Use of Virtual Environments to Support Developmental Testing of the Biological Aerosol Warning System (BAWS)

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***ABSTRACT**: This paper discusses the development and application of a system enabling virtual testing of the Biological Aerosol Warning System (BAWS). The Army's Edgewood Chemical Biological Center is developing the BAWS as part of the Army's Integrated Biodetection Advanced Technology Demonstration (Bio ATD). The BAWS is an array of point biological aerosol detectors networked to detect biological agent hazard attacks while mitigating the likelihood of false alarms. As part of the Bio ATD, the West Desert Test Center (WDTC), Dugway Proving Ground (DPG), Utah, tested the BAWS utilizing live and virtual testing techniques. To support virtual testing, a Hazard Environment MICAD Interface (HEMI) provided digital stimulation to the BAWS using computer-generated hazard environments. The Army conducted the virtual testing in conjunction with live testing (using biological agent simulants) at WDTC. This capability allowed for expanded operational testing, easily modifiable test configurations for the assessment of parameters not feasible in live tests, and continued system evaluation during periods which meteorological conditions were not within correct parameters to allow live testing.*

1. Introduction and Background

The troops of the United States and its Allies are facing the increased threat of adversary employment of biological weapons. The DoD is investing considerable resources in the development of systems to mitigate the effects of such weapons. These initiatives include counterproliferation systems focused on denying the threat prior to use; active defenses such as Patriot missile defense system; passive defense systems including detection and warning and reporting networks; and individual and collective protection gear. To support the detection and warning mission, the Army's Edgewood Chemical Biological Center (ECBC), since fiscal year 1996, has been developing the Biological Aerosol Warning System (BAWS) as part of the Army's Integrated Biodetection Advanced Technology Demonstration (Bio ATD). An exit criterion for the ATD is a Battle Lab Warfighting Experiment (BLWE) that the Army (led by the Maneuver Support Center) is conducting in phases from Dugway Proving Ground, Utah, and Ft. Lewis, Washington [1]. The BLWE uses soldiers working with a hybrid hardware/software system to demonstrate the military worth of the ATD technologies and provides soldier interface data.

The BAWS is an array of point biological aerosol detectors networked to detect biological agent hazard attacks while mitigating the likelihood of false alarms. It employs multiple sensors and complex sensor logic to screen out naturally occurring or non-hazard background spikes (*e.g.*, wind-driven or vehicle dust) that often provide false alarms. BAWS program managers are employing modeling and simulation to support the testing of the BAWS. The Army first demonstrated the virtual test system in a series of tests conducted between Librascope's Glendale, California, facility and ITT Industries, Systems Division's Alexandria, Virginia, Simulation Laboratory. Results of this testing are documented in a report by Michael O. Kierzewski, *et al.* of OptiMetrics, Inc. [1].

In this paper, we discuss the BAWS components and architecture and the supporting testing. We also discuss benefits derived from BAWS virtual testing, the use of existing environment and sensor simulations and architectures developed by a consortium led by ECBC and the Defense Threat Reduction Agency (DTRA), data collection techniques, and calibration of the systems with live sensor data. We conclude with our observations on the correlation of live and virtual testing and the applicability of the architecture in supporting operational evaluations and other virtual testing.

1.1 BAWS

The BAWS consists two sensors: Tier I and Tier II. Only the results of Tier I sensor testing are in this paper. The Tier I sensor is a Met One (particle sizer/counter) that uses laser light scattering technology to provide particle counts and determines particle size between two size ranges, 2 and 10 microns (μm). The Tier I calculates a running mean of the particle concentration and variance from the mean. These parameters are used in the sensor's internal logic to determine when it "sees" a suspicious event that may be a biological agent attack. To support virtual testing, the Army (Lockheed Librascope) modified the Tier I sensors to accept simulated agent counts from the MICAD display/controller (BAWS Base Station). The BAWS treats these simulated particle counts as actual agent particle counts, adding them to any background counts currently being detected. The decision logic for the digitally stimulated BAWS remains unchanged from the baseline system, and the operation of these modified sensors is identical to that of the unmodified sensors. [1]

The BAWS are deployed as a network of sensors reporting to the BAWS Base Station (BBS). The sensors continuously count background particles. When the BAWS detects a three-sigma rise in particle count (actual sigma may vary depending on actual meteorological conditions), it sends an *alert* to the BBS. Localized non-hazard events can cause an individual BAWS sensor to alert. To reduce false alarms, the BBS only generates an *alarm* when three or more co-located BAWSs generate simultaneous alerts.

Testing of the BAWS requires trigger of sensors spread over a relatively large geographical area with environmentally approved biological agent simulants. The hazard environments used in live testing—if they are to be representative of real threats—must be correlated at each of the sensor locations. Stimulating individual BAWS sensors with uncorrelated triggers (*vs*. a coherent hazard representation) will lead to inadequate and unreliable detection algorithms. These factors limit live testing to the WDTC. Testing in other locations requires a virtual cloud representation.

1.2 West Desert Test Center

The WDTC, located at Dugway Proving Ground, Utah, is the DoD focal point for test and evaluation (T&E) of chemical and biological (CB) weapons defense equipment. The CB defense test mission centers around testing equipment and methodologies for contamination avoidance, decontamination, and collective and personnel protection. Testing is conducted with real chemical and biological weapons agents in surety and biosafety level-3 laboratories and with agent simulants in outdoor field testing. The DoD has focused resources at WDTC providing the infrastructure and expertise for a Joint-Service developmental and operational CB defense testing capability unsurpassed throughout the world. Additionally, WDTC is home to an internationally recognized meteorological division, which plays an integral role in the CB defense test mission.

WDTC is developing and implementing computer modeling and simulation (M&S) and digital testing to augment and enhance the CB defense test mission in coordination with the Army Test and Evaluation Command (TECOM) Virtual Proving Ground (VPG). The TECOM VPG will be the T&E cornerstone for DoD's Simulation Based Acquisition (SBA) initiative, a revolutionary process for conducting traditional DoD acquisitions. As part of a new way to conduct CB defense equipment testing, the WDTC is developing and acquiring models and simulations that provide digital representation of important test parameters and systems under test. WDTC has teamed with ITT Industries to provide a digital representation of the CB threat environment using the Nuclear, Chemical, Biological, and Radiological Environment Simulator (NCBR).

The Bio ATD is the first test at WDTC incorporating both live and digital stimulations of test hardware, the BAWS Tier I units. Bio ATD test personnel used digital representations of biological threat clouds from the NCBR and real biological threat simulant clouds from aerial disseminations in complementary fashion during a four-week test period to evaluate the performance of US Army and Marine personnel in their operation of the BAWS Base Station (BBS). Digital challenges from the NCBR were used solely to evaluate system connectivity and performance following deployment of the BAWS by *average* soldiers. The Army used digital stimulation of the BAWS during nighttime trials when unfavorable meteorological conditions persisted, precluding dissemination of live biological agent simulants—and during daytime trials conducted after BAWS deployment exercises.

2. Simulations

The BAWS testing used a mix of existing simulations and new simulations linked using distributed simulation standards. The first round of testing used the Distributed Interactive Simulation (DIS—as defined in IEEE 1278.1a) for simulation connectivity. Future versions will use the DoD's High Level Architecture (HLA) and the Real-time Platform Reference (RPR) Federation Object Model (FOM). Version 1 of the RPR FOM does not contain objects corresponding to the Environmental Process PDU in IEEE 1278.1a-1998, so the Army, DTRA, and supporting contractor organizations are supporting standards development activities to ensure that these data representations are supported for future testing. DTRA is currently sponsoring the migration of NCBR to the HLA as part of its Weapons Effects Conformation—High Level Architecture initiative managed by the DTRA Counterproliferation Support and Operations Directorate's WMD Assessment and Analysis Center.

The NCBR and the Hazard Environment MICAD Interface (HEMI) served as the two principal simulation tools for the BAWS testing. The Army's ModSAF provided operational context for the trials. The MaK Stealth and Data Logger supported 3D visualization and data logging for after-action review and analysis. Figure 2-1 shows the architecture used in support of the BAWS virtual testing.

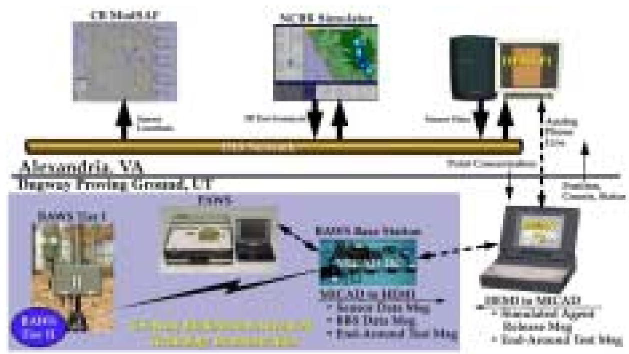

Figure 2-1: The BAWS simulation architecture leveraged existing software applications.

2.1 Hazard Environment MICAD Interface (HEMI)

The HEMI provides the digital hazard representation for the BAWS sensors. The Army's Edgewood Chemical Biological Center sponsored HEMI development to support BAWS testing. The HEMI receives the biological hazard cloud as a series of Gaussian puffs generated by the NCBR. The BBS sends the location of each BAWS to the HEMI. Using the location and virtual hazard cloud, the HEMI calculates the number of particles for each sensor for each time increment. The HEMI sends the simulated particle count for each BAWS to the BBS. To facilitate integration, ITT Industries and Lockheed Librascope developed an interface control document (ICD) to define the messages between the HEMI and BBS. The HEMI and the BBS are connected via a serial interface. For the initial testing, the HEMI and BBS were connected directly with a serial cable. The communications facilities at WDTC did not support a direct connection, so the HEMI and BBS were linked with radio modems.

The bandwidth required for communications between the HEMI and BBS is low. The bandwidth required to support the hazard cloud puffs is high. The serial connection between the HEMI and BBS required that the HEMI be physically close to the BBS. The high bandwidth requirement for the puffs required the HEMI to be located with the NCBR. These competing needs required the HEMI to be in two places at one time. The HEMI is divided into two parts, referred to as HEMI P1 and HEMI P2 to accommodate these design constraints. The HEMI P1 is generally co-located in simulation facility with the NCBR and other simulation tools. The HEMI P2 is located on the testing range with the BBS. The P1 and P2 are connected via modem/routers making the connection appear to each as a 10Base T Ethernet. The bandwidth required between the P1 and P2 can be carried over standard phone lines. This provides a reach-back capability from the range to a simulation center.

Efficient management of the Gaussian puffs received from the NCBR is a significant part of the HEMI. Puff management is discussed in detail in *Developing Biological Hazard Detection Tactics, Techniques, and Procedures Using Distributed Simulation* 98F-SIW-140 [2].

2.2 Nuclear, Chemical, Biological, and Radiological Environment Simulator (NCBR)

The NCBR is an existing simulation developed by a consortium led by the Army's Edgewood Chemical Biological Center and the Defense Threat Reduction Agency to provide hazard clouds for distributed simulation. In real time, the NCBR calculates a high-fidelity, three-dimensional (3D) hazard environment as a function of hazard delivery system (source term), meteorological conditions and complex (3D) terrain. The DTRA SCIPUFF and the Naval Surface Warfare Center's VLSTRACK Gaussian puff models provide the means for the NCBR to calculate CBR hazard environments. The NCBR makes the data available to other simulations via full 3D representations of the environments (instantaneous air concentration), 2D grids (dose, deposition, air concentration, and lethal dose, or LD, contours), and at a point via a subscription process. Figure 2.2-1 portrays a sample 2D conformal (to terrain) NCBR instantaneous air concentration calculation showing the effect of complex terrain on the cloud. SBCCOM has served as the proponent for configuration control and release of the NCBR and DTRA WMD Analysis and Assessment Center is supporting the migration of the tool to the DoD's emerging High Level Architecture (HLA) standard for distributed simulation.

Figure 2.2-1 NCBR 2D Concentration Contour

The NCBR met the BAWS testing requirements by developing dynamic and coherent hazard cloud representations (see discussion in Section 1.2). The Bio ATD architecture used the HEMI to calculate particle counts at each sensor's location based upon simulated threat biological weapons attacks.

The NCBR has been discussed in previous SISO papers including *Transferring Ownership of ModSAF Behavioral Attributes* 99S-SIW-097 [3] and *Developing Biological Hazard Detection Tactics, Techniques, and Procedures Using Distributed Simulation* 98F-SIW-140 [2].

3. Test Plan

The Army developed the Bio ATD/BLWE test plan to demonstrate the military utility of the ATD technologies and provide soldier interface data. The BLWE used a combination of live biological simulant aerosol challenges and virtual biological aerosol challenges to stimulate the BAWS Tier I sensor array, providing BBS operators with a realistic representation of a biological weapon attack. The test plan defined a preliminary two-week test period in March 99 as a preparation for live and virtual test procedures and methodologies. Live biological simulant aerosol testing was scheduled for a four-week test period in June 99 with two weeks of virtual testing concurrent with live testing supporting evaluation of BBS operators. The final week of testing—for the evaluation of soldiers deploying the BAWS—consisted solely of virtual challenges.

Traditional live testing for agent-sensing devices consists of a series of simulant aerosol clouds generated in a fashion as to emulate a BW attack. Limitations in dissemination technologies for live simulant releases result in a reduced capability for testers at WDTC to emulate BW attacks. Generation of simulant aerosol clouds from ground and airborne dissemination devices can only approximate a cloud from a BW munition. Additionally, meteorological conditions must exist which favor transport and diffusion of the cloud at ground level across an established test grid on which the test devices are located. Dissemination limitations and unfavorable meteorological conditions reduce the effectiveness of live field-testing.

Incorporation of a virtual test system in the Bio ATD/BLWE test plan allows for continued evaluation of the BAWS and BBS operators performance during periods of unfavorable meteorological conditions. Additionally, a variety of BW attacks with variations in munition type, detonation location, and meteorological conditions were scheduled to stimulate the BAWS Tier 1 sensor array. In an attempt to develop data to be used for calibration of the simulation and to develop the basis for future validation studies test personnel developed test plans containing similar digital and live trials.

3.1 Live Tests

Live biological simulant aerosol challenges consist of non-pathogenic, innocuous bacteria, virus, or proteins used to emulate pathogenic biological weapons agents dispersed from an aerosolizing device mounted on a moving or stationary ground or aerial platform.. Live biological simulant testing for the Bio ATD consisted of the simulant for *Bacillus anthracis* spores, *Bacillus subtilus* var. *niger* (commonly referred to as BG), disseminated from a compressed air dissemination device mounted on a small aircraft. The pilot flew the aircraft approximately 50 feet above ground level, disseminating a line of one to five km in length over a 12-second interval. Each release contained from 8-12 kg of BG. Meteorological conditions favorable for release included winds in the one- to six- m/s range and preferably from the south. However, test personnel could release simulants from other locations if prevailing winds dictated a change.

Live aerosol clouds, generated to challenge BAWS sensors, were *refereed* with TSI aerodynamic particle sizers (APS) and New Brunswick Slit Samplers (NBSS) that were co-located with the BAWS Tier I units. APS data provided total particle concentration and particle size distributions in the 0.4- to 15-micron size range. The slit samplers provided viable (live—there is a decay of the live particles with time) particle concentrations. APS data were also used to determine presence of the aerosol cloud at the BAWS Tier 1 sensors, which is the indication for the NBSS to be started. Five NBSS were used at each site. Four were set to collect data for two minutes and were actuated in series, while one was set to collect running background data for 30 minutes. Experimenters compared data from the BAWS Tier I sensors and the referee devices.

3.2 Virtual Tests

Virtual trials consisted of digital representations of aerosol threat clouds generated in the NCBR. The HEMI calculated particle counts for each BAWS Tier I sensor based on data calculated from the NCBR-generated virtual hazard. The HEMI transmitted particle counts to the real Tier I sensors via a hardware link from the HEMI to the BBS on a periodic basis (see Figure 2-1). The total particle counts (simulated plus real background) were then sent back to the BBS through the normal radio communication channels for the BAWS and analyzed by the BBS, with the BAWS logic determining if alarm criteria were met. Virtual challenges represented varying munition types, detonation locations, and meteorological conditions. Virtual challenges were limited only by the ability of the underlying physics-based models to represent real environments or test items.

3.3 Data collection

Data collection for live testing focuses on the dissemination parameters for aerosol generation, meteorological conditions during the trial, and characterization of biological simulant aerosol at the BAWS Tier I sensor locations. The primary purpose of the data collection was to determine the correlation with a real BW attack and to provide additional data for BAWS alarm logic development. Data collection for virtual trials focused on input parameters for the transport and diffusion model VLSTRACK (munition type, detonation location, and meteorological conditions), which generated the virtual threat cloud. Bio ATD personnel recorded BAWS Tier I sensor data from the simulated trials to observe the effects of varying simulation parameters. Both virtual and live stimulation of the BAWS Tier I array was used in BBS operator evaluation.

Conducting live and virtual challenges coincident to one another provides an opportunity to calibrate simulation output to actual data as well as validate the simulation. Calibration and validation require that simulation input parameters match actual parameters recorded during a trial. Meteorological conditions and dissemination parameters in the live and virtual trials must be similar for valid data comparison. The intrinsic differences between the representation of BW attacks generated in live and virtual testing and the difficulty in representing environmental and meteorological conditions in the simulation complicate both calibration and validation.

The emphasis of the Bio ATD is the BBS operator performance evaluation and not validation of the simulation. Resources for a validation of the simulation were not within the scope of this study, although actual results will be analyzed to determine if they may be used for calibrating the simulation in an attempt to better emulate live field trials. Simulation of live trials could then lead to a test design enabling validation studies. Currently the NCBR approximates BW munitions and straight line aerial releases of biological simulants. A separate simulation was used to generate the semi-circle flight path used for the live testing.

4. Test Results

The BAWS testing at WDTC had two kinds of results, enhanced operational testing and simulation calibration. The operational testing support was the primary interest of the BAWS developer (ECBC). The simulation calibration results were used to improve the simulations and provide data for future VPG activities at WDTC.

The BLWE for the Bio ATD conducted at the WDTC in June 99 provided data for an analysis of the performance of the BAWS in the hands of soldiers (primarily the BBS operators) and the capability of *average* soldiers to configure the equipment. Additionally, the Army will analyze live data to determine its usefulness for simulation calibration for future robustness in system evaluation and validation studies. Live and virtual testing served to stimulate the BAWS Tier I sensor array to provide realistic simulated biological weapons attacks for BBS operators to respond and to check the proper connectivity of BAWS after field configuration. The evaluation of soldier performance in the configuration and operation of the BAWS is critical to evaluation of the detection system for continued acquisition decisions.

Soldier performance evaluation for the BLWE was supported with 18 live trials conducted on 16 nights during a four-week period. Experimenters conducted 44 virtual challenges during four days of night tests and four days of day tests over a two-week period. Both series occurred in June 1999. Live trials were not conducted in accordance with specific test plan parameters. Rather, experimenters altered test configuration and execution to enable dissemination from the aircraft in locations dictated by the winds. The array of 10 BAWS Tier I sensors were configured in an east-to-west orientation 500 m apart with the preferred dissemination from the south with southerly winds (secondarily from the north if northerly winds are present). Some live trials were conducted in east/west orientations due to unfavorable wind directions in an attempt to leverage the live test configuration due to financial concerns related to the high cost of live testing. Analyses of soldier performance with the live BAWS tests will be detailed in the Bio ATD/BLWE test report.

The 44 virtual trials conducted for the BLWE included a variety of BW attack scenarios providing robustness in sample number and variation. Virtual testing employed two munitions types as input parameters to VLSTRACK. Unitary and cluster bomblet medium range missiles with varying payload quantities served as the basis for the simulated biological aerosol clouds. Detonation location and height of the missile and meteorological conditions were varied in the simulations..

4.1 Operational Testing Value

The financial investment required for the infrastructure necessary to conduct live biological simulant aerosol testing is very large compared to that required for digital challenges. Live testing in the CB environment will always be required for a final check of a system's utility, capability, and readiness for battlefield deployment. However, simulation provides an economical vehicle for conducting large numbers of tests covering broad parameter spaces. These data augment live testing operational evaluation but can also be used to determine the best conditions and scenarios for live testing, preserving live testing resources for use in the most advantageous manner. Value in operational testing is the beginning to developing better simulations for use in developmental testing, creating embedded training, and providing an organic situational analysis tool for deployment situations.

4.2 Comparison Results

The authors were writing this paper at the same time as the virtual testing at WDTC. Live and virtual test data from the BLWE exercise are in the analysis stage. Early observations on the utility of the virtual challenges for operational evaluation are positive from the soldiers as well as the evaluators. Comparison of live and virtual stimulations of the BAWS for operational evaluation will be included in our presentation at the Fall 1999 Simulation Interoperability Workshop.

5. Future Plans

The recent rounds of testing of the BAWS at WDTC were part of a longer, multi-year test plan. The BAWS program will use the same simulation infrastructure to support virtual testing in FY99 at Ft. Lewis, Washington. The FY00 BAWS test program is currently configured to rely solely on virtual testing. WDTC will also use hardware and software of the BAWS for future virtual proving ground initiatives at Dugway.

5.1 BAWS Testing

The Army has established an aggressive test schedule for fiscal year 2000. The FY 2000 testing will rely solely on digital stimulation of the BAWS networks. The Army has currently scheduled testing for Ft. Lewis, Washington, Nellis Air Force Base, Nevada, Langley Air Force Base, Virginia, Camp Pendelton, California, Panama City, Florida, Ft. Lee, New Jersey, Ft. Leonard Wood, Missouri, Ft. McDill, Florida, and the JRTC. In each case, these sites can not accommodate live testing with biological agent simulants. Virtual testing will enable testing of the BAWS at sites otherwise precluded from live testing.

5.2 VPG at WDTC

As part of the VPG program at WDTC, the NCBR/hardware interface simulation will be used to plan and execute operational tests. Acquisition of the hardware and software required for simulation operation at WDTC will provide an additional tool in the arsenal of test infrastructure and methodologies. The existing simulation may be modified to support operational testing for both point and stand-off CB sensing equipment. Advances in the underlying physics-based models and incorporation of additional sensor inputs in the simulation, such as direct weather inputs, will allow for more robust testing and prepare the way to provide digital stimulation to engineering-level models representing sensor technologies. WDTC considers this a first step toward the role of the CB community to provide a T&E infrastructure for the DoD's initiative in Simulation Based Acquisition.

5.3 Simulation Improvements

The simulations used for the Bio ATD testing provided significant value to the testing. However, the testing revealed the need for additional capabilities. These included the capablity to provide live meteorological conditions to the simulations, provide virtual meteorological conditions to the live sensors, and conduct urban transport and dispersion environment modeling. These added capabilities will be developed and implemented when funding is available.

As currently configured, the simulations loaded the meteorological conditions at the time the tests began. If the live conditions changed, the change was not reflected in the virtual world. The proposed capability would capture live meteorological conditions and feed them to the simulations. The virtual hazard cloud would then respond to changing conditions.

The virtual test capability is very useful when the live conditions do not permit release of a simulant cloud. During this type of test, the meteorological sensor on the BAWS detects the live conditions which do not necessarily match the conditions used by the simulation. This mismatch has the potential to impact the detection algorithm. The proposed improvement is to provide the BAWS meteorological sensors virtual data similar to the way simulated agent counts are provided to the particle counter. This would require changes to the simulations as well as changes to the BAWS software.

The hazard cloud simulations used for BAWS testing can not model transport and dispersion in urban environments. There are proof-of-principle urban transport and dispersion models, but most do not run in real-time. In addition to running in real-time, the model must publish the hazard data in a format that can be transmitted to and used by the sensor model. Future plans include adding urban transport capablity to the NCBR.

The authors, at the time of the writing of this paper, were also in the final stages of the DTRA-funded migration of the NCBR Environment Simulator to the DoD's mandated architecture for distributed computing, the HLA. Because the DoD had yet to fund the migration of any of the high-fidelity sensor models to the HLA, the NCBR developers plan to test NCBR HLA compliance and interoperability (Real-time Platform Reference Federation Object Model) with the Chemical/Biological ModSAF (variant of ModSAF undergoing incorporation into the ModSAF/OneSAF baseline) using the Army Simulation, Training, and Instrumentation Command's DIS/HLA Gateway. These activities should be complete at the time of the Fall 1999 Simulation Interoperability Workshop. It will require nominal future effort to modify the existing DIS sensor models for HLA compliance.

6 Conclusions

While several communities have conducted virtual testing, this effort proved the benefits of using simulation to support the live testing of biological detection systems. Distributed simulation standards enabled rapid development of a BAWS virtual test capability. The Integrated Biodetection Advanced Technology Demonstration personnel modified and integrated an existing modeling and simulation infrastructure with fielded BAWS sensor in a short (few month) timeframe. This provided the DoD with a capability to test the BAWS under a broad range of test conditions, when existing meteorological conditions were unfavorable, and without releasing large quantities of biological agent simulant. The use of virtual testing provided the soldier trainees with a broader experience base and wastes less of their time waiting for favorable/acceptable meteorological conditions.

Bio ATD and VPG personnel also learned the importance of data collection. It is necessary to collect the same data (and of the same fidelity) from virtual and live tests in order to make an adequate comparison. It is also necessary to select the correct metrics when making these comparisons. For example, in operational testing, it is necessary to compare soldier and system response to the live and synthetic stimuli, not necessarily specific particle counts at a specific sensor.

The Army and DTRA are exploring the use of the architecture developed and used for this effort (and previous effort—see Ref. [2]) to support a broader array of virtual testing activities. The modular nature of the architecture supports the affordable development and testing of other virtual systems.

7 References

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