

DEVELOPMENT OF VISUALIZATION, MODELING, AND SIMULATION TECHNOLOGY FOR CROSS-APPLICATIONS IN LIVE FIRE TESTING AND TRAINING

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INTRODUCTION

Visualization, modeling, and simulation technology today can provide extremely high fidelity representations of real world terrain scenes and features, as well as very high physical and functional fidelity replications of equipment, systems, and weapons effects. This technology - actually a combination of technologies - has been developed for increasingly more realistic training of individual weapon system and sensor operators, subteams, and teams in simulated combat environments. Such simulations have demonstrated great value in providing cost-effective training, but in recent years there also has been a growing appreciation of modeling and simulation in development of tactics and doctrine; in mission planning and mission rehearsal; and in test and evaluation applications.

It has been recognized that simulations can serve multiple objectives. At the same time also, it has been recognized that modeling and simulation techniques used in training scenarios have significant limitations, especially with respect to weapons effects, since the standard approach has been to model effects based on probabilities, or simple hit/miss binaries. The arena of live fire testing, however, has of necessity focused on physics-based modeling for its simulations and predictions of outcomes. We want to bring the test and training applications together.

This project develops data and techniques for using training modeling and simulation to enhance live fire testing (LFT) - and for using live fire data and models to enhance training, mission planning, and mission rehearsal simulation systems. The enhancements in both arenas will take the form of more realistic (higher fidelity) and more cost-effective training and testing.

Our first target application has focused on live fire testing of land vehicle(s) as they move and maneuver over variable terrain under variable operating and environmental conditions. Recent work in the area of Distributed Interactive Simulations (DIS) have noted the need to have new data structures and data access methods for developing high fidelity, dynamic terrain and environmental databases that can support current polygonal-based training simulations as well as future applications (Kilby et al., 1994). Additionally, these high fidelity representations will enable the modeling and simulation of factors that previously could be evaluated only via physical prototypes (Kuhl and Wargo, 1994).

Also, the use of geographic information systems (GIS), visualization, and simulation technologies will enhance current techniques for live fire testing of maneuvering vehicles, munitions, and countermeasures by providing capabilities to:

- Vary the terrain and environmental conditions in which tests are conducted;
- Examine the requirements for testing of single and multiple maneuvering vehicles;
- Assess smart munitions and submunitions, and related vehicle countermeasures;
- Display and replay tests in ways that promote "what if" assessments and increase understanding of test results;
- Improve prediction of test results;
- Involve actual operators for maneuvering and control of vehicles during testing.

BACKGROUND

There are many reasons for utilizing visualization, modeling, and simulation

technology in live fire testing. Among those stated by O'Bryon, 1996 include:

- Increased speed and processing of data;
- Reduced cost;
- Better representations of the physical world;
- Assist decision-makers in the face of alternatives; and
- Reduce the limitations on testing placed on us by environmental restrictions, personnel safety, and international treaties.

There are also reasons to utilize these modeling and simulation tools for subsequent training applications. For instance, data made available through modeling and simulation of live fire testing of new systems would provide useful information that helps train soldiers by enhancing crew training to better report the results of firing engagements at threat systems (Julian and Wojciechowski, 1996).

This project seeks to develop applications through visualization, modeling, and simulation that provide real world representations of live fire test data and provide the benefits for testing and training outlined above.

PROJECT CONCEPT

The concept for this project is to develop a Dynamic Simulation Toolkit that can be used to interpolate 'static' test data to determine dynamic vulnerability and survivability; including environmental effects, countermeasures, and vehicle dynamics (maneuver). Since these factors will determine weapon guidance errors and fuze initiation, the 'static' LFT data must be interpolated to yield the real world expected results. This is accomplished through the determination of aim points and fuzing functions as a result of these factors, and by determining the correct LFT data to be applied for a specific scenario. This is an area of great concern because there are very few models and/or tools that adequately provides for both the prediction and understanding of live-fire events (Dietz and Saucier, 1997). The Dynamic Simulation Toolkit is being developed to address this issue

and provide a toolbox for future training scenarios.

Figure 1 provides an overview of the project concept. The potential for technology transfer is shown through the dashed boxes. Technologies from the areas of robotics, smart traffic management, and smart highways are enabling technologies for the implementation of the Dynamic Simulation Toolkit with a Simulated Navigation and Maneuvering System (SNMS).

Demonstration Development

The visualization, modeling, and simulation demonstration consists of a two and three dimensional representation of vehicles maneuvering in real battlefield environments. The scenario is based on a convoy of U.S. military vehicles moving single file through a hostile area. One vehicle is disabled either by enemy fire or mechanical breakdown. The remaining vehicles must continue to move on toward their destination, going around the disabled vehicle. Movement around the disabled vehicle is determined by the surrounding terrain, i.e. - the remaining vehicles must go around to the right side of the disabled vehicle due to an impassable depression on the left side.

A complete definition of this prototype demonstration, includes:

- software/hardware platform definition;
- input database format definition/construction;
- terrain database format/construction;
- vehicle identification/specifications; and
- scenario definition/development..

The software/hardware platform for the demonstration consisted of Mak VR-LINK Toolkit, Stealth Viewer, Logger, MultiGen, and ESRI's ArcInfo TIN running on a Silicon Graphics Platform. Initial database development was performed on a Silicon Graphics UNIX machine and was later ported to a Silicon Graphics OS2 environment.

ArcInfo was used to generate GIS databases needed to support terrain database development. These databases conformed to a

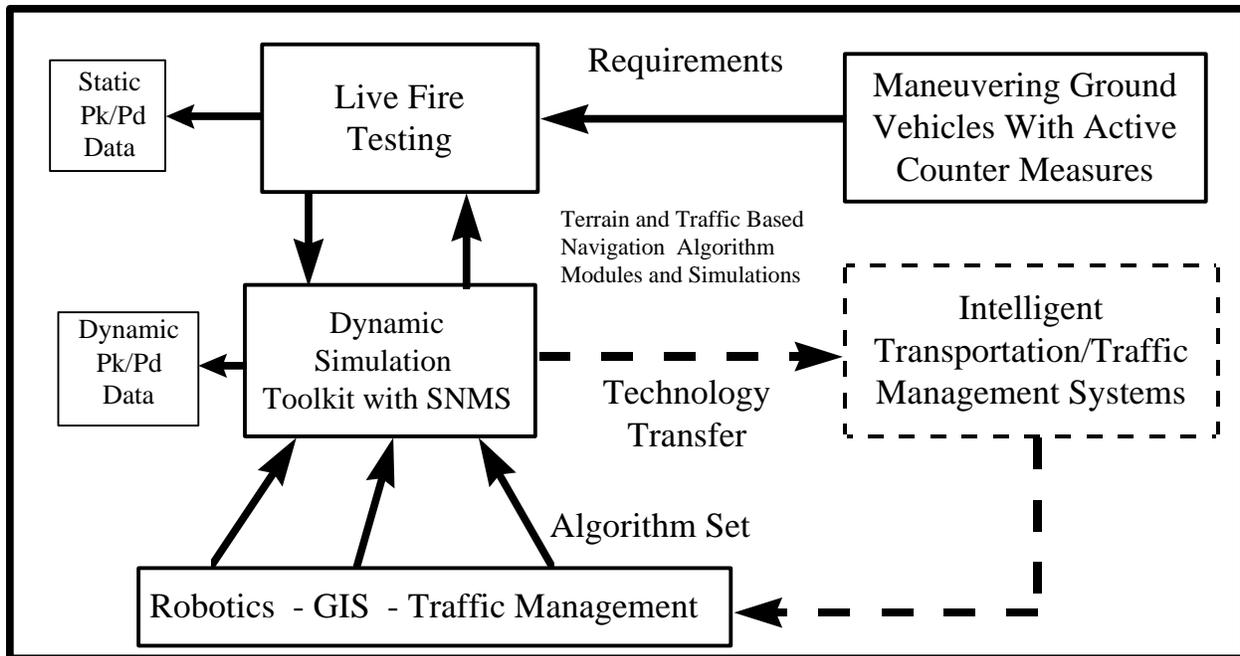


Figure 1. Project Concept

standard database design that facilitates fast and accurate translation to the three dimensional modeling program, MultiGen, and represents geographic features such as land cover and elevation. The resulting database of the GIS and 3D modeling integration is a terrain backdrop for moving and maneuvering ground vehicles in a simulation environment.

The vehicle identified for the demonstration was US Army M-2 Bradley. This vehicle was chosen based upon the availability of live fire test data. Incorporated into the vehicle model were maneuvering characteristics, dynamics, countermeasures, and control functions. Ultimately, techniques demonstrated and proven in this program can be applied to new development systems such as the Marine Corps AAUV.

Using these terrain and vehicle elements, scenarios were developed which are compatible with live fire testing and evaluation with respect to intelligent vehicle movements. For example, if a multiple warhead weapon is fired at a moving convoy knocking out the lead vehicle, can the remaining warheads hit targets after evasive maneuvers by the remaining vehicles have been initiated? This can also support survivability of

the vehicles by demonstrating abilities to avoid incoming weapons using evasive maneuvers. The scenario will model pre-programmed evasive maneuvers by the vehicles. These maneuvers will be determined with respect to terrain passability.

Simulation Visualization

Users can visualize the scenarios in two ways:

- **Plan View.** This view consists of two dimensional GIS view of a game board, showing movement of the vehicles through the database.
- **God's Eye View.** This view allows the user to see the entire game board from any three dimensional perspective, allowing close-up views and 'out-the-window' views from within the vehicle.

This demonstration utilizes the functionality of the live fire Dynamic Simulation Toolkit which allows the user to visualization the outcomes of alternative engagement scenarios over varying terrain. The components of this toolkit will be discussed in more detail in the following section.

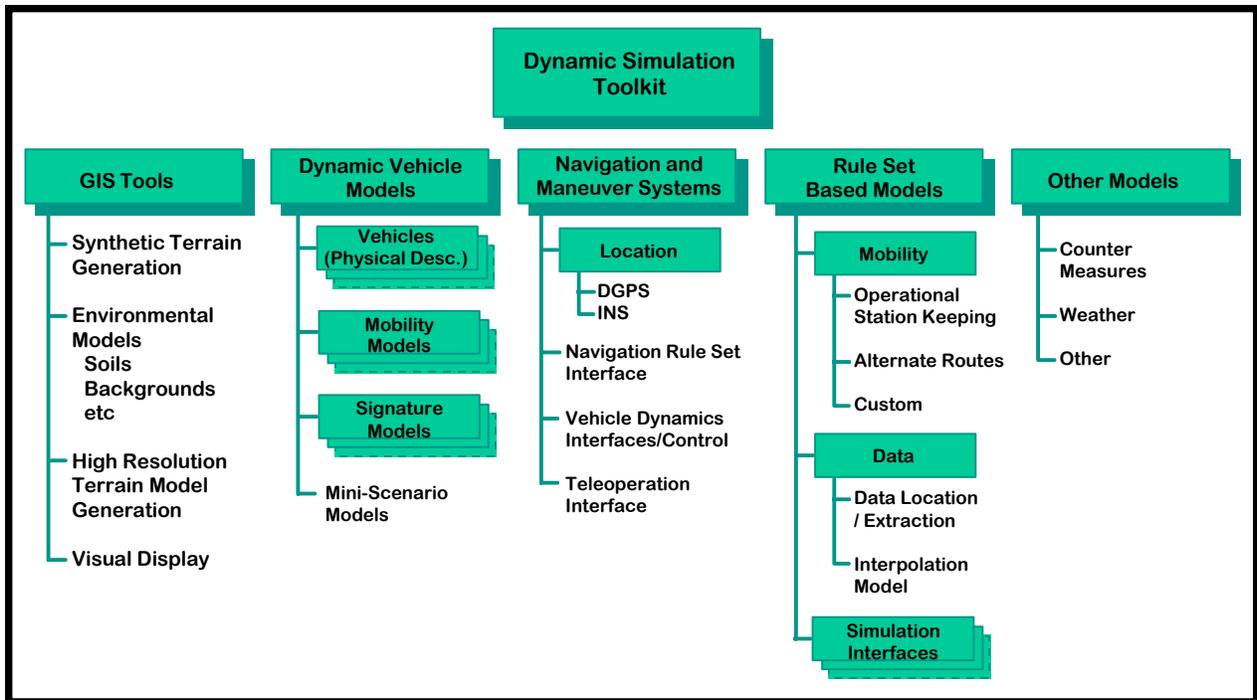


Figure 2. Live Fire Dynamic Simulation Toolkit

DYNAMIC SIMULATION TOOLKIT

Figure 2 displays the five functional areas incorporated into the Dynamic Simulation Toolkit.

This toolkit is envisioned as a set of integrated tools, based on existing and COTS software, which can simulate combat vehicles operating in synthetic environments representative of real world scenarios.

The toolkit contains the custom SNMS module which provides control of simulated or real vehicles in a designated test area. This module provides for the vehicles control, appropriate maneuvers, countermeasure deployment, and alternative route selections based on conditions and dynamic situations.

The following sections briefly describe the other attribute areas of the Dynamic Simulation Toolkit.

Geographic Information Systems Tools

GIS tools allow for the development and incorporation of terrain, environmental, and other

relevant spatial features in a three dimensional simulation. Also, the inherent locational nature of the GIS allows user to know where in the simulation a vehicle is located using a predefined set of coordinates (lat/long, UTM). Subsequently, routines that allow vehicles to navigate through the simulation can be constructed using these coordinates in a process known as waypointing. Waypointing simply refers to the process of moving from point A at coordinates X1, Y1 to point B at coordinates X2, Y2 while avoiding obstacles such as depressions or tree lines.

Dynamic Vehicle Models

Dynamic vehicle models act as much like their real world counterparts as possible. Using the toolkit, vehicles are modeled with actual dynamics (characteristics) and kinematics (movement). The vehicle models are integrated with a command/rule set for navigation. This constrains the vehicles to movement within the simulation based on queries to the terrain database and does not allow a vehicle to move over impassable terrain.

Navigation and Maneuver Systems

Maneuvering and navigation algorithms have been integrated with the vehicle dynamics/kinematics to form a comprehensive vehicle model that can navigate through a given terrain while avoiding obstacles and rough/impasses areas.

The toolkit has multiple location determination systems that aid in navigation and maneuvering for both simulated and remotely controlled vehicles - DGPS and INS. DGPS or Differential Global Positioning Systems are positioning systems capable of sub-meter accuracy. INS or Inertial Navigation System can be integrated with the DGPS to achieve navigation accuracies of approximately 20 cm in a defined area of operation.

The integration of these navigation and maneuvering systems with a high resolution GIS terrain database allows for the control of vehicle movements throughout the simulation.

Rule Set Based Models

The rule set based models are complete command sets for mobility, data extrapolation, and simulation interfaces. The rule sets have been developed to support intelligent navigation of model vehicles. The sets are based on vehicle type and characteristics as well as terrain. A combination of C, C++, and Arc Macro Language has been used to develop the rule sets. Subsequent simulation results in the vehicle comparing terrain characteristics to the command set to determine the best route around obstacles to get from one point to the next.

Other Models

The other models in the toolkit are for ground vehicle countermeasures and environmental considerations. These models were not deemed

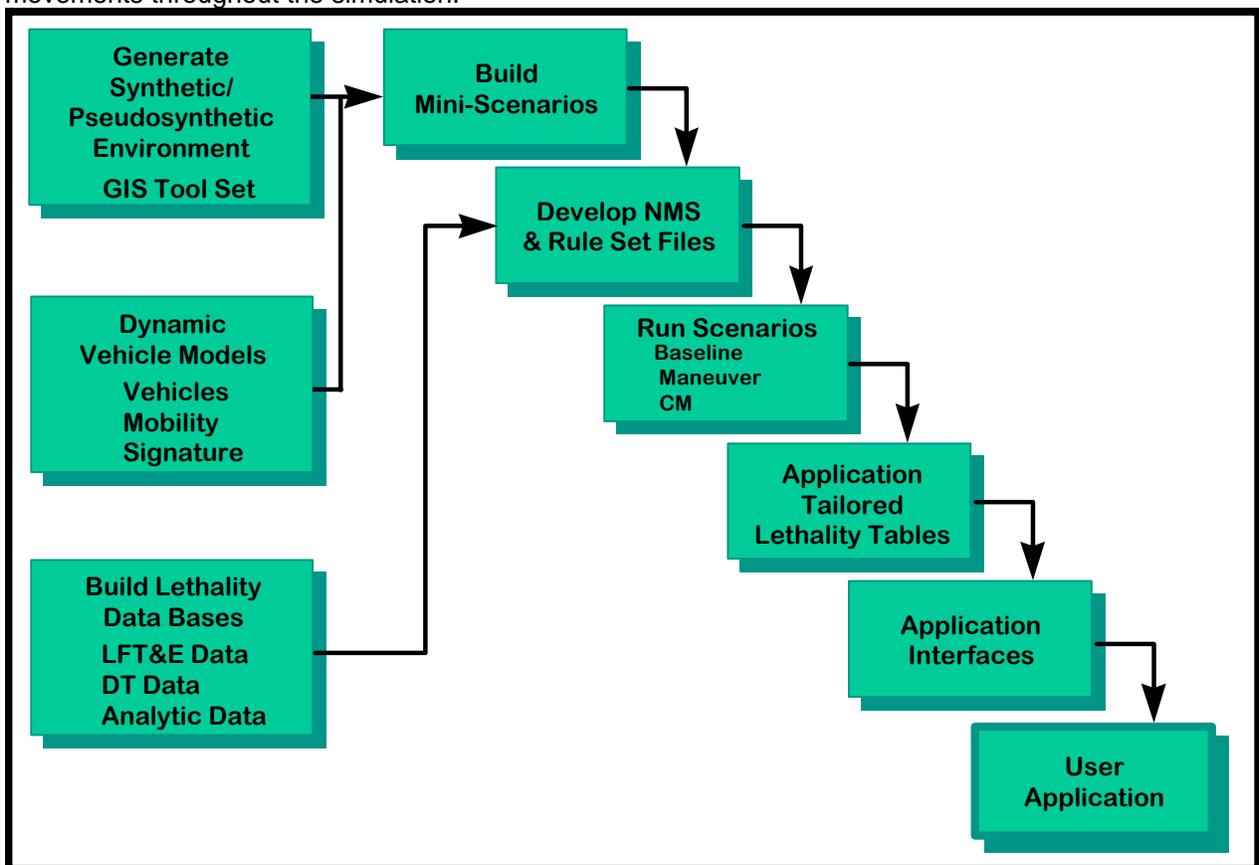


Figure 3. Toolkit Applications

as essential to the initial demonstration development but they will be incorporated into the toolkit as the project matures.

MINI-SCENARIO APPLICATIONS

Figure 3 displays the various applications that can be developed by integrating the elements contained within the Dynamic Simulation Toolkit. These applications permit the expanded use of lethality tables based upon dynamic simulations. The underlying concept here is that to date, much of the live fire testing is 'static' type testing pitting weapon against combat vehicle using statistical aim points. This validated effects data is used to generate lethality maps and subsequently, "probability of kill tables" for weapon-target pairs. Finally, this data is used in simulations using weighted averages such that a single random number draw will generate an outcome. Thus no direct accounting is made for

crew actions such as maneuver and countermeasure deployment. This can be particularly frustrating when simulations are used in training and proper action is not rewarded in the outcome.

The dynamic type simulation that the toolkit enables, takes into account maneuvering vehicles in different environments and with various countermeasures. The mini-scenarios define specific actions in terms of rules to be invoked upon reaching obstacles or when initiating engagements or being engaged. The SNMS will then maneuver the vehicles in accordance with the rule-based doctrine and kill/damage probabilities will be determined based on the resulting geometry and conditions. These dynamic changes will occur even during weapon time of flight intervals. Thus, the commonly used 'static' probability of kill tables can be interpolated to account for the dynamic environment of the engagement.

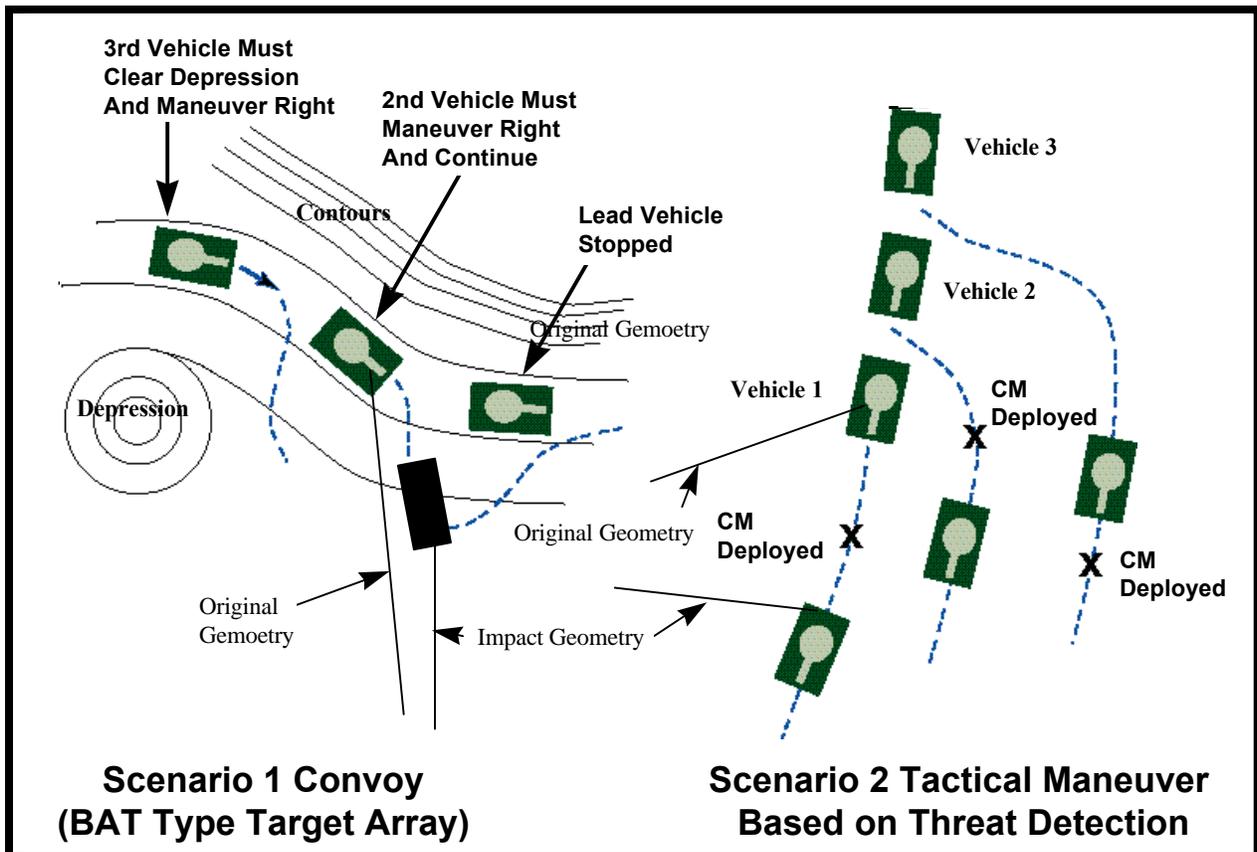


Figure 4. Mini-Scenarios

The current effort is focused on application of the LFT data with an eye towards eventually applying these results to the test planning and conduct for future LFT programs. The concept of Live Fire Testing in a realistic, dynamic environment is driven by the issues previously discussed, namely, dynamic vehicles employing passive, active, and reactive countermeasures in a real environment. This concept can be represented by two basic scenarios as shown in Figure 4. In scenario 1, a column of vehicles is in convoy and a vehicle is disabled (or destroyed) through a failure or as a result of an attack. This vehicle then becomes an obstacle to the following vehicles which must either maneuver around the obstacle or select an alternative route. In scenario 2, a tactical formation of vehicles encounters a threat and employs countermeasures an maneuver to counter the threat.

These basic scenarios have been used to demonstrate and validate the Dynamic Simulation Toolkit and SNMS developed under this program. The key factor demonstrated here is the use of true engagement geometry's as opposed to initial acquisition or firing to calculate hit points, and subsequently kill mechanism effects. The next phase is to implement this technique using the toolkit in a ModSAF tactical scenario. A comparative analysis will be conducted to assess the impacts and effects of using this methodology.

CONCLUSIONS

1. The Dynamic Simulation Toolkit and SNMS prototype, with its customized tools for visualization, modeling, and simulation, offers a unique approach to supplementing live fire testing and training processes. It is unique in two ways. The toolkit is a set of integrated tools that can simulate combat vehicles operating in synthetic environments representative of real world scenarios. The toolkit enables the correction of lethality data for movement and maneuvering as well as allows for visualization of effects. Additionally, the toolkit makes use of actual data from LFT&E, not the commonly used averages.
2. The visualization, modeling, and simulation software can be utilized to develop dynamic Pk/Pd tables by representing various shot

scenarios in real world environments, supplementing the commonly used static Pk/Pd probability of kill tables.

These unique capabilities have some important potential benefits for both the live fire testing and training community. Such as:

- *Enhanced Pre- and Post-Test Analysis.* Pre- and Post-test analyses will be enhanced through the ability to record, playback, and save scenarios and test results. Also the Dynamic Simulation Toolkit and SNMS permits testers to conduct "what if" scenarios by varying conditions and rerunning the test(s).
- *Enhanced Training Capabilities.* The toolkit can serve as a testbed for improved use of actual test data in training scenarios and simulations. Enhanced training primarily will be realized through more realistic simulations, student feedback, and reduced instructor/operator or analyst/controller workload/requirements.

Future efforts of this project will focus on refining the modules of the toolkit and further developing multiple alternative mini-scenarios that embrace the potential benefits of visualization, modeling, and simulation technology for live fire testing and training.

ACKNOWLEDGEMENTS

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