The 1992 I/ITSEC Distributed Interactive Simulation Interoperability Demonstration

Margaret Loper, Brian Goldiez, and Scott Smith
Institute for Simulation and Training
University of Central Florida
Orlando, FL 32826

ABSTRACT

The first demonstration of the Distributed Interactive Simulation (DIS) Protocol Data Unit (PDU) standard was conducted at the 14th Interservice/Industry Training Systems and Education Conference (I/ITSEC) in San Antonio, Texas in November 1992. This effort was sponsored by the Defense Modeling and Simulation Office (DMSO) and the US Army's Simulation, Training and Instrumentation Command (STRICOM).

The DIS standard protocol data units (PDU) and current communications architecture were utilized along with the common visual databases using Project 2851 (P2851) data. The demonstration was an integrated display of both standardization efforts. The Institute for Simulation and Training (IST) at the University of Central Florida developed the detailed design of the demonstration system, coordinated the effort for the government, and provided technical support to those organizations who demonstrated interoperability at the I/ITSEC. Planning Research Corporation (PRC), the P2851 contractor, prepared the databases.

This paper describes the approach used and lessons learned from the interoperability demonstration. The planning and integration effort consisted of three components. First, the scope of the demonstration had to be determined. This included three main issues: the communications network, the DIS standard, and the terrain database. Second, before integration occurred, each simulator had to be tested for compliance with the DIS standard. The testing was conducted at the San Antonio Convention Center during the week prior to the I/ITSEC Conference. The last component of the effort was the scenario developed for the opening plenary and banquet demonstrations. The scenario was dependent on the outcome of testing and was therefore the most dynamic component of the effort.

ABOUT THE AUTHORS

Ms. Loper received a B.S. degree in Electrical Engineering from Clemson University in 1985 and a M.S. degree in Computer Engineering from the University of Central Florida in 1991. She is currently Principal Investigator for the Distributed Interactive Simulation (DIS) project at the Institute for Simulation and

Training, Orlando. Her current research interests include simulation networking, OSI protocols, and multicast communications.

Mr. Goldiez is the Director, Research and Development at the Institute for Simulation and Training at the University of Central. His research interests include modeling and analysis of dynamic systems, systems testing methods, and verification, validation, and accreditation methodologies. He received a B.S. in Aerospace Engineering from University of Kansas and a M.S. in Computer Engineering from the University of Central Florida.

Mr. Smith received a M.S. degree in Computer Science from the University of Central Florida in 1981. He has more than 14 years of experience in Software Engineering and Operating Systems design. He has worked in product development in both commercial and defense sides of the computer industry. At IST he has served as Principal Investigator on a research project investigating the generation of automated forces in a networked simulation environment. He is currently managing several projects related to the development of Distributed Interactive Simulation. His areas of interest include modeling of human behavior in real-time simulations, Aggregate-level wargames, and application of advanced computer architectures to DIS.

The 1992 I/ITSEC Distributed Interactive Simulation Interoperability Demonstration

Margaret Loper, Brian Goldiez, and Scott Smith
Institute for Simulation and Training
University of Central Florida
Orlando, FL 32826

INTRODUCTION

In March 1992, the concept for a real-time demonstration of the Distributed Interactive Simulation (DIS) standard, known as DIS 1.0, was conceived for the 14th Interservice/ Industry Training Systems And Education Conference (I/ITSEC) held in San Antonio, Texas on 2-5 November 1992. The demonstration was held with concurrence of the sponsoring I/ITSEC organization, the US Air Force, and was sponsored by the Defense Modeling and Simulation Office (DMSO) and the US Army's Simulation Training and Instrumentation Command (STRICOM).

The DIS standard protocol data units (PDU) and current communications architecture were utilized along with the common visual databases using Project 2851 (P2851) data. The demonstration was an integrated display of both standardization efforts. The Institute for Simulation and Training (IST) at the University of Central Florida coordinated the effort for the government and provided technical support to those organizations who demonstrated interoperability at the I/ITSEC. Planning Research Corporation (PRC), the P2851 contractor, prepared the databases.

This joint activity involved a wide variety of organizations. Each participant brought expertise in one or more aspects of the demonstration. In particular, IST developed selected portions of the demonstration system and also served as a clearing house for interested parties desiring more information, wishing to participate, or needing help with specific technical aspects of the effort.

SCOPE

Though the extent of what DIS can support is broad, the scope of the demonstration was restricted by the limited preparation time. The I/ITSEC demonstration was a joint application that utilized manned and unmanned simulated vehicles plus one live vehicle (not meeting DIS requirements). In addition to the manned and unmanned simulators, a few I/ITSEC demonstration participants simply "listened" to the network and used the information as input to radar simulations or to a "window" into the battle environment. The I/ITSEC application demonstrated the capability of heterogeneous simulations to interact in a common environment using the DIS protocol. The degree of correlation and the realism of the exercise was limited by the lack of experience with the standards.

The scope of the demonstration was defined by the participating companies through a set of planning meetings held at IST. At these meetings, issues pertaining to the network, DIS standard, and terrain representation were discussed and voted on. Issues which required further research before coming to a decision were taken as action items by IST, studied, and presented to the participants at the following meeting. All action items and decisions were documented in a report called "Actions and Decisions" which was distributed to all organizations participating in the planning meeting. The planning meetings took place over a period of seven months. In concert with several meetings, tutorials were held on different components of the demonstration.

General

Over the 8 month period, 28 organizations directly supported and/or participated in the planning meetings and demonstrations. There were a total of 18 manned and unmanned simulators, 22 "listen only" devices (network monitors, Stealths, etc.), and 1 live device used in the demonstration. This translated into 8 air simulators, 7 land simulators, 3 sea simulators, and 1 live land vehicle. Of the 18 manned and unmanned devices, 4 were Computer Generated Forces (CGF) systems. The organizations and types of simulators which participated in the demonstrations are shown in Table 1. In addition to the simulator participation, the planning meetings and demonstrations were supported by STRICOM, USAF ASC, DMSO, PRC, Evans & Sutherland, and Star Technologies.

COMPANY NAME	TYPE OF SIMULATOR
BBN	Plan View Display, CGF, Stealth
CAE Link	AH-64, Stealth, Data Logger
Concurrent	Network Monitor
GD Air	F16
GD Land	M1
Grumman	E2C
Hughes	UAV, JSTARS
IBM/ECC	After Action Review, Battle Master, M1
IDA	Stealth, Data Logger, Plan View Display
IST	CGF, Network Monitor, Data Logger, Stealth
Lockheed-Sanders	TSAD, Scenario Monitor, Patriot
Loral/GE	M1 Tank, Live M1, Taper (Live), Plan View Display
McDonnell Douglas	F16/SAM Sites, Network Monitor
Motorola	Surface Ship
NRaD	LHD Surface Ship, Stealth
NTSC	F/A-18, Surface Ship
Reflectone	Radar
Rockwell	F16
SG/Mak Tech.	Stealth
TSI	Stealth

Table 1: I/ITSEC Demonstration Participants

The I/ITSEC participants spent a total of two weeks in Texas.

The first week, 26-31 October, was for testing and integrating the DIS simulators. Testing, performed by IST, included all aspects of networked simulation: communication protocols, DIS PDUs, terrain orientation, appearance, and interactivity.

The second week was the I/ITSEC Conference where two formal exercises were scheduled and presented. The first demonstration was presented during the opening session of the I/ITSEC Conference on Monday, 2 November 1993 in the Lila Cockrell Theater adjacent to the convention center exhibit hall. The second demonstration was given immediately before the I/ITSEC banquet on Tuesday, 3 November 1993. This demonstration was given in the exhibit hall on a screen erected directly over the IST booth located at one end of the hall. In addition to the formal demonstrations, the DIS network was available for use during regular conference hours. This time was divided into: 1) free play, where participants could get on the network and engage in non-scripted play with other people, and 2) 30 minute blocks, where participants could "own" the network and conduct an exercise of their choosing.

The participants decided in early planning meetings to make the network public. Any organization could play on the network as long as it did not interfere with any other player on the network. The decision to develop a mutually beneficial network was based on the philosophy of "demonstrating, not evaluating" the DIS Interoperability Network.

During both weeks, a voice communication network was established using contractor furnished walkie-talkies to provide a capability to control and coordinate the rehearsal play.

Network Design
The network design for the I/ITSEC demonstration consisted of two parts: one network for testing simulator interoperability during the eight months prior to the conference and another network for the actual DIS demonstration at the San Antonio Convention Center. Accordingly, the design of the network took place in two phases. The first phase included the design and implementation of a network at IST which allowed participants to test their DIS simulators against a system known to be DIS compliant. The second phase of development was the design of a network which supported the demonstration of DIS during the formal exercises, the free play, and the 30 minute time slots during the week of I/ITSEC. One issue which spanned both the IST network and the I/ITSEC network was the choice of communication protocols. Several options were available and the decision was based, in part, on the recommendation of the communication architecture for DIS (CADIS) draft standard being developed by the DIS workshops.

The choice of protocols for the I/ITSEC demonstration was decided by popular vote. At the initial March meeting, participants made several proposals:

Layer	Possible Choices
Application	DIS
Network[1]	UDP/IP SIMNET Assoc. CLTP/CLNP Null
Link[2]	Ethernet IEEE 802.3

The OSI Connectionless Transport Protocol/Connectionless Network Protocol (CLTP/CLNP) was quickly eliminated as too new and too complex to implement for a near term demonstration, and a null network layer had little support. The SIMNET Association protocol was eliminated as being too closely associated with a particular company and product, whereas UDP/IP was an existing standard which could be purchased COTS.

A poll of the I/ITSEC participants at the May meeting showed a clear preference for Ethernet over IEEE 802.3, and so Ethernet was selected. Hence, I/ITSEC used a protocol stack of DIS/UDP/IP/Ethernet.

DIS Standard

The DIS standard used in the demonstration was Version 1.0 dated 8 May 1992. See Reference [1]. Version 1.0 of the standard covers a large scope of what DIS can support. Due to the limited preparation time, certain rules and restrictions were placed on the way this version of the standard was actually used. In addition to these restrictions, a set of policies was negotiated to determine the level of interoperability to be achieved.

The DIS standard defines a set of PDUs that achieve the basic requirements for distributed interactive simulation. Each PDU is divided into two fundamental parts: a mechanism and one or more policies. Mechanisms are static and are not changed. These are the PDU fields. For each PDU field, there are a variety of policies that may be applied. For example, in the Entity State PDU there is a field (mechanism) for a dead reckoning model. There are several dead reckoning algorithms (policies) that can be used. The policies used in the I/ITSEC demonstration were negotiated by participants during the planning meetings held at IST.

Only a subset of the PDUs listed in the DIS standard were used for the demonstration. These were the Entity State, Fire, Detonation, and Collision PDUs. Though the Collision PDU was part of the exercise, air entities were exempted from collision tests. This decision was based on a quick survey taken after 20 October when IST received a request from one of the participants that air entities be exempted from collision tests. IST contacted the air participants, upon which they unanimously agreed that collisions were not necessary for the I/ITSEC DIS demonstration.

Terrain Representation

The delivery of the terrain database was the responsibility of the P2851 team, a joint project designed to develop common database formats. Vendors took the common data formats and converted the data into a form suitable for their computer image generators. Data from one vendor can be put into the P2851 format and be made available to other users. There are several formats available from P2851 which include the *generic transform* database (GTDB) format and the SSDB interchange format (SIF). SSDB refers to the Standard Simulator database which is the format P2851 uses internally. The SIF data format was selected for use by I/ITSEC participants.

The SIF database used for I/ITSEC was selected to be a 100 x 100 km area which included portions of Fort Hunter Liggett, CA. The geodetic coordinates of the southwest corner of this database were chosen to be N35-15-0, W122-4-0. Terrain, culture, and models were to be prepared for this area.

TESTING

The verification and validation of DIS compliant systems for the I/ITSEC demonstration were accomplished through the development of a testbed at IST. To make the testbed a reality, four key elements had to be developed: a test plan, a test system, test methods, and testing policies and procedures.

First, a test plan had to be developed which would serve as a guideline for testing simulator compliance with the DIS PDU standard. The test plan defined the interoperability requirements for participation in the DIS I/ITSEC interoperability demonstration. The level of interoperability defined was for the demonstration only and did not constitute conformance with the DIS standards for other applications. However, the test plan can be considered a subset of a full test implementation. The test plan was *developed by IST over* a period of four months and was then presented to demonstration participants for comment and review.

Second, a test system that was known to comply (by means of passing the test plan) with the DIS PDU standard was needed for organizations to test their DIS simulators against. This "golden system" had to be open and accessible to all participants who wanted to test their DIS simulators. The test system chosen was IST's Intelligent Simulated Forces CGF Testbed. Prior to testing, the CGF system underwent a conversion from SIMNET to DIS.

Test methods, the third element, were also important. How would demonstration participants access the test system at IST in order to test their systems against the test plan? Three economical and flexible alternatives were established which provided participants with a means to test via modem, data logger, or in-house. The modem method was only partially implemented.

The fourth element was the "Testing Policies and Procedures" document which established the ground rules IST followed throughout testing to ensure a fair and level playing field for all organizations participating in the demonstration.

Minimal testing took place prior to I/ITSEC; therefore, the majority of all systems had to be tested once IST personnel arrived in Texas. During the first week, IST tested 41 systems in 84 hours, with all but one system passing the test plan. Desensitized test data and integration information is presented in [2]. By mutual agreement, each company's test results are confidential.

THE FORMAL DEMONSTRATION

IST developed the scenario for the formal demonstrations. The scenario was designed to provide a setting to demonstrate DIS interoperability and the capabilities of the participant's networked simulators without fear of intentional or inadvertent destruction by another player. To ensure a "win-only" scenario *for demonstration participants*, BBN's CGF system was used to provide opposing forces. They were not allowed to fight back and died when fired upon.

The control console was a Stealth or "magic carpet" which provides an "eyeball" view into the 3-D computer generated synthetic environment. The Stealth view was shown on the three center screens. This magic carpet was used to transport the audience to any point in the environment. The job of its operator was to give the audience the best view of the battle.

The scenario used for both formal demonstrations is described below:

(1) Two bogeys (SU-25s) were generated by BBN and detected by the E-2C. One target was assigned to the USS Ticonderoga and the other was assigned to the F/A-18 Combat Air Patrol.

(2) The *first ship seen* was the USS Wasp. It was generated in the NRaD booth. The NRaD ship had the ability to display any airborne or surface threat on its radar display by capturing location data from the DIS network.

(3) The second ship seen was the USS Perry and was generated in the Motorola booth. The Motorola ship also had the ability to display any airborne or surface threat on its Tactical Plot, as well as to launch missiles against these threats.

(4) The *third ship seen* was the USS Ticonderoga, generated in the NTSC booth. The NTSC ship also had the ability to display any airborne or surface threat on its SPA-25G radar and tactical plot.

(5) The first bogey came within range. The *Weapons Free* command was given to the USS Ticonderoga. The Stealth was used to show results of the firing of the missile from the ships and aircraft.

(6) Two F/A-18s were directed by the E-2C to intercept and destroy the second

bogey. The *Weapons Loose* command was given to the F/A-18s. The lead F/A-18 was generated in the NTSC booth.

(7) The second F/A-18 was generated in the Rockwell booth in the exhibit hall, but the pilot was physically located at the Rockwell plant in Los Angeles. The locations of targets and friendlies on the DIS network were being sent from the Rockwell booth via land lines to the domed simulator in California. The pilot flew his aircraft in response to these images and the resulting aircraft locations were transmitted back to the booth and into the DIS network for others to see and interact with. The Stealth was used to show results of the firing of the missile from the lead aircraft.

(8) The scenario play then jumped inland to view the land forces in the Hunter Liggett area. To save time the Stealth was attached for a ride on CAE Link's Apache helicopter. The Apache flew North at over 100 knots into the engagement area at Fort Hunter Ligget.

(9) The first unit seen was a Patriot Detachment generated in the Lockheed Sanders booth. The Patriot simulator had the ability to display, acquire, and engage air threats on the DIS network.

(10) The Patriot Radar picked up two approaching enemy attack aircraft on their display and the command was given to the Patriot battery, *You Have Permission to Fire*. As the Patriot battery was overflown, the Stealth was detached from the AH-64 to allow the audience to watch as the missiles were launched. The enemy aircraft were CGF entities generated in the McDonnell Douglas booth. The Apache continued north and spotted two enemy tanks (also CGF entities) generated by BBN. The Apache helicopter was given the command, *You Have Permission to Fire*. The Stealth was used to spot the action and the Hellfire missile firings.

(11) The next places visited were the battle positions of Task Force Alamo which was responsible for the defense of a critical road junction. As the Stealth approached the Task Force, a total of four tanks were exposed. Two of the tanks were seen off the right side of the road. An M1A1 tank was deployed forward in a fixed observation position in support of the dismounted infantry to their front. The tank was generated in the IBM booth.

(12) The first M1A1 tank to be seen was generated in the Loral booth. Two more M1A2 tanks which were

seen on the right side of the road were generated in the General Dynamics Land Systems booth.

(13) Placed well forward of the vehicle positions was a dismounted infantry (DI) fireteam. It was located to cover a route of advance not visible from the vehicle positions. This DI fireteam was generated by the IST CGF Testbed.

(14) Just ahead of the DI fireteam was seen the first of many Opposing Force (OPFOR) vehicles generated by the BBN CGF system in their booth in the exhibit hall.

(15) The IST DI fireteam was ready to engage the lead enemy vehicle with a Dragon missile. The DI fireteam was given the command, *Permission to Fire*. The audience watched as the DI kneeled, aimed, and fired the Dragon, destroying the lead OPFOR vehicle.

(16) The Stealth operator was commanded to rejoin the tanks in their battle positions to watch as the battle unfolded. The Task force was given the command *Permission to Fire*. The M1 simulators engaged the OPFOR with direct fire.

(17) An unmanned aerial vehicle was sent into the battle area. The UAV was generated in the Hughes booth. The UAV was assigned to fly through enemy held territory and to transmit simulated real-time TV sensor visual data back to the commander. The commander, seeing an advancing enemy armored column, called for close air support.

(18) An F-16 was generated in the General Dynamics, Ft. Worth booth and was flown from a simulated F-16 cockpit. The F-16 was tasked to engage an enemy mobile missile vehicle, a SAM. The SAM was generated in the McDonnell Douglas booth.

ISSUES AND RECOMMENDATIONS

Several systems level factors are important to consider when configuring and testing simulators and networks which are going to be integrated into a DIS environment. These factors include: minimizing the number of new technologies which are going to be integrated (i.e., P2851 and DIS), assessing simulator and network capabilities during the design phase (and not the implementation phase), avoiding the use of partial or reduced scope tests, testing ALL aspects of the design, having back-up designs which have been tested prior to implementation, and having sufficient time and support mechanisms in place to conduct necessary tests. Each of these areas will be further expanded below.

Combining the prototype products for the first time presents difficulties which should be avoided. Such was the case with P2851 and DIS.

Neither project had running prototypes for the I/ITSEC. The difficulty in the case of I/ITSEC came during integration. It was impossible to determine if a problem was due to terrain mis-correlation or misuse of DIS. For example, floating tanks in a visual scene could be the result of incorrect coordinate transformations, incorrect dead reckoning, or correlation problems between differently rendered databases. The causes of such situations are impossible to determine from I/ITSEC data. In the future, prototype products should be evaluated prior to integration with other system elements.

Simulator and network capabilities should be assessed during the design phase. In the case of I/ITSEC, the simulator and network capabilities were determined when the system was implemented during the rehearsal period. Part of the reason for the lack of information was the lack of validated tools to assess network performance given certain simulator and network characteristics. The second reason for the lack of information was an unwillingness by participants to assess or provide information on their simulators' capabilities. IST believes the lack of simulator information was due to the participants' lack of a firm commitment to the I/ITSEC hardware and proprietary considerations. The development of network assessment tools useful to simulation's needs will solve part of the problem. A willingness to share information or to make non-disclosure agreements will solve proprietary information problems.

Partial test procedures should be avoided. Interoperability was achieved at the I/ITSEC partially by leaving details of the scenario open until just prior to the demonstration. The need was partially due to not using detailed test procedures. I/ITSEC participants did not have time (or probably budget) available to develop special software specifically for testing. IST's detailed test procedures required simulators to perform in ways for which they were not originally designed. For example, IST may have asked simulators to pitch up 90° in order to check Euler angles and proper interpretation of rotation commands. These rotations were to be performed at the center of the earth to separate translation from rotation problems. A tank simulator may not have had such a capability. This problem can be avoided if testing procedures are standardized resulting in one time development of test software.

All aspects of the simulator network design should be tested. IST did very little testing of simulators under conditions involving adverse or erroneous data. In addition very few network performance tests were conducted. IST should have conducted performance tests of the various components of its own testbed and the integrated testbed system performance. Such tests would have resulted in better data gathering capabilities.

Backup designs which have been tested are important to one time demonstrations. The network problems just prior to the start of I/ITSEC have been documented. Something similar to a "failure modes and effects analysis" should be conducted in advance to anticipate problems and determine spare requirements.

Sufficient time should be planned into development efforts or demonstrations. There was insufficient time available to design, build, and test the simulation network at I/ITSEC. The demonstration was successful, in part, because the audience had no expectation of what was going to be demonstrated and the scenario could be adjusted to accommodate the special needs of simulators and the network. Future demonstrations or integration efforts must have realistic time budgets, if for no other reason than audiences now have an expectation of DIS and P2851 capabilities and are going to expect ever increasing sophistication of simulator networking.

CONCLUSIONS

Demonstrations can be useful if properly structured. The DIS demonstration served to show technology advancements and the utility of simulator networking to a wide group of interested parties. The DIS demonstration also served as an excellent example of technology transfer. Companies worked together to arrive at common understandings and solutions to interoperability problems. This helps to guide the development of standards and testing methods. Demonstrations should set out clear goals and show how those goals have been met. Demonstrations should be used as a means to collect data. The DIS demonstration at I/ITSEC was the first instance of data collection for simulator networking which was made available to the public.

The DIS protocols work. DIS is a robust set of protocols which have a wide range of applications. However there are several cautions which must be observed in using DIS. First, DIS is still developmental. The various versions of DIS are not compatible with each other making interoperability difficult. It is hoped that the emergence of DIS 2.0 will provide a stable baseline for product development and system implementation. Second, the DIS standards provide a wide range of options to users. The options must be selected for each instance of simulator interoperability. Third, the PDU level of standards is incomplete for interoperability. Definition of the environment (or methods to assess simulated environment similarities) is necessary for interoperability. Fourth, sound testing methods are necessary for DIS conformance and interoperability. Finally, the DIS Steering Committee needs to carefully manage the proliferation of DIS. Uncontrolled proliferation of PDUs or arbitrary control of new ideas could restrict the applicability of DIS.

REFERENCES

[1] Military Standard (Draft), Protocol Data

Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation, Version 1.0, IST-PD-90-2 (revised), 8 May 1991.

[2] I/ITSEC DIS Interoperability Demonstration Test Procedures and Results, M. Loper, B. Goldiez, S. Smith, H. Ng, M. Craft, M. Petty, G. Bulumulle, and C. Lisle, IST-TR-93-04, February 16, 1993.

ACKNOWLEDGEMENT

This work has been supported by the U.S. Army's Simulation, Training and Instrumentation Command (STRICOM) under contract N61339-91-C-0103. The views and conclusions in this document are those of the authors and do not represent the official policies of the funding agency, the Institute for Simulation and Training, or the University of Central Florida.

1. The Transport and Network Layers are combined as "network."

2. The Data link and Physical layers are collectively called "link."