Proceedings of the 1993 Winter Simulation Conference
G.W. Evans, M. Mollaghasemi, E.C. Russell, W.E. Biles (eds.)

SEAMLESS SIMULATION MIXING LIVE AND VIRTUAL SIMULATIONS

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ABSTRACT

The Loral Corporation has integrated the technologies of simulation, simulators, computer image generators, communications, and field instrumentation to demonstrate a Seamless Simulation, i.e. the linking of real vehicles, manned simulators, and computer generated vehicles in a common synthetic environment. These demonstrations allow live vehicles to see and be seen by and engage and be engaged by simulated vehicles. This technique offers a wide range of opportunities for highly realistic simulations and for better validation of them.

In February and again in May 1993, the Mounted Warfare Battle Laboratory at Fort Knox with Loral assistance conducted a series of Seamless Simulation demonstrations. The demonstrations involved a platoon leader and his crew in an actual tank on a real Fort Knox range leading a platoon of manned simulators located at the Mounted Warfare Testbed against live and simulated forces. The platoon leader was provided a view of the simulated battlefield in his tank and could direct his virtual platoon in real time over a tactical radio link. In this demonstration, all the participants (live and simulated) were able to see and shoot at each other. In addition, the platoon members were able to communicate as if they were all on the range. The demonstration was made possible by use of the new Distributed Interactive Simulation (DIS) protocols. This paper discusses those demonstrations, their predecessor demonstration in November 1992, their relation to the upcoming Synthetic Theater of War (STOW) Advanced Technology Demonstration (ATD), and their implications for the future of simulation.

1 INTRODUCTION

Simulation has many uses in the military. We evaluate new concepts for doctrine and weapon systems with it, we assess the development of these weapon systems, we test the resulting products, and we use it to train the force. Yet each of these applications of simulation has developed as a separate community with individual needs and capabilities in fidelity, speed of operation, etc. This paper primarily addresses the linkage of exercises (live simulation) involving soldiers on test and training ranges with manned simulators (virtual simulations). Computer simulation of additional vehicles was an integral part of the experiments, but wargames (constructive simulations) were not used. However, all aspects of Seamless Simulation have potentially significant implications for other simulation communities such as analysis and evaluation, especially in validating outcomes and forcing us toward more predictive simulations.

2 BACKGROUND

Field training allows the military to gain critical experience before meeting the enemy in battle; while operational testing on test ranges evaluates the suitability and effectiveness of both our weapons and our tactics. To maintain a military technological and readiness edge over potential opponents, we must make our operations on training and test ranges as realistic as possible. However, safety considerations, environmental constraints, and severe budget cuts limit our ability to depict many battlefield factors on these ranges. It is also becoming increasingly difficult and expensive just to bring together all the participants needed for a full combined arms team exercise including combat support and combat service support.

One way of achieving increased fidelity on our ranges and at the same time filling in the missing contingents is to electronically interconnect computer simulations, manned simulators, and live vehicles and then use elements of each to create a synthetic environment which is far more realistic than anything (other than actual combat) that we have previously been able to create. With this linkage, field training, exercises, and tests can now incorporate representations of environmentally damaging activities such as flares, simulate dangerous weapons such as missiles, and generate large numbers of expensive target and support vehicles all through simulation. The use of simulation in the field significantly reduces the expense of actually creating these conditions and buying the necessary weapons, ammunition, equipment, and targets.

Meanwhile, computer simulations and manned simulators linked to the live vehicles also benefit, particularly from the constraints of reality imposed by the actual range conditions, e.g. the maximum speed of movement over a particular type of terrain, actual detection ranges under given weather conditions, impacts of terrain and vegetation on gunnery, etc. The best features of both simulation and ranges are thus combined in Seamless Simulation.

In November 1992, a milestone was reached in the integration of live and virtual simulation when the Loral Corporation first demonstrated Seamless Simulation using the Distributed Interactive Simulation protocols at the November 1992 Industry/InterService Training Systems and Education Conference (I/ITSEC). The I/ITSEC demonstration provided an early glimpse into the feasibility and potential value of Seamless Simulation and subsequent Army sponsored Seamless Simulation demonstrations expanded on this beginning. This paper describes these demonstrations, provides an insight into lessons learned from them, discusses conclusions on the use of Seamless Simulation, and makes recommendations for future applications both military and nonmilitary.

3 THE SEAMLESS SIMULATION DEMONSTRATIONS

3.1 The I/ITSEC Demonstration

The I/ITSEC Distributed Interactive Simulation (DIS) Demonstration in November 1992 was a Government challenge to industry to come together and employ the new DIS protocols and standards to link a wide range of simulators and simulations which had never been designed to interact with one another. Jointly sponsored by the Defense Modeling and Simulation Office (DMSO) and by the Army Simulation, Training, and Instrumentation Command (STRICOM), the demonstration included the largest number of heterogeneous simulators ever gathered on a single network. The Loral Corporation participated in the I/ITSEC DIS Demonstration by providing an M1 tank simulator on the DIS network. However, Loral also expanded the scope of the demonstration by creating the conditions for live vehicles to interact directly with simulated vehicles. This expanded element of the I/ITSEC demonstration employed a combination of standard Army Tactical Engagement Simulators (TES) such as the Multiple Integrated Laser Engagement System (MILES) from the Loral Electro-Optical Systems Division, nonstandard TES equipment, in this case TAPER from Loral's Space and Range Division, and one of a kind experimental equipment from Loral's Western Development Labs.

The Loral I/ITSEC Seamless Simulation demonstration at I/ITSEC was focused on proving basic concept feasibility of direct viewing and subsequent engagements between live vehicles and simulated vehicles both manned and unmanned. As a learning tool, it was intended to provide a look at the technical challenges of Seamless Simulation so that future research efforts could be focused to overcome these hurdles.

Army STRICOM is now fielding Simulated Area Weapons Effects (SAWE) training simulators which interface directly with instrumentation on live vehicles and dismounted players. This next generation of instrumentation allows vehicles and players on the range to receive aural notification (bang) of a hit or near miss from artillery, mines, and chemical munitions. However, there is as yet no fielded capability to simulate visual cues of more distant effects such as smoke and explosions. There is also no simulation of direct fire from simulated vehicles (as opposed to real vehicles armed with laser engagement equipment). The Seamless Simulation challenge, therefore, was to provide an affordable means of allowing live vehicles and players to directly see and shoot objects existing only in the simulated world and for the live vehicles to be seen and be shot by both live and simulated opponents. This will be a major objective of the Advanced Research Projects Agency (ARPA) sponsored Synthetic Theater of War (STOW) Advanced Technology Demonstration (ATD) which is scheduled for 1997. The STOW 97 demo will involve joint Service representation and will utilize large scale wargames (constructive simulations), manned simulators (virtual simulations), and actual tanks, aircraft, etc. (live simulation).

As shown in the Figure below, the I/ITSEC demonstration equipment was set up at two sites: the I/ITSEC Convention Hall in San Antonio, TX, and the TEXCOM Experimentation Center (TEC) at Ft. Hunter-Liggett, CA. In the Loral booth on the convention floor in San Antonio, a local area network using the DIS protocols tied together Computer Generated Forces (CGF), a Plan View (2D) Map Display, an M1 manned simulator, three dimensional (3D) visualization displays, and a Seamless Simulation Controller as an interface to Ft. Hunter-Liggett. The Loral local network was connected to the Government DIS Demonstration network at the conference.

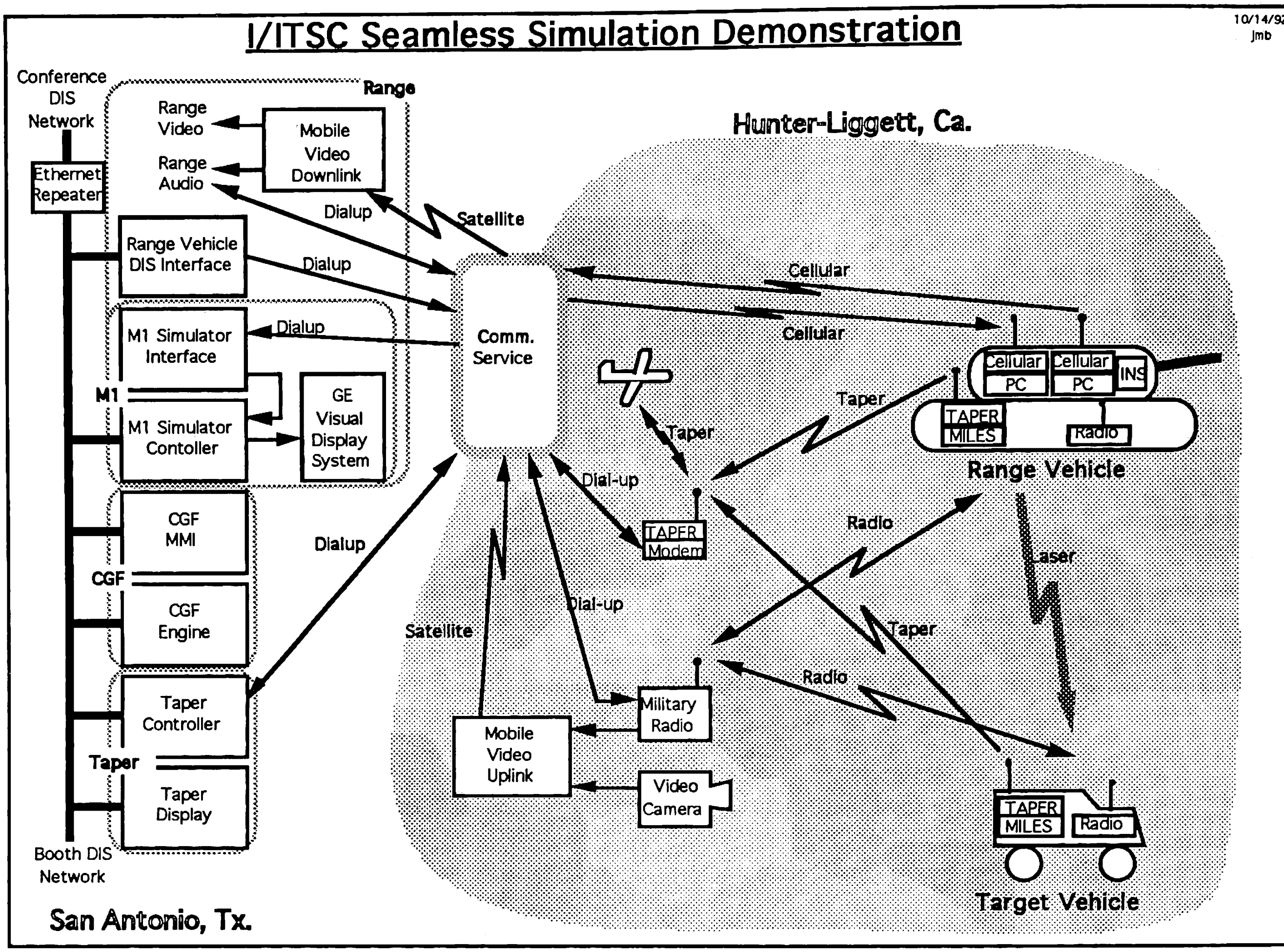

Figure 1: I/ITSEC Seamless Simulation Demonstration

The terrain database for the range at Ft. Hunter-Liggett, CA was used to generate the synthetic environment for the DIS Demonstration in San Antonio. Thus, when information on the position of the real vehicles at Ft. Hunter-Liggett was communicated to San Antonio, the vehicles appeared in their proper locations in the simulation. Likewise, through communications links to Ft. Hunter-Liggett, the simulators and simulated vehicles generated in San Antonio could be observed by the live vehicles and their crews at Ft. Hunter-Liggett. Specifically, Loral instrumented an Army M1A1 tank at Ft. Hunter-Liggett to permit it full interaction with the simulated vehicles generated at San Antonio. It could see and be seen by, shoot and be shot by, the simulated vehicles generated in San Antonio. The M1A1 tank and the other vehicles at Ft. Hunter-Liggett were also instrumented with MILES laser engagement systems which allowed engagements between the live vehicles on the range.

Other live vehicles in the Loral Seamless Simulation demonstration included a second M1A1 tank, two HMMWV trucks, and a light aircraft. Each of these vehicles was instrumented with a Loral TAPER system. TAPER is an off-the-shelf, fully integrated, command and control instrumentation system. It consists of a microprocessor integrated with a Global Positioning System (GPS) and a radio transceiver. The position, status, and event data from each of the range target vehicles was transmitted to a central controller on the range. This information was consolidated at the controller and relayed to San Antonio where it was converted into appropriate DIS format, put on the network, and displayed. These target vehicles could be shot by either simulated vehicles or live vehicles but could not see or return fire at simulated targets because they were not provided with a simulation visualization system. This latter constraint was due solely to limited funding.

3.2 The AUSA Demonstration

In February 1993 and again in May 1993, the

Association of the US Army (AUSA) sponsored Battle Lab and Louisiana Maneuver conventions in Orlando Florida as part of the Army's initiative to introduce both concepts to industry. As part of that effort, the Mounted Warfare Battle Laboratory at Fort Knox with Loral assistance conducted the first in a series of Seamless Simulation demonstrations. Beaming in the demonstration live from Fort Knox, MG Paul Funk, the Fort Knox commander described the demonstration in real time as live video of the range and simulated views of the synthetic environment were each displayed. The demonstrations involved a platoon leader and his crew in an actual tank on a Fort Knox range leading a platoon of manned simulators located at the Mounted Warfare Testbed against live and simulated forces. The platoon leader was provided a view of the simulated battlefield in his tank and could direct his platoon in real time over a tactical radio link. In this demonstration, all the participants (live and simulated) were able to see and shoot at each other. In addition, the platoon members were able to communicate as if they were all on the range. As the number of human participants increases in the Seamless Simulations, it becomes increasingly easier to have confidence in the results. Humans notice all kinds of problems when participating in a simulation from the inside rather than observing its results externally.

At the May 1993 Louisiana Maneuvers Convention, the Seamless Simulation demonstrations were expanded and repeated several times each day. The most notable expansion was the addition of a Line of Sight Antitank (LOSAT) system prototype deployed on the Fort Knox range receiving both live and simulated data on its electronic representation of the battlefield. This was a relatively small advance in terms of simulation technology, but it was a significant demonstration of the use of simulation to greatly expand our capability to test developmental systems on realistic battlefields long before production versions are available. In addition to the live prototype on the range, both a manned LOSAT simulator and computer generated LOSATs participated in the demonstration. In viewing the synthetic environment, it was difficult to tell them apart. One of the themes of the 1993 Louisiana Maneuvers was the continuous use of simulation from concept through development to training. This theme is not new, but for the first time there is the potential to use the same synthetic environment and many of the same models and data bases to perform a consistent set of evaluations in simulation, not just for one system, but for all of them.

Another advance was the detailed rendering of the St. Vith range at Fort Knox. An earlier synthetic representation of the range was relatively gross and did not correlate well with the range itself. For the May AUSA Louisiana Maneuvers Demonstration, detailed terrain features and man-made structures were added to the St. Vith range data base allowing participants knowledgeable of the area to recognize key terrain features and orient themselves. This relatively quick tailoring of a new data base gives additional support to the concept of rapid data base update.

4 LESSONS LEARNED IN THE DEMONSTRATIONS

4.1 Conception and Planning

The concept for generating a Seamless Simulation using live vehicles as part of Loral's participation in the I/ITSEC Demonstrations was developed as a way of involving multiple elements of Loral in a common effort employing the DIS protocols. The Loral participants included three Loral divisions, Loral Western Development Labs (LWDL) which supports STRICOM in the Advanced Distributed Simulation Technology program, Loral Space and Range Systems (LSRS) which is STRICOM's, Mobile Automated Instrumentation Suite (MAIS) contractor, and Loral Electro-Optical Systems (LEOS) which produces the Army's Multiple Integrated Laser Engagement Systems (MILES). This combination of experiences in virtual simulation, field instrumentation, and training devices provided a highly effective, multi-disciplined, team approach to rapidly develop a Seamless Simulation capability. Such combinations of talent are very much in keeping with the DIS concept of linking dissimilar simulations and data bases from a variety of sources.

4.2 Subcontractor Contributions

The Seamless Simulation demonstrations also required approvals from the Government and support from several subcontractors. During the I/ITSEC demonstrations (which were completely industry funded), Loral was fortunate to quickly obtain supporting subcontractors willing to participate. General Electric (GE) in Daytona, FL (now a division of Martin Marietta Corporation) made a major contribution by providing one of their PT2000 computer image generators, a very scarce marketing resource. GE also converted the Project 2851 database of Ft. Hunter-Liggett range to display on their image generator and expended a significant effort to add data on specific range cultural features so that the scene displayed contained the key terrain and visual cues such as towers, berms, and tree lines which the live tank commander could observe and use to orient himself. Technology Systems Inc. (TSI), a small R&D company in Maine, worked overtime and weekends to accommodate the changes required to ruggedize their Personal Computer (PC) based 3D visualization system for installation in a tank. Kearfott leased Loral a highly capable Inertial Navigation System (INS) and made the necessary modifications for us to use it to determine the tank's hull orientation, its turret orientation, and its gun elevation so each item could be accurately depicted in the simulation and factored into the engagement data. In future demonstrations, it is hoped that differential GPS can be used to obtain essentially the same data directly from the GPS without the need for a supplemental INS.

4.3 The Demonstration - Site Operations

To enhance the realism of the demonstration for the observers, a live video feed was provided from the range to the demonstration site. The live video is useful in communicating the idea that some of the vehicles being depicted in the synthetic environment are live at a remote range, but it has little or no use in actual testing or training exercises. In fact, differences between the live view on video and the visualization representation of the same terrain is often disappointing to viewers seeing them together for the first time. Most viewers, however, are willing to "suspend disbelief" when viewing the simulated terrain alone, but this level of acceptance decreases when the live and simulated representations viewed together are seen to be considerably different. Consequently, considerable effort was placed on adding significant features into the synthetic environment's terrain data base and orienting the scenario to best advantage. In general, personnel viewing the demonstration found the video very helpful in perceiving that something was actually happening on the range, but somewhat confusing in that simulated vehicles did not appear in this view of the real world.

For the demonstrations occurring at Fort Knox, detailed photographs of the terrain were taken from ground level and US Geological Survey aerial photo maps were purchased to give multiple views of the range. As simulation display technology increases in capability, the challenge increasingly becomes how to efficiently display (and for that matter simulate) what we have traditionally dealt with in basically two dimensions. Programs such as the Special Operations Forces Aircrew Training System (SOF ATS) are creating systems to render new terrain data bases in 48 hours, but practical limitations still exist on what can be done automatically. For example, we do not yet have an easy way to "paste" terraced roads on steep hillsides in mountainous terrain such as Bosnia. We also need to work to bring photographic mapping and virtual representation more closely in line. If you look closely at any of the virtual scenarios, you will notice that all the trees are the same height. This is not of much concern to two dimensional wargames or even to three dimensional tanks, but it can make helicopter mission rehearsals potentially dangerous when repeated in the real world.

5 LESSONS LEARNED ABOUT THE TECHNOLOGY

5.1 Communications to and from the Range

For the I/ITSEC demonstration, commercial cellular telephones with modems were used to support data links between San Antonio and Ft. Hunter-Liggett. By using standard, off-the-shelf phone systems we were able to avoid potential development and integration difficulties we might have encountered by utilizing range radio communications or other systems. The cellular phone systems did, however, limit the size of the demonstration by restricting the bandwidth available to send the real time event data needed to maintain the remote view of the synthetic environment.

5.2 Bandwidth Limitations

The modems used were limited to 2400 bps in order to avoid compression, buffering, and retransmissions which might have scrambled the DIS Protocol Data Units. Furthermore, the phone systems only supported point-to-point communications. For transmitting DIS data to multiple vehicles, a broadcast communications system is generally more efficient. Likewise, to receive data from vehicles in the field, a multiplexed radio system allowing multiple sources to be combined into a single output is recommended to avoid contention and maximize throughput. On subsequent demonstrations, the Loral Space and Range Division's TAPER technology was configured to support both of these requirements. Given additional integration time and funding, using the TAPER technology to perform all of the range functions would be desirable. A long-haul land-line phone connection could then be established to transmit the data from the base station on the range to the remote simulation site(s). It should be noted that satellite communications and even land-line communications of thousands of miles generate latencies which can become visible to the simulation participants.

By using only a few vehicles and reducing the size of the DIS Protocol Data Units (PDUs) the demonstrations could have supported up to five vehicles on the range using only cellular communications. But there are other ways to inexpensively expand the scenario. One is to filter the traffic. For example, to conserve bandwidth for the I/ITSEC demonstration, only enemy vehicle DIS traffic was sent to the battlefield. However, then the platoon leader on the range was not able to directly observe the rest of his simulated platoon. In subsequent demonstrations, this limitation was overcome by providing additional bandwidth to support larger integrated exercises on the range.

As another alternative, even smaller packets of data could be sent or we could only send change PDUs. Based on estimates from the DIS Range Working Group, it may be possible to reduce the information actually transmitted to 50-100 bits per report on vehicle position, status, and key events. This is critical to having large numbers of live vehicles participate in Seamless Simulation since each participating vehicle currently transmits every PDU and bandwidth is very limited on most ranges.

5.3 Range Visualization Systems

Based on discussions with the military personnel involved in the I/ITSEC and AUSA demonstrations, the most frequent suggestion for Seamless Simulation is for a transparent LCD display device integrated with the vehicle's standard optical systems. Using this approach, large numbers of icons of vehicles, explosions, etc. could be overlaid on the actual terrain background and the simulated terrain would not be shown. This would allow faster scene updates because fewer polygons are required, but presents problems of correlating the displayed icons with the actual terrain to avoid burying them, having them float, or not properly obscuring them. This and other approaches to improve the display techniques are being studied for future projects. The INFOSCOPE Project which TSI is currently conducting for ARPA as part of an SBIR program is one such program. In another, Loral Space and Range Systems is installing flat plate displays in tanks at the 24th Infantry Division as part of a command and control demonstration. Each of these and other similar experiments brings us closer to full integration of Seamless Simulation capabilities.

5.4 Seamless Simulation Gateway

The I/ITSEC demonstration employed a Seamless Simulation Gateway which listened to the DIS network and filtered out all traffic not pertinent to the vehicle on the range, for example deleting information on units outside of a given range. It also performed the translation of the network standard PDUs into the much smaller range PDU format and interfaced the DIS network to the instrumented tank on the range. Using the terminology of the newly formed Field Instrumentation Working Group, the gateway translated Type 4 PDUs to Type 2. The Seamless Simulation demonstration architecture is based upon this module being present and the success of the demonstration indicates the viability of such an approach. It is anticipated that the further development of such gateways will allow large numbers of relatively small nodes to join the large distributed networks now being formed in a manner which avoids their having to process the total traffic on the network.

6 OPERATIONAL CONSIDERATIONS

During the Louisiana maneuver demonstrations, there were several instances where the television video view of the range differed significantly from that of the synthetic environment displayed on the manned simulators. This was particularly noticeable during fog, rain, near darkness, and low sun angles which produced long shadows. Until more advanced simulators become the norm rather than the exception, there is not much that can be done. But that day is coming soon. In the meantime, methods of occulting the scene of the older generation of computer image generators are being investigated.

With respect to the simulation of conditions such as rain, it should also be noted that live operations in the real world are noticeably impacted by the environment. It was fairly obvious, however, that computer generated vehicles often took little or no note of the condition of the terrain or visibility on the range. Providing the ability for entities generated in digital computer simulation to recognize and properly react to terrain and weather constraints is another major challenge in producing a fair fight and a more realistic simulation environment. By separating the perceptual portion of the computer generated forces (the simulated war fighter) from the physical model of the weapon or vehicle, we are having considerable success in developing modular semi-automated forces (ModSAF) with the capability to react realistically not only to the environment, but to the military situation, as well.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Military Applications

Seamless Simulation is feasible, but it will take a lot of work before we reduce it to day-to-day routine. However, the effort is now primarily engineering. Many of the toughest technology challenges have been solved by ongoing advances in the supporting technology. The biggest challenge to remain may be one that faces the entire simulation community. We are simply too fragmented to get maximum benefit from all the simulation advances achieved by the trainers, the test groups, the analysts, or the operational support personnel. We must get the instrumentation people, range people, display and communications, data base, and simulator people together and sharing data and techniques on a regular basis. We must design our equipment and instrumentation to serve multiple purposes, we must make maximum use of existing software and techniques, and we must promote standards which allow this interoperability.

The Army has recently declared that the Modular Automated Instrumentation Suite (MAIS) will not be reserved only for testing, but could be used to supplement training instrumentation and therefore should be compatible with other Army instrumentation and simulation. The mechanism for doing this is the DIS protocols. Within a year, a set of DIS Range Protocols should also be adopted by the DIS Steering Committee. This will facilitate the use of Seamless Simulation on a wider basis as well as focus it on future instrumentation to support Service ranges and the vehicles, aircraft, and ships on them.

There are still many questions concerning the ultimate value of Seamless Simulation and how best to apply it. To answer such questions, Loral has continued to examine various combinations of instrumented platoon leader and company commander vehicles operating on range while the rest of the troops participate in exercises from manned simulators or command posts. Together they can then operate as an integrated unit within a common synthetic environment against a wide variety of threats and with many supporting units (all computer generated) without the costs and risks of taking everyone to the range. Data collected on such experiments contributes directly to defining specific requirements for Seamless Simulation. To show the direction of Seamless Simulation, the Army is now defining requirements for an entire brigade to be represented in a virtual world with all supporting and opposing elements accurately depicted in computer simulation. Similarly, the Navy is developing the Tactical Combat Training System (TCTS), a "go to sea" virtual environment for entire battle groups.

7.2 Nonmilitary Applications

While the initial applications of Seamless Simulation have been military, one can envision many dual uses of this technology for education and training. For example, classes in high schools could participate in environmental experiments with other schools some of which were located in classrooms while others were actually in the field collecting data. Heavy equipment training could also take on new dimensions with the addition of an embedded training mode including virtual reality. Constructions sites are potentially dangerous and just as with the military, live training is typically limited due to safety concerns.

We have just begun to demonstrate the capabilities of Seamless Simulation and many potential applications remain to be explored. Loral welcomes other participants in the Seamless Simulation world and looks forward to significantly larger demonstrations.

ACKNOWLEDGMENTS

The author wishes to acknowledge and thank Mr. Keith Briggs, Mr. James Exter, Mr. Thomas Radgowski, Mr. Gregory Unangst and their many respective staff members whose efforts on Seamless Simulation made this work possible.

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