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AN EXAMPLE OF SIMULATION USE IN ARMY WEAPON SYSTEM DEVELOPMENT

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ABSTRACT

The use of modeling and simulation in the development of military weapon systems began to expand several years ago as the costs of flight testing began to rise. Since then, the role of modeling and simulation has expanded to include areas such as planning and conducting warfare, system development, and acquisition in an effort to minimize system development and acquisition costs.

This paper discusses the use of modeling and simulation in the development of the Pre-planned Product Improvement (P3I) Brilliant Anti-Armor BAT submunition. A High-fidelity Flight Simulation (HFS) is being developed that combines the tactical flight software, high fidelity infrared/millimeter wave seeker model, 6-Degree-of-Freedom flight dynamics model, and validated infrared and millimeter wave synthetic imagery into one integrated digital simulation. The HFS development methodology emphasizes the use of tactical software, legacy models, and high fidelity imagery and encourages commonality between the HFS, Hardware-In-the-Loop, and system effectiveness simulations. Animated graphical displays provide visualization of both the trajectory and the scene/environment. The use of this methodology is increasing the accuracy of the simulation and reducing development costs. The HFS development is on schedule with the master program plan, and is being utilized for captive flight test prediction analyses and system performance studies.

1 INTRODUCTION

The use of modeling and simulation in the development of military weapon systems began to expand several years ago as the costs of flight testing began to rise. Since then, the role of modeling and simulation has expanded to include areas such as planning and conducting warfare, system development, and acquisition (Sanders 1998). The output from high fidelity validated simulations is being used more and more to supplement flight test data, subsequently reducing the number of flight tests, in order to help minimize both system development and acquisition costs (Sanders 1998).

The Pre-planned Product Improvement (P3I) Brilliant Anti-Armor BAT submunition High-fidelity Flight Simulation (HFS) is being developed by the U.S. Army Missile Research, Development, and Engineering Center, Systems Simulation and Development Directorate, as a tool to support performance assessment, system design, and algorithm development of the P3I BAT submunition. When completed, the HFS will combine the tactical flight software, high fidelity seeker model, high fidelity 6-Degree-of-Freedom (6-DOF) model, and validated infrared (IR) and millimeter wave (MMW) synthetic imagery into an integrated digital simulation. At this stage in the development of the submunition, the tactical flight software is not yet available, but all other components of the HFS are in place.

This paper addresses the simulation methodology used for the development of the dual mode IR/MMW HFS, the current uses for the HFS, and also future enhancements. The P3I BAT HFS is called “dual mode” since the seeker has dual sensors - a millimeter wave radar and an imaging infrared focal plane array. It also discusses the simulation development that encompasses the subsystems that are integrated into the HFS, how they are to be used, and how they interact with each other.

2 BACKGROUND

2.1 P3I BAT Submunition

The P3I BAT is the Pre-Planned Product Improvement for the Base BAT submunition. An exploded view of the P3I BAT showing the various components and their locations is shown in Figure 1 (Army Tactical Missile System-BAT Project Office 1998).

The BAT and P3I BAT systems, after being dispensed from a host vehicle such as the Army Tactical Missile System (ATACMS), perform as autonomously guided smart submunitions that are designed to search, detect, and defeat armored vehicles in many weather

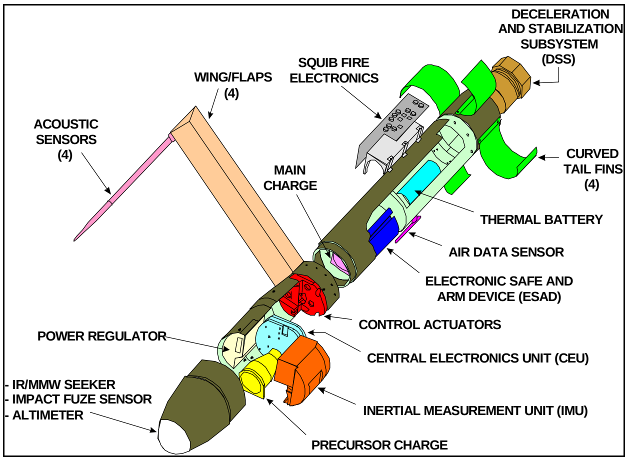

Figure 1: P3I BAT Exploded View

conditions. A total of 13 BAT or P3I BAT submunitions can be carried in one ATACMS Block II missile (Computer Sciences Corporation 1997). Six P3I BATs can be loaded into one ATACMS Block IIA missile, which has a longer range than the Block II.

The Base BAT submunition, whose primary mission is to attack moving armored target arrays, initially utilizes acoustics to determine a general location of the target, then employs a two color IR seeker for acquisition and terminal homing. The P3I BAT submunition has the same physical characteristics as the Base BAT configuration, but incorporates an improved seeker and warhead that allow it to engage soft targets. These features greatly expand the possible engagement environments and target set. The P3I BAT target set includes armored vehicles such as tanks or personnel carriers that are moving or stationary, hot or cold, Surface to Surface Missile Transporter Erector Launchers (SSM TELs), and Multiple Rocket Launchers (MRLs).

2.2 Use of Models and Simulations in Army Acquisition

The Army is expanding the use of modeling and simulation in the development of weapon systems. This is due primarily to the increase in costs of system acquisition, development, and flight testing. For example, the estimated average unit cost to procure one ATACMS with 13 BAT submunitions is $2.1 million, exclusive of the cost of flight testing (DOTE 1999). Several years ago, the Army began to establish policies that required program managers to develop a Simulation Support Plan (SSP) which documented how modeling and simulation were to be used throughout the acquisition life cycle of the program (SARD-DO 1996). A new initiative, Simulation Based Acquisition (SBA), is now being developed to efficiently manage modeling and simulation as a resource to achieve acquisition objectives by the program manager (Fallin 1997). This initiative is based on the SSP process, however, SBA emphasizes the use of modeling and simulation as a resource to be managed, not just as a "tool to be taken for granted" (Fallin 1997).

2.3 HFS

The P3I BAT High-fidelity Flight Simulation is a high fidelity non-realtime closed-loop simulation of the P3I BAT submunition that begins at dispense out of the carrier vehicle, and ends at submunition impact. The HFS is an engineering level simulation. These models are very detailed and primarily focus on individual components, their effects, and interactions (OASARDA 1998).

The HFS was originally proposed as a tool to support an independent assessment of the two competing seeker designs for the P3I BAT submunition (Kissell 1996). By integrating the seeker developer's detailed seeker models into the HFS environment, the performance of each seeker design could be analyzed, the effects of the seeker on overall system performance could be quantified, and it could be determined if the seeker design would meet the system specification requirements. This information obtained would be provided to the sponsoring Project Office so that they could determine which seeker design best met the requirements for performance, cost, and producibility. The HFS, in combination with the Hardware-In-the-Loop simulation, was proposed to support the competitive selection, otherwise known as a downselect competition, since the P3I BAT submunition system was not going to be flight ready in time for flight test data to be available before the downselect milestone was scheduled. As it actually turned out, however, the HWIL was not completed in time due to funding cutbacks, and the HFS was the only closed loop high fidelity simulation able to provide data for the downselect decision.

3 ISSUES

There were several areas of concern over the initial development of the HFS. These concerns included budget and personnel constraints, a short timeline, and a lack of flight data. At the time, an end-to-end, dispense to impact, simulation of the P3I BAT did not exist.

To address these areas of concern, several tradeoffs were made. In order to meet the budget and time constraints, the Base BAT simulation would be obtained to use as a starting point, although many submodels would require modification or replacement. The submodels would also require upgrading as validation efforts on Base BAT continued. Experienced personnel from other programs were moved onto this project to accomplish it on time. One last issue remained: how to present both an IR and a MMW scene to the seeker models in such a way that the submunition system would react as if it were in the field.

The critical test for the development of the P3I BAT High-fidelity Flight Simulation was to explore whether millimeter wave radar "imagery" could be incorporated into the simulation and utilized at the same time as the infrared imagery, with the same good results as those obtained using IR-only. Discussions were held with members of the LONGBOW (millimeter wave) missile system hardware-in-the-loop (HWIL) simulation team to obtain their expert opinions on the feasibility of the idea. They provided considerable information on the procedures and processes used to simulate MMW targets using the HWIL MMW radar arrays in realtime (Saylor 1996). After these discussions, it was determined that these realtime HWIL modeling processes could be adapted to be run in a non-realtime all digital simulation in combination with the IR imagery.

The solution proposed to the project office was to build a simulation that could provide an accurate performance assessment of the two seeker design concepts under competition. The idea was to build a simulation that would provide enough detail so that the selection of the best seeker design could be accomplished with some degree of confidence. In order to get a good overall performance estimate, the seeker design models, integrated with the submunition system, would be simulated in several weather conditions across several geographic locations in the world, against several types of targets. These performance scores would be used in combination with the cost and producibility scores to choose the best overall seeker design.

4 METHODOLOGY

The many constraints placed on obtaining independent performance assessment data to provide to the project office created the need to establish a new simulation development methodology for the formation of the HFS. The primary reasons this new methodology was developed were to:

- Reduce simulation development time,
- Reduce labor expenses, and
- Provide an accurate assessment of the system's performance.

It was also realized that as an important end result of following this methodology, risk to the program would be minimized by having a credible simulation that provided accurate performance assessment results.

To address the constraints, the simulation development methodology that was established to build the architecture for the P3I BAT HFS encompassed four primary areas:

- Reuse of the Base BAT subsystem models common to P3I BAT.
- Use of actual tactical flight software-in-the-loop.
- Maximize use of common subsystem models between the HFS, Hardware-in-the-Loop (HWIL) and the system effectiveness simulation, STRIKE.
- Maximize model fidelity while keeping runtime constraints in mind so that potential system deficiencies could be uncovered and remedied at the earliest stage in the program. This includes both high fidelity models and the use of validated infrared imagery and millimeter wave measurement data for targets and backgrounds.

The following sections discuss this new methodology in detail.

4.1 Definitions

Before explaining the methodology to develop a high fidelity simulation, let us define the term "fidelity" in this context. The fidelity of a model refers to the level of detail "resulting from a set of modeling assumptions about the system it represents" (Gossage, et al. 1996). Low fidelity models differ from high fidelity models in that "low fidelity models are characterized by simplifying assumptions which reduce their level of detail compared to high fidelity models" (Gossage, et al. 1996). However, what constitutes "high" and what constitutes "low" fidelity is completely dependent on the application that the simulation is being used for. In the case of the HFS, we wanted to know what factors significantly affected the location of the aimpoints and hitpoint of the submunition on the target. This application requires a very high level of detail in not only the submunition models, but also the scene/environment models.

4.2 Code Reuse

The decision to reuse the Base BAT models saved development time, verification and validation (V&V) time, analysis time, and therefore labor dollars. Models such as the aerodynamics had been previously verified and validated, so they were reused directly from the Base BAT simulation. Some models, such as the acoustics, could not be directly reused due to system upgrades but could be utilized as the starting point for the simulation upgrades.

Included in this area of the methodology architecture was the emphasis that the seeker simulation written by the seeker subcontractor should be used as delivered, and not be translated from C to Fortran or redeveloped from scratch simply as a means of gaining understanding of the seeker algorithm processes. Although the translation or redevelopment process would help with the understanding of the algorithm methodology and provide a means of independently verifying and validating the code implementation, the costs, time involved, added V&V procedures, and increased risk of adding errors to the code made the proposal a poor one from a cost/benefit standpoint. This translation or redevelopment process would have to be repeated with each delivery of an update to the seeker simulation, thus increasing the possibility of introducing errors to the simulation with each update. The hardware developer has the most experience with that particular system and knows their system the best, so they should be the one to develop the model of that system. One more advantage of reusing delivered code "as-is" is that you also eliminate any possible protest from the developer claiming that the simulation results obtained are not a true or fair representation of their system.

4.3 Tactical Flight Code

Tactical flight code is the embedded software that is used on the real submunition. Using the actual tactical code saves simulation development time, V&V time, debugging time, analysis time, and labor dollars. By using tactical code directly instead of developing a simulation of the code or translating the code from one computing language to another, V&V activities are reduced to insuring that the proper versions of the code are being used. A compiler option is selected to compile the tactical code for use in the non-realtime HFS. This approach to simulation development was started with the Javelin missile system simulation and has been an integral part of the Javelin program's success (Phillips 1996). Most programs do not take this approach because of the complexity involved in interfacing actual flight code to simulation code. To incorporate actual flight software, hardware interfaces must be understood as well as the effort required to interface sometimes very different programming languages such as Fortran, Ada, C, and C++. However, once the interface has been defined, it provides the software developer a simple inexpensive solution for designing and testing flight code that does not require burning EPROMs.

4.4 Common Submodels

Maximizing the use of common submodels between the HFS, Hardware-In-the-Loop, and STRIKE simulations simplifies V&V activities and reduces the potential risk of configuration management errors. It is important to ensure that these simulations are using the same version of the submodels. When a submodel is upgraded in one simulation, it must be upgraded in all simulations so that the results obtained can be directly compared. If not, the results cannot be directly compared across simulations.

The system effectiveness simulation, STRIKE, provides the many (submunition)-on-many (targets) performance capability. STRIKE, although capitalized, is not an acronym. The STRIKE simulation typically provides the kills-per-launcher-load data that is used to determine if the P3I BAT system meets the Operational Requirements Document specifications. One launcher load consists of two ATACMS missiles. Kills-per-launcher-load refers to the number of BATs that actually killed targets out of the total number of possible kills.

A depiction of the P3I BAT simulation submodel commonalities is shown in Figure 2 (Drake, et al. 1998). The ovals show which submodels are included within the HFS, HWIL, and STRIKE. It is easy to see that many of these submodels overlap between the various simulations. Only two submodels, the 6-DOF and the lethality models, are shared between all three simulations. The HFS and HWIL simulations provide false target density (FTD), Probability of Detection (Pdet), and Probability of Acquisition (Pacq), Probability of Hit (Phit), and Probability of Kill (Pk) data to the system effectiveness simulation, STRIKE. Dr. Herbert Fallin, Director, Assessment and Evaluation, Office of the Assistant Secretary of the Army (Research, Development, and Acquisition) wrote in a recent article that using output data from one model as input data for another model is more efficient and permits reductions in the program's cost and schedule (Fallin 1997).

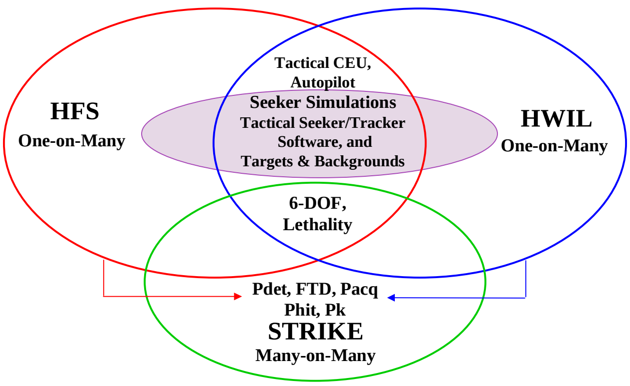

Figure 2: Common Submodels between Simulations

To ensure that the same submodels are being used across all simulations, a simulation configuration management plan must be in place that all developers adhere to. These plans discuss areas such as the process by which individual models will be tracked, software version descriptions, configuration identification documentation, dates of release, the software change process, and the responsible agency (Parker 1997).

4.5 Maximize Model Fidelity

The determination to incorporate as much fidelity into the simulation as possible without slowing down the runtime to unacceptable levels was proven to be critical during the

Javelin missile system performance assessment (Phillips 1996). The traditional point source target model was found to be inadequate for testing the tracker software. A point source target appears as a simple featureless hot spot to an infrared sensor. As such, the feature-based tracker software could not be exercised thoroughly using the point source. More detailed target and background models are necessary to test advanced tracking algorithms. The decision was made to use validated synthetic IR imagery and test the seeker/tracker simulation incorporated into the 6-DOF with that imagery. The results obtained running this new approach were much closer to the results obtained during the flight tests.

A simplified target model can have varying effects on the sensor and tracking algorithm processing of the seeker. The preferred outcome of using a model is to not bias the simulated output. However, simplistic model outputs have been seen to change the apparent effectiveness of the weapon system for better or worse. The key word here is apparent because the target model does not reduce or enhance the true effectiveness of the actual hardware weapon system; it just appears that way. This can lead to two types of error. If the target model gives a false decrease in the apparent effectiveness of the weapon system, then the worst outcome will be that additional funding and time are wasted to upgrade models that are already adequate. If the target model gives a false increase in the apparent effectiveness of the weapon system, then the outcome may be devastating in that soldiers may be killed when the weapon system that is supposed to protect them fails. The Systems Simulation and Development Directorate has found that using high fidelity targets helps to minimize the likelihood that the simulation will produce falsely enhanced results.

Another advantage to utilizing high fidelity models is that potential system deficiencies can be uncovered earlier in the development process if the high fidelity models are implemented early in system development. Some of the advantages of early error detection and elimination include increased ease in fixing the problem, it is cheaper to fix when found early and it is usually faster to fix at that time.

5 SIMULATION DEVELOPMENT

There are three basic types of processes used for modeling and simulation development. These are: using an existing simulation as is; modifying an existing simulation; or developing a new simulation (DMSO 1996). All three types were followed for the development of the HFS.

As stated previously, many of the component models utilized in the P3I BAT HFS originated with the Base BAT system. These legacy models include the actuators, aerodynamics, and mass properties of the submunitions. Since design changes were not made to these components, these models could be used directly without code modifications. Other legacy models, such as the acoustics, are being upgraded with new capabilities. The development of these models begins with the existing model, then incorporates the new capabilities. This process saves time by not having to start over from scratch. Brand new models for the P3I BAT submunition included the seeker, inter-process communications, and the IR/MMW scene/environment.

5.1 HFS Architecture

The High-fidelity Flight Simulation architecture is comprised of the following four subsystems: the master executive, the 6-DOF model, the seeker model, and the scene/environment model. These subsystems can also be further subdivided into component level models. Each subsystem process can be operated using two methods: in an integrated multi-process environment which can be used for system performance analysis, pre-flight predictions, and post-flight analysis; or in a standalone mode for subsystem design evaluation, algorithm development, and sensitivity studies.

The HFS is typically run in a Monte Carlo (stochastic) mode, and the results stored on disk. When the run set is completed, these results are then played back from the saved data. This playback tool allows the user to view animated frame data such as focal plane array images, MMW raster images and geometry data from previous HFS runs. In addition to being a data analysis tool, this playback option is very useful for demonstrations.

5.2 Master Executive

The master executive creates the inter-process communication (IPC) devices and initiates the subsystem processes. The master executive permits communication between parallel processes. These parallel processes use a "shared arena" that is mapped into each process' user space, which results in most of the IPC functions not having to call the operating system. The master executive initializes the shared arena, allocates space to shared memory, places the memory address into the shared arena, creates shared arena semaphores for inter-process synchronization, and creates children processes. While the HFS is running, the master executive monitors all subsystem processes and logs any errors. Once execution has completed, the master executive shuts down all subsystem and children processes, cleans/detaches from the shared arena, and removes all IPC devices (Drake 1997; Drake 1999b; and Nichols Research 1997).

5.3 6-DOF Model

The 6-DOF flight dynamics model was developed by the prime contractor with assistance from the project office's support contractor. The 6-DOF is used to simulate the P3I BAT mission from dispense to impact. The one submunition 6-DOF flight dynamics model currently integrated into the HFS was extracted from STRIKE, the many-on-many effectiveness simulation and was subsequently modified to include an Input/Output (I/O) driver and IPC routines. The additional I/O driver allows the user to print any variable that is equivalenced to the Common Array to the screen, a file, or binary plot file. The IPC routines allow the 6-DOF model to operate in a multi-process environment through a Fortran to C interface.

HFS 6-DOF visualization routines have been developed for analysis, software development, code debugging, and demonstration purposes. These graphics routines display the submunition trajectory, acoustic ground detections, weighted acoustic centroid position, and target position throughout the flight of the submunition including a 3-D submunition position plot, a 2-D footprint plot, and a 3-D submunition view. The submunition trajectory is shown in Figure 3.

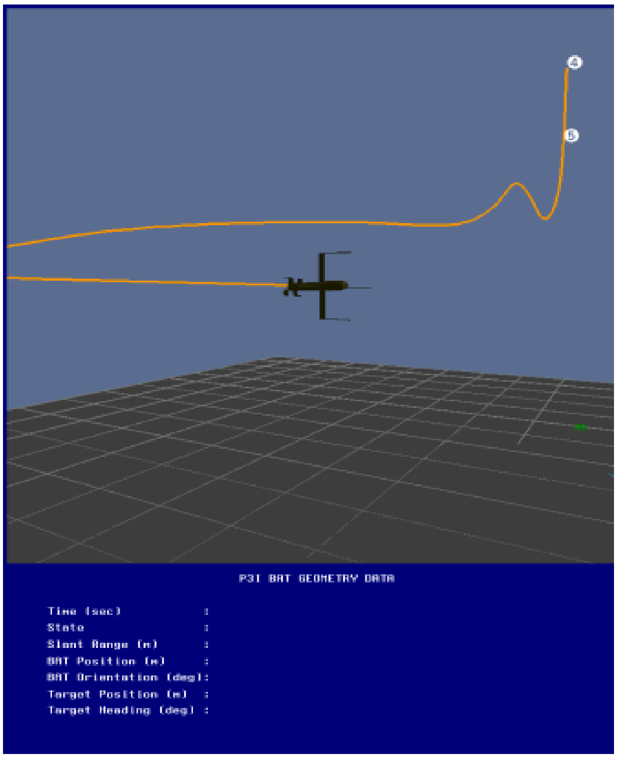

Figure 3: HFS 6-DOF Trajectory Visualization Display

There have been several recent additions to the visualization routines in the HFS scene generator. They now include a dynamic display of submunition data, the seeker infrared FPA image, and the output of the seeker algorithms at various stages. The user can also define variables to be displayed as strip charts. In addition, the playback option has been upgraded to allow the user to log this data to a file during runtime, and then display it later (Drake 1999a).

Great care has been taken to ensure that the visualization routines accurately portray the actual performance of the P3I BAT submunition. Many graphical representations of systems are only useful from a demonstration viewpoint. In other words, the viewer will see many nice pictures without the underlying physics accurately portrayed. That is not the case with the HFS. The HFS is a “what-you-see-is-what-you-get” (WYSIWYG) simulation. If the submunition cannot make a particular maneuver or track a particular target in clutter in the real world, every effort is made to ensure that you will also not see it in the HFS.

5.4 Seeker Simulation

The seeker simulation was developed by the seeker subcontractor and independently verified and validated by Systems Simulation and Development Directorate personnel. Both a high fidelity and a low fidelity model were developed. Two models are necessary since the high fidelity model requires a considerable amount of runtime to achieve the accuracy needed. This accuracy is not required for trend analyses or other types of ‘quick-look’ studies. Using high fidelity models when the added details do not produce more accurate answers is a waste of computing time and money. The HFS utilizes the high fidelity model exclusively since detail is critical to endgame performance analysis.

The P3I BAT seeker simulation is the high fidelity simulation that models the hardware (optics, electronics, etc.) and the software functions (seeker controller/processor, search, acquisition, aimpoint selection, and aimpoint track algorithms) of the dual mode IR/MMW P3I BAT seeker. Within the HFS seeker subsystem, IPC routines are added to allow the seeker to operate in the multi-process environment, read 6-DOF and scene/environment data from shared memory, and to be synchronized with the 6-DOF and scene/environment processes.

The dual mode seeker is not engaged until the submunition reaches a certain state of the flight. At this point, the HFS 6-DOF visualization graphics switch to the seeker simulation graphics. These graphics are shown through the end of the flight. The seeker simulation graphical displays include the 3-D input IR scene being fed to the seeker simulation, the focal plane array image output from the infrared sensor, the region-of-interest, the electro-optical detections and their corresponding threshold scores, the millimeter wave raster image, the MMW detections, a 2-D MMW range Doppler map showing pixel intensity, the seeker fused data vector, and the geometry data for the target and submunition.

5.5 Scene/Environment

The infrared scene/environment library provides all the routines necessary for the IR scene/environment process to generate high resolution infrared representations of a simulated battlefield. The IR scene/environment library incorporates the following features: textured background, gimbal auto-calculation option, flight trajectory file option, atmospheric extinction option, center temperature calculation, topographic database option, and many others. These features are very complex and time consuming to implement and as such are not commonly seen in simulations. The library is written in the OpenGL programming language, and is portable across multiple computer platforms. An example IR input scene is shown in Figure 4 (Motz 1998).

Figure 4: Example Input IR Scene

The scene/environment library contains many individual models. These models include infrared and millimeter wave models of tanks, personnel carriers and other targets, terrain topography databases, background class maps, and countermeasures. The library generates the scene with respect to the submunition seeker position and line-of-sight (LOS) angles generated by the 6-DOF model.

6 VERIFICATION AND VALIDATION

Verification and validation of the High-fidelity Flight Simulation is an ongoing process. A common process for conducting V&V has been developed. This approach is being used for the P3I BAT HFS V&V and is summarized in the following paragraphs.

The first step in the validation process is to select the input/output parameters for each model. Out of these parameters, the analyst must determine which are critical parameters. Critical parameters are parameters that can either influence the test method or lead to significant design changes in hardware or software if they are not accurately characterized (Computer Sciences Corporation 1997).

The next step is to determine error margins for which the critical parameter outputs will be acceptable when compared to empirical results obtained from test data. The analyst must then establish a scheme for grading the degree of verification or validation accomplished for each submodel output parameter and for the overall simulation results. The next step in the process is to duplicate the test scenarios using the simulation, and generate critical parameter output values to compare against the associated test data. The analyst will then quantify the degree of verification or validation achieved from each output critical parameter and for the overall system simulation by using the previously developed grading scheme (U.S. AMCOM 1998). The results from this process are then briefed and documented in accreditation notebooks.

During the validation of the HFS, experimental test data is received first. This test data is taken from flight tests, captive flight tests, and hardware laboratory tests. Next, a Monte Carlo set of 100 runs is performed. These sets are made with statistical draws on possible system errors such as noise, misalignments, and calibration errors. Measured data, such as mass properties, which includes weight, center of gravity and moments of inertia, are also entered into the Monte Carlo simulation. The measured data is held constant during the simulation runs. Initial conditions of the test, such as wind speed and direction, submunition tip-off rates, altitude at dispense, and speed, number, and type of targets are also entered and held constant. The Monte Carlo simulation set is then run, and the output from the Monte Carlo runs are plotted against the test data. The test data should fall within the +/- 1 sigma values 68.3% of the time, +/- 2 sigma values 95.5% of the time, and +/- 3 sigma values 99.7 % of the time for a Gaussian distribution for the Monte Carlo simulation output. If it does, the simulation is considered valid for that test. If it does not, the model (or models) is investigated to determine where the mismatch occurred, and then upgraded to account for the new data.

To date, validation efforts have been limited since no flight tests of the P3I BAT submunition have taken place. However, as stated earlier, many of the modules do not require extensive verification and validation since they are taken directly from the Base BAT simulation, which has been previously validated. P3I BAT system specific V&V has been performed on data taken from the captive flight tests that have been flown, in addition to laboratory bench tests. These tests were all performed in an open loop configuration. Due to the immaturity of the P3I BAT submunition at this time, no closed loop data has been collected. The primary area that has been examined is target detection in various clutter backgrounds using all modes of operation: infrared-only, millimeter wave-only, and IR/MMW dual mode. Probability of detection (Pdet) and false target density (FTD) values between the captive flight tests and HFS were compared and found to be within the acceptable error margin.

There are requirements for a formal accreditation process for the HFS. Accreditation will be performed in support of Live Fire Test & Evaluation in Fiscal Year (FY) 2002 and FY03, a Production Cut-In Decision in FY02, and a Continued Production Decision in FY05. Verification and Validation plans are currently being made to accomplish this activity.

7 CURRENT UTILIZATION

The High-fidelity Flight Simulation is currently being used in several studies. These studies include an aimpoint analysis to investigate the effects of the aimpoint on overall target vulnerability, and a warhead lethality study. To support these studies, Monte Carlo run sets of the HFS are performed using various target and background clutter configurations. These runs are usually spread out across several computers at the same time to minimize total run time. The terminal hitpoint data are then provided to the warhead lethality analysis group. Data that are provided typically consist of azimuth and elevation hitpoint locations on the target, and velocity at impact. Scatter plots of the aimpoint distribution superimposed on a target are very useful for statistical analysis in areas such as being able to quickly determine directional trends and biases.

The HFS is being used to perform pre-flight predictions and post-flight analysis for an upcoming captive flight test to be held later this year. The predictions are covering areas such as target detection, false target density, and target acquisition. Post-flight analysis will be performed using the collected imagery and comparisons will be made between the expected and actual values. This effort will directly contribute to the V&V of the HFS.

8 FUTURE ENHANCEMENTS

There are several ongoing and planned activities to enhance the capabilities of the High-fidelity Flight Simulation. These activities are primarily centered around the scene/environment, seeker, and tactical code areas. The purpose of these enhancements is to provide added detail to the simulation, with the goal of providing a more accurate estimate of performance of the actual system. Scene/Environment generation capabilities are continually upgraded as new models become available. These upgrades include the addition of discrete objects such as individual trees and buildings, and realistic target exhaust plume heating and obscuration effects. Battlefield effects such as burning targets will also be added as those models are developed. As the P3I BAT seeker design becomes more mature, those models associated with it will be upgraded to reflect the design changes. Along the same lines, modifications to the tactical code will also be incorporated as the embedded software development progresses further along the life cycle. These modifications are scheduled to occur in the central electronics unit (CEU) area, which includes the autopilot and tracking functions. The CEU is currently in the design phase of the program, so these modifications will not take place for at least another year.

Another effort planned for this year is to incorporate interoperability capabilities into the HFS by making it High Level Architecture (HLA) protocol compliant. This activity is currently waiting on additional funding to be provided from the sponsoring project office before it can be implemented, and is expected to be a short term task based on HLA experience with other Army weapon system programs. High Level Architecture compliance is necessary to accommodate the Army simulation standards for interoperability.

The simulation development methodology used to date is not considered to be the final version of the process. As simulation technology matures and computer hardware advances are made, more accurate means of predicting system performance will become feasible. For example, algorithm detail can be increased and the runtime remain the same by upgrading the computer system to a faster processor. As they are upgraded, many of the legacy Fortran-based models may be rewritten in object oriented programming languages such as C++. This allows for ease in upgrades to the model and provides increased modularity and flexibility of the individual submodels.

9 CONCLUSION

The development of the P3I BAT High-fidelity Flight Simulation is on track with the program management schedule. The methodology developed has been followed and no major problems have been observed. Verification and validation efforts are in step with the test data currently available. Preliminary analyses indicate that the HFS is providing an accurate assessment of the system at this stage in development. The use of this methodology is increasing the accuracy of the simulation and reducing development costs. Increased accuracy is being accomplished primarily by the use of high fidelity target and background synthetic imagery and high fidelity models. The use of tactical flight software when it is available will also provide increased accuracy of the simulation. Costs are being reduced by sharing models across simulations, using legacy models where appropriate, and eliminating unnecessary code rewriting and translation. Use of this methodology reduces risk to the program by ensuring the development of a credible simulation that produces accurate results. As the simulation development progresses, the HFS will become an even more powerful tool for performance assessment, system design, and algorithm development.

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