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USING MODELS AND SIMULATIONS TO ENHANCE MILITARY TESTING

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ABSTRACT

The Modeling and Simulation (M&S) branch at Dugway Proving Ground provides high-fidelity simulation that support a variety of United States Army testing programs. Dugway Proving Ground's primary mission is to provide developmental and production testing to support the nation's chemical and biological (CB) defense programs. To enhance existing test programs, Dugway incorporates many capabilities that allow modeling simulated trials under conditions that could not otherwise be replicated due to environmental and safety regulations. Each M&S capability is subjected to formal verification and validation (V&V) processes that help ensure accurate simulation representation. Finally, all of the models and simulations can be performed locally, distributed to other test centers throughout the United States, or even to international locations using standard simulation architectures. This paper describes how the U.S. Army can use the M&S of entities such as CB threats and sensors, weather, and collective protection equipment to better serve military testing needs.

1 INTRODUCTION

The testing of chemical and biological (CB) defense components and systems has been the primary mission of Dugway Proving Ground since its establishment during World War II (Thomas, Baker and Thompson 2012). Since the late sixties, CB testing in the United States has been restricted to specially designed test chambers that are capable of handling live agents (National Security Council 1969). When large-scale outdoor tests are needed, chemical simulants are used that closely mimic the behavior and effects of live agents but are environmentally safe. Because of these safety and environmental restrictions (SIPRI Yearbook 1993), U.S. Army scientists began developing a modeling and simulation (M&S) program that would complement existing chamber and field tests by simulating test scenarios that could not otherwise be performed. Additionally, utilizing M&S technologies drastically increases the amount of testing that can be done, while at the same time, significantly reducing costs.

The simulation of field test scenarios can be conducted locally as part of a Dugway Proving Ground specific test or as part of a larger, distributed test event throughout the U.S. Department of Defense (DoD). These kinds of distributed exercises have been valuable in demonstrating the feasibility of conducting large-scale tests from remote sites without the costly need of transporting equipment and personnel to a single location.

This paper will focus on the recent advances and applications of utilizing M&S technologies in various military testing applications. While most of the focus will be on CB defense testing applications, the overall principle of using simulations to provide valuable information to military testing will be addressed.

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2 PAST MODELING AND SIMULATION EFFORTS

2.1 Distributed Test Events (DTE)

One of the initial uses of distributed testing to support military programs began with the Distributed Test Event (DTE) program. This effort was sponsored by the U.S. Army Test and Evaluation Command (ATEC). The goals were for the development and application of a synthetic environment capability operating in a distributed test framework that could be used to support testing of the Army systems that would eventually support today's warfighter. To face this challenge, the ATEC implemented a program to tie its geographically dispersed test centers together to benefit from the resultant synergies realized from multiple commodity-specific test capabilities functioning in an integrated and interactive framework. In other words, each test center would provide a simulation component that was specific and unique to their organization. For example, Dugway Proving Ground supported these tests by providing CB defense simulations, since CB testing is unique to Dugway and part of its key testing mission.

There were five formal DTE exercises. While each event had specific goals, the overall objectives focused on the following:

- Demonstrate the ATEC test centers capabilities to support distributed testing using live, virtual, and constructive representations of test articles and environments.
- Collect data in support of distributed testing lessons learned.
- Demonstrate the capability to support the collection of data at the component or System of Systems (SoS) level in a tactically correct mission environment.

Dugway's role in the DTE event consisted of providing a simulated chemical release into the tactical scenario. Additionally, Dugway provided detailed sensor models that represented the Joint Services Lightweight Standoff Chemical Agent Detector (JSLSCAD). As the simulation progressed, the sensors would detect and track the hazard, while monitoring the exposure states of the 400+ entities that were involved with the scenario. These entities would then react according to where the hazard was located as well as to the amount (concentration) of hazard they had been exposed to.

2.2 Joint Battlespace Dynamic Deconfliction (JBD2)

The Joint Battlespace Dynamic Deconfliction (JBD2) test was a recent event that utilized the Joint Mission Environment Test Capability (JMETC) network to conduct a distributed exercise. The JMETC network is discussed in greater detail in section 3.2. The goal of the JBD2 test was to conduct a distributed test using Future Combat Systems (FCS) Common Control Nodes (CCN), Army test centers, FCS System of Systems Integrated Labs (SoSIL), and appropriate joint assets. Coupled with this exercise was the Joint Test and Evaluation Methodology Program (JTEM). The purpose of JTEM is to recommend best practices for a consistent approach to describing, building, and using appropriate representation of a particular Joint Mission Environment (JME) across the acquisition lifecycle. JTEM has summarized the methods, processes, and test artifacts to consistently represent a JME into six steps, which are (Dryer 2007):

- Define the test and evaluation (T&E) strategy for testing
- Characterize the test
- Define the test
- Implement live, virtual and constructive environments
- Execute the test
- Evaluate the test

Dugway's role in this exercise was to utilize a software program called WeatherServer which provides detailed weather parameters to the participating entities. These weather files consisted of seven distinct parameters that were distributed across the JMETC network via the Test and Training Enabling Architecture (TENA). Additional details on WeatherServer are provided in section 4.

3 CURRENT DISTRIBUTED TESTING CAPABILITIES

3.1 The Distributed Test Control Center (DTCC)

The key facilities for conducting distributed testing within ATEC are the Distributed Test Control Centers (DTCC). These facilities are located at various test centers within the United States that provide a dedicated site for conducting distributed testing. Each of these centers have similar configurations but can be customized to meet the needs of the individual test center or the needs of a particular distributed event. The DTCC at Dugway Proving Ground, for example, consists of two separate rooms each measuring about 900 square feet. Located between the two rooms is a common server room that houses the roughly 40 Windows and Linux servers. During distributed events, simultaneous test and training activities at various installations are conducted under common operational battlefield scenarios. In local tests, the DTCC is used as a centralized test control point or as an adjunct visualization area.

Teams of test controllers use the DTCC to participate in simulated or live events within Dugway Proving Ground, in other networked locations, or in a distributed environment, using a system-of-systems approach. Events may include CB defense testing, analysis and modeling, unmanned aircraft system (UAS) tests, meteorology and weather information transmission, data management (e.g., gathering, fusion, dissemination, 3-D visualization, or archiving), test monitoring and control, and sponsoring an observation point for visitors (Thomas, Baker and Thompson 2012).

Data is shared with multiple military installations, contractors, or academia as required over the Secure Defense Research and Engineering Network (SDREN), predominantly via the Joint Mission Environment Test Capability (JMETC) node. A picture of one of the Dugway DTCC facilities is shown in Figure 1.

Figure 1: The Dugway DTCC during a recent distributed test event.

3.2 The Joint Mission Environment Test Capability (JMETC)

The Joint Mission Environment Test Capability (JMETC) is a program that provides readily available persistent network connectivity to the Department of Defense (DoD) and to joint services' distributed test capabilities and simulations, as well as for industry test resources. JMETC uses the SDREN, a network established to support research, development, testing, and engineering (RDT&E) and science and technology (S&T) activities within the DoD.

JMETC links distributed facilities and its customers to efficiently and effectively evaluate warfighting capabilities within a joint context, and provides compatibility between testing, experimentation, and training. As a distributed LVC testing capability, JMETC supports the acquisition community during program development, developmental testing, operational testing, and interoperability certification, including demonstration of Net Ready Key Performance Parameters (NR KPP) requirements in a customer-specific joint mission environment.

In addition to connectivity, JMETC provides common middleware, standard data interfaces, tools, data management, and a reuse repository for collaboration. JMETC is also aligned with and complemented by the Joint National Training Capability (JNTC) to foster test, training, and experimental collaboration (Thomas, Baker and Thompson 2012). Figure 2 shows the current JMETC sites.

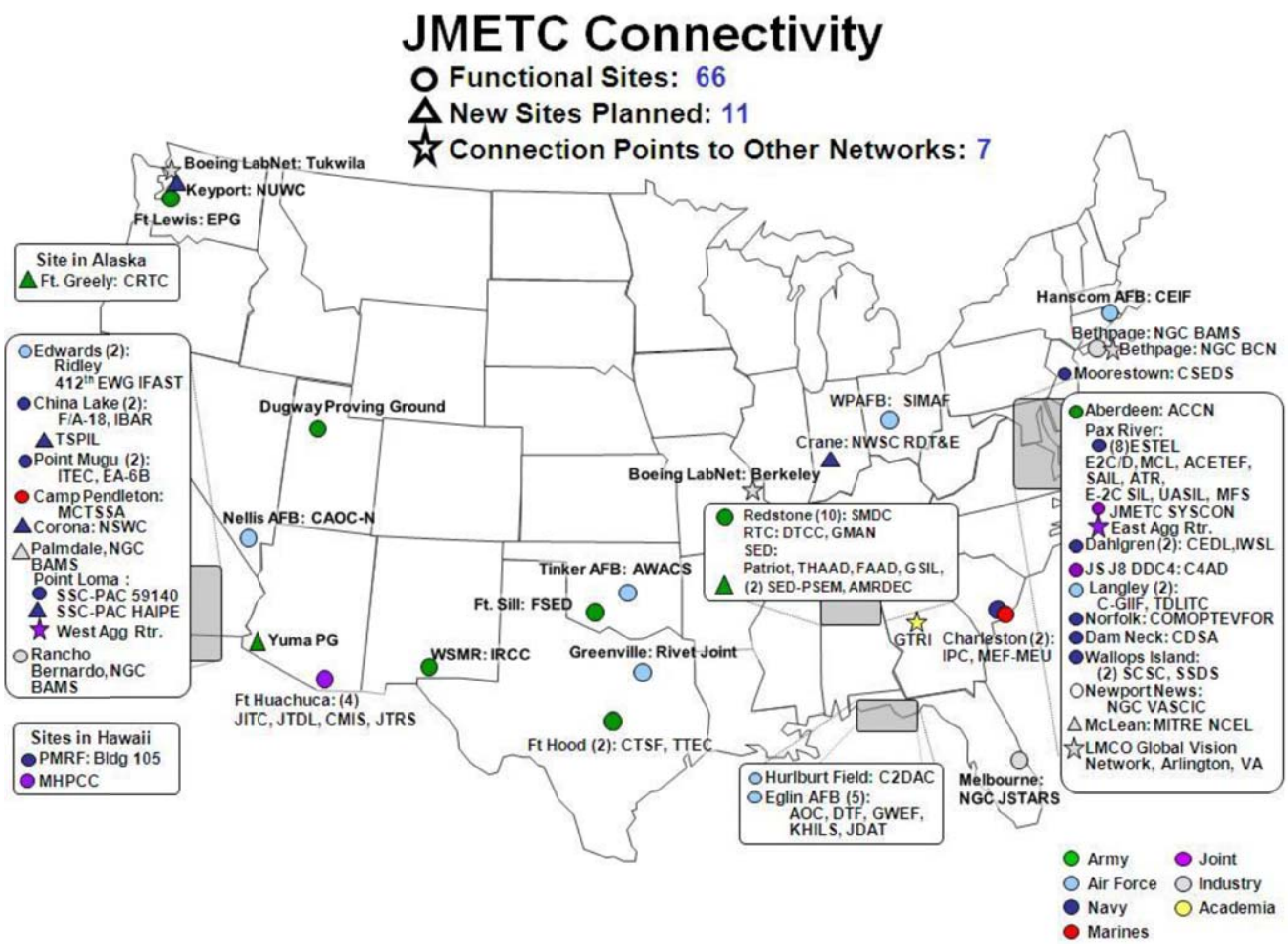

Figure 2: Current JMETC Connectivity

Dugway was established as a JMETC node in 2010, providing the joint test community with a valuable set of capabilities in the areas of weather data dissemination, chemical/biological modeling and simulation, test control, visualization, monitoring, and data handling. Additionally, as a JMETC node, Dugway is tasked with providing distributed weather for tests that require meteorological inputs. This capability is realized via the TENA WeatherServer software.

4 WEATHERSERVER (WSX)

The Test and Training Enabling Architecture (TENA) is the middleware of choice for the JMETC. The Dugway weather object models (OM), identified as DPG-Weather and DPG-Atmosphere, have been adopted by the TENA community as the standard.

TENA WeatherServer (WXS) is a data dissemination platform consisting of a high-performance, data-compacting server and a software package. WXS ingests gridded binary (GRIB) files from the Four-Dimensional Weather (4DWX) system, parses the files, and, by utilizing one or both of the OMs, converts the data to a TENA-compliant format, and stores the results. WXS responds to a subscriber's request by retrieving and packaging the data from the requested areas, and then disseminates the data back to the subscriber.

The DPG-Atmosphere OM is an automatic publication of a predetermined set of seven weather parameters (e.g., winds, temperature, pressure, precipitation, clouds, soil saturation, and humidity) that are the most frequent parameters required by subscribers. Every subscriber receives all updates of the seven weather parameters.

The DPG-Weather OM allows subscribers to request data subsets from the selection of 94+ parameters, specifying time, location, and data types; the publisher returns those values to the subscriber. A requested geographical area may be a single point, line, two-dimensional plane, or three-dimensional volume. Combining the two methods allows clients to receive the weather data they require while minimizing the impact of the server's traffic on the network (Thomas, Baker and Thompson 2012).

5 CHEMICAL AND BIOLOGICAL (CB) MODELING AND SIMULATION (M&S)

The use of M&S technologies to support CB defense testing presents its own unique challenges. While most of the capabilities discussed in the previous sections are not specifically designed for CB defense testing, they can certainly be utilized to enhance and improve it. The following sections will focus on capabilities that were designed with CB testing in mind. Additionally, attention will be given to specific CB testing challenges and ways that these can be minimized. Finally, due to classification and security reasons, past specific CB tests will not be identified.

Based on previous M&S experiences, CB defense testing can usually be broken down into four key aspects. Each of these components, when combined, help testers better define the threat and how to deal with it.

1. Identification: What is the threat? Is it chemical, biological, or a toxic material? How hazardous is it?
2. Location: Where is the threat? Where did it come from? Where is it headed? How will weather conditions affect its behavior?
3. Consideration: What is the threat concentration at any particular time and location? What is the health impact on the warfighter? How should the warfighter respond?
4. Education: What lessons were learned from this simulation? How can the simulation be improved? Were any capability gaps identified and if so, how can they be mitigated?

5.1 Chemical-Biological Simulation Suite (CBSS)

The Chemical-Biological Simulation Suite (CBSS) is a set of distributed simulation software tools designed to represent all aspects of CB defense on the tactical battlefield, including applications to analyze strategies, and to provide cost-effective test programs and training of U.S. and allied soldiers. The CBSS is used to:

- Develop effective CB defense materiel
- Evaluate tactics, techniques, and procedures
- Provide constructive testing over a wide range of terrain, weather, and delivery conditions
- Provide broad scenario-based training
- Support live sensor testing at Dugway

5.1.1 Chemical/Biological Synthetic Natural Environment (CBSNE)

The Chemical/Biological Synthetic Natural Environment (CBSNE) is a component of the CBSS that provides CB hazard representations for distributed test programs. CBSNE creates high-fidelity, three dimensional (3-D) hazard environments as a function of hazard delivery systems, time-varying meteorological conditions, and complex 3-D terrain. The model makes environmental data available to other simulations, including 3-D representations of airborne vapor and aerosol concentrations, and (over two-dimensional grids) dosage, deposition, and air concentration contours.

CBSNE utilizes either the Naval Surface Warfare Center's Vapor, Liquid, and Solid Tracking (VLSTRACK) model (Bauer and Wolski 2001), or the Second-order Closure Integrated Puff (SCIPUFF) model (Sykes, Lewellen and Parker 1986), for the simulated transport and dispersion (T&D) of chemical/biological vapors or aerosols. The Winds Over Critical Streamlined Surfaces (WOCSS) consistent-mass/flow model provides high-resolution, 3-D wind field data to VLSTRACK. The Compact Terrain Database (CTDB) delivers a common representation of complex terrain based on National Geospatial-Intelligence Agency (NGA) data (Thomas, Baker and Thompson 2012).

5.1.2 Chemical Biological Dial-A-Sensor (DAS)

The Chemical Biological Dial-A-Sensor (DAS) software tool is another CBSS component that uses modular architecture to recreate the performance of a chemical or biological detector as would be demonstrated under live testing. DAS represents variable-fidelity CB detectors in standalone or distributed simulations and exercises. Users may specify (dial) the physical and simulation characteristics of a detector system based on the parameters of its technology family's characteristics. "Families" of sensors represented within CBSS include: point chemical detectors, standoff passive chemical detectors, standoff active/imaging chemical detectors, point particle-counting biological sensors, and ground-sampling chemical sensors. An image of a standoff chemical detector mounted on a mobile platform is shown in Figure 4. Figure 4 also shows the simulated hazard plume as it disperses along a digital terrain representation.

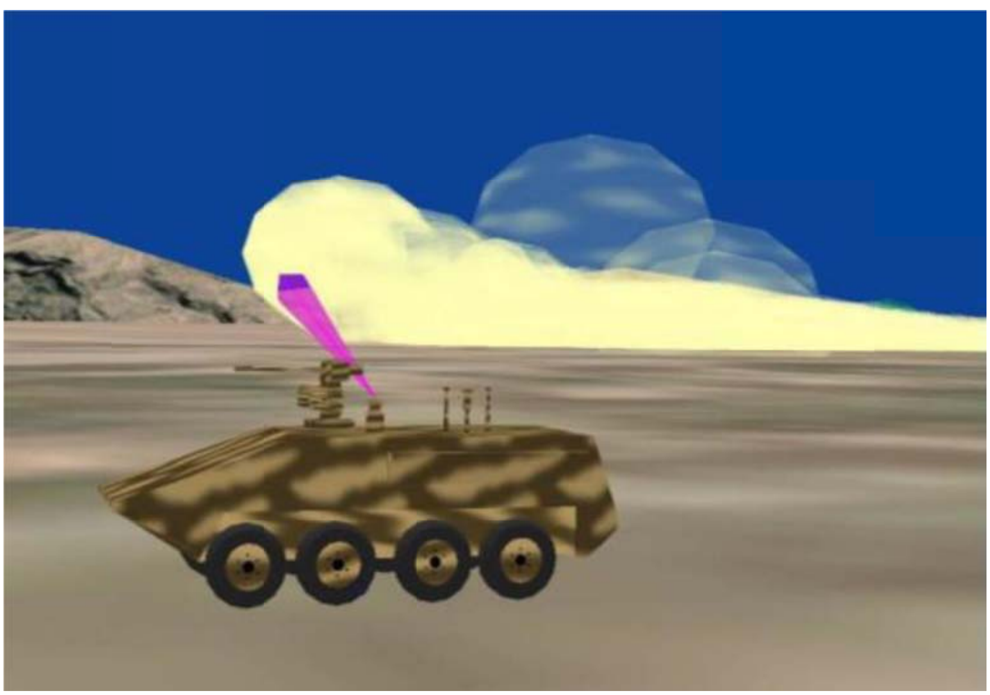

Figure 4: Dial-A-Sensor representation of a standoff chemical sensor

5.1.3 Exposure Toxicity Server (ETS)

The Exposure Toxicity Server (ETS) is part of the CBSS toolkit and is used to track entity exposure levels during simulation exercises. ETS monitors each battlefield entity's concentration and dosage level and provides the user with these data values at a pre-defined temporal scale. This toxicity information can also be published across a network in the standard North Atlantic Treaty Organization (NATO) Allied Tactical Publication (ATP) 45 format (Briscoe 2005). These ATP 45 messages can then be passed up the chain of command, allowing field commanders the ability to provide appropriate warfighter response to the detected threat.

5.2 Transport and Dispersion Models Used in Test Programs

The key component to support any M&S program that involves CB testing is the use of well-defined transport and dispersion (T&D) models. There are many models available to the DoD and choosing which model to use for any given test can be rather subjective. Sometimes the customer dictates which model they would like to use for their test. More often, however, the customer leaves this decision up to the M&S scientist assigned to their test. Choosing which T&D model to use is as much an art as it is a science. Because of this, CB threat simulations are often run using multiple T&D models, results are compared, and tactical decisions are made. This is not the ideal scenario, however. Only a few published papers have made comparisons between different T&D models but none of them have specifically addressed the unique category of T&D modeling of CB threats (Chang et al. 2003; Bacon et al. 2005). This paper does not focus on the comparison of T&D models for CB testing. For comparisons between some of these kinds of models, the reader is directed to Chang et al. (2003), Garten et al. (2003), and Johnson-Winegar (2003). The following sections will, however, touch briefly on three of the main T&D models that are used within the DoD to support CB threat modeling.

5.2.1 Vapor, Liquid, and Solid Tracking (VLSTRACK)

The Vapor, Liquid, and Solid Tracking (VLSTRACK) program is a transport and dispersion (T&D) model that uses two different instances to support field testing and test support programs. One VLSTRACK instance is embedded within the CBSNE toolkit and allows the T&D model predictions to be available to the other CBSS tools. The second standalone instance (Standalone-VLSTRACK) is a Windows-based, government off-the-shelf (GOTS) application. Both instances are used extensively to predict hazard propagation routes and downrange concentration/dosage profiles. Additionally, a classified version of VLSTRACK, that contains data on agents not available in the unclassified version, can also been used when required by test customers.

5.2.2 Hazard Prediction and Assessment Capability (HPAC)

The Hazard Prediction and Assessment Capability (HPAC) is a validated threat modeling program that uses the Second-order Closure Integrated Puff (SCIPUFF) T&D model (DTRA 1999). HPAC/SCIPUFF is used to support various field and chamber tests by conducting both pre- and post-test threat simulations. These simulations provide valuable data to the test community indicating probable hazard trajectory, what downrange concentrations to expect, and where to place referee instrumentation. Additionally, HPAC/SCIPUFF simulations can help fill data gaps by modeling tests that cannot be conducted due to costs, schedules, and/or environmental regulations.

5.2.3 Joint Effects Model (JEM)

The Joint Effects Model (JEM) is the latest T&D model to be introduced to the DoD community. JEM is an Acquisition Category (ACAT) III program that will provide a single, validated capability to predict the transport and dispersion of chemical, biological, radiological, and nuclear/toxic industrial hazard events and their effects (Joint Effect Model Briefing to CBIS 2007). JEM is designed to incorporate components from previous validated T&D models such as HPAC and VLSTRACK.

6 BRIDGING THE GAP IN MILITARY CB DEFENSE TESTING

Each of the above mentioned capabilities and technologies have proven very valuable in military testing, particularly in the testing of CB components and equipment. These models and simulations are not perfect, however. As new equipment, sensors, clothing, shelters, etc. become available to the warfighter, current testing protocols need to be updated and adjusted. Doing so can sometimes uncover a technology gap where the existing M&S tools are not adequate for future testing needs. To remedy this shortfall, newly funded programs are building M&S capabilities that will meet future military CB testing needs. The following sections will discuss some of these emerging technologies and how they will be applied to meet future military testing needs.

6.1 The Advanced Chemical Release Evaluation System (ACRES)

One of the most difficult and technically challenging tasks in conducting field tests of CB detector systems is the processing and analysis of referee system data. Typically the system under test (SUT) performance is measured against the referee systems in order to quantify the SUT performance. The data from the referee systems are used to characterize the spatial and concentration characteristic of the field test release simulant. The difficulty with this task is compounded based on the type of sensor being tested (e.g., point and/or standoff sensor), the sensor technology base (e.g., photoionization, infrared, scattering, photographic), as well as the type of sensor performance data collected (e.g., concentration, concentration pathlength, or length). To further complicate matters, each type of detector possesses an inherent measurement error attributable to its class. In areas where these measurements overlap, these instrumental errors must be weighted against one another. They must also be considered for estimating hazard release characteristics at points within each release where data are sparse or non-existent (Carter, Kleimeyer and Green 2011).

To address these shortfalls, Dugway scientists collaborated with private industry to develop the Advanced Chemical Release Evaluation System (ACRES). The computational cycle begins with fusion of sensor data, which is combined through a series of Schmidt-Kalman filters to produce an optimized estimate of cloud states. These cloud estimates are then propagated via a transport and dispersion model. Using meteorological and cloud release data, predictions of agent cloud simulant concentrations at gridded points throughout the cloud ensemble can then be made. These predictions, in turn, predict referee sensor measurements for the next time-step that are then combined and "fused" with new sensor data. This process is repeated until the cloud has exited the referee area (Flaherty et al. 2011). At present, ACRES is a post-test tool, though future plans are to enable it for near-real time analysis of streamed ground truth data (Carter, Kleimeyer and Green 2011).

6.2 Dugway Developmental Detector Test Bed (D3TB)

The Dugway Developmental Detector Test Bed (D3TB) is a software tool that provides realistic representations of CB threats for assessing point and standoff detection systems in a simulated environment. The need for this application was apparent in the shortfalls in current field and chamber testing procedures. Field tests are restricted to simulants, requiring large budgets and are subject to the meteorological conditions at the time of their release. Chamber testing shortfalls are manifest in the fact that under these enclosed conditions, sensors are not able to be challenged against true environmental backgrounds, such as terrain and interferents. D3TB helps bridge these capability gaps by allowing the sensor performance to be predicted under conditions where outdoor testing is neither feasible nor possible.

An example might be to estimate detector performance in a real tactical environment with live agent. The tactical environment poses a challenge over a controlled test environment, in that the environmental backgrounds are not only cluttered with interfering species (e.g. industrial emissions, smokes, fuel combustion byproducts), but also may differ in the type of topography (e.g. grassland vs. desert), as well as climate (temperature, humidity, etc.).

Another example of how D3TB is used to support testing involves the reduction of field test complexity. A full test matrix might have a large number of variables, and directly testing all of them in the field can be impossible from standpoints of both time and resources. By providing the capability to conduct large numbers of simulations over the entire test matrix, D3TB offers a relatively quick and inexpensive method for generating statistical information in order to assist testers and evaluators in determining which of those variables to prioritize in their final test design. In this way, M&S provides a valuable, cost-effective, and expedient complement to actual field testing (Carter, Kleimeyer and Green 2011).

6.3 Collective Protection (COLPRO) Modeling

The final enhancement that is currently used to support military CB testing is a newly developed collective protection (COLPRO) model. The COLPRO model was built to address a number of shortfalls in testing. The first gap addressed the ability to test various COLPRO platforms within a single simulation. Models existed that allowed for testing individual platforms, such as shelters and vehicles, but these could not be used to test multiple platforms at the same time. Secondly, previous capabilities focused on the use of a single T&D model for simulating COLPRO effectiveness. While effective, the use of only a single T&D model may not always provide the best representation of the hazard for a given situation. Finally, many historic COLPRO simulations utilized computational fluid dynamics (CFD) analysis to predict hazard effects on the platform. CFD calculations provide a very detailed, high-fidelity representation of the COLPRO system. The cost of such high resolution predictions comes in the form of a drain in both time and manpower. In order to mitigate these testing gaps, a new COLPRO model was developed.

The COLPRO model was developed in collaboration between Dugway, private industry, and various national laboratories in the United States. To address the three above mentioned shortfalls, the COLPRO model was designed with the following features:

1. Native support for numerous types of COLPRO platforms (shelters, buildings, and vehicles)
2. Incorporation of four separate T&D models:
    - Vapor, Liquid, Solid Tracking (VLSTRACK): used for outdoor dispersion
    - Second-order Closure Integrated Puff (SCIPUFF): used for outdoor dispersion
    - Realistic Urban Spread and Transport of Intrusive Contaminants (Meso/RUSTIC): used for outdoor dispersion (Burrows et al. 2007)
    - CONTAM: used for indoor dispersion
3. Use of Meso/RUSTIC T&D model as an alternative to CFD modeling

In addition to these upgrades, the COLPRO model also utilizes complex 3-D terrain files to ensure accurate downrange hazard propagation. Figure 5 shows a screen capture of a typical hazard release as it interacts with building and vehicle COLPRO platforms. The spheres in the image represent sensors that are set to change colors when exposed beyond preset toxic levels characteristic of the threat type. The red sphere located above the vehicle indicates that entity has not been able to effectively protect the occupants from the released hazard. The green spheres inside the building show that the building overpressure and filtration system are sufficient to protect the building from the exposed threat.

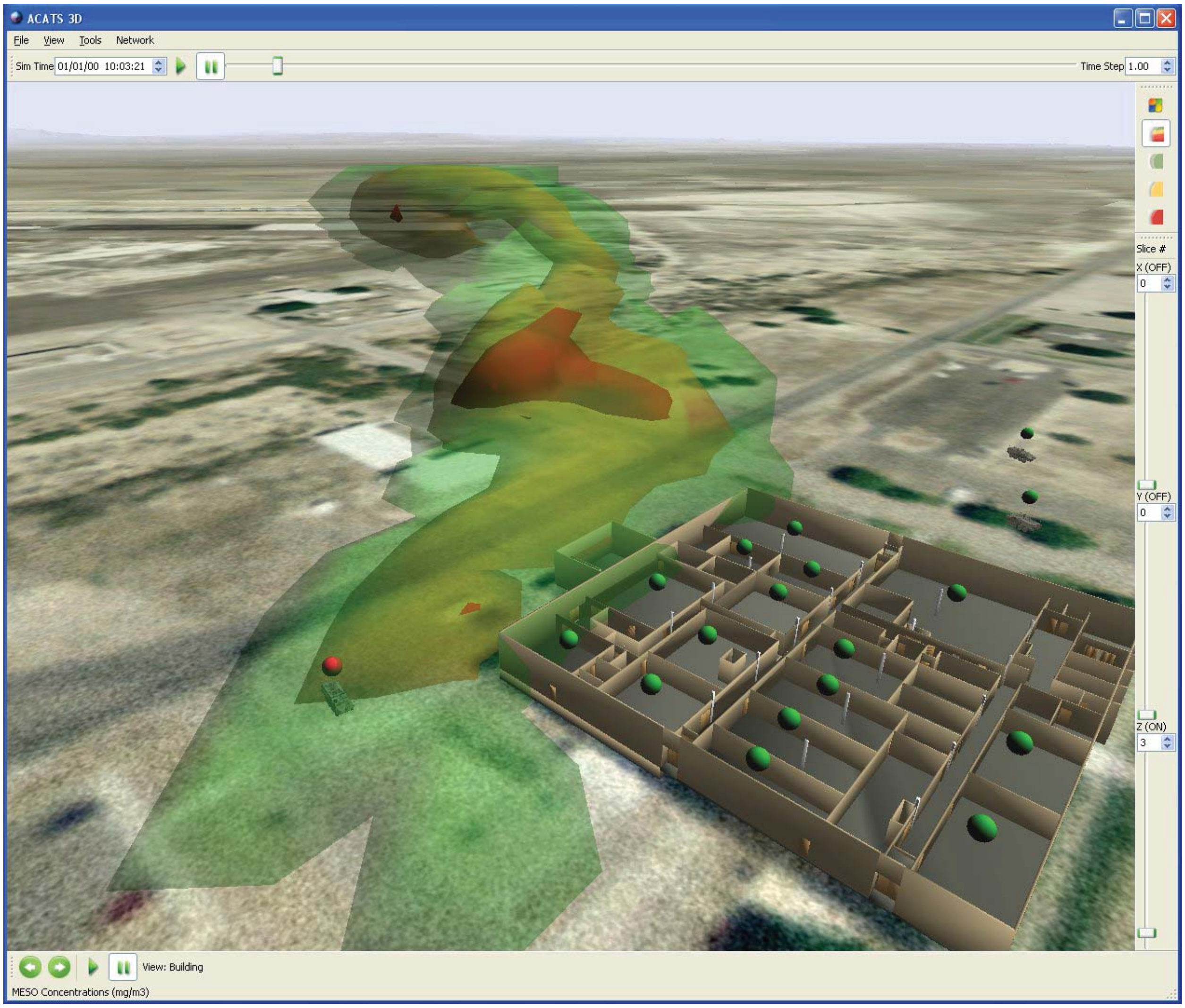

Figure 5: Screen capture of COLPRO model with building and vehicle platforms.

The COLPRO model is currently in the final stages of an independent verification and validation (V&V) and will be ready for full use in test support in September 2012.

7 CONCLUSIONS

This paper describes how the use of models and simulations compliment current military testing needs. These examples are in no way meant to be inclusive of all M&S activities within the military, but rather to point out certain test scenarios where M&S has proven beneficial. Furthermore, while many of these capabilities have focused on their use in CB defense testing, the intent is only to illustrate their applications within a certain context, in this case, CB testing. However, many, if not all of these technologies reach far beyond the CB realm and could easily be incorporated into numerous other military, commercial, or industrial testing situations.

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