Integration of a Proprietary Missile Server for Assessment of Training Research Effectiveness

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ABSTRACT

The Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Readiness Research Division, Mesa, AZ (711 HPW/RHA), in cooperation with Raytheon Missile Systems, Tucson, AZ (Raytheon), developed and integrated a full-fidelity advanced medium-range air-to-air missile (AMRAAM) weapon server into a high-fidelity AFRL F-16 flight simulator. The project goals were to bring manufacturer-proprietary missile fly-out performance into the Air Force Distributed Mission Operations (DMO) environment, to assess simulation effectiveness, and to enhance operator training. Three separate AMRAAM models were evaluated and tested against operational performance metrics to assess capability and potential training impact: the current model employed by the Air Force F-16 Multi-Task Trainer cockpit, the model implemented within the Air Force eXpert Common Immersive Theater Environment (XCITE) synthetic battlespace, and the proprietary AMRAAM Raytheon Simulation (ARS). Multiple parameters were compared, such as maximum range, minimum range, time of flight, maneuvering performance, and target intercept. Testing constraints were overseen and validated by subject matter experts. The results showed that successful integration of a real-time original equipment manufacturer-proprietary missile model with Air Force DMO assets was feasible. Furthermore, fly-out testing results identified specific parameters and situational relationships crucial to improving warfighter instruction during brief and debrief. This performance comparison of currently employed weapons models with the Raytheon AMRAAM model, highlighted the training effectiveness available through the careful integration of manufacturer-proprietary modeling and simulation tools.

ABOUT THE AUTHORS

Lt Christopher McCracken is a Threat Systems Engineer at the 711 HPW/RHA. He is the government primary investigator and project lead for the Raytheon CRADA. Lt McCracken earned his Bachelor of Science degree in Aerospace Engineering from Embry-Riddle Aeronautical University in Prescott, AZ.

Mr. Paul Breeden is a Principle Engineer with 10 years of defense industry experience in Systems Engineering and Software development and is currently with Raytheon. Paul has supported many aspects of missile design and test over his career. His current assignments include development and integration of high-fidelity Raytheon and Government models into operational kill chain testbeds. Paul received his BSCS and MSCS from the South Dakota School of Mines & Technology.

Mr. Geoff Van Ess is a Senior Software Engineer with Lockheed Martin Global Training and Logistics. Since 2007, he's been developing solutions for simulation and threat system challenges at the Air Force Research Laboratory in Mesa, AZ. Previously, he spent four years with Lockheed Martin Space Systems Company developing simulation environments for a variety of missile and space programs. Mr. Van Ess received his Bachelor of Science degree in Computer Engineering at the University of Washington.

Mr. Bryan Walsh is a Principle Engineer with 13 years of defense industry development experience in Systems Engineering and Operations Research and is currently with Raytheon. Bryan's focus has been developing and applying detailed engineering simulations to conduct air to air missile performance analysis. His assignments have included extensive modeling, simulation, and analysis work for the AMRAAM, AIM9X, and JSOW. His current assignments include analysis and demonstration of advanced missile and system of system concept designs. Bryan received his BSME degree from the University of Arizona.

Mr. Craig Eidman is a Senior Electrical Engineer with the 711 HPW/RHA. He is the Technical Advisor for all laboratory synthetic environments, Electronic Warfare Training, and advanced M&S efforts. Mr. Eidman attended the United States Air Force Academy where he earned a Bachelor of Science in Electrical Engineering in 1983. He served in the Air Force as a Command Pilot flying fighter and attack aircraft in multiple theaters. Additionally, he has a Masters of Aeronautical Science from Embry-Riddle Aeronautical University with distinction and was an Outstanding Graduate of the United States Air Force Air War College.

Maj(ret.) Michael Kamrowski is a Senior Principle Systems Engineer with Raytheon Missile Systems in Tucson, Arizona. He has been involved with modeling and simulation activities throughout his career and his assignments as a USAF officer. Since 1995 Mike has focused on integration of modeling and simulation technology across the Raytheon business units including development of the Raytheon Mission Analysis Simulation Technologies & M&S Toolkits. Maj(ret.) Kamrowski received his BS degrees in Electrical Engineering and Computer Science at the University of Utah, an MS in Business Management at the University of Northern Colorado, and an MS in Computer Engineering at the Air Force Institute of Technology (AFIT).

Mr. Logan Williams is Research Electrical Engineer for immersive training environments at the 711 HPW/RHA. He has previously served as the lead systems engineer for the F-16, A-10, and KC-135 aircrew training systems, and has over a decade of experience in networked control systems, optical system design, and physics-based modeling & simulation. Mr. Williams has earned Bachelor of Science degrees in Electrical Engineering and Physics, as well as a Master of Science in Electrical Engineering from the University of Utah.

Mr. Kyle Tygret is a Senior Staff Systems Engineer with Lockheed Martin Global Training and Logistics supporting the 711 HPW/RHA. At 711 HPW/RHA, he has assisted in the design and development of Computer Generated Forces applications, XCITE and NGTS, a rangeless onboard aircraft Electronic Warfare (EW) trainer, Imbedded EW System (IEWS), JTAC TRS design, development, and delivery of two domed training systems, and live networked host applications for F-16, DCGS, BCS-F, and Radio Frequency(RFTE), as well as EW/EA sensor models. Mr. Tygret earned his Bachelor of Science degree in Electrical Engineering at Arizona State University. His work experience includes ten years at Lockheed Martin Skunk Works providing handling qualities simulation/systems integration laboratory for F-117, YF-35, and other aircraft and avionics simulations for the YF-22. Additionally, he spent two years at Lockheed Martin Information Systems supporting MC-130P Weapon System Trainer (WST) avionics and EW system upgrades, and MH-53J and MH-60G WST host and visual systems upgrades. Mr. Tygret has twelve years supporting AFRL at Mesa, AZ.

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BACKGROUND

This paper is written to describe the process and ongoing testing, for a Cooperative Research and Development Agreement (CRADA) activity between the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Readiness Research Division, Mesa, AZ (711 HPW/RHA) and Raytheon Missile Systems, Tucson, AZ (Raytheon). 711 HPW/RHA and Raytheon are engaged in a collaborative effort to assess three separate Advanced Medium-Range Air to Air Missile (AMRAAM) models, both government-owned as well as proprietary, to evaluate the representative differences of Original Equipment Manufacturer (OEM) engagement performance parameters to those of government models utilized within training applications. These comparisons identify potential areas for degraded training effectiveness, as well as situational relationships crucial to improving warfighter instruction during brief and debrief (Gehr, Schreiber, & Bennett, 2004). A key assumption for this effort is that the OEM model is the most representative model of a real-world AMRAAM available, thus it is reasonable to conclude that alternate models derived from other sources will likely be less representative than the OEM and may result in degraded training.

The 711 HPW/RHA's overarching mission is to research, demonstrate, and transition leading-edge human performance methods and technologies that provide the warfighter the necessary knowledge and skills to dominate the decision environment (711 HPW/RHA, 2009). 711 HPW/RHA contributed software engineering expertise, combat platform simulators, weapon simulations, testing facilities, subject matter experts, and performance assessment tools for this research activity.

The Raytheon Missile Systems development facility located in Tucson, AZ has extensive investment in high-fidelity missile simulations and distributed model technologies to support internal development and contract activities. System of Systems modeling is emphasized by all product lines to ensure that delivered products not only meet all required specifications, but effectively achieve their intended mission objectives. Raytheon Missile Systems contributed software engineering expertise, weapon simulations, proprietary product development, and subject matter experts for this research activity.

OVERALL RESEARCH OBJECTIVES

The long-term goal of this effort is to investigate and develop modeling and simulation (M&S) tools and technologies to create high-fidelity, physics-based, synthetic combat environments for improvement of training within DoD Live, Virtual, Constructive (LVC) and Distributed Mission Operations (DMO) architectures. This partnership provided Raytheon with access to knowledgeable 711 HPW/RHA personnel who are currently engaged in mission-related LVC and

DMO research, highly specialized research and testing facilities, and data from high-fidelity, physics-based models. 711 HPW/RHA benefited by gaining access to expertise and products including ARS and other high-fidelity models for integration into operational training environments. With a functional proof-of-concept, additional threat models can be more readily incorporated into Air Force networked training devices to improve warfighter proficiency and assure high accuracy in weapon performance.

This specific project researched the AIM-120 in simulation, due to potential inconsistencies among weapon representations within the Air Force inventory. Individual battlespace and weapon system simulations bring built-in missile models with differing fidelity, guidance schemes, and agility due to varied source information and build dates (Bennett, Gehr, & Schreiber, 2006). Warfighters utilizing differing representations in separate simulations over time, may inadvertently experience negative training effects. This project specifically investigated the severity in the differences of two stand-alone government simulations incorporating different AIM-120 models: the eXpert Common Immersive Theatre Environment (XCITE) synthetic battlespace and the F-16 Multi-Task Trainer (MTT) manned simulator. Performance comparison aimed to reveal whether or not the stand-alone simulations behave similarly to one other, as well as how they differ from the Raytheon ARS proprietary missile model. Aggregation of data over time supported evaluation of training effectiveness and assessment of potential technology insertion candidates. Additionally, the effort identified potential gains for the greater DoD simulation community, regarding utilization of proprietary weapon representations within training.

INDIVIDUAL WEAPON SIMULATIONS

F-16 Testbed AMRAAM

The F-16 MTT is an extremely high-fidelity, manned simulation testbed running converted aircraft Operational Flight Program (OFP) code. The weapon load-out and flight performance models a Block-30, US F-16 air superiority fighter. The MTT is rapidly reconfigurable and used in aircrew proficiency training, as well as mission rehearsal. Similarly configured testbeds are in use across the Air Force. The included AMRAAM model is pre-loaded into the system software and reflects sensitive missile performance specifications from numerous sources. Expected advantages with this missile model are the built-in nature of the weapon representation and a lack of incurred network transmission latency at weapon release. Anticipated disadvantages for this system include potentially outdated source information, complexity in weapon model code updates, and the lack of an internal radar capability for each created missile entity. The simulator operates on Distributed Interactive Simulation (DIS) networking protocols and is capable of real-time distributed simulation. Figure 1 shows the MTT interface to the test DIS Network.

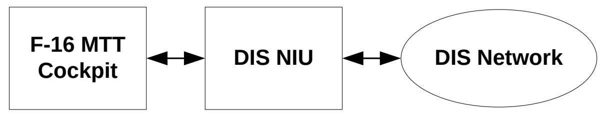

Figure 1. F-16 MTT Cockpit Network Interface

XCITE Environment AMRAAM

The XCITE synthetic battlespace is a physics-based tool developed at AFRL to assist human performance research by supporting manned training testbeds, scenario generation, distributed combat events, command and control simulation, mission rehearsal, autonomous computer generated forces, and electronic warfare training. This software is utilized by user communities throughout the Air Force. The included AMRAAM model comes pre-loaded within the program software and reflects sensitive missile performance specifications from numerous original sources. Expected advantages are the capability to rapidly update weapon characteristics, a lack of incurred network transmission latency at weapon release, and a fly-out supported by energy-based aerodynamic calculations. Anticipated disadvantages include potentially incomplete source information and the lack of an internal radar capability for each generated missile entity. The program operates primarily on DIS networking protocols and is capable of real-time distributed simulation. Figure 2 shows the XCITE interface to the test DIS Network.

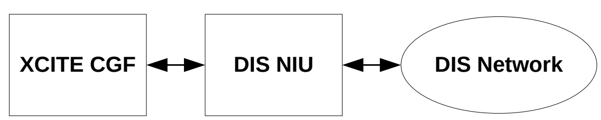

Figure 2. XCITE Network Interface

Real-Time Missile Arsenal: ARS

Raytheon developed the Digital Mission Analysis Model (DMAM) architecture, which includes concurrent detailed LVC-based models integrated using industry standard interfaces. DMAM models are designed to be easily integrated with new simulation experiments, without modification to the underlying component simulations. The primary ARS missile model for evaluation is extracted from the DMAM without change, along with compatible middleware elements for a DIS exercise. In order to incorporate this existing real-time Test and Training Enabling Architecture (TENA) infrastructure, instead of recreating a novel solution under DIS protocols, a DIS/TENA translation program is required between ARS and the test DIS Network supporting both 711 HPW/RHA simulations. In this way, significant network source code changes are avoided for all tested simulations.

The extracted ARS missile model is embedded as part of a TENA logical range. The functional configuration used for the 711 HPW/RHA experiment is composed of a System Factory application, instantiating multiple ARS missile applications as required, a Platform Proxy, the TENA distribution engine, and the S-Gate translation module (standard DIS Protocol Data Unit [PDU] and TENA Logical Range Object Model [LROM] message format). The Platform Proxy converts between DIS free-form PDU umbilical and uplink data and the LROM TENA methods. The CRADA design evolution aims to extend existing functionality shown in Figure 3, to be easily integrated into other testbeds.

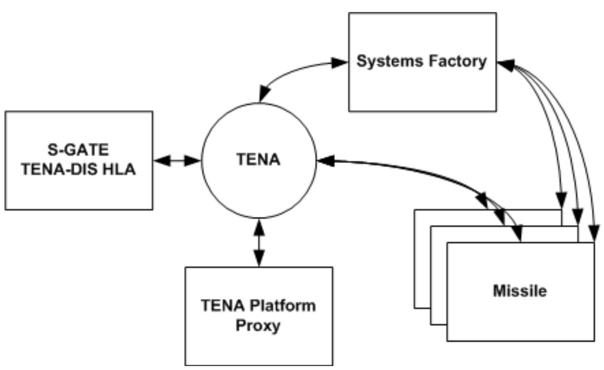

Figure 3. Extracted ARS Functional Configuration

Figure 4 depicts the overall experiment configuration after integration of all systems. The DIS/TENA gateway acts to transfer initialization, environmental, umbilical, and target position update data between the associated missiles. The Subsystem Factory supports a message to instantiate a missile into the federation. Once instantiated, all missiles run through fly-out to intercept or miss against provided XCITE targets.

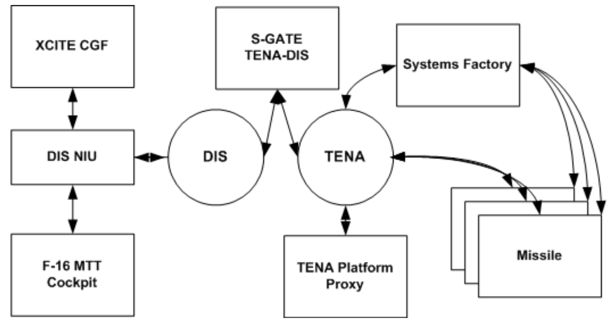

Figure 4. Experimental Configuration

Figure 5 shows the order of internal operations expected to launch an ARS missile. In this example, the initialize and launch messages are separate to give the missile application time to initialize and receive state information, before handling launch execution. The two operations may be combined; however, there is no guarantee the missile will execute fly-out within a normal tactical timeline. Although not explicitly shown in the figure, aircraft bus data provided to the missile at fire is also included in the launch message. Entity state data for the launcher and targets are expected to be available throughout launch and fly-out. Execution begins with the sending of a Fire PDU. Each missile sends its entity state data from launch until detonate.

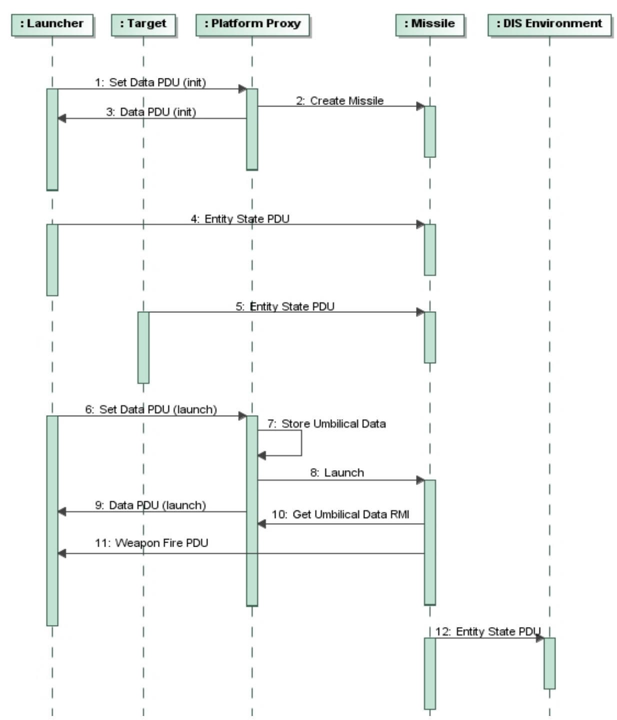

Figure 5. ARS Missile Launch Sequence

Figure 6 shows the order of operations expected to support an ARS missile for the duration of fly-out.

Update data is packed within a Radio Signal PDU. All non-tactical information returned from the missile during fly-out, is sent inside a Comment PDU.

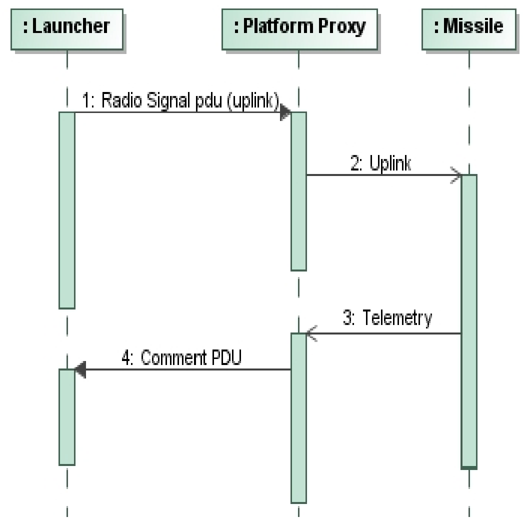

Figure 6. ARS Missile Support Sequence

Figure 7 shows the order of operations expected during an ARS missile detonation. Termination statistics are returned from the missile using a Comment PDU. The missile execution is concluded with the sending of the Detonate PDU.

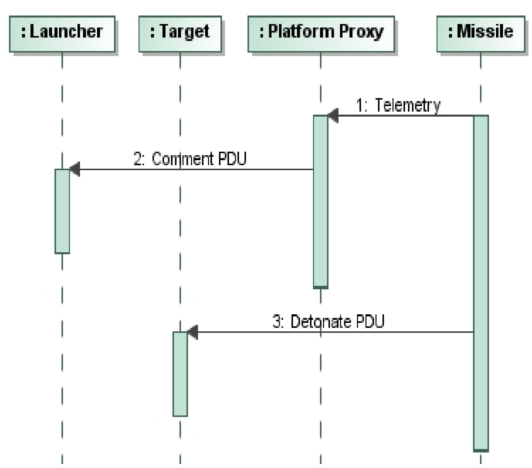

Figure 7. ARS Missile Detonate Sequence

Expected advantages available with this model are the OEM weapon flight characteristics based on real-world test performance, 6-DOF missile fidelity, and internal radar representations for each generated missile entity. Anticipated disadvantages include interface complexity in bridging TENA and DIS message protocols and incurred network transmission latency at weapon release due to gateway processing.

SPECIFIC WORK COMPLETED

Test Preparation

The first phase of this research was to attempt full integration of the Raytheon ARS 6-DOF missile model simulation into the MTT full-fidelity testbed. This accomplishment would establish the proof-of-concept for the notional ARS missile server architecture to provide real-time weapon support to a DMO capable manned simulator. The F-16 MTT internal missile model could be enabled or disabled by setting an initiation file flag, prior to system start up, alternately allowing the query and fly-out of the Raytheon ARS instead of the native model. For the experimental concept to be feasible, the MTT cockpit running on DIS protocols would need to query a missile shot from the Raytheon ARS missile server running on TENA protocols. Such a successful engagement would enable further testing and model comparisons in varied operational flight regimes.

In order to span the gap of protocol translation, a commercial DIS/TENA translation program was ultimately purchased and implemented. Initially, 711 HPW/RHA personnel endeavored to create an in-house gateway tool to link the two protocols; however, resource constraints precluded this solution. The commercial gateway software was loaded onto a stand-alone computer on the network between the MTT and ARS to enable runtime translation of incoming messages between protocols. This software relayed test interactions and allowed all participating simulations to run without significant change to underlying network source code, preserving the real-time functionality of the individual simulations. To verify that the gateway solution would not impose unacceptable temporal penalties between message interactions, known sensitive reaction times for F-16 aircraft systems were compared to the values of observed interactions across the DIS/TENA gateway. By using commercial packet analysis software and noting the network time stamps on Set Data PDUs at weapon release, versus the resultant Fire PDUs at missile generation, the average processing delay times across the gateway were quantified. The resulting incurred simulation latency, when compared to the real-world system interaction time delays at the sensitive level, was found to be unappreciable to the weapon system operator.

In addition to the modification of the initiation file flag to disable the native missile model, the MTT required a slight weapon fire code change to transmit an addressed Set Data PDU emission each time the weapon release button on the stick was pressed. This PDU would be ingested, converted, and retransmitted dynamically at the gateway into its corresponding TENA Set Data message and sent to the waiting ARS missile server stand-alone computer. Within the ARS missile server, this operation would execute the generation and firing of a missile entity when the correctly addressed Set Data message was received. The completed sequence would then create the proprietary Raytheon AMRAAM entity on the test DIS Network, to be fired at the intended virtual target outputting Entity State PDU information.

For testing purposes, the Set Data PDU was chosen in order to facilitate data capture. If a Fire PDU were sent at MTT weapon release instead of a Set Data PDU, the data capture software would receive the message and begin recording the missile engagement ahead of ARS entity creation. This would incorrectly record the Raytheon time of flight, causing data capture confusion and inconsistent test results between models. Thus, the Set Data PDU was used to relay creation and fire messages from the stick to ARS, reserving the resultant Fire PDU at missile instantiation to be the only point at which a missile entity was created and time stamped. As a result, the F-16 MTT testbed was successfully enabled with the 6-DOF, proprietary, representative model from the manufacturer, via hand-off to the ARS missile server for fly-out operation after weapon release.

The XCITE synthetic battlespace was enabled to query missile server shots as well, in a similar fashion to the MTT testbed. This allowed for more rapid testing of scenario script configurations; instead requiring a man in the cockpit to prepare test situations. CGF aircraft within the synthetic battlespace were enabled to cue shots from the ARS weapon server, in addition to firing their native XCITE missile models. To create this arrangement, weapon code changes were written within XCITE to send an appropriately addressed Set Data PDU, when keyboard hotkeys were pressed on the host system. The ‘i’ key initiated the cloning routine after program startup, by setting the destination address for XCITE Set Data PDUs to that of the listening ARS server. The ‘c’ key sent a create Set Data PDU to the ARS server. The ‘f’ key sent a fire Set Data PDU to the ARS server.

Once the fire was initiated, the ARS server software guided the missile from the firing CGFs local position toward the relative target, under the proprietary performance of the ARS. Thus, the virtual threat environment was also enabled with the 6-DOF, representative model from the weapon system manufacturer. This accomplishment was another proof-of-concept, in that it identified the possibility of enabling CGFs within a synthetic battlespace with the same 6-DOF weapon performance via missile server as the F-16 MTT cockpit. The ARS-enabled CGFs were used to set up and test scenario initial states, as well as compare inherent missile performance against that of the proprietary ARS. All test entities were assessed at the same iterative data points and their missile kinetic flight parameters measured. Results provided a picture of the weapon effectiveness in comparison to that of the ARS for varied operational flight regimes.

Data Capture Tool

In order to capture the individual performance parameters of acceleration, velocity, position, altitude, attitude, and time of flight throughout testing the Performance Evaluation Tracking System (PETS^{SM}), a tool created at 711 HPW/RHA for real-time warfighter performance assessment, was chosen (Keck, Portrey, & Schreiber, 2006). The tool ingests more than 20 individual parameters from each tracked missile shot, capturing detailed position and kinetic characteristics throughout all flight regimes. The software package was installed on a third stand-alone computer on the test DIS Network, in order to devote full CPU time to consuming parametric traffic at a capture update rate of 200 milliseconds. Recorded shot data was categorized by initial test conditions and reconstituted in Microsoft Excel to visualize changes over time for each specific weapon model, as well as compare characteristics between models. The situational variables of launch aircraft acceleration, velocity, position, altitude, and attitude were kept as consistent as possible by scripting all scenario initial conditions within the XCITE synthetic battlespace. These scripts were rerun for each test configuration to minimize variability at launch. Best-fit interpolations were taken over each weapon type’s captured shot characteristics, to baseline statistical error and establish standard deviations.

Test Execution

Once all systems were networked to transmit and receive through the commercial gateway software, explicit proof-of-concept testing was initiated. This testing resulted in stimulation of the Raytheon missile server, from the DIS F-16 cockpit testbed, through the gateway as hypothesized. The XCITE synthetic battlespace provided target entities for all testing events. All XCITE virtual targets were of the same aircraft type and aspect-dependent cross-section for all test engagements. Thus, the first phase of research, attempting to fully integrate the Raytheon ARS 6-DOF missile model simulation into the F-16 MTT full-fidelity testbed, was a success.

With a successful proof-of concept demonstrated, the second phase of testing began. This required detailed operational shot comparisons of the government AMRAAM simulations used in training applications to characterize the respective fly-out performance of each, against that of the proprietary Raytheon simulation. These results would determine the scope of further effectiveness assessments required. The significance of this effort would quantify how well the native MTT and constructive XCITE AIM-120s currently used in various Air Force training capacities, compared to the fly-out performance of the Raytheon ARS representation based on real-world test data. Analyzing operational engagement metrics, measures of effectiveness within training could be determined as to whether or not these current Air Force models potentially introduce negative training effects to operators through repeated use of differing AMRAAM fly-out data.

The first model to be assessed was the ARS launched from the manned F-16 MTT platform in multiple operational test engagements. By setting the software flag within the initiation file to enabled, the F-16 cockpit was set to launch the ARS, instead of its internal AMRAAM representation at weapon release.

While the commercial gateway worked generally well for most required uses under this effort, for data capture it was inadequate in one area. When translating TENA Weapon Release, as well as Weapon Fire messages generated from the ARS missile server, the gateway would produce a single resultant DIS Fire PDU; however, it could not process the TENA Weapon Release message data. The unpassed information from the Weapon Release resulted in a 0.0.0 triplet in the Munition Type field when translated into DIS. The PETS recording tool required this information properly identified, in order to capture weapon initiation data during execution. Therefore, the DIS Fire PDU received by the PETS tool on the DIS Network, did not initiate the recording of a missile shot engagement. The Detonate PDU for that engagement, however, was properly populating the Munition Type field for the weapon at the termination of the shot. So to remedy the 0.0.0 triplet problem, all testing was recorded with a local 711 HPW/RHA DIS logging and playback tool; both for test capture, as well as the ability to replay in real-time. For ARS tests, the Munition Type field remained unpopulated after initial shot execution. Once the initial recording was complete, the associated triplet that was successfully generating from the associated Detonate PDU was copied from the DIS logging tool text file. With the Munition Type triplet extracted from the Detonate PDU potion of the log text file, it was then inserted into the Fire PDU of the log where the incorrect 0.0.0 was captured. This process was repeated within each log file of each recorded ARS engagement. Finally, each log file was rerun in real-time through the playback portion of the tool, with the correct Munition Type triplet back into the file through post-processing. This process initiated successful PETS data capture without incident and did not affect the underlying fly-out, only modifying the recording procedure of PETS.

The AIM-120 model inherent to the XCITE synthetic battlespace was the next version tested to compare kinetic performance results with all other AMRAAM types. All scripts that had been set up in previous engagements were rerun with XCITE F-16 entities firing their internal weapons, in all regimes. The results of this testing were collected by PETS, without the extensive post-processing required for the ARS as previously described, and compared against those of other tested platforms.

Finally, the native AIM-120 incorporated into the F-16 cockpit testbed was tested for parameterization in operational engagements. By resetting the software flag within the initiation file to disabled, the pre-loaded F-16 MTT weapon model would again be fired at release. The results of this testing were collected by PETS and compared against those of other tested platforms.

In order to ensure the validity of the experiment to training and operational communities, all test engagements were selected and overseen by subject matter experts. These individuals were all former aviators in the F-15 or F-16 aircraft, with real-world experience in the utilization of the AIM-120. Missile and testing specifics for this effort involved sensitive information and tactics and the actual numerical parametric results would reveal sensitive performance capabilities; thus they are not included in the findings of this document.

CONCLUSIONS

A proprietary missile server is feasible for use within current Air Force DMO systems. This effort provided a proof-of-concept for real-time interaction between Air Force LVC-capable simulations and a manufacturer created weapon system model. Both the F-16 MTT manned simulator, as well as the XCITE synthetic battlespace tool, can effectively query and interact with the AMRAAM Raytheon Simulation. This is a first-ever achievement in linking the Raytheon proprietary ARS representation directly into multiple Air Force networked research training simulations. This success creates a methodology for further weapon model integrations, potentially expanding working relationships between government researchers and defense contractors in pursuit of other manufacturer proprietary training effectiveness assessments.

Differences were noted in fly-out characteristics between all three tested simulations, showing varied effectiveness does exist within the separate missile representations, and may contribute to negative training effects over time for weapon system operators.

Commercial off-the-shelf gateway software is capable of basic message relay to enable disparate protocol message translation. The majority of DIS/TENA messages can be captured, converted, and retransmitted without appreciable latencies in small scale testing.

Radar models and target position updates were a compound issue of comparison for the separate simulations. The only simulation currently equipped to appropriately model missile radar function and incremental position updates, respectively, was the ARS. So while test data was captured on the native XCITE and MTT missiles, fully representative real-world performance was not observed. This is a shortcoming for both Air Force simulations, leaving questions as to how comparable navigation parameters were between those particular simulations in flight.

The dynamic launch zone indication within the MTT cockpit seemed to be too short to participating subject matter experts for the types of engagements observed, indicating a potential issue within the software. Testing was uninhibited, however, as shots were taken at set distances, regardless of favorable or unfavorable cockpit indications. The initial engagement conditions were the source of comparisons, not explicitly the human systems interface to the user. However, these visuals within the MTT caused annoyance to pilots flying out the tests.

THE WAY AHEAD

Further detailed testing in maximum range, minimum range, time of flight, maneuvering performance, and target intercept are required to completely assess the potential training benefits available through utilization of a proprietary weapon server within a DoD training environment. Baseline testing for each of these areas has been accomplished; however, large scale testing must still be completed to supply a suitable data pool from which to make conclusive training effectiveness comparison and determinations. Then both government missile representations will be updated to reflect discovered discrepancies in flight characteristics.

As testing continues over the long term, it is recommended to have the current commercial gateway translation broker fixed or replaced to translate all desired messages and avoid the significant post-processing burden of manually repopulating the Munition Type field, as well as attempt to further improve mitigation of incurred latencies in message translation (Aldinger, Leppard, & Marsden, 2009).

Future Air Force AMRAAM models should incorporate more robust internal missile radars, target position update structures, and navigation error calculations for realistic weapon flight performance. Follow-on representations must include detailed logic for both the mid-course phase of flight and the terminal phase, incorporating an active radar seeker (Raytheon, 2008). To streamline future testing, it is also recommended that the cockpit display portion of the underlying F-16 MTT code be evaluated to assess the need for recalibration.

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