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AN INNOVATIVE APPROACH TO MISSILE SYSTEM DESIGN

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ABSTRACT

This paper will address several system effectiveness tools developed by the U. S. Army Missile Command's Missile Research, Development, and Engineering Center (MRDEC). MRDEC has expanded upon the traditional lethality modeling tools and methodologies and incorporated novel ideas utilizing visualization and design level engineering assumptions.

Effectiveness and lethality were not traditionally included in the early stages of missile system development, but were calculated based on the results of individual component performance. Detailed system effectiveness studies were an after-thought, with a lack of feedback in the missile development cycle. In recent years the MRDEC has worked with PEO Tactical Missiles Project Offices and contractors in refining a process to fully explore a design level approach to missile system development. This paper will discuss mini-map technologies, connectivity of flight simulation performance and warhead performance for missile and/or component development, and new visualization tools to assist the analyst in the accessing and analyzing the computed data.

MRDEC is demonstrating that the utilization of design level effectiveness studies is critical in the development of missile system requirements, design, and evaluation. By increasing design level lethality inputs in the development cycle, the overall process can be optimized with full understanding of how changes affect the system performance.

INTRODUCTION

This paper documents efforts at the AMCOM MRDEC to allow lethality data to be utilized at early stages in missile system development. Various design level codes have been created from low level penetration calculations to full evaluation level assessment tools. These tools are a part of an innovative approach in the development of missile systems. The utilization of test data combined with simulation modeling and results has provided a new perspective in the development of missile systems. By combining results of both simulation and test, a missile designer can determine, at an engineering design level, the relative performance of the missile system. By combining test analyses into the design level tools, a realistic estimate/analysis for missile performance is provided.

This paper will cover three recent tools and techniques that allow data to flow from test to evaluations. The three methods presented will show how the test and simulation data are combined to explore missile effectiveness. The methods presented allow insight into system strengths, weaknesses and possible improvements.

DISCUSSION

DETONATION POINT TOOLS

The first of the three methods to be explored is most applicable in a simulation environment. This is the exploration of data through a detonation point perspective, commonly called mini-maps.

To understand the concept of a Mini-map, one must draw upon the knowledge of the traditional representations of vulnerability/lethality data. The concept of a view plane projection of a target is a standard concept that has been utilized to compute and retrieve Probability of Kill given a hit (Pk/h) estimates. The view plane projection is a useful technique when describing attacks on a target by specific shots that can fall anywhere on the target. Specifying an attack azimuth and elevation for a given target creates a set of horizontal and vertical points (h, v). This set of (h, v) points forms a grid which can be used to display the two dimensional projection of the target from this aspect or to record lethality data. An example of this grid plane and data is shown in Figure 1.

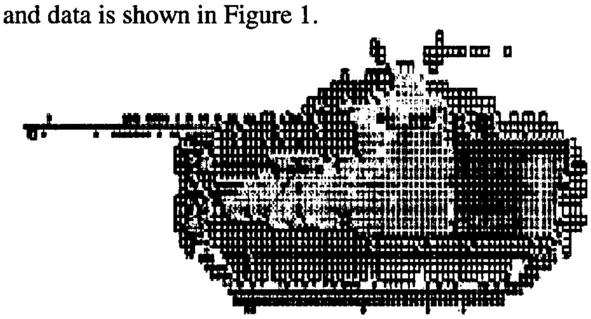

Figure 1. Example 2-D Pk/h estimate grid cell map.

When utilized to record Pk/h estimates, the path of the lethal mechanism is typically perpendicular to the viewing plane. Values are recorded for a random point in the grid cell on the viewing projection. An interesting limit of this approach is observed when visualizing data of missile systems with canted warheads, or large aerodynamic pitch. The data, for these cases, is stored into the grid that corresponds with the velocity vector and not in the location where the lethal mechanism creates a perpendicular intersection with the target. This geometric dilemma is shown in Figure 2. The traditional approach is valid as a storage location, however, it serves to muddle the true relationship between the lethal mechanism and the target.

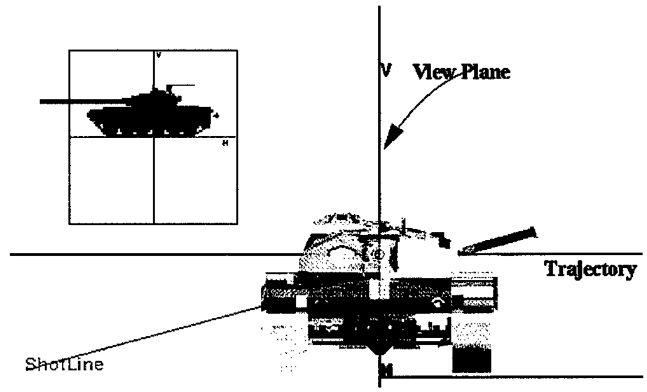

Figure 2. The standard grid for horizontal and vertical plane computations.

The concept of a Mini-map is primarily a data representation which links the lethality data to the point of lethal mechanism impact with the target or to the detonation point of the warhead in a target frame of reference. Methods similar to this have been utilized in the past for fragmenting munitions, but have found little use in the standard assessment for shaped-charge (SC) or Explosively Formed Projectile (EFP) warheads. For a fly-over-shoot-down system, this potentially could be a grid of points that extends over the entire target and includes all feasible burst points without regard to sensor performance. For missile systems that impact their target, this grid could be a set of points forming a hemisphere surrounding the target geometry. This set of hemispheres would represent potential surfaces for the lethal mechanism delivered to that point in space (representing such parameters as variation in missile pitch, yaw or even fuzing). The Mini-map would have this data stored in a 2D table per potential point. Thus, a multidimensional map or Mini-map would be associated with each point surrounding the target.

The advantage is that these maps could be utilized for trade studies and could show clearly advantages and disadvantages of system level performance on such parameters as missile pitch, yaw and fuzing. The tie to missile flight simulation is important in this type of trade study, and data in this format could quickly be tied to simulation runs. The search would first take place on finding the nearest detonation point in the database, then matching the exact shotline path for the lethal mechanism. This approach would also allow various levels of detail because averages of the Mini-map values can yield the set of values available if the lethal mechanism initiated at that point in space. An example of a mini-map for a fly-over-shoot down type of missile system is shown in Figure 3.

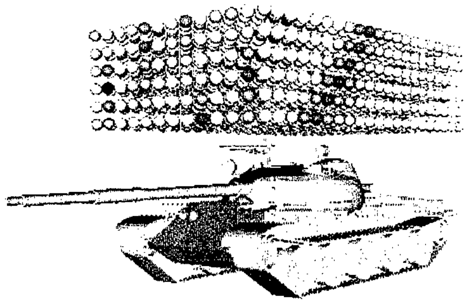

Figure 3. Detonation space mini-map example of a fly-over-shoot-down missile system.

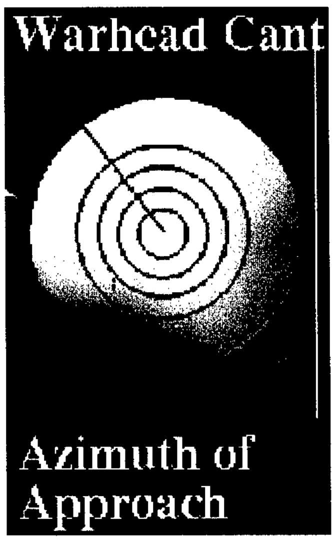

Figure 3a. Potential data stored for each lethal Mechanism path from detonation point.

Figure 3a shows notional data that could be stored for each detonation point in figure 3. Warhead cant is a critical variable in designing top attack weapons. Data precomputed and stored as a mini-map can display information on number of critical components hit, armor thickness, compartment hit, and number of lethal fragments generated. This data displayed in the proper geometric relationship to the target can allow true insight into design differences based upon estimates of system performance.

FLIGHT TEST EVALUATION TOOLS

The second tool provides a missile developer with design level effectiveness from the flight test perspective. This method has been utilized by several project offices within PEO Tactical Missiles and is an excellent way to explore and understand system impacts. It is called the Post Flight Analysis Tool or PFLAT.

This methodology was developed to be flexible; as with many missile flights, data can be limited. Terminal angles, approach azimuths and a physical recording of missile impact are the key parameters needed. Measurements from tests are taken from several sources, from telemetry packages and high speed video, to a manual measurement of the impact based on target features. The PFLAT tool takes this information and allows for a manual merging with the two-dimensional Pk/h grid cell estimates or other design level data. The closest elevation and azimuth angles are selected from visual or telemetry estimates. The actual impact can be chosen though visual inspection of the video and target. PFLAT then queries the user for terminal angles and impact point. The code performs a ray-trace of the vehicle geometry, and scores the impact. The impact is scored with the Pk/h estimates. The (h, v) location of the hit, in the plane normal to the approach vector, is selected. That cell and the eight surrounding cells are highlighted. The estimate of Pk/h for that shot is the average of the nine cells. This methodology is based on the LOCALPk method developed by AMCOM MRDEC for computation of Probability of Kill given a shot (Pk/s) from a simulation. The Pk/h estimates are not robust enough to quote Pk/s for each shot. However, the Pk/s for several shots can be averaged. An example of output from PFLAT is shown in Figure 4.

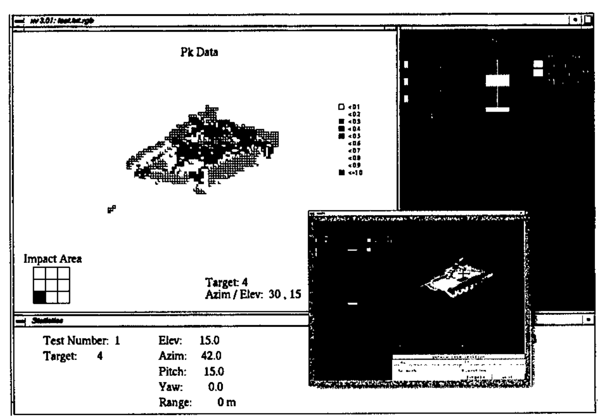

Figure 4. The PFLAT tool with an Interactive Shotline inset.

PFLAT provides an estimate of which area of the target the missile impacted, along with an associated lethality estimate. PFLAT also provides an evaluation of the post-flight predicted shotline. As shown in Figure 4, an interactive shotline tool can be utilized to explore additional shotlines. BRL-CAD™ ray-tracing is utilized to identify components and their associated material type. The degradation of the warhead through these components is also displayed.

This method was developed for design or engineering level looks at the effectiveness of a missile system in its flight. It is not meant to replace the simulation-based evaluation process typically utilized by PEO Tactical Missiles, it is instead a tool to augment the evaluation process of the missile system developer. This data can be checked against the results from simulation to see if the hitpoints match those expected from the dispersions generated by simulation.

SIGNATURE LETHALITY TOOLS

The final tool to be discussed is one that provides insight into the relationship of infrared (IR) signatures and system lethality. As new seekers utilize full imaging sensors of various types, the relationship between impact locations and system lethality can be explored in more detail. One method to explore this relationship, IRPK, was developed to assist the MRDEC in evaluation of a missile system's product improvement program. Changes to the program, as well as the addition of difficult target/background signatures instigated a desire to determine how the IR signature was affecting impacts on the target (from both a Probability of Hit (Ph) and Pk/s standpoint). Traditional output from simulation projects the target into a two dimensional grid and then places hitpoint data on this image. Figure 5 shows this output.

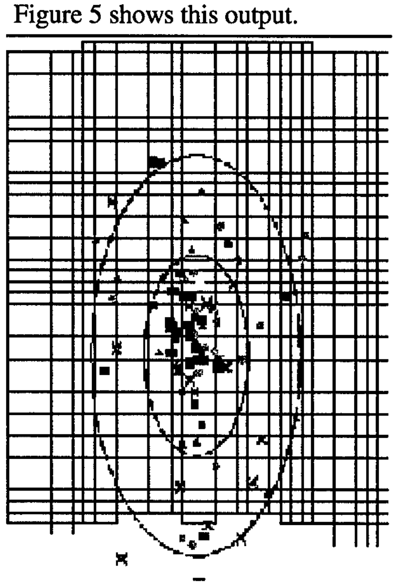

Figure 5. Typical output from endgame merging hitpoints and lethality data.

IRPK reads in the signatures provided for each Monte Carlo run from a digital flight simulation. It then takes the computation of the terminal angles and impacts for each run in the Monte Carlo set, and determines which Pk/h map and cell within that map are associated with that run. IRPK collects the Pk values for each signature and run computed by the defined scenario. IRPK displays the Pk for each shot on the appropriate signature. An example of this is provided in Figure 6.

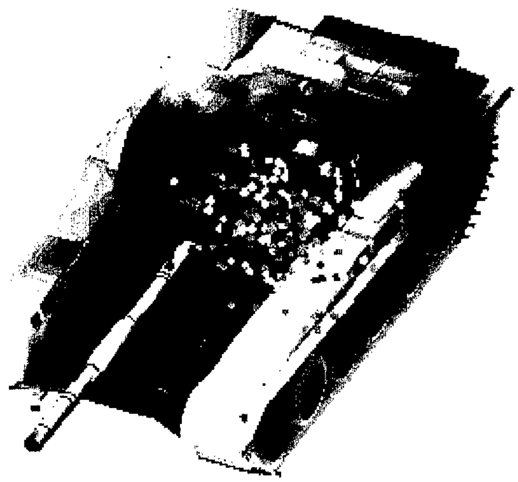

Figure 6. A captured image from the IRPK tool.

The advantage of the IRPK program is that it allows the missile developer to take real or fabricated IR signatures and explore the correlation of "hot spots" on the target, with "lethal areas" on the target. As new imaging seeker concepts gain popularity this connection between sensor image and target vulnerable area will become a critical factor in missile lethality.

CONCLUSIONS

The tools and methodologies outlined in this paper stress the need for innovative, design level estimates for a missile system developer. In times of economic uncertainty, it is imperative that the developer takes advantage of all data at their disposal early in the design process.

New guidance techniques and new armor challenges are forcing a re-examination of traditional approaches toward endgame lethality. However, low cost visualization systems combined with high resolution simulation create opportunities for weapon systems designers to utilize test data and system performance evaluations in the early stages of missile system development.

The AMCOM MRDEC is committed to providing the PEO Tactical missiles with these innovative methodologies. Leveraging of both test and simulation results provide early insight into potential problems or benefits. That equates to time and cost savings, as well as providing the soldier with the best tools to get the job done.

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BIOGRAPHY

Kimberly C. Williams
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Mrs. Williams has worked in the area of Simulation for the last 15 years with a concentration in Lethality/Vulnerability for the last 8 years. She is employed as an Aerospace Engineer by the U.S. Army Aviation & Missile Command. Her major efforts include the effectiveness of army missile systems, i.e. Javelin, Longbow, Bat, and EFOG-M, and is responsible for the development of models which tie lethality data to full missile fly-out simulations (including missile dynamics, seeker and tracker performance). She has presented numerous papers on Lethality and Simulation for both the Computer Simulation Society and the American Defense Preparedness Association.

Glenn E. Romanczuk
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Mr. Romanczuk is a charter staff member at the UAH Visualization & Simulation Laboratory. His primary area of expertise is Vulnerability / Lethality approximation methods and penetration mechanics. Several unique methodologies have been created for use in design level studies. These include the 3DPimmsMan suite for Probability of Incapacitation for personnel in bunkers or rooms, the Dangerous Shotline methodology, and numerous other interactive methods

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Mr. Pitts is a Research Associate in the UAH Research Institute. His research interests include volume visualization, polygonal decimation techniques, solid geometry to boundary representation tessellation techniques.

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Mr. Strickland is employed as a Senior Computer Scientist with CG^2, Inc. He has served as the Principal Investigator for numerous contracts in lethality assessment support and has 12 years experience in lethality / vulnerability modeling and simulation. These support contracts cover all aspects of lethality analysis including target modeling, penetration analysis, shotline analysis, warhead / target interaction, visualization, methodology development, and analysis of P_K data.

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