

1-1-2000

Virtual Environment Technology Laboratory Research Testbed: Project Report #8 Year Two Final

Glenn A. Martin

Find similar works at: <https://stars.library.ucf.edu/istlibrary>
University of Central Florida Libraries <http://library.ucf.edu>

This Research Report is brought to you for free and open access by the Digital Collections at STARS. It has been accepted for inclusion in Institute for Simulation and Training by an authorized administrator of STARS. For more information, please contact STARS@ucf.edu.

Recommended Citation

Martin, Glenn A., "Virtual Environment Technology Laboratory Research Testbed: Project Report #8 Year Two Final" (2000). *Institute for Simulation and Training*. 209.
<https://stars.library.ucf.edu/istlibrary/209>

Virtual Environment Technology Laboratory Research Testbed

Final Report

Glenn A. Martin

September 7, 2000

IST-TR-00-05



I 20

Virtual Environment Technology Laboratory
Research Testbed

Project Report #8
Year Two Final

August 2000

CONTRACT K-8-55071-1552793-3926



Institute for Simulation & Training

SUBMITTED TO:

**VIRTUAL ENVIRONMENT TECHNOLOGY LABORATORY
4800 CALHOUN
HOUSTON, TEXAS 77204**

**VIRTUAL ENVIRONMENT TECHNOLOGY LABORATORY
RESEARCH TESTBED**

CONTRACT K-8-55071-1552793-3926

**PROJECT REPORT #8
(YEAR TWO FINAL)**

August 2000

SUBMITTED BY:

**INSTITUTE FOR SIMULATION AND TRAINING
UNIVERSITY OF CENTRAL FLORIDA
3280 PROGRESS DRIVE
ORLANDO, FL 32826-0544**

**GLENN A. MARTIN
RESEARCH ASSOCIATE
407-658-5544
martin@ist.ucf.edu**



Institute for Simulation & Training

**Virtual Environment Technology Laboratory
Research Testbed**

Year Two Final Report

**Glenn A. Martin
Institute for Simulation and Training**

August 2000

Abstract

The University of Central Florida's Institute for Simulation and Training (IST) is assisting the University of Houston (UH) in research directed towards the development of Virtual Environments for team training. IST serves as a focal point for collaboration between UH and the Naval Air Warfare Center Training System Division (NAWC/TSD) and the Army Research Institute (ARI) Orlando Field Unit. IST performs research in the area of shared virtual environments and in the interface between prototypes produced from this project that operate within the Higher Level Architecture (HLA). This report describes the work done for the University of Houston during Years 1 and 2 with updates to Year 1 material as appropriate.

1.0 Background

Under this project, IST is assisting the University of Houston in research towards the development of Virtual Environments for team training. In particular, IST has the following overall project activities:

- Assist in transferring research results from this project to NAWC/TSD and ARI and assist in transferring research results from NAWC/TSD and ARI to UH.
- Provide a site for the demonstration of prototypes produced by this project for NAWC/TSD, ARI, and the U.S. Army STRICOM.
- Explore the integration of prototypes produced by this project with other virtual environments developed by NAWC/TSD, ARI, STRICOM, and other government agencies and contractors.
- Collaborate directly with UH in advancing the state-of-the-art in integration of dismounted infantry into virtual environments, the representation of human figures, and the addition of autonomous and semi-autonomous behaviors of human figures.
- Perform collaborative research on shared virtual environments, exploring different communication technologies and protocols as well as mechanisms to enable cooperative activities within shared virtual environments.
- Investigate the integration of prototypes produced in this project with other virtual environments that communicate via HLA.

To this end, IST was responsible for the following activities during the project:

- Install software developed at the University of Houston Virtual Environment Technology Laboratory and provide demonstrations of prototypes to NAWC/TSD, ARI, STRICOM and other government agencies and contractors.
- Serve as a “node” within a shared virtual environment testbed to assist in the conduct of experiments involving cooperative behavior within shared virtual environments and in the investigation of alternative communication technologies and protocols.

- Initiate an exploration of the integration of virtual environments developed at the University of Houston with those developed by NAWC/TSD, ARI, and other government agencies and contractors.
- Initiate a study of the representation of human figures in virtual environments via HLA.

This report discusses the status of these four tasks as well as describing some additional work performed under this contract not specifically mentioned above. Some of the material of this report is directly from the Year 1 report; some of this report is based from Year 1 but has been updated to reflect additional activity of the current year; still other parts of the report cover all new work performed during Year 2.

2.0 Software Installation

In year one, three software packages from VETL were identified for installation at IST. These include the Checkpoint Charlie application, the Space Station application and the Mars application. These particular applications were chosen to provide appropriate demonstrations for VETL at IST and to provide a good mechanism for testing the network connectivity between IST and VETL.

Checkpoint Charlie was the first application installed at IST. It was placed on an Onyx Reality Engine 2 (RE2) machine from Silicon Graphics with a 6-tracker Ascension Flock of Birds magnetic tracker. The software and configuration files were installed by VETL personnel and tested by IST personnel. Initially, the application did not work but IST personnel were able to figure out settings for various environment variables and the application ran correctly. Checkpoint Charlie was demonstrated for guests visiting from the Interservice/Industry Training Systems and Education Conference (I/ITSEC) in November 1998.

The second application to be installed was to be the Space Station application. It was chosen because of feedback from Bowen Loftin of VETL during his I/ITSEC visit. However, VETL personnel felt that the Mars application was simpler to install and could adequately test network connectivity between the two sites so the Space Station application was not installed at IST.

The Mars application was the final application to be currently installed at IST. It was installed on both a Silicon Graphics Onyx RE2 and a Silicon Graphics Octane Mxi. After configuration by VETL personnel, the application ran fine between these two machines. A test between the VETL site and the IST site found the Internet connectivity to be too slow to be adequate. More discussion of this problem follows.

During year two, no software packages were identified to be installed at IST. However, as part of IST's Virtual Environment Research Testbed project with the U.S. Army Research Institute, IST's software was installed at VETL. In previous discussions, IST and VETL agreed that this software could be very useful in performing some Internet2

shared environment experiments (although they could not be completed before Dr. Bowen Loftin's departure from the University of Houston).

2.1 Database Support

VETL personnel expressed a desire for a more intricate database for the new revision of Checkpoint Charlie currently under development. IST supplied a section of the Quantico database in OpenFlight format to VETL for their consideration. The database fragment features 2 or 3 likely intersections for use with the Checkpoint Charlie scenario. The Quantico fragment was culled from the large Quantico MOUT database, with all external references resolved and all images necessary for textures. The fragment was supplied on CD-ROM in May 1999.



Scene from Quantico Database Fragment

2.2 Articulated Arm Software

IST has developed inverse kinematics software to emulate natural movement of an avatar's arm according to real world sensor position and orientation. In anticipation of near term networked Virtual Environment collaboration between IST and VETL, staff at VETL requested this software for testing. The articulated arm code has been packaged as a separate software class and has been provided to VETL with documentation.

2.3 Holding a Rifle in a VR Pod

IST was asked to offer some suggestions for supporting and aiming a rifle while fully immersed in the Checkpoint Charlie scenario. We recognize the need to portray three essential rifle stances: standing by, ready position, and aiming/firing. Within the immersive environment, two factors effect how the rifle can be portrayed within the VE: 1) whether one or both arms are tracked, and 2) whether it is necessary to have both hands physically supporting the real world rifle.

These two conditions suggest a matrix:

One Tracked Arm	One hand holding physical rifle	Two hands holding physical rifle
Two Tracked Arms	One hand holding physical rifle	Two hands holding physical rifle

Due to the obvious need to conserve resources, we will consider only the single tracked arm option. It is possible to implement the rifle so that only one physical hand holds it. In the virtual world, the left supporting hand can always be drawn in holding the barrel despite the location of the true physical position of the hand. This approach allows the free left hand to remain on the perimeter of the pod as a safety measure. A hand held constantly on the railing of the VR pods provides balance to someone with their vision occluded by an HMD, and it also helps to keep the participant centered in the pod, rather than walking up on the railing. Portraying the weapon in stand by and ready mode is easy; to render the position of the gun when aiming or firing, the orientation of the barrel can be derived by extending a vector between the body and a tracker on the trigger hand. The drawback of this method is that the disparity between the true position of the left hand and the rendered position could be confusing to the participant.

Another possibility is to place the tracker on the weapon and use both hands to steady it. From the point of view of proper marksmanship, this option offers better realism. It requires, however, that the participant forgo support with either hand while aiming, firing, or acting ready with the weapon.

The final choice between these two options should result from the nature of the exercise. If marksmanship and proper marksman technique is an essential element of the simulation, then the second option is desirable, and the pod railing can be outfitted with an extra dense layer of cushioned padding to alert/remind the participant of the railing. If, however, the marksmanship aspects of a simulation scenario are better suited to a dedicated marksmanship trainer, then the first option above is the proper choice.

3.0 A Shared Virtual Environment Testbed

As mentioned above, IST was responsible for serving as a “node” within a shared virtual environment testbed. IST was asked to perform a survey of possible communication

technologies between the IST site and the VETL site. Five (besides the Internet) were identified and these include ISDN, Frame Relay, Private Point-to-Point connection, DirectPC, and Internet2/vBNS. They all provide alternatives to the Internet with the exception of DirectPC (which simply supplies an alternative with a fewer potential number of hops). The table below shows a survey of bandwidth and costs for the various options (note that these prices are based on costs associated with installing the option at IST -- costs at other locations may vary):

Network Type	Measures		
	Bandwidth	Capital Cost	Variable Cost
<i>ISDN</i>	128kbps	\$250 installation	\$85 per month
<i>Frame Relay</i>	128kbps	\$760 installation	\$325 per month
<i>Point-to-Point</i>	128kbps	\$3000 installation	\$2425 per month
<i>DirectPC</i>	400kbps (download)	\$350	\$130 per month
<i>Internet2/vBNS</i>	622Mbps (backbone)	\$0 (already installed)	\$0 (already installed)

IST currently has an ISDN line installed and available for testing shared virtual environments. In addition, the University of Central Florida and IST have been connected to Internet2. As part of the Army Research Institute Virtual Environment Research Testbed, IST's "multiplayer" software was installed at VETL. Although affected by Dr. Loftin's departure from the University of Houston, this is still an excellent foundation to investigate shared virtual environments on Internet2.

4.0 Integration of Virtual Environments

The possibility of deploying a multiplayer immersive environment between NAWC and IST was first broached to Robert Breaux at the VR 99 conference in March. He responded enthusiastically and IST contacted Breaux after the conference. An open house demonstration of the IST multiplayer installation was tentatively planned contingent on the completion of a human factors experiment currently underway at IST. This open house will be held in the near future and will cover this project as well as others at IST.

5.0 Human Figure Representation in the High-Level Architecture

IST was asked to initiate a study of the representation of human figures within the High-Level Architecture (HLA). In the general sense, representing human figures is difficult. This is caused by many factors including the shear flexibility of the human body (i.e. number of joints), large number of postures possible (standing, kneeling, prone, etc.) and the use of a representation in live, virtual and constructive simulations (perhaps

simultaneously). A relatively large amount of work is available in human figure representation in the general sense. Such work, however, is only just beginning in the High-Level Architecture. Therefore, this report will survey human figure representation across the board with the thought that this general work can also be applied within the HLA domain. Much of this was documented in the Year One Final Report; however, it is included here for completion and to show updates that have occurred to specific projects over the past year.

5.1 Individual Soldier Mobility System

Pratt et al [1] explored inserting an articulated human into a virtual environment in a system they called Individual Soldier Mobility System (ISMS). They performed a review of the human body and found thirty-nine degrees of freedom in seventeen joints that they felt needed to be represented. Of these, they chose a subset to use in a dismounted infantry simulator. These include one degree-of-freedom (DOF) each at the elbow, knee and toe, and three DOFs each at the head, neck, shoulder, wrist, waist, hip and ankle.

Network communication within the ISMS was performed by a point-to-point connection to an ISMS/DIS gateway. The gateway wrote DIS-compliant PDUs to the network. Applications wishing a more complete representation of the human figure were required to communicate with the gateway through a series of prototype (non-DIS) PDUs. Pratt et al chose this method in order to avoid using large amounts of bandwidth by using a DIS Entity State PDU. Their own figures indicate their method uses 232 bytes compared to 814 bytes using articulated parameters within DIS.

5.2 O’Keefe IV and McIntyre III

O’Keefe IV and McIntyre III [2] wrote a paper discussing assessment strategies for individual combatants. While most of this work is out of the scope of this report, they did perform a small investigation of human figure representation. They found that realistic representation of human figure movement requires the rotation and “forward/backward” movement of both feet, both calves, both thighs, the waist, the torso, both shoulders, both upper arms, both forearms, both hands and the head. This includes more than 50 DOFs for what they call “medium-resolution” modeling of a human figure.

5.3 Dismounted Warrior Network

The Dismounted Warrior Network (DWN) project linked together a variety of different dismounted infantry simulators and SAF. Results were documented by Reece and Dumanoir [3]. The DWN consisted of four different dismounted infantry simulators. They all used various hardware platforms for image generation as well as tracking which can be found in Reece and Dumanoir’s paper. One system represented human figures on the network by using DIS PDUs with human animation enhancements for the limb positions. All other systems used the DI-Guy system from Boston Dynamics. DI-Guy

uses a series of postures (walking, standing, crouching, kneeling, etc.) to represent human figure position. Based on the posture set, the human figure orients its articulated parts into a pre-programmed set of angles.

Both human figure animation systems are eventually converted into an IEEE 1278.1 standard DIS PDU. The 1278.1 standard encompasses posture, gait and (sometimes) activity in a life form state. The possible state values include:

- Upright standing still
- Upright walking
- Upright running
- Swimming
- Parachuting
- Jumping
- Wading
- Kneeling
- Prone
- Crawling
- Sitting
- Squatting
- Crouching

The entities are then shown using the animation for the appropriate value above rather than any true representation of what the human subject is actually doing.

5.4 Fully Immersive Team Training

Parsons et al built what they call Fully Immersive Team Training (FITT) [4]. It was originally built for the Army Research Institute so they could study team training in virtual environments. Due to the limited domain of the software (an isolated network for data collection purposes), FITT simply enumerated the articulated parts necessary for representing its human figures. To allow for additional future use, all three orientation components were provided for fifteen joints (neck, both shoulders, both elbows, both wrists, torso, waist, both hips, both knees and both ankles). This representation was used in both the model as well as the DIS Entity State PDU. In this case, each articulated parameter was assigned a type value chosen to avoid other known type values in the existing DIS standard.

5.5 Veridian Real Guy 200

Veridian, Inc. has an Individual Combatant system called RealGuy 200. To accomplish their human figure representation, they use the DIS Data PDU to send the joint angles with specific coded type values. The basic information being sent is the same as the IST FITT system described above, but is just in a different location. This system is now in use by the IST FITT system and the new A-TES STO work being completed by Sparta, Inc.

5.6 H-Anim

The H-Anim group was formed in order to develop a specification for a standard VRML humanoid representation [5]. Because the group is focused on 3D Internet applications,

the group tends to be more focused towards VRML. However, much of the discussion related to this standardization effort can be used in studying representations of human figures in HLA. In fact, the H-Anim group itself suggests that their VRML Humanoid can actually be driven by various inputs including Jack and similar systems, keyframe animation, Java3D, Living Worlds, MPEG-4 and other interpolators. The MPEG-4 group is also coordinating its efforts with the H-Anim group so the two standards will work together.

The standard being produced by the H-Anim group focuses more on the modeling aspects. Due to this, they include other modeling aspects such as origin locations, starting orientation of both the overall body and each articulated part, original facial pose (“eyebrows at rest, the mouth closed and the eyes wide open”), and measurement units (meters). For joints, the specification identifies 94 joints within the human body including not only the typical arms and legs but also spinal joints, finger joints and facial joints (see [6]). It also includes a method for defining “non-standard” joints.

For use in multiple scenarios, the H-Anim specification also allows for multiple levels of detail for a VRML Humanoid. They suggest four different levels thereby allowing an application to build to a certain level and have the ability to interact with other applications built to that level. The base articulation level contains only the position and orientation of the body itself and no articulated part information. The next level is defined as a typical low-end real-time 3D hierarchy and includes 17 joints. The following level adds more complexity but keeps a simplified spine and includes 71 joints. The final level is the complete H-Anim hierarchy and includes all 94 joints. Shockley and Morgenthaler used all these various levels in their HLA work using H-Anim [7].

5.7 Human Figure Starter SOM

In January 1999, the Defense Modeling and Simulation Office (DMSO) organized a few representatives to develop a starter Simulation Object Model (SOM) for representing human figures within HLA. A SOM is basically a model of functional requirements that a Federation Object Model (FOM) should possess, and a starter SOM is intended to serve as a starting point for anybody interested in sharing the information. In this case, the Human Starter SOM contains a common starting point for the representation of human figures shared through HLA. Barham, Pratt and Fullford describe the progress to date on the Human Starter SOM [8].

Participants in the Human Starter FOM include:

- Boston Dynamics, Inc.
- Defense Modeling and Simulation Office
- Lockheed Martin Information Systems
- MAK Technologies, Inc.
- Reality by Design, Inc.
- Science Applications International Corporation

- U.S. Army Soldier and Biological Chemical Command (Natick Soldier System Center)

The group was kept small to keep focus, but a number of other organizations that also have interest in human representation in HLA were consulted as “reach-back” groups. They were asked to provide comments and give reviews. It is interesting to note that no academic presence exists in the core participant list.

In Barham et al [8], they provide the following design considerations in the Human Starter SOM development process:

- the SOM should address entity level simulations across the live, virtual and constructive domains
- the SOM should serve as a base and is not meant to be complete but needs to be extendible
- a relatively flat SOM structure will provide easy mapping of data elements into other FOMs and SOMs (as well as allow subscription to only the data that is needed)
- interoperability factors will not be limiting because “bridge” federates can be used to aid in interoperability problems
- if a candidate data element is too complex to figure out and/or is not currently being used by most simulations involving human figures, then it probably does not need to be included in the Human Starter SOM

To date, the Human Starter SOM group examined many possible parameters to place within the SOM. Of those, they chose ten including position, orientation, velocity, affiliation, life state, physical appearance, posture, posture transition, equipment and action. Many issues are involved within each parameter (such as coordinate system, origin location, etc.) but this report leaves that to the Barham et al paper.

5.8 Summary

Some of the objectives we maintain in researching and developing the framework for a human figure FOM/SOM are:

- 1) To provide a useable simulation environment for a wide variety of simulation scenarios beyond military applications such as peacekeeping, general mission rehearsal, civil service applications (police, fire, FEMA, etc.) and space-based simulation and training applications.
- 2) To find a hybrid approach to avatar articulation, which falls somewhere between IEEE, 1287.1 and the FITT system, which is based strictly on transmission of real-time joint positions, derived from position tracking systems. The value of keyframe animations of avatars is obvious in terms of bandwidth reduction and

the ability to portray complex movements that are difficult to carry out in an immersive environment. There are times, however, when a real-time *actual* representation of a participant via his or her avatar is important, maybe even essential to a specific simulation task. An example of this type of movement or gesture would be pointing or directing a partner with arm movements.

We feel that an effective human figure FOM must allow for certain SOM specific canned movements as well as the ability to directly manipulate the posture of the avatar by tracker data.

- 3) Dead reckoning algorithms for modern HLA-DIS simulation applications have become quite sophisticated. We see the need for another layer of granularity as the individual human is introduced into simulation scenarios. Dead reckoning must be able to interpolate intermediate positions between two different postures in a smooth and natural way.

It is our belief that a human figure SOM should be extensible in the manner of the H-Anim level-of-detail approach. As stated above, the FITT data packet includes 15 joints, which provides ample 'medium-granularity' of movement for most dismounted infantry simulations. It is similar to the H-Anim level two representation and the Veridian Data PDU. Extensions to a baseline SOM built around this representation would include:

- Gesturing figure SOM. For simulation agents who rely on hand gesture signaling and recognition, this SOM would provide a layer that included finger joints for left and right hands. Specifications for this Object Model would allow for predefined gestures from the current library of U. S. Army field gestures, as well as real-time transmission of finger deflection for the introduction of unique gestures outside of typical field unit control gestures that are scenario specific.
- Facial Expression. A repertoire of *primary emotional states* would greatly enhance the baseline human figure SOM for certain simulation applications. Daniel Goleman [9] suggests a list of 8 primary emotions: Anger, Fear, Sadness, Surprise, Disgust, Shame, Enjoyment, and Love. These emotions can be represented by rotation and displacement parameters applied to the eyebrows, eyelids, eyeballs, upper lip, lower lip, jaw, and shoulder position.
- Broader ranges of avatar animations are needed for the many simulation tasks that could be required of the FOM. For example in a fully immersive, or even partially immersive simulation environment, it would quickly become tedious to pantomime loading of a simulated field artillery unit. If the point of the simulation exercise is to train a gunner on sighting and unit command via hand gestures, then the repetitive task of loading the shell into the breach would be better animated at the push of a controller button by the trainee. In order to foster an environment that integrates new avatar movements like these into a SOM quickly, a standard for motion capture of human movement should be established.

This specification could include details on the role of dead reckoning, tracker placement, and report rate.

While representing human figures is not trivial, the H-Anim approach seems to be gaining more and more appeal internationally. It is used within VRML, MPEG-4 and other smaller groups (and even is getting attention at HLA conferences). In addition, the Veridian Data PDU method is gaining use within the Orlando-based simulation community. It is fairly similar to what most organizations representing human figures to that fidelity level were using, and adopting it allows for easier interoperability.

6.0 Conclusions

Three of the four tasks defined in this project were relatively simple (consisting of hosting demonstrations, participating in networked environments, etc.). The task of exploring human figure representation was more involved and led to a good review of what has been accomplished thus far. Somewhat surprisingly, much work into human figure representation has been performed. They all use varying levels of fidelity, which makes the H-Anim approach most interesting in that it supports all levels of fidelity. It also seems clear that it is growing as a standard (although that alone does not make it adequate). However, H-Anim seems flexible enough that IST is in process of adopting it as a tool in modeling human figures. In the long run, all the systems covered in this report have important advantages and disadvantages that have to be weighed. No one solution will probably ever exist to satisfy all needs although an approach like H-Anim (providing built-in flexibility) seems to be the closest.

References

- [1] Pratt, David R., Paul T. Barham, John Locke, Michael J. Zyda, Bryant Eastman, Timothy Moore, Klaus Biggers, Robert Douglass, Stephen Jacobson, Michael Hollick, John Granieri, Hyeongseok Ko and Norman I. Badler. "Insertion of an Articulated Human into a Networked Virtual Environment." Proceedings of the 1994 Artificial Intelligence, Simulation and Planning in High Autonomy Systems Conference, Gainesville, FL, December 7-9, 1994.
- [2] O'Keefe IV, John A. and Robert T. McIntyre III. "Virtual Assessment Environment for Individual Combatant Systems." Proceedings of the Simulation Interoperability Workshop, Orlando, FL, Spring 1997.
- [3] Reece, Douglas A. and Paul Dumanoir. "Conventions for Representing Humans in a DIS Exercise: The DWN Experience." Proceedings of the Simulation Interoperability Workshop, Orlando, FL, Fall 1998.
- [4] Parsons, James, Don Lampton, Kimberly Parsons, Bruce W. Knerr, David Russell, Glenn Martin, Jason Daly, Bryan Kline and Mathew Weaver. "Fully Immersive Team Training: A Networked Testbed for Ground-based Training Missions." Proceedings of the Interservice/Industry Training Systems and Education Conference, December 1998.
- [5] <http://ece.uwaterloo.ca/~h-anim/newspec.html>
- [6] http://ece.uwaterloo.ca/~h-anim/h-anim1_1f.gif
- [7] Shockley, John W. and Mark Morgenthaler. "Using H-Anim to Represent Human Figures in HLA-Compliant Simulations." Proceedings of the Simulation Interoperability Workshop, Orlando, FL, Spring 2000.
- [8] Barham, Paul T., Shirley M. Pratt and Deborah A. Fullford. "The Development of the High Level Architecture (HLA) Human Starter Simulation Object Model (SOM)." Proceedings of the Computer-Generated Forces Conference, Spring 1999.
- [9] Goleman, Daniel, "Emotional Intelligence", Bantam Books, 1995

