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12TH INTERSERVICE/INDUSTRY TRAINING SYSTEMS CONFERENCE 1990: SIMNET FIGHTER AIRCRAFT APPLICATION

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This report describes the preliminary investigation defining problems of expanding real-time simulation of fighter aircraft to a distributed simulation network. The 12th Interservice/Industry Training Systems Conference (I/ITSC) was selected as the test site to prove the concept. I/ITSC provided an arena for linking simulators from several manufacturers and laboratories. Six fighter aircraft simulators participated in the network along with a simulated ground control intercept station and semiautomated forces providing threat aircraft.

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PREFACE

This research supports the current Research and Technology Plan whose general objective is to increase combat readiness by developing and demonstrating more cost-effective ways of acquiring and maintaining new skills. The work was conducted under Work Unit 2743-25-19, Multiship Research and Development (MULTIRAD) Network, whose principal investigator is Dr. Herb Bell.

12TH INTERSERVICE/INDUSTRY TRAINING SYSTEMS CONFERENCE 1990: SIMNET FIGHTER AIRCRAFT APPLICATION

INTRODUCTION

Networking Background

The Defense Advanced Research Projects Agency (DARPA) initiated development of technology for a credible force-on-force simulation for the Army. This program has yielded significant breakthroughs in realtime large force, ground battle simulation. This technology has now transitioned from research and development programs to being incorporated into the Army's training programs.

These large force simulations offer numerous advantages over field exercises. Lack of adequate exercise locations for every Army unit often meant lengthy periods between large force exercises. Other factors included in the cost of actual field exercises; transportation, vehicle maintenance, fuel, and ammunition limit the ability to practice in large force, live fire exercises with decreasing defense budgets. To overcome these difficulties and reduce costs, simulation exercises were believed to be able to complement unit training. However, the ability to network large numbers required for realistic training needed to be developed. Simulation networking (SIMNET) has been developed under DARPA's guidance. Numerous types of ground vehicles and aircraft (generally helicopters) have been simulated and networked together. Now hundreds of devices at several Army installations can conduct networked war games.

The Air Force Human Resources Laboratory, Aircrew Training Research Division, now reorganized as the Armstrong Laboratory, Human Resources Directorate, Aircrew Training Research Division (AL/HRA) has taken the initiative to apply SIMNET concepts to fighter aircraft training. AL/HRA has pursued the ability to network aircraft simulations to provide team training for aircrews and their controllers. Our approach thus far has been to maintain SIMNET compatibility. Maintaining SIMNET compatibility is achieved by keeping all the existing information within the version of SIMNET the Army is using and adding extra information required to operate aircraft avionics. Ensuring compatibility with existing SIMNET will lead to the ability to conduct large scale joint simulation exercises. The AL/HRA effort will develop the technology to connect aircraft simulations into the Army's SIMNET.

Network Participants

For the 12th Interservice/Industry Training Systems Conference (I/ITSC), 5-8 November 1990, Orlando, Florida, up to six fighter aircraft simulators and a ground control intercept (GCI) station were networked using a modified SIMNET protocol. Simulators participating in the demonstration were developed by three different manufacturers and AL/HRA's and AL/HRG's

(Logistics Research Division) on-site contractors. Other network fighter aircraft participating in the 12th I/ITSC SIMNET application included; 2 AL/HRA F-16 Combat Engagement Trainers (CET) one in the Air Force Human Resources Laboratory booth the other at Williams AFB, AZ, an F-16C Air Intercept Trainer (AIT) at Williams AFB and an AL/HRA F-15 Modular Aircrew Simulator System (MASS), developed by McDonnell Douglas Training Systems, located in the Paragon booth, a General Dynamics A-16 simulation in their booth, and an F-16 part task trainer (PTT) connected from Fort Rucker, Alabama. All network participants are shown in Figure 1. Other applicable network participants included the semi-automated forces (SAF) from the Bolt, Beranek and Newman (BBN) booth generating threat aircraft and ground forces and a GCI simulator in the Air Force Human Resources Laboratory booth. The GCI simulation was developed and manned by AL/HRG, Wright-Patterson AFB, OH.

AITs were originally designed for the Air Force National Guard and Reserve to serve as a hands-on, throttle-and-stick (HOTAS) trainer for F-16s. AIT usage has expanded to include all F-16 replacement training units for the initial acquisition of radar/weapons HOTAS skills. AITs consist of basically a three cubic foot box, containing the VME chassis, side mounting plates for the throttle and stick and an opening for a chair as the seat. Radar information is presented on a radar multifunction display (MFD) built into the chassis front and the out-the-window and heads-up-display (HUD) is provided by a 19" Silicon Graphics monitor, placed on top of the chassis, driven by a Silicon Graphics 4D/70GT Personal IRIS operating at 60 Hz non-interlaced.

CETs are also part-task trainers for F-16Cs. CETs were developed at AL/HRA to research the feasibility of a glass-cockpit providing the fidelity required to train radar and tactical employment skills as a follow-on to the AIT. A CET consists of; a cockpit shell with side-stick, throttle, seat, 25" head-down touch screen display for cockpit instrumentation-radar MFD, radar warning, stores management, and flight instruments all driven by a VME-based simulation, and a single 19" Silicon Graphics IRIS display for a limited out-the-window and HUD generated by a Silicon Graphics 4D/70GT Personal IRIS. The head-down display has been covered by a molded plastic overlay to show only the instruments. Touch screen response is achieved through tactile feel buttons built into the overlay. In the SIMNET configuration the network interface unit (NIU) is added directly into the VME bus.

Audio capability for the CETs is available using the UHF radio system, transmitting via the push-to-talk switch on the throttle assembly. Audio output is directed from the CET to the SIMVAD portion of the NIU where it's digitized and passed via SIMNET voice protocol onto the Ethernet network. Audio reception from other network participants is received and processed based on the radio packet information. The NIU acts as the filter for receiving voice traffic from the network. If the NIU is set to the same exercise number and radio frequency, accomplished during initialization, the NIU will process and pass the digitized packets to the SIMVAD subsystem for conversion into an audio signal. The signals are then passed to the CET audio system and on to the pilot's headset.

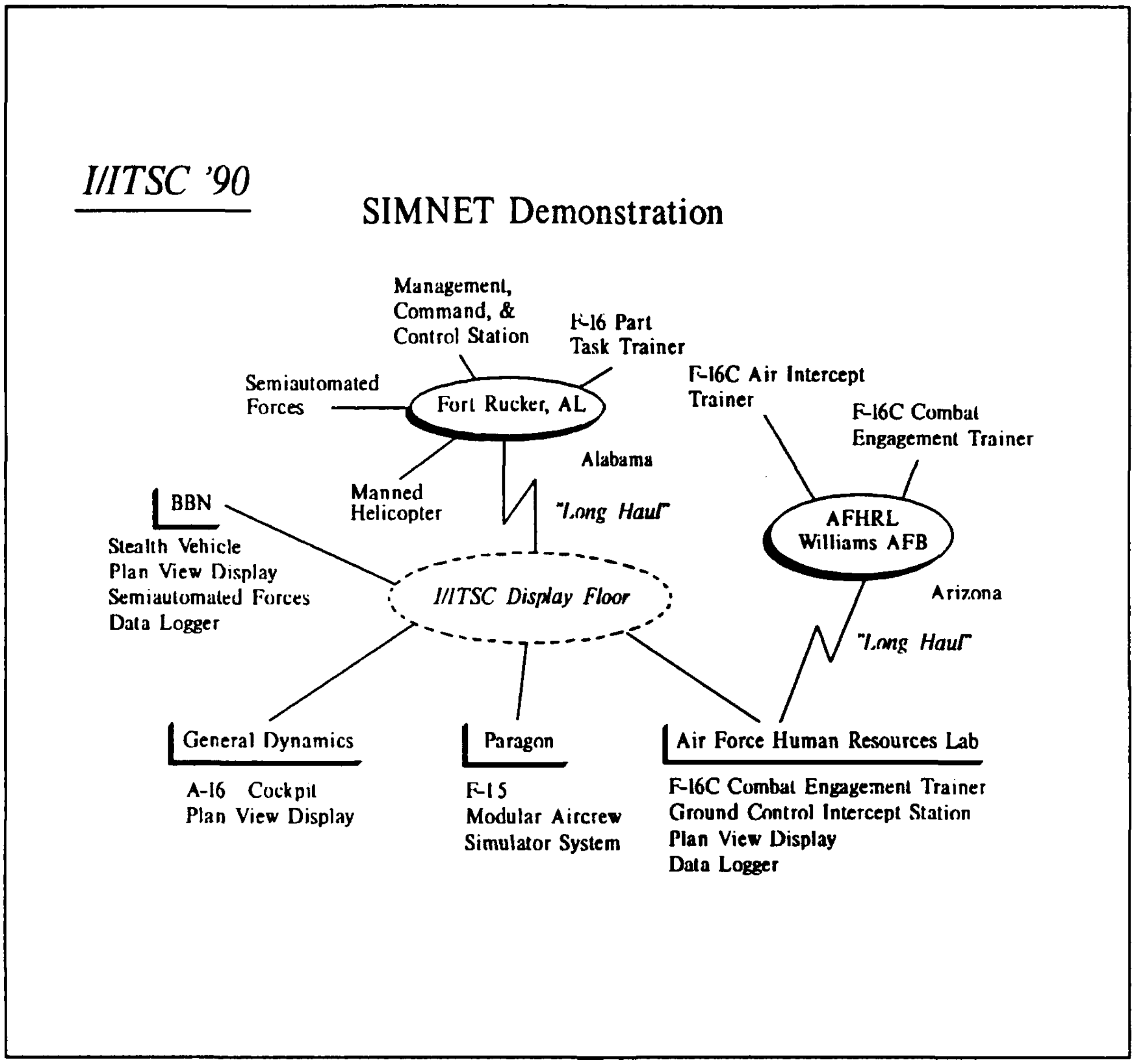

Figure 1 Network Configuration-12th IITSC, 5-8 November 1990

Audio capability for the AL/HRA AIT and F-15 MASS simulation, F-16 PTT at Fort Rucker, and AL/HRG's GCI simulator consisted of interface units with push-to-talk switches connected directly to the NIU's SIMVAD subsystem. The General Dynamics A-16 audio system was interfaced to the simulation similarly to the CETs.

The F-15 MASS was integrated to the NIU as a cooperative effort of BBN and McDonnell Douglas Training Systems personnel. Initial integration of the F-15 MASS simulation to an NIU was accomplished at AL/HRA, final integration was accomplished in Orlando prior to the 12th I/ITSC opening.

The General Dynamics A-16 integration to the NIU was entirely an internal company project. The NIU was loaned by AL/HRA for their integration work and use through the 12th

I/ITSC. The NIU and SIMNET protocol definition documentation were provided to General Dynamics by BBN at the request of AL/HRA. This cooperation expanded the user base for applying SIMNET to an industry developed, fighter aircraft simulation. General Dynamics gained the ability to connect into the distributed simulation network for threats and cooperative aircraft for joint tactics employment. AL/HRA and BBN benefitted by having another user providing inputs for future upgrades to the SIMNET protocol.

The F-16 PTT connected from Fort Rucker was a generic fixed wing simulation developed by BBN. The simulation was a modified AH-64 simulator, an A-10 HUD, a GAU-8 cannon, and BBN flight dynamics for an F-16A. Eight channels of out-the-window imagery was generated by a BBN Advanced Simulation, GT 111 image generator. Seven channels are generated out to 3.5 km with the eighth channel-area of interest, boresighted to the centerline, generated to 7 km. All image generation, aircraft performance, and sensors were generated by the GT 111. A situational display, god's-eye view was available in lieu of simulating a radar.

The GCI station from AL/HRG was developed under contract by System Research Laboratory. The GCI station can simulate either a 407L Tactical Air Control Station (TACS) or an E-3A Airborne Warning and Control Station (AWACS) display. The GCI station simulation was hosted on a SUN SPARC IPC station linked via Ethernet to an NIU. The GCI station simulation operates in a receive only mode. The NIU captures only aircraft messages then passes them to the SUN system. During the 12th I/ITSC the GCI simulated an AWACS display. The only data passed from the GCI NIU to the network is when a radio transmission is made from the GCI controller. Radio calls from another simulator to the GCI controller were handled the same as for the AIT.

MISSION SCENARIOS FLOWN

During the course of the 12th I/ITSC several overall mission scenarios were flown. The one scenario which remained constant throughout was the General Dynamics A-16 and F-16 PTT mission. The A-16 flew only close air support (CAS) missions teamed with the F-16 PTT long-haul connected from Fort Rucker. The A-16 was attacking targets generated and controlled by the BBN SAF systems. The missions the AL/HRA simulators flew varied depending on the simulators connected to the network and whether the long-haul connection to Williams AFB was active. Only air-to-air (A-A) missions were conducted due to AL/HRA's simulation capabilities. The SIMNET protocol was certainly capable of supporting air-to-ground (A-G) operations as evidenced by the General Dynamics A-16 and F-16 PTT mission.

In scenarios involving the I/ITSC network and the long-haul to Fort Rucker, SAF generated air threats-MIGs. These scenarios would be modified to allow both offensive counter-air (OCA) and defensive counter-air (DCA) missions by the CET and the F-15 MASS simulators. SAF would generate MIGs in either a point defense combat air patrol (CAP) or in a sweep toward the CET and F-15 MASS in their defensive CAPs. SAF generated MIGs were basically dumb targets with no weapons, flying programmed routes.

For the times when the SAF MIGs were flying a CAP, the CET and F-15 MASS functioned in an OCA mission role. They would perform sweeps to engage and destroy the SAF MIGs using their own radars and GCI guidance. During the other missions the CET and F-15 MASS were in a point defense role defending against the attacking SAF MIGs.

During the twelve periods when the long-haul connection with Williams AFB was active, the link with the main I/ITSC network was severed due to the data limitations of the 56kbps (kilo bits per second) data line. Prior to the conference we estimated the network capacity for a 56kbps line would only accommodate the data transfer for six aircraft simulators. Since the I/ITSC network involved three aircraft plus the one from Fort Rucker and up to eight MIGs generated by SAF (SAF v. 3.9.12 could generate 60 vehicles total), the decision to have a separate network configuration when connected to Williams AFB was made prior to the conference. The decision to use a 56kbps line was made on the basis of cost. If a T-1 line bandwidth had been available, the need for a separate network configuration for the long-haul connection would not have been necessary.

In the long-haul configuration the CET and AIT at Williams AFB were a team in an OCA role against the CET and F-15 MASS with GCI control at the I/ITSC conference. Digitized voice radio communication was available between the AIT-CET and CET-MASS-GCI. The GCI controller provided real-time updates for the CET and F-15 MASS at I/ITSC. The AIT-CET pilots were required to acquire and appropriately target and employ against the CET and F-15 MASS threat.

Typically A-A missions lasted 5-10 minutes. The A-16 and F-16 PTT predominantly continued to employ in the CAS role throughout the conference and were generally not reset. Scenario participants were initialized using the SIMNET Plan View Display (PVD). Altitude, airspeed, and heading were assigned during each set-up. Reinitialization between missions was accomplished in less than a minute. Normally the CETs, AIT, and F-15 MASS were the only cockpits being initialized between missions. SAF MIGs were reset for the SAF system at the BBN SIMNET control station.

SIMNET PROTOCOL

The protocol used for integrating the simulations was the DARPA/BBN SIMNET Release 6.6 protocol. Original plans called for the use of protocol extensions to demonstrate enhanced capability to pass active sensor data on the network. This was not completed prior to the 12th I/ITSC and therefore SIMNET Release 6.6 Protocol Data Units (PDUs) were implemented. This protocol allowed rapid integration of dissimilar devices, via the use of the Network Interface Unit developed by AL/HRA and BBN Systems and Technologies Division.

The Protocol Data Units supported in the NIU for the 12th I/ITSC were:

* Activate Request
* Activate Response
* Deactivate Request
* Vehicle Appearance
* Fire
* Impact

along with support for sending and receiving voice packets.

This is not an all-inclusive list of SIMNET packets, however it was adequate for the demonstration. These packets allowed the simulators involved to participate with a minimum of performance degradation. The simulators were initialized into the situation using the ..tivate pair, were displayed across the network using the vehicle appearance packet, could launch air-to-air missiles with the fire packet and indicate the result of the launch with the impact packet, and finally, could tell the network they were leaving the situation using the deactivate packet. This level of network support was deemed sufficient without protocol extension for the purposes of demonstration.

Although protocol extensions were not included for the 12th I/ITSC demonstration, progress in this area has continued. Protocol extension is required to integrate a weapon's sensor systems onto a SIMNET network. When parameters of importance are found that don't fit into the existing protocol, an extension is necessary. The first area considered for protocol extension was radar transmissions. Although SIMNET 6.6 includes a radiate PDU, it was insufficient to support the radar warning sensors on the aircraft.

A new PDU, the radar PDU, has been implemented since the conference. The radar PDU was designed to support radar interaction between cockpits on the network without severely loading either entity involved in the relationship. This is achieved by including a list of the players within the radar beam. This list is not intended to be all-inclusive, but to allow the sharing of data to simplify the detection problem for players. By also specifying moding and directional parameters, remote players can uniquely identify the type of energy transmitted. Use of the data transmitted in the PDU, in conjunction with data kept in a host table allows rebuilding of the radar volume if the receiving simulator requires such. The radar system and mode is communicated using a hierarchy to allow remote players to decode only those elements it can use. Very sophisticated hosts may use all the data presented, however, limited fidelity devices may interpret only the highest level of data.

Protocol extensions needed in several other areas have also been identified; although not implemented prior to the 12th I/ITSC. The principle areas of interest are in countermeasures and weapon guidance. The field of countermeasures includes both electronic defenses, as well as expendables for the purpose of defeating active sensors. Electronic countermeasures may be supported by the existing radar PDU, but further research is in progress to investigate this possibility. In the area of weapon guidance, consideration is being given to the ability for the launching vehicle to transfer fly-out responsibilities. This would allow the fly-out calculations to be performed by the device most capable, rather than forcing the launch vehicle to determine weapon termination.

Considerable research remains in the area of protocol extensions; especially in the electronic warfare area. The effort described here has not attempted to resolve all concerns, but to maximize the utility of the existing network for AL/HRA's research and development evaluation.

VISUAL DATABASE ISSUES

To ensure an acceptable degree of visual correlation among the AIT, CETs, and the other networked aircraft simulators participating in the conference, two versions of the Hunter-Liggett visual database were developed by AL/HRA. An IRIS version was used for the AIT at Williams AFB and the CET on the I/ITSC conference floor. The IRIS provided each cockpit a single channel of visual display boresighted straight ahead of the aircraft centerline. The CET at Williams AFB required a second version of the database developed for the Advanced Visual Technology System (AVTS) for display on the Display for Advanced Research and Training (DART).

The AVTS supplied 5 channels of high fidelity imagery using a head tracking/channel switching algorithm to drive 7 display channels of the DART providing 300 degrees horizontal by 200 degrees vertical total field of regard. The CET/AVTS/DART, AIT/IRIS, and CET/IRIS hooked into the same SIMNET as the other conference participants providing a demonstration of networking dissimilar simulations and visual display systems.

The IRIS version was based on a BBN-supplied, Hunter-Liggett database in their SIMNET Database Interchange Specification format. Custom software was developed to transform the terrain polygons into an IRIS format. The IRIS terrain skin exactly correlated with the original BBN database. Due to limited development time, the BBN-supplied culture was not implemented in the IRIS Hunter-Liggett terrain database. Since the IRIS displays were used for A-A missions, the lack of cultural features was not noticeable. The correlation of the IRIS database, without cultural features, to the other databases on different simulators proved to be completely adequate for A-A missions. Gouraud shading was implemented on IRIS databases providing a subjectively pleasing appearance. The general color of the terrain was modeled as green as opposed to BBN's original brown. IRIS moving models for other airborne players were displayed as F-16s.

The major problem encountered in the A-A scenarios was the limited size of the Hunter-Liggett database. The database was approximately 27 x 30 nautical miles.

The AVTS Hunter-Liggett database was based on Defense Mapping Agency, Digital Terrain Elevation Data (DTED) Level 1 and Digital Feature Analysis Data (DFAD) Level 1. The AVTS database modeling system is designed for DTED and DFAD input data. A software effort to implement the BBN terrain skin on the AVTS was considered and abandoned due to time constraints and image generator database incompatibilities. The terrain skin mismatch between the IRIS and AVTS databases was very slight with virtually no visible difference. Lack of visible differences is primarily due to the difficulty in discerning fine terrain detail displayed on the small IRIS screen. During the conference, no network information concerning other aircraft was passed to AVTS. Consequently no visual representations of other aircraft were available to the CET pilot flying at Williams AFB. This enhancement was implemented after the conference. The CET/AVTS pilot had to rely on radar contacts and audio communication to both the GCI and the wingman for air-to-air information.

The AL/HRA visual database effort in support of this conference was implemented in less than three months. The databases which were developed were adequate, although a bit small, for the A-A missions which were flown. The database effort also contributed greatly to the success of demonstrating networked simulations of air-to-air scenarios using SIMNET protocols with dissimilar cockpits and image generation systems.

DISCUSSION

Prior to this application of the SIMNET protocol, numerous concerns regarding the ability to network fighter aircraft using distributed simulation had surfaced. Some believed the dead reckoning of models and the large changes in position associated with fighter aircraft would cause several undesirable side effects which would render SIMNET useless in the high 'G,' rapidly changing A-A environment. Some of those concerns include; different CPU speeds (simulator, visual, NIU), weapon effects and fly-outs, and the ability to integrate an NIU to the simulation host.

The greatest concerns were related to the ability to network simulators of different CPU speeds. In the CET applications the VME is operating at 30 Hz, the IRIS 4D/70GT is at 18 Hz, and the NIU linked to the SIMNET Ethernet is at 15 HZ. In the limited scenarios using an A-A missile as the only weapon, no noticeable problems were encountered. No missiles missed due to slow position updates from the network. Visual jitter, aircraft jumping, was occasionally observed but did not preclude being able to fly in visual formation with other aircraft. Jitter was most apparent during maneuvers of four G's or more. Maneuvers at lesser G's were virtually free of jitter.

To overcome any adverse effects on weapons fly-outs and their effects, the aircraft simulator shooting the missile continues to fly it in to the target. This allows the missile to fly as the shooter "sees" the target. This arrangement worked well for the 12th I/ITSC application when no countermeasures were available. Countermeasures-chaff, flares, and jamming will significantly affect weapon fly-outs. These countermeasures coupled with a highly maneuvering target aircraft will be much more susceptible to transport delays.

Target aircraft maneuvering and employing countermeasures faster than updates can reach the shooting-controlling simulator-aircraft would be counterproductive. If the transport delays in the network simulation system preclude the shooting aircraft from flying out a weapon, an alternative would have the target aircraft simulator fly-in the weapon. This would bypass the transport delays of having the shooting aircraft simulator fly-out the missile and possibly negate the effects of "last-minute" maneuvers and other countermeasures. If the target aircraft simulator were to takeover the weapon fly-in, after launch and activation (self guiding), all aircraft maneuvers and countermeasures would be included in modeling the fly-in. Any last minute maneuvers or countermeasures would be included in determining whether any damage occurred.

CONCLUSION

SIMNET works for fighter aircraft simulators and will be implemented in the MULTIRAD program at AL/HRA to network 2 F-15 MASS, 2 CETs, several AITs, and a common threat simulation system. The MULTIRAD program will continue researching team training concepts and extend the capabilities of networked simulation. The first applications will be to provide a research testbed for beyond visual range (BVR), A-A engagements. As less costly and more capable visual systems become available, application to A-G missions for networked simulators will be made.

SIMNET offers an immediately available method of linking ground and aircraft simulators for large force-on-force simulations. By maintaining the basics of the SIMNET protocol the capability of connecting into the Army's existing network exists for truly integrated joint training exercises.

Incorporating full-up weapon systems trainers, within a TEMPEST area, into a realtime network allows practice with all aircraft avionics and employment of actual tactics along with all team members. These type exercises are not available now, short of actual combat. Team training will be the largest benefit of realtime, networked simulation.