learned by examining the associations of a resource.

Table 1: MSC-DMS Valuation Weight

MSC-DMS Component	Valuation Weight	Comment
POCs	Medium	Names of Persons and Organizations are often an intriguing search area. Matches at this level could be useful in learning about other resources associated to these POCs that also satisfy the search criteria.
Keywords	High	Keywords are defined within a metadata resource for the purpose of easy discovery; in other words they mean something. Therefore it is important to keep keywords hi on the list of tags to be explored when a search engine is examining resources.
Usages	High	There is a lot of solid information that can be captured in the Usages component including purpose, application domain, limitations, history, and capabilities. If matches are found it is likely that such resource is a good candidate.
Media	Medium	If the search criteria is specific on identifying the media it is attempting to locate, than this component of the MSC-DMS should not be considered lightly by a search engine.
Glyph	Low	Typically search of information is very rarely focused on the visual representation of the resource.

Table 1: MSC-DMS Valuation Weight

3. M&S Catalog Effort

The M&S Catalog effort is the first project that has begun to apply a search engine against resources tagged with the MSC-DMS. Various sources enter into negotiated data exchange agreements to permit indexing by the search engine. The M&S Catalog, via a web portal, offers a search and discovery capability to respond to user queries about M&S resources. The catalog is a web-based application that stores and indexes data and metadata, taking advantage of the MSC-DMS XML schema [6]. Its welcome screen is shown in Figure 9 **Error! Reference source not found.**

Figure 9: M&S Catalog Welcome Screen

Sources currently include the Navy Modeling and Simulation Resource Repository (MSRR), DoD MSRR, Air Force MSRR, Army MSRR, and Analysis M&S Tool Registry. The M&S Catalog collects (meta)data from its sources by a combination of web crawling and direct insertion of content. In its current implementation, the search engine is powered by a Google Search Appliance (GSA). The GSA engine can natively process HTML files typical of web sites, but it does not "understand" XML tags in general. (Meta)data following the MSC-DMS XML schema must be translated into a simpler, one-layer-deep system of "meta tags" as illustrated in Figure 10.

```
<metadata>
   <meta name="title" content="Extended Air
      Defense Simulation - EADSIM"/>
 <meta name="description" content="The
      Extended Air Defense Simulation (EADSIM)
      is a many-on-many simulation of air,
      missile, and space warfare. It is used
      to support analysis, training, test,
      and operational planning. EADSIM is one
      of the most widely used simulations in
      the world with over 350 user agencies
      worldwide. EADSIM is managed by the U.S.
      Army Space and Missile Defense Command,
      as the executive agent for the Missile
      Defense Agency (MDA)."/>
<meta name="POC" content="John Doe (256)
      555-1111, DSN xxx-1111 E-Mail: john.doe@
      smdc.army.mil"/>
</metadata>
```

Figure 10: Example Meta Tags Searched by GSA

This translation works fine for fields provided by the MSC-DMS like *Title* and *Description*, but is problematic for complex elements like *POC*. For example, a search for records with a POC containing a specific person's name and a specific agency name might return records that contained one POC with the person's name and another POC with the agency name, but no POC with both – in other words, a "false positive" hit.

To allow more precisely controlled "targeted search", the M&S Catalog project will establish a data store to receive the full MSC-DMS-formatted XML records provided by sources. This collection of intact XML records can then be queried using XQuery. Results returned from the data store search will be collated with results returned from the parallel text-based search performed by the GSA.

The MSC-DMS-inspired data store will not replace the GSA, because we have no intention of reinventing the web-crawling or text-search wheels, although use of an open source search engine is a future possibility. However, it will be necessary to solve some problems to avoid chaos. Large among these is maintaining consistency. When one record is returned by the data store search and another is returned by the GSA search, how do we know whether they are the same record? Similarly, when a source sends us a record, how do we know whether it is a completely new record or an update of a record we already have?

One possibility for the problem of record identification is to have the sources provide a unique identifier (ID) associated to the resource. Since the sources must already have a way to keep their own records straight, we should take advantage of it. Two records from different sources about the same underlying resource, if they are tagged with different unique IDs, would be treated as two different records, although they might both be returned (or ignored) as results for a search.

The MSC-DMS can support such record identification in multiple ways as described in Section 2.3. However, it is still a matter of negotiation among the participants to determine which MSC-DMS elements should be used for this purpose.

A broader but related question is how to associate records returned from the GSA and from the data store when they are NOT identical. Matching titles and phrases within description fields is conceptually straightforward, but more interesting would be records that share associations. Finding associations in the MSC-DMS schema is easy: they're explicitly marked. Finding such associations in results of a text-based GSA search would be more challenging. One possibility is to pick out words or phrases from the MSC-DMS association elements, then look for them as text strings in the GSA result set.

Another intriguing possibility is to allow end-user feedback of which results are best (or worst) associated with each other. It might be possible to construct a mechanism that constantly improves itself based on such feedback.

Problems like these will provide ample challenge to keep sharp coders interested in their work. Current research into Semantic Web technologies shows great promise for improving contextual relationships across web-based resources and is being investigated for application to the handling of M&S resources.

4. Other M&S Resources and Repositories

Beyond the large-scale M&S repositories managed by various DoD agencies and organizations, there are numerous repositories managed by industry, schools, and non-governmental organizations that hold potentially valuable M&S resources. Some of this information is searchable in the so-called "surface web," while much of the information is found in the "deep web," the vast collection of information not accessible by web search engines [6]. A worthwhile long-term objective of the M&S Catalog and MSC-DMS is identification of auxiliary M&S resources that may be discoverable that can further benefit the M&S community.

As an example, the Naval Postgraduate School Modeling, Virtual Environments, and Simulation (MOVES) Institute manages a number of repositories of 3D graphics models expressed in the Extensible 3D Graphics (X3D) international standard for 3D on the Web. One repository, the Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) repository holds over 1,200 3D models and model components available for reuse by the M&S community. These are XML files using the X3D standard to describe scene graphs. A standard set of metadata, called the Savage Modeling and Analysis Language (SMAL), is used inside the files to describe the content and provide author and other historical information about the development of the model. As models are added to the repository, this metadata is read to auto-generate HTML files providing a catalog that can be browsed by users. While these generated HTML pages are indexed by web search engines, the underlying X3D files are not. During this autogeneration process, an easy addition is execution of an Extensible Stylesheet Language Transformations (XSLT) file to generate MSC-DMS metadata from the SMAL metadata embedded in the X3D files. These metadata files can be provided to the M&S Catalog to enable these resources to

be discovered for reuse. Over time, we anticipate that such voluntary provision of discovery metadata will bring about ever-greater visibility into the many collections of M&S resources that have been developed across government, academia, and industry.

5. Summary

As stated in SISO's vision statement, those involved in supporting modeling and simulation interoperability and reuse include "developers, procurers, and users, worldwide. [1]" These stakeholders require ways for systems and simulations to connect, interoperate, and function cooperatively. To this end, a primary goal is "to promote and achieve reuse."

In this paper, we have explored ways to achieve this goal by way of leveraging the capabilities of the MSCDMS schema. The MSC-DMS is the result of integrating common practices and templates used within the M&S community for tagging resources. It offers a concise, practical, and flexible schema including the types of "citation-based associations" and "weighted based valuation" of metadata content that can be leveraged to better support the search and discovery of M&S assets. We have also examined the M&S Catalog, supported by the MSC-DMS in parallel with a Google mining engine, which uses negotiated data exchange agreements with a variety of sources to respond to user queries about M&S.

We highly recommend that DoD community members take an important step towards cataloging M&S resources in a common way, by adhering to the MSCDMS structure. Doing so will help bring to bear associations that allow search engines to find relevant M&S resources, thereby supporting our interoperability and reuse needs.

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ABOUT THE AUTHORS

PAUL GUSTAVSON is Chief Scientist at SimVentions, Inc, and has over 19 years of experience including the design and development of DoD standards, simulation systems, software applications, and numerous technical publications and tutorials on simulations and software development. Currently he is supporting the M&S Coordination Office (M&S CO) in helping to identify key metadata needed for the cataloging and discovery of M&S resources. He has been an active leader within the Simulation Interoperability Standards Organization (SISO) involved in multiple standards efforts including the Base Object Model (BOM), Distributed Simulation Engineering and Execution Process (DSEEP), and HLA Evolved. He is a co-author of several books including "C++Builder 6 Developer's Guide." Mr. Gustavson holds a Bachelor of Science degree in Computer Engineering from Old Dominion University.

ALI NIKOLAI is the former Principal Data Engineer on the System Engineering Technical Assistance contract for the Defense Modeling & Simulation Coordination Office

(M&S CO), She provided technical support on issues and projects regarding data management, including: 1) Analyzing both current and future issues and DoD policies involving data in regard to M&S initiatives in the DoD M&S community; 2) Developing plans and managing technical projects for the M&S CO. Ms. Nikolai has over 30 years of experience in systems management and development serving DoD clients, including management of the DoD Data Architecture program for DISA. She also has provided system engineering and logistic support for the active Army and the Reserve Component. Ms. Nikolai holds a Bachelor of Science degree in Biology from Gannon University in Erie, PA and a Master of Science in Management from Troy State University in Alabama.

ROY SCRUDDER is an Associate Director at the US DoD Modeling and Simulation Coordination Office (M&S CO) where is he is the lead for data activities. He has over 25 years experience in information systems analysis and development, concentrating the last 13 years in information management for M&S. Mr. Scrudder's professional experiences are in the areas of data management and data engineering with a specialization in metadata. He has served as the director for the M&S Resource Repository Board of Directors an led the Analysis of Alternatives for future capabilities in that area. Mr. Scrudder holds a Bachelor of Science degree in Applied Mathematics from the University of Tennessee.

CURTIS BLAIS is a Research Associate with the Naval Postgraduate School MOVES Institute. His primary areas of research and development include application of semantic web technologies to improve interoperability and for identifying and delivering valued information in network-centric environments such as the Global Information Grid. Mr. Blais earned Bachelor of Science and Master of Science degrees from the University of Notre Dame. He is currently a Ph.D. candidate in the MOVES program.

RICHARD DAEHLER-WILKING has been a computer scientist in the Command and Control Department of the Space and Naval Warfare Systems Center Charleston, South Carolina, since 2000. He is a longtime participant in the NETWARS community, having led the development of models for both EHF Milstar and UHF DAMA satellite communications. More recently, he has begun supporting NMSO and now serves as technical lead for the DoD M&S Catalog project. He has a Bachelor of Arts degree in Mathematics from Reed College, a Master of Arts degree in Mathematics from the University of Oregon, and a Ph.D. from the Medical University of South Carolina in biometry (systems science track). He taught mathematics, computer programming, and physics at the college level for 25 years. His hobbies include alpine skiing and barbershop harmony.

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Experimenting with Simulation and Stimulation

Experimenting with Simulation and Stimulation

Andy Ceranowicz
Alion Science and Technology
Alexandria, VA
aceranowicz@alionscience.com

Brett Dufault
Alion Science and Technology
Alexandria, VA
bdufault@alionscience.com

Don Beesing
Alion Science and Technology
Alexandria, VA
dbeesing@alionscience.com

ABSTRACT

Four trends have been reshaping simulation support for human-in-the-loop experimentation at the Joint Innovation and Experimentation Directorate of Joint Forces Command. The first is the need to interoperate with nonmilitary partners such as civilian agencies and emergency responders. The second is the rapidly expanding role of the World Wide Web as the communications medium of choice. The web opens new channels for the simulation to stimulate. Third, the domain of interest for military leaders and planners is expanding from traditional armed conflict to include many aspects of civilian affairs both in war and in peace. Finally, there is the continuous pressure for greater efficiency in all endeavors. While these trends have been long standing, their combined effects crystallized for us when we were asked to support the Noble Resolve series of experiments. Unlike previous experiments, the participants included the Department of Homeland Security and state emergency management personnel. The common operating picture was not presented on GCCS and the protocols were not LINK or OTH-Gold. Instead, web based common operational picture tools such the Department of Homeland Security's Integrated Common Analytical Viewer and websites were the participant's interface to the experiment. The domain was not combat but earthquakes, evacuation, and rescue; and we needed to execute with a minimum of operator support. These factors led us to reconsider the balance between stimulation and simulation; when to use one over the other and how to deliver stimulation content. In the process we have developed a more flexible and efficient approach for combining simulation and stimulation and delivering stimuli via a variety of Internet channels.

COMMAND POST STIMULATION

Experiments with manned command posts have to be supported by appropriate stimuli and context to make the commander and his staff behave as they would in the real world situations the experimenters envisioned for them. As contractors supporting experiment engineering at USJFCOM's Joint Futures Laboratory, our job has been to provide simulation support for these experiments and we have traditionally though of ourselves as simulation engineers. However, the demands of our participation in the Noble Resolve series of experiments have caused us to rethink our role from providing a simulation to that of providing and delivering the content needed to drive the experiments. This generalization has helped us to rethink the mechanisms we use for producing and delivering stimuli for our experiments.

The Experiment Environment

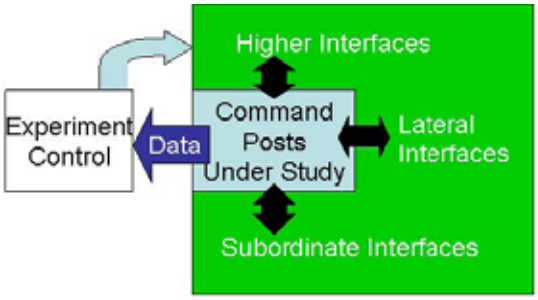

Figure 1: Experiment Environment

As with most things, a command post can be thought of as a system with a set of inputs and outputs, i.e., interfaces that connect it to the outside world. Its situation awareness is determined by its initial knowledge, usually based on a series of briefings called "the road to war", and the information it obtains through its interfaces. The experiment environment transports the command post from the real world

into the experiment's world by providing the appropriate stimuli for those interfaces as shown in Figure 1. Several command posts may be under study and in those cases the communications between the command posts are usually of great interest.

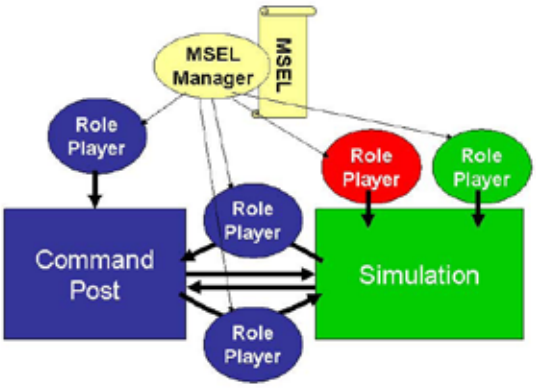

Figure 2: Components of Experiment Environment

The experiment environment typically consists of four components: the initial scenario, the Master Scenario Event List (MSEL), the simulation, and the role players. The scenario sets up the initial conditions for the experiment. A MSEL is a list of events that are to occur while the command post is conducting its mission. It defines the stimuli that the experimenters will use to drive activity in the command post. Experiments often consist of varying the composition of the command post, its organization and information flows, and/or the hardware/software used to facilitate information exchange to see how well the resulting command post functions under various MSELs. The function of the simulation is to keep track of the state of the experimental world, update it, and to impose restrictions on its evolution. The role players are needed to bridge, what might be termed, the impedance mismatches between the command post and the simulation. For example, the simulation may output a text report and the command post may want a voice radio report. More significantly, the simulation outputs may be low level, lack context, or be very repetitive and the role player may need to transform them into something humans would actually report. Role players are also used to translate the command post outputs to the simulation's inputs. Figure 2 shows a typical configuration of one of our experiment environments.

A MSEL manager controls the release of scenario events (SEs) from the MSEL into the environment. SEs can be injected directly into the command post by a role player, e.g., a new mission can be added to the commander's tasks, or they can be injected into the simulation and filtered by sensor and reporting models before they become known to the command post. Opposition force activities are controlled by SEs for the red role players. They usually do not communicate directly with the blue command post, but instead enter commands to the simulation to replicate opposition actions. In some experiments the red role players are unconstrained and fight to win; however those experiments are rare. Civilian population actions and environmental events, such as riots or bad weather are implemented by the green role players. The command post may get some of its inputs, such as Global Command and Control System (GCCS) tracks, directly from the simulation and in some cases the personnel in the command post can give commands directly to the simulation. In these cases an emulated command and control system with special interfaces for controlling simulation entities is typically used. However in most cases, command post orders are implemented by blue role playing simulation operators and simulation outputs are filtered through blue role players before reaching the command post.

Noble Resolve

The Noble Resolve series of experiments at USJFCOM seeks to help the military execute its new role in disaster relief and consequence management for domestic emergencies. It has become obvious to most people that disasters on the scale of Katrina require a prompt federal response and the military is an important component of this response. However, it is one of many different government and civilian responders and it must understand how to effectively coordinate its efforts with that of civilian organizations.

Interface Technology Evolution

The revolution in communications that has come with steadily shrinking integrated circuits and advancing communications technology makes today's command post a far cry from those that existed only a couple of decades ago. The communications mechanisms available to those commanders were limited to radios, telephones,

paper/text reports, and relatively primitive command and control systems. This helped make the stimulation of these command posts tractable. As long as one could use a simulation to track the major units and platforms in the conflict and drive the C4I system, all the other interfaces were human to human and could easily be supported by role players. However, the emergence of the internet now provides many different forms of interaction including web sites, blogs, collaboration systems, email, and instant message clients. While most of these media, especially those requiring interaction, are still best handled by role players, others such as web sites may require large amounts of information to be generated very quickly since in the real world many different people would be generating them. Additionally, video has become ubiquitous and is available from almost any part of the world under all conditions. From TV news to YouTube, video is a constant staple of our daily lives and an important information source for command posts. Virtually every emergency operations center (EOC) has a number of television channels running to keep up with the information being reported by the news agencies. Video is also available as streaming video and video downloads over the Internet. Video is not something a role player can adlib, so new stimulation mechanisms are needed to provide video inputs.

Partnering with Civilian Agencies

The communications capabilities of civilian command posts such as EOCs have typically been more limited than those of their military counterparts. Many agencies outside of DoD are now expanding their capabilities and the capabilities they are developing are different than traditional military command and control systems like GCCS. Instead they are adapting geographic information systems, web based systems, client servers, and email to meet their needs. Alabama has recently developed a system called Virtual Alabama that is built around Google Earth [AL DHS]. Thus any military command post that expects to interoperate with civilian command posts needs to have appropriate means to do so. Fortunately almost all are web based. In the Noble Resolve series of experiments JFCOM J9 has been attempting to ensure that military command posts can effectively exchange information with their civilian partners. One initiative by the Department of Homeland Security (DHS) to standardize command and control for civilian EOC's is called the integrated Common Analytical Viewer (iCAV). It is a web based system with servers that provide a georeferenced view of resources, emergencies, and responders. There are many different systems that are vying to capture the emergency response market and it may not standardize for a while. Thus the experiment environment must be able to support inputs into a variety of web based command and control type systems.

Focus on Civilian Interaction

Over time civilians have become more and more important in our experiments. In urban warfare, they were the background that irregular forces hid in and an important part of tactics was figuring out how win the loyalty of the local population. In homeland defense scenarios, the local population is our own and the task is the rescue of our citizens from natural and man-made catastrophic events. As a result many of the combat models that we have previously relied on are no longer relevant to the problem. Instead models of earthquakes, tsunamis, evacuation and delivery of critical supplies are needed. While many simulations of these phenomena are available, such as the Federal Emergency Management Agency's HAZUS-MH model for earthquakes, flooding, and hurricanes [FEMA], these models are not built for network communications with other simulations. Even if they were, it would not be helpful since their output is not compatible with the entity representations that we use. They are risk analysis models that provide estimates of the levels of damage and injury that will be produced and the areas affected. Their output has to be interpreted by other models to produce specific entity state data that can be used for command post stimulation. The Noble Resolve experiments have required us to look at a variety of different models to find those we can apply to the experiment environment.

Increased Efficiency

While the desire to deal with the civilian aspects of problems expands the areas of interest for command posts and advancing technology gives the command post the ability to track events in ever greater resolution, there is a simultaneous pressure to generate experiment stimulation at lower cost. Primarily this pressure is for reductions

in the personnel required to support the experiment and in particular to reduce the number of role players required. Thus there is need to decrease the impedance mismatch between the raw stimuli and the command post interfaces to enable automated delivery.

STIMULUS GENERATION

Until Noble Resolve we were comfortable with the use of four central simulations to generate the content that we presented to command posts [Ceranowicz].

- Culture Sim provided the civilian background for our experiments.
- The Dynamic Terrain Sim dealt with the destruction and modification of buildings and infrastructure.
- JSAF (Joint Semi-Automated Forces) and similar Service simulations modeled force movements and interactions.
- SLAMEM modeled sensors and fused their outputs to produce tracks and reports.

Content generation began with the MESL team generating a set of SEs. These were then sent to the M&S operators who transformed them into scenarios that they would run during the experiment to implement the SEs. During the event the operators acted as role players and interpreted orders from the command posts and adjustments from experiment control with new commands to the forces under their control. While there are Noble Resolve applications such as Maritime Domain Awareness (MDA) where much of this approach is still viable, for other areas we needed a new approach. Instead of being a background to work around, the population is now the center of interest. Instead of combat we are interested in rescue and instead of C4I we are interested in videos and websites.

Stimulation vs. Simulation:

Our end goal is stimulation of the command post interfaces and as mentioned previously there are two primary ways to achieve it. One is to go directly through a role player into the interfaces and the other is to filter the SEs though the simulation. Often we confusingly call the former stimulation and the latter simulation and ignore that they are just points on the same continuum. We shall continue that confusion here and rely on context to sort out the meaning. As simulation engineers we have naturally favored simulation, feeling that the stimulation was unprincipled and lacked rigor. However, there are very valid reasons for using stimulation instead of simulation. If the study requires tight timing between the arrival of one stimulus and that of the next, stimulation is clearly the preferred approach. Simulation provides no guarantee that a stimulus will ever make it to the command post. If fact the more simulation there is between the point of stimulus injection and the command post interfaces, the less likely it is that the command post will find out about it. Second, the study may want to compare responses to identical stimuli by different command posts. Stimulation gives you repeatability. On the other hand, simulation allows command post actions to modify the effects of the stimuli, supports interactivity, and simplifies the design of the SEs since the designer does not have to anticipate how and when the command post would learn about the SE.

Level of Stimuli and the Simulation Gap

Initially command post experiments where stimulated by aggregate level simulations since all the data reported to the command post consisted of the state of high value assets such as ships, aircraft, and battalions or above. However, as sensor technology evolved and the number of tracks monitored by command posts increased we moved to entity level simulations such as JSAF and SLAMEM that better supported the modeling of sensor detection and fusion. With the widespread presence of video inputs in today's command posts, even more detailed simulation is required. However, simulating at high resolution makes it difficult to simulate large populations and to generate realistic aggregate reports directly from the simulation; especially for human in the loop simulations. Since JSAF is controlled at platoon and company level, knowledge of higher missions and progress can only come from its operators/role players. There is a fundamental gap in the information available in the simulation and what the command post is interested in.

Furthermore, while military organizations do have top down mission plans that can be captured in simulation, the same is not true for civilian agents and organizations that

operate in a bottom up fashion with different individual goals. Summarizing what is happening in these simulations for the command post is beyond our current technology, although many specific summary reports like number of injuries and incidents can be easily generated. A general capability would require the construction of synthetic reporters that could interpret the low level activities of many different agents to produce explanations of what was happening. The simulation engineer's ideal of inserting all SEs directly into the simulation and having the simulation automatically generate all the reports and pictures that the command post will need is not practical today.

NOBLE RESOLVE 07-2

Thus we had to reconsider our preference for a simulation heavy approach and move in the direction of stimulation. Our first experiment was called Noble Resolve 07-2 (NR07-2). It was a discovery experiment investigating the ability of different organizations to utilize iCAV as a Common Operational Picture (COP) tool. The experiment included a variety of drivers including an earthquake in Portland, Oregon and the explosion of a radioactive dispersion device (RDD) on a ship in the Pacific with other RDDs believed to be heading to the United States mainland.

Since the sites involved in the study only supported phones and relatively low bandwidth Internet connections for email and Internet browsers, the interfaces we had to stimulate were limited. Naturally since the experiment was focused on iCAV, using iCAV as one of our delivery mechanisms was a primary requirement. As the MSEL developers put together their SEs for the event, it was evident was that although the SE's included some very detailed events and interactions they were also very sparse. They only covered a small fraction of the events that would happen during a disaster, not unlike the portrayal provided by an evening television newscast. So, another one of our tasks was to fill in some of the events surrounding the skeleton provided by the MSEL. The MSEL developers also asked us to use the simulation to provide visualization of their SEs. Since JSAF and its predecessors were developed for virtual reality applications, that was feasible. In addition, we decided to emulate the news media via a news website and a TV news broadcast.

Content Production

Content production for NR07-2 was broken into two tracks. The first was the amplification and illustration of the MSEL through a set of news stories. This involved taking the SE descriptions, adding some additional ones, and writing complete news stories for them. For each news story, we either created a video using JSAF or by using an appropriate still picture. All the video clips were created before the experiment by running scenarios with JSAF and Culture, rendering them with JStealth, and piping the video output via an s-video cable to a "Mythdora" Linux system configured to record the video. While this approach lost resolution it was a low cost approach that avoided the stuttering we experienced with software capture approaches due to the processing load. The videos were then edited, titled, and dubbed in the Pinnacle video editor. Finally we used the video editor to voice over the video or the still picture with the news stories.

The second track filled in the details not covered by the MSEL. To do this we simulated aspects of the Portland. earthquake. Our goal was to create incidents in Portland resulting from the earthquake that emergency workers modeled in JSAF would have to respond to. These incidents were added to those described in the SEs. All the incidents would then be shown on iCAV and users could then drill down into each incident to see its magnitude and if it had been responded to. As the incidents were resolved, they would disappear from the iCAV display.

Our original intention was to get a copy of HAZUS¬MH from FEMA and run it to get an estimate of the relative probabilities of damage for Portland given the location and magnitude of the earthquake. But HAZUS-MH was backordered and we could not obtain a copy in time. So we turned to the literature and found some studies of earthquakes of approximately the right magnitude in the Northwest. Using the results of these studies and a terrain model of Portland which we had built for JSAF, we adapted our Dynamic Terrain simulation to generate building damage due to the quake which roughly followed the probability of damage predicted in the maps from the reports and the MSEL descriptions. The results were around 3,000 damaged buildings, many of which were on fire. Although we were

unsure that this was a realistic result, the scenario called for a large number of gas leaks and subsequent fires and we needed a disaster of sufficient magnitude to justify a national response, so we used it for the experiment. The next piece of information we needed to generate incidents were the people that required assistance. A damaged building by itself would not have necessitated an emergency response in this environment. Although we had some estimates of the number and severity of injuries to expect, we did not have a similar relative likelihood of their spatial distribution. So we made the assumption that the primary injury mechanism was falling debris from damaged buildings, we distributed the injuries throughout the damaged buildings based on a number of factors including building size and function. We neglected injuries to people away from any buildings.

Once the injuries were assigned we created a set of incidents for them. Each incident corresponded to a single building that contained people that needed to be rescued and/or was on fire. In reality we expect that clusters of damaged buildings will be aggregated under one incident command post, but we did not have time to implement such an aggregation. We assumed that any people that were mobile would self evacuate to a treatment center. Therefore only people that were seriously injured or unable to move were considered part of incidents that would require responder assistance. We did not want to model the specifics of each incident and response. For example we did not want to say there are three people trapped on the third floor, one critical who is pinned beneath a collapsed building column at the north side of the building. Instead we simply characterized the event by the number of minutes required from each type of responder to resolve the incident. The general pattern in all this work was to search out relevant data, use that data to build conditional probability models consistent with the MSELs, and then draw from those models to populate the experiment environment. Since we were drawing the effects of a single earthquake from these distributions and our goal was simply to provide plausible data for viewing on iCAV, we felt that this approach was adequate for the experiment. It was necessary to be able to fuse together many different sources of data with different resolutions to shape the resulting disaster. Once computed the incidents were stored in a database table for injection during execution.

Another mechanism we used to generate content was the recording of real world activity. For the MDA part of the experiment, we recorded two weeks of data on the movements of shipping traffic from the Automatic Identification System [USCG] , the real time tracking system for maritime shipping. After preprocessing the data we turned it into logs that could be replayed by our Culture simulation. This allowed us to populate the simulation with realistic ship traffic. The reason for replaying it through our culture simulation was that it allowed us to override the recorded movements of shipping as needed to respond to events in the simulation. For example, one of the SEs called for the Portland harbor to be evacuated after the earthquake due to oil spills. This allowed us to modify the recorded data to implement that SE. The key restriction is to maintain consistency between the recorded data, the MSEL, and the state of the simulation.

We did not completely abandon execution time simulation. During the experiment we ran the DT sim in a deterministic fashion to damage the buildings in Portland and create fires. We injected the incidents that we had precomputed into JSAF and JSAF operators sent responders to the sites to resolve the emergencies. We simulated the movements of merchant ships carrying RDDs and showed them sailing among the prerecorded merchant traffic. We also simulated traffic leaving Portland, UAVs over flying the quake area generating live video and the output of Portland traffic cameras.

Content Delivery

In order to support this experiment with reduced role player manpower we turned to a new approach to deliver the SEs. The heart of this approach was an event database that synchronized the execution of the experiment and delivered different views of the same event both to the command post and to the simulation. For example, the event database held a SE to initiate the earthquake in the simulation and another one shortly thereafter to report the earthquake in the news and in iCAV. The importance of delivering multiple views of the same event is that each view can be targeted to a particular interface with an appropriate level of abstraction. The event database is an electronic MSEL, which we implemented using a LAMP archi-

tecture (Linux, Apache, MySQL, and PHP).

To setup and manipulate the event database we developed a tool called EventGen, a script generated web interface to the event database tables. It allows MSEL developers and the experiment support team to enter, edit, and then delete experiment injects prior to the experiment and then monitor and control their injection into the experiment during execution. EventGen supports a variety of injects. The SEs used for NR07-2 included INFO events, which were informational events placed in the MSEL to remind the experiment controllers when they needed to take a role player action such as to make a phone call or send an email. They were not injected automatically. NEWS events injected news stories that were viewed by experiment participants on an experiment web site called ENN.com. They were automatically injected at specified simulation times. The remaining event types were JSAF events designed to be automatically injected into the JSAF federation via High Level Architecture (HLA) interactions creating effects in the simulation.

During experiment execution, the event database is queried by a number of programs that look for SEs which they know how to inject into the experiment environment. When they find one whose injection time has arrived, they inject it. For example, the Event JSAF monitored the database for JSAF events. This arrangement is somewhat reminiscent of blackboard AI systems [Erman]. For NR07-2 simulation time was controlled by the JSAF federation. For applications that were not federated into the JSAF federation, a web interface called the WebProxy provided a way for web applications to use http queries to interact with the running JSAF federation. To get the current simulation time a web application would send an http request to the WebProxy, which would respond with the current time. SEs in the event database could be assigned absolute simulation times or times relative to another SE. If the experiment controllers desired, they could override the automated injection of SEs and hold or release SEs as needed. If an operator held an SE whose execution time other SEs depended on, they would all be held until the first SE was released. Because EventGen was a web application, it was easy for controllers at multiple sites to track the progression of the MSELs.

News events were injected through another PHP script that would create a new ENN.com web page whenever a user's browser made an https request. When the script receives the https request it makes a query to the JSAF WebProxy to get the current simulation time. It then uses that time to query the event database for all news stories with inject times less than the current simulation time. The query results were used to produce a webpage containing recent news events and another containing the older news stories.

The JSAF Events were implemented by the Event JSAF; a JSAF started with the –eventgen flag. It periodically sends an SQL query to the event database to see if there are any JSAF SEs that are ready to be injected. If so, the Event JSAF uses the columns of the matching event database rows to fill out JSAF interactions and send them out to the federation. For the NR07-2 Event JSAF used detonation interactions to trigger the earthquake in Portland and to set off the RDD. The SE for the earthquake was followed by additional injects that looked at the table of precomputed incidents and generated situational awareness objects (SAOs) for them in JSAF federation. These objects were automatically displayed on the JSAF GUI and informed the operators of the incidents, their locations, and the types of emergency responders required. The operators responded by assigning the appropriate available responders to the incidents. Additional SEs were available to cause the civilian population to form and disperse crowds, and to cause people to avoid an area but since the crowd scenes were prerecorded prior to the event there was no need to cause the crowds to form during the event.

Video in NR2 was delivered in two different ways, file downloads and streaming video. First, it was delivered via links on ENN.com that users could select to download and play an .avi file for each news story. Second, it was delivered via streaming video clips. Streaming video was used to model a television news channel such as CNN. A background stream of CSPAN video was used as the normal programming because CSPAN video of government proceedings provided easily accessible public domain content. At the time that each new SE was injected, an operator would queue a "breaking news" alert and then a news video would be played over the background programming. The same

video clips that accompanied stories in ENN.com were used for "breaking news"; they just appeared first as TV stories. Needless to say this manual procedure did endure a few errors during the experiment week. We have subsequently automated the queuing process with a video jukebox program that monitors the event database and kicks of the video clips automatically.

A real time view of the disaster areas was provided by UAV's modeled by the SLAMEM simulation. Continuously updated streaming video was produced by JStealths set to mimic the cameras on the SLAMEM UAVs. The streaming video could be accessed via links on the ENN.com page as well as from UAV Icons on iCAV. The ENN.com page also provided links to traffic cam views of the Portland highways. A single JStealth was used to produce multiple traffic cam views. Clicking on a traffic cam link would send a request to reposition the JStealth view and return the resulting picture to the WebProxy, which translated it into an interaction. This caused the JStealth to reset its view to that of the camera whose view was being requested. Once the scene was rendered, the screen was captured and returned to the WebProxy, which sent it back for display in the user's browser.

From the experiment view point the most important new development was iCAV Connect. It was an application that could take data from the database and send it via a Simple Object Access Protocol (SOAP) interface to iCAV. This allowed us to push injects to iCAV where they would be displayed as icons in their map layers. This made it easy to display any information stored in the database such as news stories and incidents on iCAV. However, we also wanted to show entities from the JSAF federation, such as commercial shipping and first responders. To do this we relied on our existing JLogger. This logger takes HLA Federation Object Model (FOM) data and records it to database tables. This allowed iCAV Connect to access these tables and send our simulation data to iCAV for display. Ship state, incidents, incident command posts, UAV state, access URLS, and News Events were all sent to iCAV and used populate its layers. However, the SOAP mechanism was not very efficient or flexible. Updating data required deleting the old data and resending the new data. Furthermore, all the data had to be sent to iCAV even if no one was looking at those particular layers or in the appropriate area to see it. A better way of stimulating iCAV is through the web mapping service (WMS) interface it provides. However, the time constraints of the experiment did not give us sufficient time to set up our own WMS server [Mitchell].

Post Experiment

The NR07-2 experiment ran very well. The degree of interest in the news part of the stimulation was much higher than in the JSAF first responder simulation, but that was to be expected from the high level of the audience. After the experiment we invested additional time cleaning up our tools and extending them; packaging the resulting system under the name Experiment Event Tool Set (EETS) which is shown in Figure 3. In addition to the visual juke box and a WMS server, we added a mode where EETS could run without JSAF by providing it with an independent clock that could be synched to JSAF when required. We also developed a Google based COP mashup [Merrill] for events where we did not have access to iCAV. We extended the interface between JSAF and EventGen to allow EventGen to automatically launch and control JSAF scenarios and we automated the first responders that had required human operators in during the experiment. Finally we extended EETS to support SEs for automatically sending email messages, so that activity no longer required role players, at least for the initial email. We obtained and ran some tests with HAZUS-MH but found that the default data sets provided with the model are of limited accuracy. The idea is that local communities will receive the software and modify the data to fit their area and then run it. So if local studies are available it may be better to use those results rather than running the model with the default data.

DATABASE CENTRIC EXPERIMENTATION

Unifying Preparation, Execution, and Analysis

The MySQL database was an important part of our NR 07-2 experiment. In previous experiments we had relied on MySQL solely as tool for logging simulation data for subsequent analysis. Under this new approach it became an important part of the other two phases of experimentation: data preparation and execution. For data prepara-

tion it allowed us to collect and sequence the SEs to form the MSEL. During execution it drove the presentation of news, provided control over the execution of the MSEL, and provided the data used to stimulate iCAV and control JSAF. Upon finishing NR07-2 it was obvious that much more of our preparation for the experiment could have been preformed in the database, including all the calculations of building damage and the allocation of casualties for incidents. We realized that a database could form a unifying link between all the phases of the experiment. It could provide a single collection point for all the experiment data: source, stimulation, and results, making the development, validation & verification (V&V), and analysis of the experiment easier.

Unifying Stimulation and Simulation

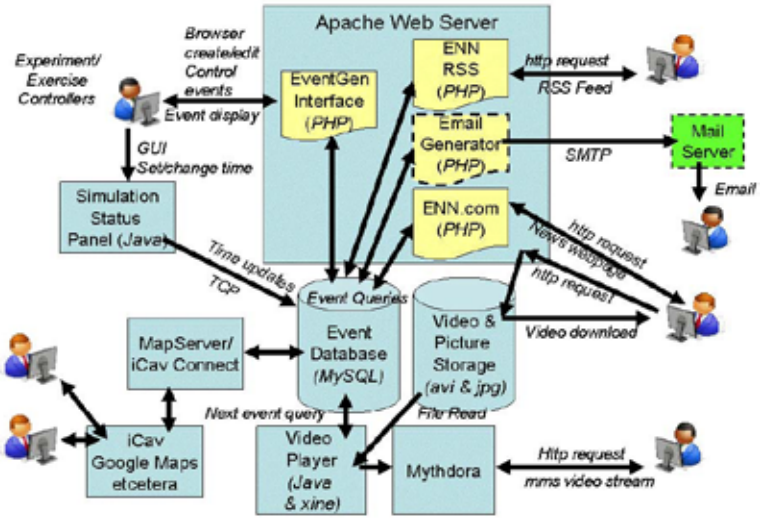

Figure 3: Standalone EETS Architecture

We even went as far as to wonder whether the simulation component of the experiment could be performed through the database as well. Why go through the effort of transforming and maintaining simulation data in specialized formats for large simulations like JSAF. The data is hard to enter and hard to review once it has been entered; requiring people versed in the details of the individual simulations to access it. If the data were available in a neutral database format it would make analyzing, changing, and verifying it much easier for independent researchers versed in SQL; a much less challenging requirement than knowing the details of each specific simulation.. Clearly, this approach is not suitable for high performance low latency simulation. After all databases are essentially glorified file systems and you would be using this file system for your run time communication and data structures. However, there are many experiments that do not require low latency and could benefit from a homogeneous data sharing approach. Tracking logistics and other event based low update rate processes might well be simulated in a database. The benefit of using the same data tables to hold the source data, execution data, and results might offset the inefficiency of simulating directly in a database. So we decided to try and write simulation programs that would run on top of a database. This approach is certainly not unprecedented. Many simulations have used databases to hold their initial conditions, data, and results. However, here we were focusing on using the database to integrate the contributions from different simulations and applications executing over all the phases of the experiment rather than to support a single simulation.

A Framework for Distributed Simulation

One of the benefits of database centered simulation is that databases are designed to support distributed client server computation. The database process is independent of any of the client processes that use it. They can be located on the same computer as the server or on a remote computer accessing the database from a LAN or a WAN. A great deal of work has also been done to make building web systems on top of databases easy. Thus the path to web based paradigms like mashups and service orient architectures (SOA) is clear. This makes it easy to implement multiple simulation processes that work together to support a single experiment. They don't have to connect to each other or know about each other, they just have to be able to connect to the database and work with a common set of tables. In this respect a table definition is very similar to a packet layout used for distributed simulation. Furthermore like networks, databases are language neutral. If one developer insists that C++ is the only language fit for simulation development and another will only use Java, there is no problem, the database will be equally accessible to both. A big barrier to the

extensive use of databases in the past was the cost of high performance databases. However, recently open source databases such as MySQL and PostgreSQL have matured to the point that they can provide services comparable to the expensive commercial databases. A recent development in MySQL that is especially important for distributed simulation is MySQL Cluster [Davis]. This is a database engine that allows MySQL to be run on a cluster of computers with all the tables located in memory. This has the potential of eliminating much of the overhead of writing files and provides access to the computing power of up to 63 machines. We are starting to explore the use of the cluster as a distributed simulation medium.

Persistence

The other feature for simulation that a database approach supports naturally is persistence. Distributed simulation is focused on distribution in space with a single simultaneous execution. All the simulation components run at the same physical time advancing logical time in concert. This approach is especially prevalent for training, experimentation and rehearsal applications where the goal is to provide a single common experience for the audience. In the analysis world, the constraints are less rigid and multiple runs and a sequence of feeding results from one simulation to another are used to examine different components of a problem at different resolutions and from different viewpoints. By using a database to hold both the inputs and the results of simulations in a neutral format, it should be easier to automate the flow of data through simulation components that run in series as well as in parallel and keep track of the results of different cases. A database centric experimentation approach seems to have enough potential benefits to be worth investigating.

NOBLE RESOLVE 08

Noble Resolve 08 (NR08) continues to explore the application of military forces for disaster relief. It includes a small seminar on handling mass evacuations, additional investigation of information sharing between civilian and military command posts, and investigation of force and equipment requirements to provide relief and consequence management in the aftermath of major terrorist incidents.

Mass Evacuation

This was a small seminar, primarily utilizing the news stimulation capabilities of EETS which was held in April 08. It examined how to respond to a massive evacuation due to a natural disaster even larger than Katrina. From a technical viewpoint this event was significant because it allowed us to try out three concepts that came out of NR 07-2. The first was the separation of the presentation of the simulation data from the generation of the data. This has a number of advantages including allowing the development of the injection materials to be spread out over time thus reducing surge requirements for role players as well as increasing the reliability of the experiment. Of course, it cannot be used where real time interactive responses are needed, but every experiment has some components that don't require real time interactivity. The seminar was designed to jump through a number of news stories associated with different scenario times sequentially, but the timing of the transitions was based on the level of discussion occurring after each stimulus. Thus it was impossible to predict whether the real time between two stimuli would be two minutes or two hours. In addition to the news items we were also stimulating iCAV with information about hospital and shelter utilization. This information had been simulated to support the MSEL and the time history of shelter and hospital utilization was prestored in the experiment database. EventGen was modified to advance the EETS clock to the next news item under the control of the operator. Whenever the clock advanced it would automatically place copies of the utilizations at that time into a set of tables used to drive the display on iCAV. Thus it was possible to jump randomly around the experiment timeline and the underlying iCAV data would change with it.

The second concept was the use of Web Mapping Services to drive iCAV. During NR07-2 we stimulated iCAV by pushing our data up to the iCAV site using a SOAP service which required us to upload all the data that iCAV would display prior to any requests for it. With WMS the system was configured as a mashup. A browser request to update the iCAV screen would cause iCAV to issue an automatic request to our WMS server (based on the MapServer software from the University of Minnesota [Mitchell]) to retrieve and send the latest data from our database tables to iCAV so it could

automatically layer that data over its own map data. Thus iCAV only needed to request the data that its users were interested in, which can be a great savings if the information is dynamic and not all of it is accessed by viewers.

Finally this event allowed us to try out the database centric simulation concept. A simple model of evacuees seeking shelter was developed using three PHP scripts that ran in parallel to move evacuees from entry points to roadways to shelters. The three scripts communicated only through the database tables and ran with a small executive that coordinated the advance of logical time through a sim-time table. The results were automatically copied to log tables in the database, which were then available to support the iCAV display. The simulation for the event was run on a single computer. After the event we were able to run the program on a Linux cluster using MySQL cluster with a significant reduction in execution time.

Information Sharing

The NR 08 Information Sharing Event is scheduled to run in July 08. The event includes earthquakes as well as other incidents across the country that will stress the Federal response. The focus is on the ability of higher level response cells to communicate with a variety of web based coordination tools. An important component of this experiment is the use of WMS to allow response cells using different COP tools to share their data with iCAV and make it accessible to all participants. We are leveraging our WMS experience to create a web site where uses can input information to display on iCAV.

As in NR 07-2 we are supporting the event with news stories and incidents. For this event we will employ the newly added Email events that allow EventGen to automatically send emails to experiment participants in response to SEs. Our new video jukebox will be used to emulate TV news without the need for human intervention to queue the news stories. Finally we hope to scale up our simulation of evacuation to run on a large MySQL cluster for this event.

Consequence Management for Terrorist Incidents

In this event, scheduled for Sept 08, we are going to support an experiment to investigate our ability to respond to major terrorist incidents. The technical goal for this event is to use a distributed database to support all phases of the experiment, data collection and preparation, stimulation and simulation, and analysis.

CONCLUSIONS

Command post stimulation is becoming more difficult because the range of phenomena that command posts are interested is expanding rapidly. Commanders are utilizing political, economic, social, information, and infrastructure means in addition to military power to successfully complete their missions. They are also taking advantage of new Internet and video technologies to monitor their areas of responsibility. At the same time we want to reduce the cost of producing command post stimulation for training, rehearsal, and experimentation. The approaches we have been experimenting with including automated MSEL delivery at different resolutions and a homogenous treatment of preparation, execution, and result data may help to address the problem. Noble Resolve 08 will allow us to test these ideas. If they are successful it will give us new tools to stimulate J9 experiments more effectively at reduced cost. Our goal is not to develop another large simulation or federation, but rather to create a flexible methodology for constructing stimulation/simulation out of simple models and available multiresolution data. A further goal is to make simulation technology available to J9 analysts through web based interfaces so that they can design their own stimulation inputs with a minimum of support from the simulation developers.

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ABOUT THE AUTHORS

Andy Ceranowicz is a Senior Science Advisor at Alion and the technical lead for federation and Joint Semi-Automated Forces (JSAF) development at JFCOM J9. He led the development of the Millennium Challenge 02 federation as well as the development of JSAF and its predecessors, ModSAF and SIMNET SAF. Andy graduated from The Ohio State University with a Ph.D. in Electrical Engineering.

Brett Dufault is a Science Advisor for Alion Science and Technology. He has worked on the development of JSAF (and prior to that, ModSAF). Brett holds an M.S. in Electrical Engineering from S.U.N.Y. Buffalo.

Don Beesing is a Senior Programmer for Alion Science and Technology. He has worked on the development teams for the Urban Resolve and Noble Resolve series of experiments. Don graduated from Hiram College with a Bachelor's Degree in Computer Science.

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Adaptive Behavior Models for Asymmetric Adversaries

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Randy Jensen, Jeremy Ludwig
Stottler Henke Associates, Inc.
San Mateo, CA
Jensen@stottlerhenke.com
Ludwig@stottlerhenke.com

Michael Proctor, Jon Patrick
University of Central Florida
Orlando, FL
Mproctor@ucf.edu
Jonathan.patrick@us.army.mil

Wyatt Wong
Forterra Systems
San Mateo, CA
Wwong@forterrainc.com

ABSTRACT

In order for simulation based training to help prepare warfighters for modern asymmetric tactics, opponent models of behavior must become more dynamic and challenge trainees with adaptive threats consistent with those increasingly encountered by the military. In this paper we describe an adaptive behavior modeling framework designed to represent asymmetric adversaries within a multi-player virtual environment. The framework aims to provide a means for adversary models to analyze the tactical situation during execution, and adapt their behaviors and tactics accordingly. Dynamic adaptations occur both within an exercise and across exercise runs, with an automated means to carry "lessons learned" forward from one exercise to the next and adapt tactics in subsequent training sessions. This paper provides details on two distinct areas of investigation. The first area is a survey of the space of asymmetric tactics and adaptations from real-world military operations, initially focusing on urban "presence patrols". A number of training experiments were conducted in a virtual environment to solidify the behavior modeling requirements for this specific operational area, and provide a basis for generalizing to other domains. The second research area is the design and development of artificial intelligence techniques for creating adaptive adversaries. The approach makes use of an authoring tool for defining adaptive behavior models specified as partial plans that can be instantiated with choices partly driven by reward functions using data from previous events. Based on this initial behavior specification, new adaptive behaviors can be automatically generated with methods based on evolutionary algorithms. In both cases, the adversary model adapts over time in conjunction with training events.

INTRODUCTION

In order for simulation based training to help prepare warfighters for modern asymmetric tactics, opponent models of behavior must become more dynamic and challenge trainees with adaptive threats consistent with those increasingly encountered by the military. In this paper we describe an adaptive behavior modeling framework designed to represent asymmetric adversaries within a multi-player virtual environment. The framework aims to provide a means for adversary models to analyze the tactical situation during execution, and adapt their behaviors and tactics accordingly. Dynamic adaptations occur both within an exercise and across exercise runs, with an automated means to carry "lessons learned" forward from one exercise to the next and adapt tactics in subsequent training sessions.

This paper provides details on two distinct areas of investigation. The first area is a survey of the space of asymmetric tactics and adaptations from real-world military operations, to generate a set of reference scenarios. A number of training experiments were conducted in a virtual environment to solidify the behavior modeling requirements for this specific operational area, and provide a basis for generalizing to other domains. The second research area is the design and development of machine learning techniques for creating adaptive adversaries. The approach makes use of an authoring tool for defining adaptive behavior models specified as partial plans that can adapt over time in conjunction with training events. This approach focuses on both supporting a natural method of encoding existing domain knowledge and the rapid adaptation of encoded behaviors. No aspirations are made

with respect to the psychological validity of the underlying machine learning methods.

BACKGROUND

The training challenge is to provide the training audience with practice against an enemy who changes tactics in unpredictable or devious ways, often times specifically in response to observed patterns. Classroom lecture environments are typically not a very effective option for this training challenge, having been shown to have less than a 10% retention rate (Wiggins, 1997). While field training exercises are widely regarded as effective, they are costly and require availability of training areas and supporting infrastructure to include additional personnel to "play" the threat. Virtual simulations have typically been shown to be efficient and effective replacement for live training exercises. However, a significant limitation of current threat simulation models is their lack of dynamic, contemporary, asymmetric opponent behaviors. Lacking such an opponent, training scenarios may initially create a strong positive training effect but with repeated training exercises the opponents' behavior becomes predictable and results in rapidly diminished returns on additional training.

To counter the diminishing returns of simulation-based training, opponent models of behavior must become more dynamic and contemporary. Contemporary opponent models of behavior must use asymmetric tactics, must dynamically adjust their tactics, and must generate alternative behaviors that are consistent with their perspective on warfare.

In order to provide training that exposes trainees to this kind of dynamic threat environment and the kinds of decision making they must employ in their own tactics against a thinking and reactive enemy, scripted adversary behaviors inherently cannot provide sufficient complexity to test weaknesses in the trainee's tactics. This is the motivation for the development of a system that can generate adaptive adversary behaviors for execution in simulation based training.

TRAINING SCENARIO DEVELOPMENT

A key part of this research in laying the groundwork for the application of an adaptive behavior approach was to consider specific requirements for likely scenarios that would be used as an instrument of a training methodology. In pursuit of this goal, we developed a sample set of training scenario instances with a sequence of changing adversary tactics, in order to address the overall requirement for adaptive and asymmetric nature of insurgent tactics.

Scenario Design Objectives

The scenario content was developed to properly capture the common tactics, techniques, and procedures (TTPs) of insurgent behavior in current operational settings around the world. It was important that these TTPs not be country specific. We were aiming for a sequence of events that demonstrated adaptive insurgent tactics that are based on logical responses to previous successes or failures. We also were conscious of the counterbalancing effect of the simultaneous goals of realism and tractable modeling challenges. On the one hand, realism is a critical component of any training, and even more so when the goal is to familiarize the training audience with the kinds of tactical adaptations that are the hallmark of asymmetric warfare. On the other hand, full realism ultimately presents an intractable technical challenge, as the goal of modeling a complete range of possible human actions, reactions, and tactical adaptations would require a complete model of human cognition. For example the use of videotape recorder timers to trigger improvised explosive devices (IEDs) is an element of a tactic that cannot be generated by a system that has no model of such artifacts and their associated properties in its virtual world. The middle ground is a space where scenarios based on real world insurgent tactics can be eminently realistic.

We believe that a dynamic behavior adaptation model that implements a mechanism for deciding among choice points linked to these scenarios can therefore be successful in accomplishing the training goal of experience against such changing tactics. It is also possible to introduce unpredictability in such a framework, as an explicit factor in how choice points, and therefore tactics, are selected by

the adversary models and performed.

Another influence on scenario design involved consideration of the likely training objectives in a use case where such a scenario would be employed. The process of constructing a scenario ultimately involves the combination of underlying tactics applied in the scenario with the detailed set of events that may take place in either a linear or possibly branching manner. The level of granularity of the events within the scenario ideally should match the level at which the training audience is performing decision making, such that events that do not contribute to measurements of performance tied to intended training objectives can be abstracted out of the overall scenario event list. For example, if the training objectives concern identifying enemy tactics and deciding on proper counter-tactics, and if the training objectives do not involve the details of operational procedures that factor into counter-tactics, then these elements of the training experience can be simplified. As a result, the aim in our scenario development process was to focus on events which create the conditions where the training audience must make key decisions about the possible enemy tactics being employed. Finally, we were looking for scenarios with the potential to demonstrate the use of cultural assumptions and differences, as these increasingly play a role in asymmetric warfare. Through our literature review and consultations, over 100 documented attacks were analyzed to gain a better understanding of the trends and peculiarities involved.

Scenario Structure

Twenty-six scenario permutations were developed out of an underlying "presence patrol" scenario. To design and build these scenario permutations, the team reviewed current literature and training materials, as well as the expertise of four active duty officers who had recent experience from Iraq, Afghanistan, and Kosovo. Developing multiple scenarios from documented real world instances serves to illustrate the adaptive behavior of the adversary faced by US forces. Note that collecting scenarios for the purposes of developing adaptive behaviors requires a different level of detail than simply defining scripted sequences of events. The scenarios are informed by real world events, but decompose these into choice points which, in practice, may be automatically selected or triggered based on the adaptive logic that applies as a training event or sequence of training events unfolds. This is a key element in how the parallel objectives of realism in tactical methods and realism in tactical variation are captured.

Although this paper is not intended to enumerate specific tactical details collected from real world operational lessons learned, it is informative to describe the categories into which specific choice points fall, in an overall organizational scheme for decomposing the adaptive behaviors. These categories emerged from the review of anecdotal operational information, irrespective of observations about currently existing virtual models. The following are the major categories identified, with examples:

1. Delivery mechanism: multiple and perhaps nearly infinite means of adaptation, including IEDs with various placement methods, suicide bombers, snipers, and other combinations of specific delivery methods tied to individual capabilities.

2. Munitions type: variations of specific munitions choices given a delivery mechanism, such as the explosive used with an IED or suicide bomber, or the specific weapons used by a sniper.

3. Attack location: determined by the combination of delivery mechanism and avenues of approach and/or fields of fire needed to deliver the munitions on the target.

4. Number of attacks: one isolated, two coordinated, three coordinated, with/without the use of decoys, and other variations.

5. Environment: includes both the operational setting and the mission, which may take place in a market, street, check point, searches within houses or buildings, presence patrol on city streets, and other variations.

Using these categories, scenarios were developed that provided illustrated examples of known insurgent behaviors and trends. Scenarios were developed using current military doctrine, and for this effort all scenarios were focused on squad level dismounted patrols in an urban environment similar to Iraq. In the complete set of scenario instances, each instance shows the co-evolution of

tactics by the adversary pair (insurgent vs. Coalition) over time. In any given scenario instance, the US forces conduct a tactical operation, the insurgent adversary performs a tactic designed to defeat or degrade the effectiveness of the US tactic, an outcome occurs, the US adapts and develops a counter tactic, a new outcome occurs, and finally the insurgents adapt a new tactic, which leads to the next scenario instance pairing. As evidenced in real world asymmetric operations lessons learned, sheer variation itself is a factor in the enemy's choice of new tactics, along with other considerations involved in responding to US counter tactics.

ADAPTIVE MODELING APPROACH

The scenarios were central to the construction of a decision making model for the adaptive adversary behaviors, by providing scope for the inputs and outputs that constrain the space of possible actions and reactions of the adaptive adversary model. Although the set of scenario instances represents a sample sequence of adaptations motivated by preceding successes and failures, the adaptive behavior model automatically generates differing tactics in an unscripted way. The behavior models described in this paper provide support for all of the adaptations identified in these scenario designs, with sequencing entirely driven by exercise events rather than a predefined ordering.

Our approach to the problem of behavior adaptation and creation for asymmetric adversaries contains two primary elements:

1. Initial Insurgent Behaviors: An initial set of insurgent behaviors that are created by a subject matter expert (SME). This captures the current knowledge of insurgent tactics and allows for realistic adversary performance from the first training simulation.

2. Behavior Adaptati on: Adaptive choice points that are embedded in the initial simulation behaviors allow for adaptive behaviors. The SME specifies partial behaviors through the use of choice and reward points and then the system automatically learns which particular behavior(s) work best against the current adversary.

This general approach is used to control behavior at two specific levels: tactic and agent. At the tactic level, the basic pieces of a training scenario are put in place before the scenario begins. This includes placing snipers, IEDs, ambush forces, etc. As the scenario unfolds, the behavior at the agent level controls the behavior of each agent within the scenario.

In this paper, we focus on initial insurgent behaviors and behavior adaptation at the tactical level, though the results are directly applicable to the agent level as well.

Tactical Behavior Adaptation

Tactical behaviors determine the initial conditions of a training scenario. Prior to the start of the scenario, the insurgent forces and objects are put into place by running an initial behavior. Adaptive logic in the behaviors is used to learn the most effective adversary tactics. Adaptive choice points are used to setup all of the elements of an insurgent attack such as type of attack, IED concealment, insurgent/object placements, decoys, munitions, etc. Behavior adaptation works as follows:

1. Choices are made for the current instance of a training scenario, based on the values associated with each choice.

2. The training scenario is carried out by blue and red forces. The behavior of the red forces (insurgents) during the scenario can be controlled by Agent level behaviors or by human role players.

3. At the end of the scenario, a reward function is used to update the values associated with each of the choices that applied during the scenario.

There are two important notes to make regarding adaptation. First, based on our particular implementation of adaptation the system can actually select sub-optimal tactics for novice level players while still learning what the best tactics are. This allows a degree of flexibility when implementing this work as part of a training system. Second, adaptation works on both human- and computer-created behavior. That is, the choice point logic can learn to ignore ineffective behaviors regardless of who/what created them. This is a very useful functionality when combined with the automatic creation of new behaviors.

Additionally, synthetic behaviors naturally depend heavily on the virtual environment for location markup. The relationship between the environment and certain tactics can be very close. Enemy avenues of approach, enemy fire lanes, and lack of cover and concealment (exposure) are environmental conditions that, combined with tactical failures (failure to follow rules of engagement, etc.), may predicate an attack.

Implementation Details

The adversary behaviors were encoded in an existing graphical behavior modeling architecture (Fu & Houlette, 2002), where behaviors are composed of actions, predicates, and directed connectors that describe agent behavior. As an action in a behavior can reference a primitive action, or another behavior, hierarchal behavior networks can be created.

The work described in this paper makes use of an updated version of the behavior modeling architecture that incorporates the extended dynamic scripting algorithm (Ludwig & Farley, 2008). This particular learning algorithm was selected based on its ability to quickly learn to best an opponent in modern computer games and simulations (Ponsen & Spronck, 2004; Spronck et al., 2006).

The updated behavior modeling architecture introduces two additional types of action nodes to support a specialized reinforcement learning algorithm: choice points and reward points. Each choice point represents a decision, where the behavior model learns to select the best action from the available action. Learning occurs when the results of the scenario are received as feedback by corresponding reward nodes. In this manner, the behaviors can encode the range of adaptive behavior found during the training scenario development and choose an initial scenario configuration likely to surprise the human players.

Related Work

Choice points, as used in the behaviors described in this paper, are similar to the choice points found in the Hierarchy of Abstract Machine and ALisp architectures (Andre & Russell, 2002). The extended dynamic scripting algorithm (Ludwig & Farley, 2008) builds off of previous research on dynamic scripting (Spronck et al, 2006) and hierarchical dynamic scripting (Dahlbom & Niklasson, 2006; Ponsen & Spronck, 2004).

ADVERSARIAL BEHAVIORS

Building off of both the developed training scenarios and the extended dynamic scripting algorithm, we created behaviors to adaptively determine the best initial training scenario configuration. To do this we specify the possible training scenarios as a hierarchical set of choice points, where the objective is to learn to select the scenario configurations most likely to succeed against the current players.

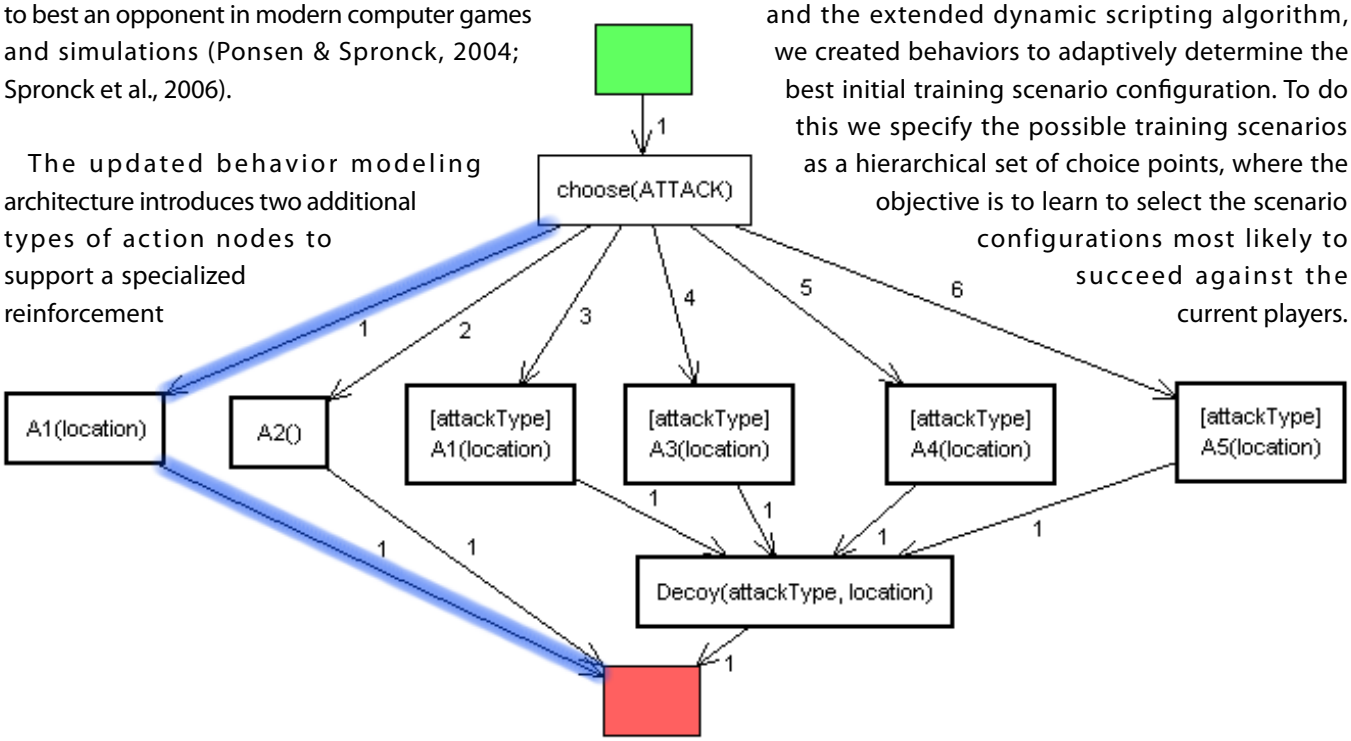

Figure 1: Main Adaptive Adversarial Behavior

An abstracted version of the top level tactical behavior is shown in Figure 1, giving example behavior structure without domain-specific content. The ATTACK choice point chooses the A1 adversarial tactic, as shown by the blue highlighting. The choice point selection is highlighted, where the A1 tactic is selected.

After the main behavior chooses the A1 attack type, control is transferred to the A1 sub-behavior, seen in Figure 2. The choice point for the A1 tactic must choose between a number of different ways to carry out the A1 tactic. In this instance, A1_2 is chosen and control transfers to the A1_2 sub-behavior.

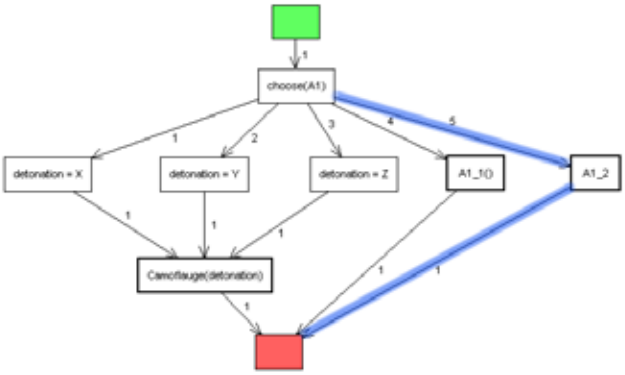

Figure 2: A1 Sub-behavior

The behavior in Figure 2 chooses the specific elements of the A1 tactic. The A1_2 behavior (Figure 3) is responsible for choosing the specific location of the A1_2 tactic in the simulated world from a number of pre-determined locations. A primitive action, selectA1_2ActiveFile, is then called to load all of the selections into the simulator world.

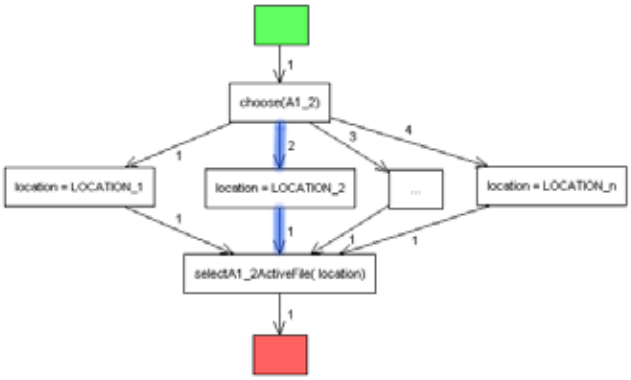

Figure 3: A1_2 Sub-behavior

The behavior in Figure 3 determines the location of the tactic elements in the simulation. After the A1_2 sub-behavior is executed, the simulation is ready for the team of trainees to begin using the simulation.

Once the simulation has ended, the results from the scenario are used to update the values associated with the actions in the choice points. This is performed with the help of a number of reward functions that supply a quantitative value that represents the success of the adversary's tactics in the scenario. For example, a reward function might take into account the current health levels of all of the members of both team or whether or not an IED was detonated. Reward points, encoded as part of the behavior model, use one or more of these reward functions to update a choice point's action values. They may also be integrated with specific incremental or decremental reward factors that take into account considerations such as unpredictability. The research effort focused primarily on the design of the approach, as opposed to the implementation of a complete set of reward functions.

FEASIBILITY STUDY

The objective of the feasibility study was to demonstrate what a training event would look like, with synthetic adversaries playing out the tactics generated by the adaptive behaviors. This study was carried out in the distributed and massively multi-player On-Line Interactive Virtual Environment (OLIVE) virtual environment, created by Forterra Systems ("Purpose Driven Virtual Worlds for Everyone").

The example training session was conducted with human players as participants in a sequence of scenario instances. The Reserve Officer Training Corps (ROTC) detachment at the University of Central Florida provided 7 cadets to fulfill this role. These cadets carried out a number of multi-player training sessions against adaptive insurgent tactics in the OLIVE environment. Additionally, two Arabic speaking students role-played the squad interpreter and female used in the scenarios and provided cultural context. Forterra also provided several support personnel as well located across the United States which had the added benefit of demonstrating the distributed training capability of

OLIVE. After a brief familiarization with OLIVE, the training demonstrations were held over a 3 day period, totaling 9 hours of presence patrol exercises. This was carried out in OLIVE's virtual Baghdad urban terrain area.

Figure 4: Patrol Formation with Six Trainees

Figure 5: Two Trainees Taking Cover

Two screenshots from the feasibility study are shown in Figure 4 and Figure 5. In order to obtain the scenario outcome desired, several actions were planned to demonstrate common mistakes that could and have been made in typical current operating environments. Unit movement techniques, actions on contact, and common tasks were maintained in accordance with current doctrine.

As an example training event, this demonstrated that the insurgent tactics can be modeled and exercised in the OLIVE environment, and that the kinds of changing tactics that would be generated by the created adaptive behaviors can mirror authentic evolving tactics identified from the operational world. The process of collecting operational information to use as the building blocks for choice points in scenarios was conducted within a feasible scope of effort, and we similarly laid out the path for codifying these.

CONCLUSIONS AND THE WAY FORWARD

One of the primary design goals was to yield an adaptive behavior methodology that can be applied in many different team training contexts. Therefore, as one outcome of the research, we identified some high level defining characteristics for potential training use cases in which this design may be applied:

- **Virtual Training.** The adaptive behavior design makes the general presumption that training will be conducted in a virtual environment where synthetic enemy agents can be controlled by automated behaviors applying tactics generated by the adaptive logic. The initial design makes use of the OLIVE virtual environment. It is worth noting that this may not be a universal requirement, as it is possible to imagine use cases even with live training, where the adaptive behavior mechanism could be provided with direct inputs summarizing the results of a live training event, which would then serve as the basis for a new set of tactics provided descriptively to the administrators of a subsequent live training event.

- **Tactically Oriented Domains.** This behavior modeling approach is ideally suited for training domains where there is a naturally measurable relationship between tactics and outcomes (or at least partial successes and failures) in the course of a training event. In order for a synthetic enemy to learn or adapt their methods, there must be a computer-definable notion of success or failure that can be associated with previously applied methods.

- **Scenario Oriented Domains.** The notion of gaining practice against an adversary with changing tactics naturally lends itself to a training mode organized around a framework of scenarios in which results

can be evaluated and lead to adaptations between exercises. Of course for this training context the notion of a scenario is strictly a template into which variability in tactics, specific events, and other details can be enacted.

A full set of developed tactical variations can be derived from an initial set of scenarios by categorizing the choice points they rely on, and annotating the virtual environment with as many possible corresponding choice values as are feasible. This essentially results in an implemented library of possible tactical variations linked to artifacts of the virtual world. This library is capable of producing a very large number of insurgent tactics, of which the concrete scenarios are only a subset. That is, while it can perform all of the adaptations outlined in the scenarios, it is by no means limited to these scenarios.

Typical Training Use Case

For the training itself, the resulting behavior adaptation mechanism and the tactical library would remain flexible for use in a variety of contexts. A likely training use case may involve one where a small team coordinates a training event. An instructor (or potentially the team leader) provides them with their orders and they plan the operation before beginning. The exercise is conducted, and they encounter an asymmetric threat employing a certain tactic driven by the system behaviors, which either succeeds or is defeated by the training team. The exercise is concluded, and the team goes through an after action review led by the instructor (or potentially the team leader), to attempt to identify what tactics the enemy was using, how successful they were, and why. Depending on the specific goals of the instructor or team leader, they may want to make it clear exactly what the enemy tactic was, or leave it implicit in what is observable in playback. AAR playback may include review from various perspectives including the enemy perspectives, or these may be limited to only friendly force perspectives (similar to the data available from real world operations). The adaptive behavior mechanisms likewise evaluate the success or failure of enemy tactics in the exercise.

A subsequent training event is scheduled. In preparation for this, two things happen. Within the behavior mechanism, adaptations have already been developed based on the previous exercise. On the human side, the training team is required to prepare for the next operation once again, this time giving specific thought to any counter-tactics or procedures they may choose to apply in the mission. Depending on the length of the exercises, this sequence may be repeated several times, either in the same part of the virtual environment and under similar basic scenario conditions, or potentially in other areas with different buildings, cover, diversions, access points, and so on.

Instructional Methods

This adaptive framework is designed to support three instructional methods: (1) best tactics, (2) team-based tactics, and (3) dynamically adjusted tactics. In the first case, all trainees see the "latest and greatest" behaviors as they have evolved from the entire history of training events. In the case of team-based tactics, each new group of trainees begins at the same starting point and the set of adversary behaviors evolve specifically in response to this particular team. For the third case, dynamically adjusted, the "latest and greatest" tactics serve as the behavior starting point; these behaviors are then automatically adjusted to make the level of play match that of the training team.

In the envisioned system, there would be one instance of the underlying behavior execution manager for each training server. This instance is responsible for defining the initial scenario setup each time a team begins a new training session and applying the resulting reward when the training session is complete. Instruction method (1) is supported by default – all training sessions started on the same server will make use of the most developed set of behaviors on that server. To support (2), we would need to add a mechanism that maps a training team to a particular behavior file. When a particular team logs on for the first time, a new copy of the behavior file is created. All adaptation/creation that occurs will only change the currently loaded behavior file. In this way, we can support team-based tactics with a small amount of additional computer programming. Finally, the underlying reinforcement learning algorithm used in the choice point mechanism has been used to successfully support dynamic difficulty adjustment (3) in previous work

by Spronck et al. (2006). Transferring these results to a given domain is relatively straightforward, combining elements of both (1) and (2). In this case the system learns the best behavior (similar to 1) while simultaneously making sub-optimal choices for the particular team (similar to 2), where the goal is to allow the human team to win with some pre-set frequency (e.g. roughly 50% of the time).

While the above solution supports (1), (2), and (3) for any particular server, additional work would be required to support transferring behaviors across servers. Specifically, this would require a universal central behavior repository, where each server could download and upload behaviors. For example, in the case of (2), the behaviors for a team would be downloaded from the central repository before the training session, updated as a result of the training session, and then uploaded back to the central repository. This would allow a team to use any training server while facing the adversaries developed in response to their behavior. In the case of (1) and (3), the additional difficulty is determining which behavior is the "best" across servers, which requires methods for determining that one behavior is superior to another.

It is reasonable to anticipate that an adaptive behavior modeling framework such as this could be utilized to support individual, leader, and small unit training in many settings. A capability to train against a dynamic thinking enemy could enhance home station and pre-deployment small unit training. With the use of distributed virtual environments, this training could occur not only in post simulation facilities but just about anywhere a high speed internet connection exists. Further, with appropriate security measures, any centralized facility could support training of deployed units at remote locations. Finally, as more databases become available, mission rehearsal exercises may be possible down to the patrol level.

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ABOUT THE AUTHORS

Randy Jensen is a group manager at Stottler Henke Associates, Inc., working in training systems since 1993. He has developed numerous Intelligent Tutoring Systems for Stottler Henke, as well as authoring tools, simulation controls, after action review tools, and assessment logic routines. He is currently leading projects to develop automated after action review for Marine Corps combined arms training, a framework for ITS interoperability with distributed learning architectures for the Joint ADL Co-Lab, and an authoring tool for virtual training demonstrations for

the Army. He holds a B.S. with honors in symbolic systems from Stanford University.

Jeremy Ludwig joined Stottler Henke in the fall of 2000 after completing his Master's Degree in Computer Science at the University of Pittsburgh with a concentration in Intelligent Systems. His research areas include behavior modeling, machine learning, and intelligent training systems.

Michael Proctor, LTC (Retired), Ph.D. IE, CMSP, currently is an Associate Professor with the University of Central Florida Industrial Engineering and Management Systems Department as well as with the UCF Interdisciplinary Modeling and Simulation program. His research interests include games for training, Interactive Simulation, Real-Time Simulation Agents, and Simulation-Based Life-Cycle Engineering.

MAJ Jon Patrick is a Major in the United States Army Acquisition Corps and has completed his Master's Degree in Interactive Simulations and Training Systems at the University of Central Florida thru the Advanced Civil Schooling Program.

Wyatt Wong joined Forterra Systems in the fall of 2005 with over 8 years experience in design, engineering, and support of mission critical systems. Wyatt's previous experiences include areas of finance, networking, and database infrastructures. Wyatt holds a Bachelor of Applied Science in Electrical Engineering from Queen's University in Canada, as well as an MBA from the Leavey School of Business. Currently, Wyatt is focused on UI and HCI design and engineering at Forterra Systems.

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Coast Guard Team Completes Accreditation of New Modeling and Simulation Tool

Coast Guard Team Completes Accreditation of New Modeling and Simulation Tool

Hunter Keeter
Alion Science and Technology

In a united effort, the Coast Guard's Acquisition Directorate (CG-9) and Capabilities Directorate (CG-7) have accredited a new decision-support computational tool called the Coast Guard Maritime Operational Effectiveness Simulation (CGMOES). A software program that uses mathematical algorithms to represent the Coast Guard's mission requirements, asset capabilities and operational environments, CGMOES is the most comprehensive, up-to-date modeling and simulation system in the Coast Guard's inventory.

CGMOES will begin immediately to support the Coast Guard's modernization efforts. One of its first major tasks will be to provide information for the *Fleet Mix Analysis*, the first iteration of a collaborative, comprehensive study identifying alternative surface, aviation and shore-based capabilities and force structures to meet future Coast Guard mission requirements.

"CGMOES is now accredited for acquisition planning (including system-wide trade-off studies) and force structure planning," said Lt. Michael S. DiPace, an Operations Research Analyst with CG-9 who helped develop, verify and validate CGMOES. "It can compare the alternative fleet mixes, in terms of operational effectiveness within logistics constraints."

In building CGMOES, the Research, Development, Test and Evaluation (RDT&E) Program also worked with Atlantic Area (LANTAREA), which is expected to accredit the tool for operational force apportionment as well.

CGMOES is a government-owned model, maintained and operated under contract with MicroSystems Integration (MSI), based in Pawcatuck, Conn.

Strategic and Operational Analysis

CGMOES is run on a network of personal computers that generate results, which analysts use to prepare reports that inform decision-makers about the effects of different choices in relationship to mission requirements. This is called "campaign analysis:" the study of the use of military and naval forces to accomplish strategic and operational objectives.

As the centerpiece of campaign analysis in the Coast Guard, CGMOES holistically analyzes requirements and capabilities in the service's core mission areas of: search and rescue; living marine resources, ports, waterways, and coastal security; drug interdiction; migrant interdiction; and other law enforcement work.

Capt. John J. Macaluso, RDT&E Program Manager with CG-9 in Washington, said that the Coast Guard will use CGMOES for a variety of purposes, including helping to ensure that acquisition projects deliver effective, affordable platforms and mission systems with the capabilities, and in the quantities, required to achieve performance goals.

Accreditation team member Dr. Joe DiRenzo III, Chief of Operational Plans and Analysis with LANTAREA, Portsmouth, Va., added that CGMOES also will play an important role in operational analysis, which "looks at the different drivers of mission demands, our concepts of operation, the capabilities of our assets and facilities, and cost and capability trade-offs, before we ever weld two pieces of metal together. This allows us to come up with different courses of action to address the same end-state strategic goals."

DiPace explained that CGMOES simulates real-world interactions of cutter, aircraft and Command, Control, Communication, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) combinations when searching for various targets and when faced with different demands, including the concept of operations with its schedules, logistics and geographic positioning.

"CGMOES is configured to provide a common backdrop across multiple alternatives for comparative assessment,"

DiPace said. "No model can mimic the real-world exactly, so we make sure the modeled environment is a reasonable baseline to test each alternative against."

Technology Legacy

This isn't the Coast Guard's first or only modeling and simulation tool. CGMOES builds on a legacy that dates to the 1970s, and includes products, such as the Search and Rescue Simulation, the Law Enforcement Simulation, the Maritime Operations Simulation (MarOpSim) and the Deepwater Maritime Operational Effectiveness Simulation (DMOES).

As an iterative step in the technology's evolution, CGMOES includes non-Deepwater assets, such as the Marine Protector-class 87-foot coastal patrol boats, Juniper-class 225-foot seagoing buoy tenders and various C4ISR systems (such as Nationwide Automatic Identification System and Rescue 21).

The more significant distinction between earlier modeling and simulation tools and CGMOES is that the others were programmed to focus on the tactical level requirements and capabilities of specific assets or force packages. CGMOES is designed to cover all Coast Guard missions, in all off-shore environments beyond the littoral, or coastal region and include logistical considerations.

The new tool allows for mission growth. For example, as the Coast Guard develops requirements for expanded operations in the Western rivers, Great Lakes and Arctic regions, there is potential for CGMOES to evolve as well.

"For relatively new missions, such as Ports, Waterways and Coastal Security, our understanding of the mission itself is evolving," Macaluso said. "In order to support acquisition, we have to do a lot of analysis. In order to analyze things that don't yet exist, we have to model and simulate them. CGMOES gives us that capability."

LANTAREA's DiRenzo added that the model also will help the Coast Guard address increasingly sophisticated threats, such as that posed by self-propelled, semi-submersible vessels.

CGMOES's accreditation is an acknowledgement and validation that its methodologies and algorithms accurately reflect the goals and objectives of senior leadership, and that its output and results are credible. The cooperation that went into this accreditation reflects the close partnerships that have been fostered among various Coast Guard organizations, including those involved in R&D, requirements, acquisition and operations.

Additionally, the continued evolution of Coast Guard modeling and simulation technology leverages interaction with Department of Defense counterparts. This interaction includes the 'Tri-Service Strategic Talks,' at which the Coast Guard, Navy and Marine Corps discuss new ways to work together. Modeling and simulation capabilities are at the nexus of the services' abilities to foster a broad, united effort, with the Coast Guard contributing unique perspectives from its mission areas.

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